Voiland College of Engineering & Architecture

Washington State University

Common Carrier

Washington State University
ME 416 - Senior Design
Microsoft Carrier Project

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Adam Lutovsky
Anas Hamadah
Bogdan Tkachov
Ernesto Castro
John Zender
Jonny Midkiff
Mathilde Idoine

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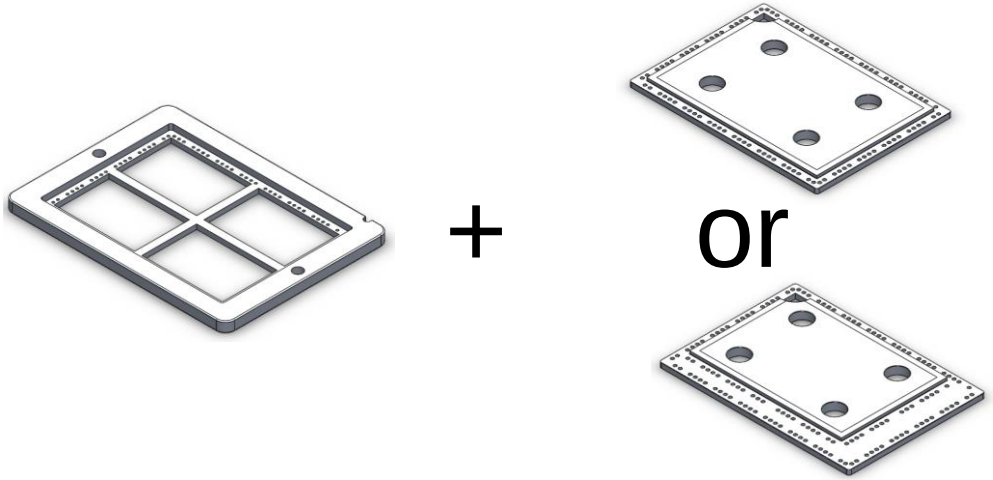
Mission

- Microsoft currently uses unique manufacturing carriers for each device/model
- Need a common manufacturing carrier
  - Reduce manufacturing costs
  - Reduce environmental impact
  - Unify design philosophies
  - Reduce fixture lead time



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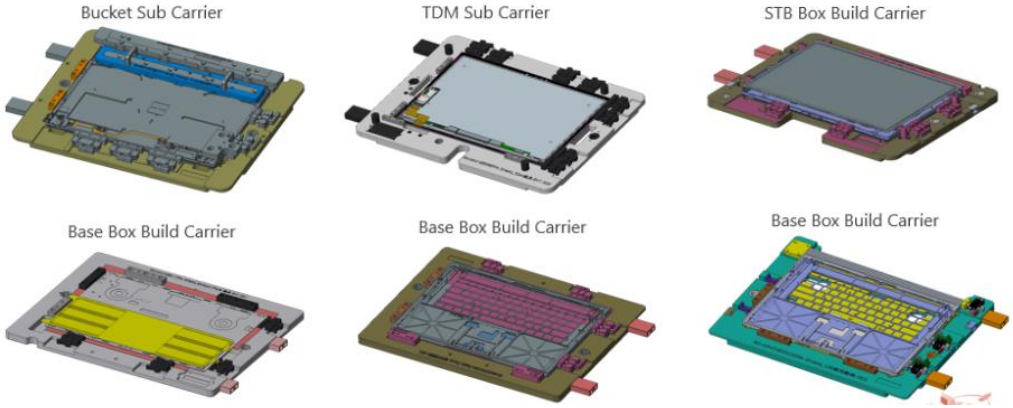


Deliverables

- Physical Prototype
- Common Carrier Cad File
- Design Analysis
  - FEA
  - Thermal
  - Fatigue
- Drawings

Requirements

Practical requirements

- Universal Carrier to be used with:
  - 13” and 15” Book Tablet
  - Pro
  - Laptop Display
- Budget: $600
- At least 80% shared parts between device carriers
- Less than 10 minute changeover time
- Less than 5 weeks fabrication lead time.

Technical Requirements

- Max force: 400 kPa
- Bond Force: 60 PSI, Area: 2,000mm^2
- Lifecycle:
  - 10 cycles/day
  - Max 150 stations/cycle
  - 600 touches/day
  - 6 to 10 high pressure station/day
- Max temperature: 120°C
- Safety Factor: 1.2

Design Criteria

Feature	Weight
Flexibility	9
Consistent Frame	9
Cost	9
Rigidity of device	3
Standard datums	3
Ease of Change	3
Access to input/output	3
Manufacturability	1
Part Commonality	1

Flexibility - Ability to accomodate all units

Consistent Frame - Using the same frame for all units

Cost - Lowest cost per carrier

Rigidity of device - How rigid is the carrier

Standard datums - Using the same datums across

Ease of change - how easy it is to adapt the carrier to another unit

Access to I/O - Access for testing purposes

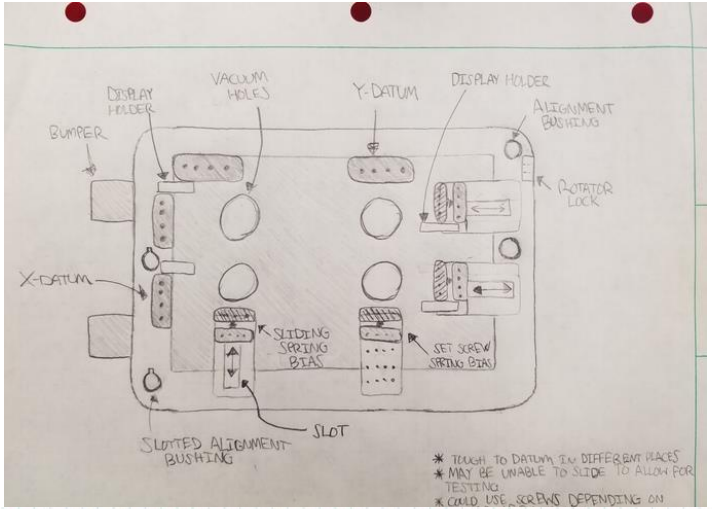
Manufacturability - ease of manufacturing

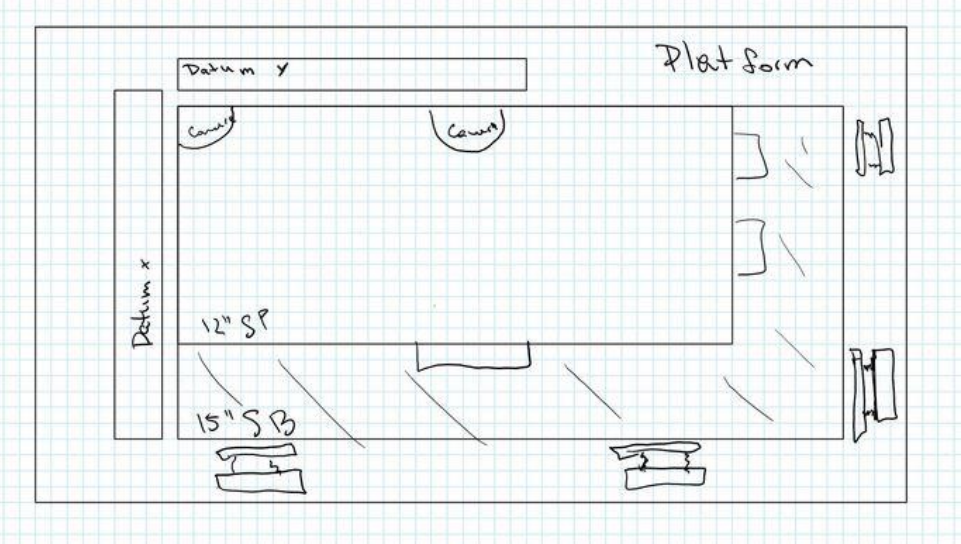
Part Commonality - uses of the same parts

Design Iteration 1 (Sketches)

Focus on:

- Simple
- Rigid
- Cost efficient
- Single frame

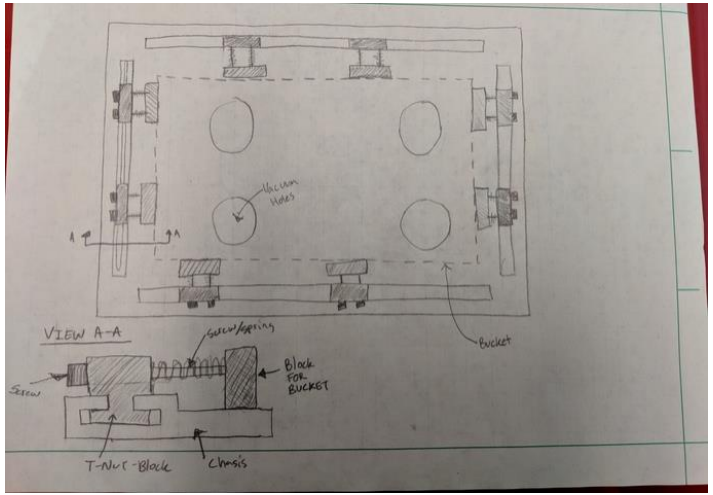


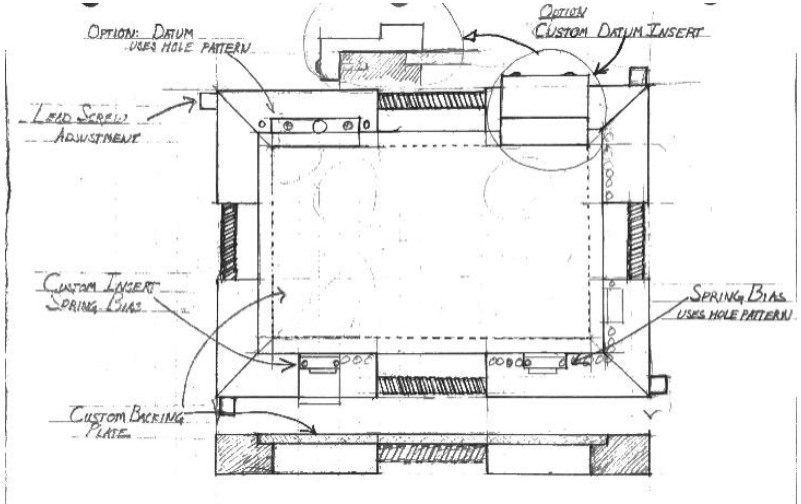


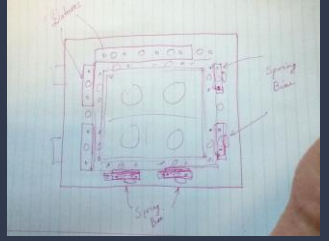
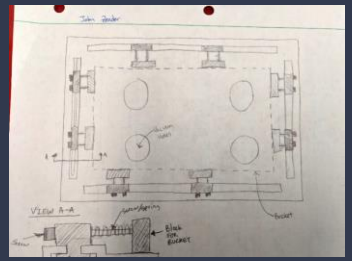
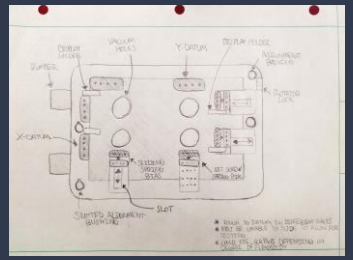
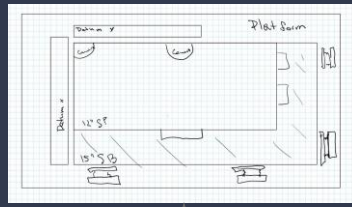
Design Iteration 1 (Sketches)

Focus on:

- Flexible
- Universal
- Adjustable
- Disregarding cost





	Range (1 lowest, 9 highest)	 Score (-1,0,1)			 ★
Flexibility	9	0	1	0	1
Rigidity of device	3	0	-1	-1	-1
Standard datums	3	0	-1	0	0
Consistent Frame	9	0	0	0	0
Cost	9	0	-1	-1	-1
Ease of Change	3	0	1	1	1
Access to input/output	3	0	1	-1	1
Manufacturability	1	0	-1	-1	-1
Part Commonality	1	0	1	1	0
Total	**42**	**0**	**0**	**-12**	**2**

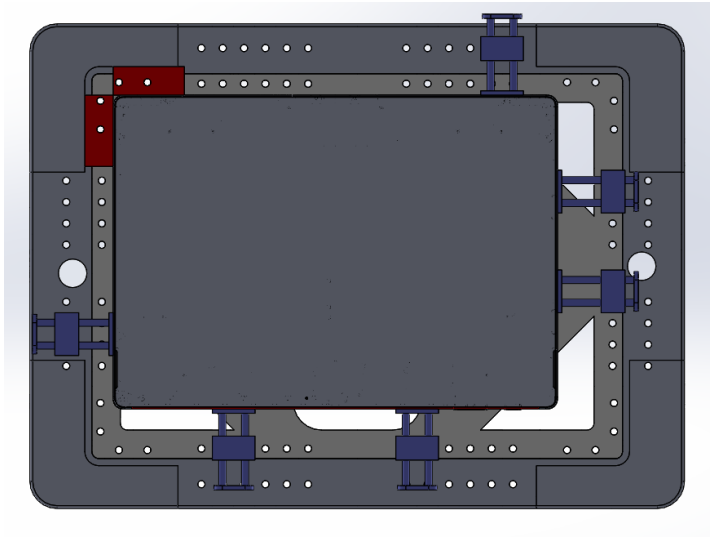
Design Iteration 2
Model 1

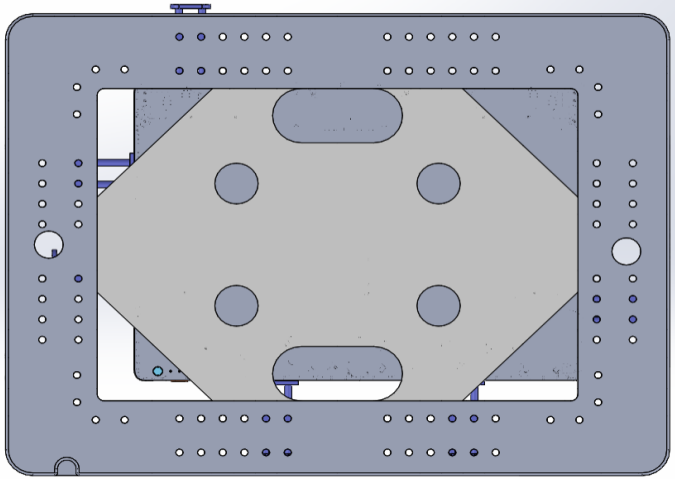
Strengths:

- Flexibility
- Commonality
- Single piece plate

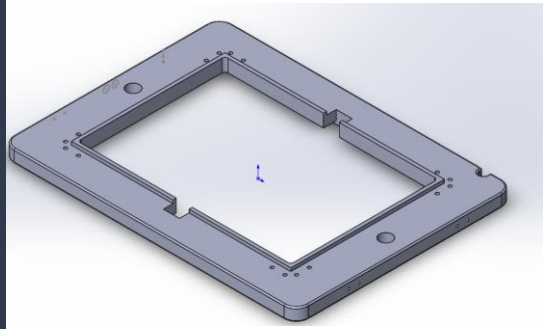
Weakness:

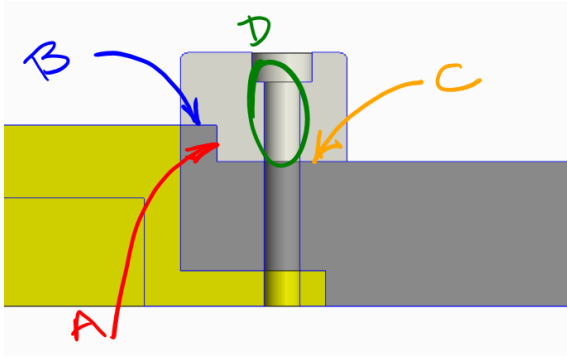
- Vacuum holes incorrect position
- Spring bias are large
- Datums too small





Design Iteration 2
Model 2



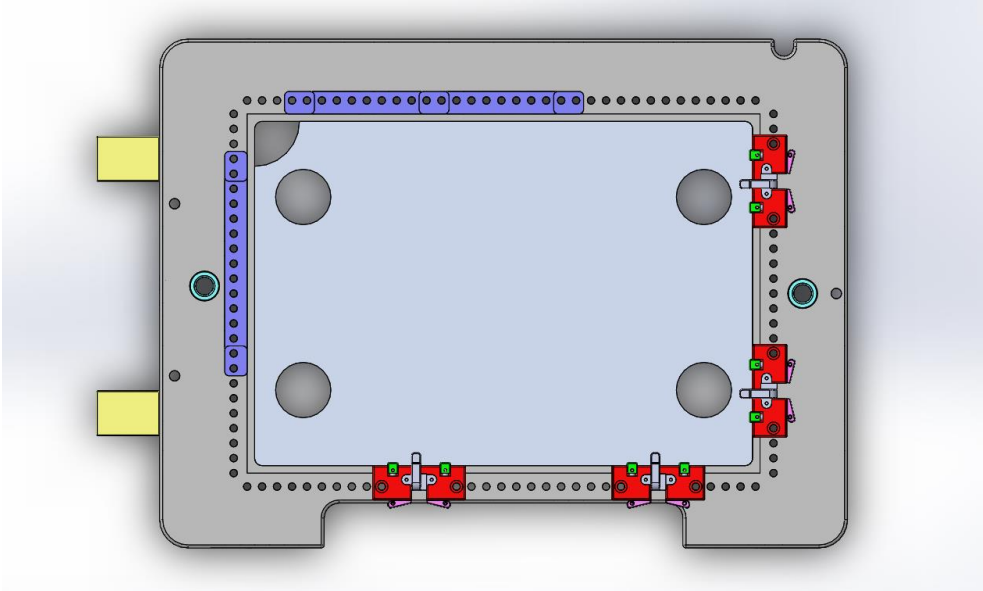


Strengths:

- Universitility
- Common datum
- Custom plate design per unit

Weaknesses:

- Tolerances between plate/frame/datums
- Higher cost due to custom plate



Consolidated Design

Consolidation of Designs

Moving Forward

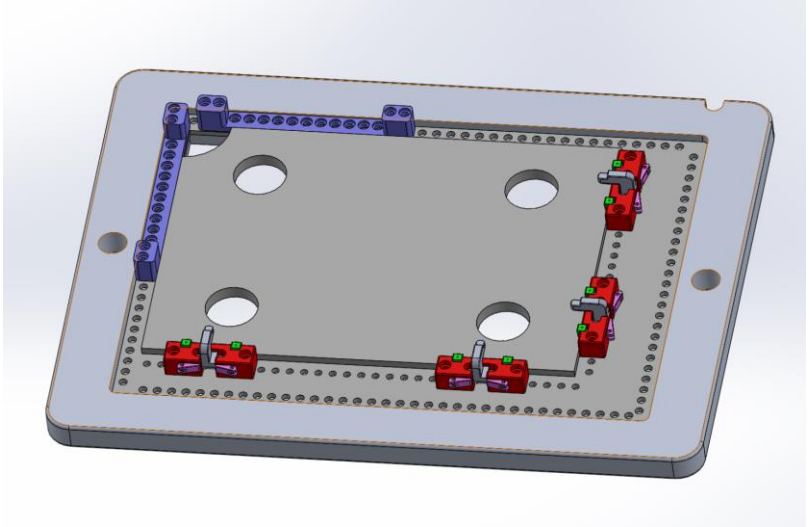
- Use custom plates
- Use flexible parts that can be used across all platforms
- Translational datums (same part for x and y axis)
- Less moving parts

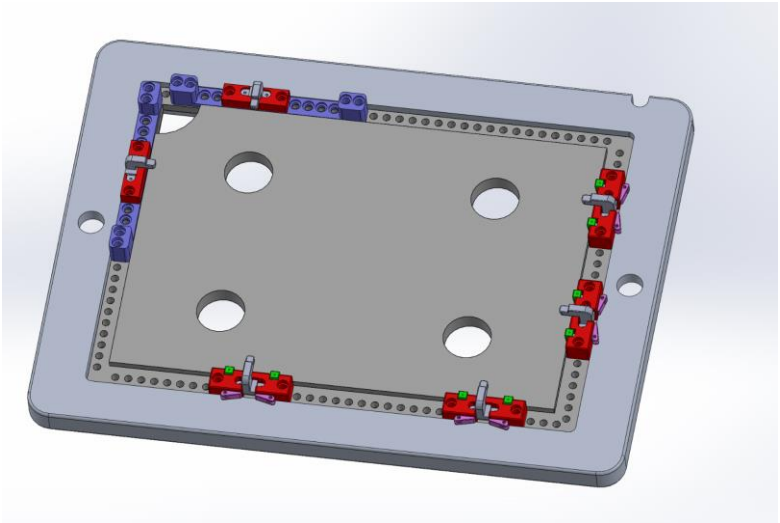
Trade off

- Cost
- Rigidity
- Ease of change

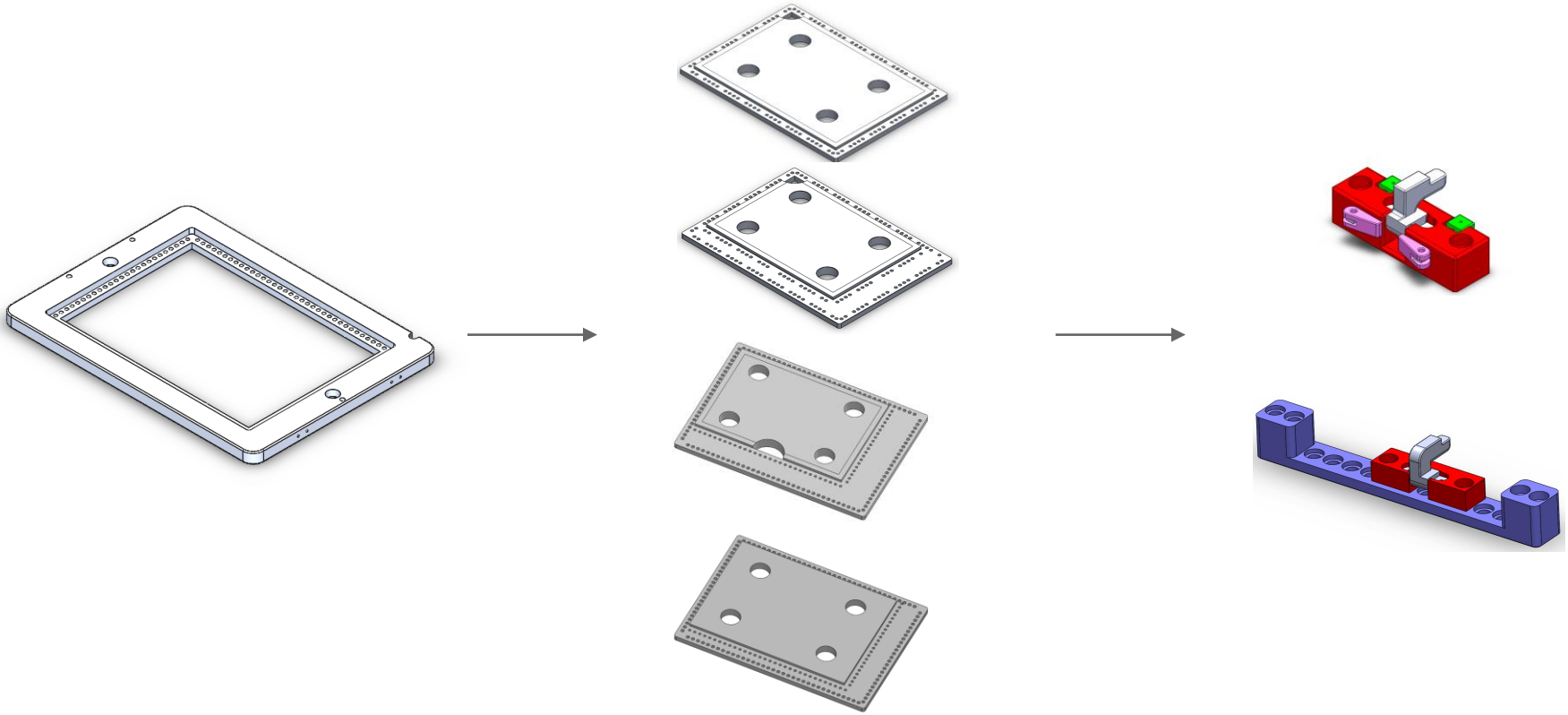
Design Concept

- Common Frame
  - Open frame with no support from crossbeams
- Threaded holes on frame, nut required for insert holes
- Four variations of insert plate
  - SB 15”, SB 13”, Pro, Laptop
- Translational datums
- Emphasis was placed on flexibility
- Limitations
  - More expensive
  - Less rigid

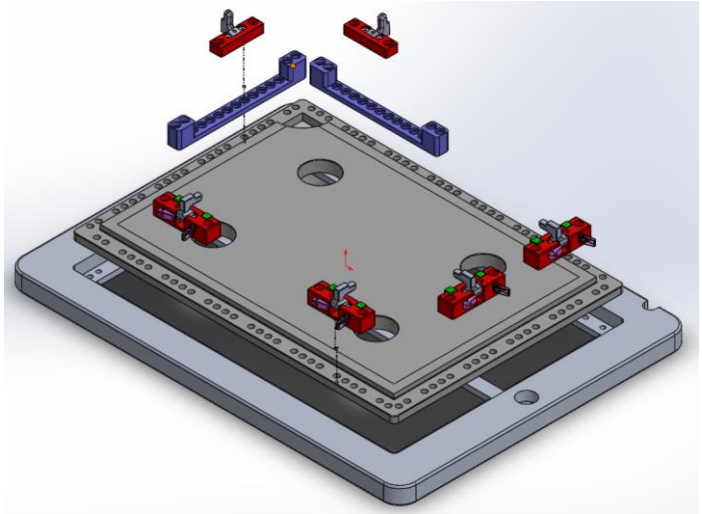




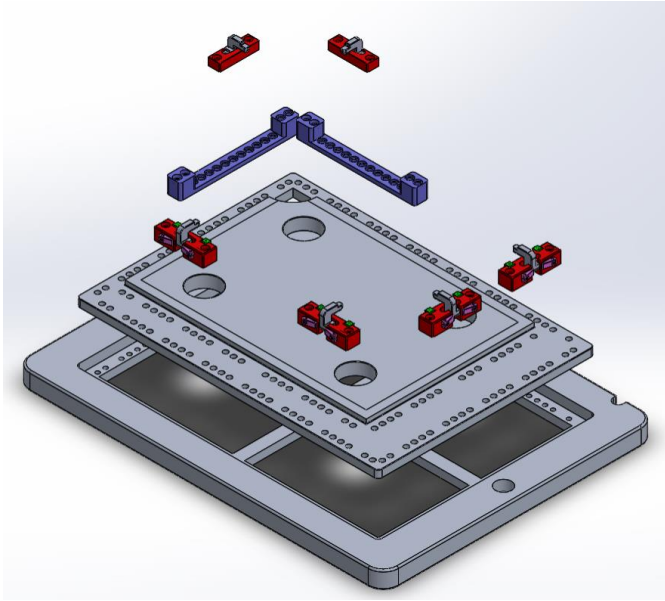
Design Concept – Combinations



Exploded View of Both Design Options

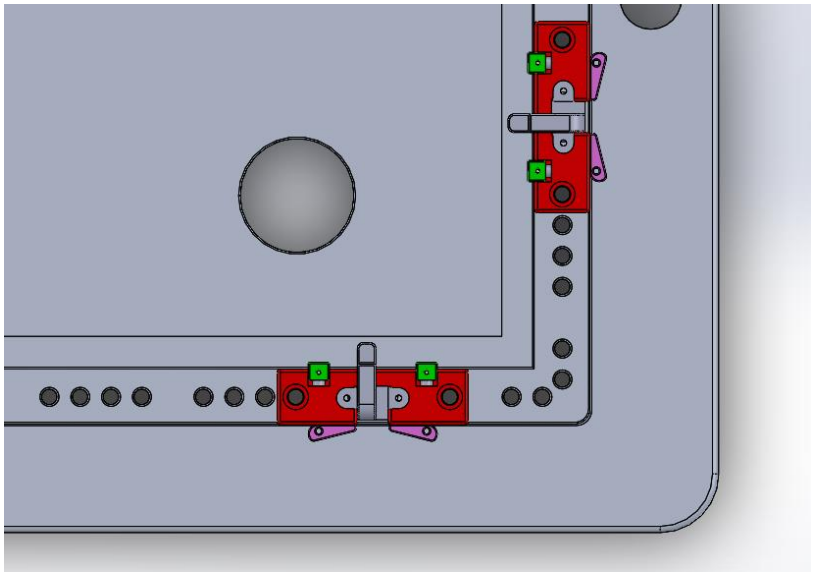


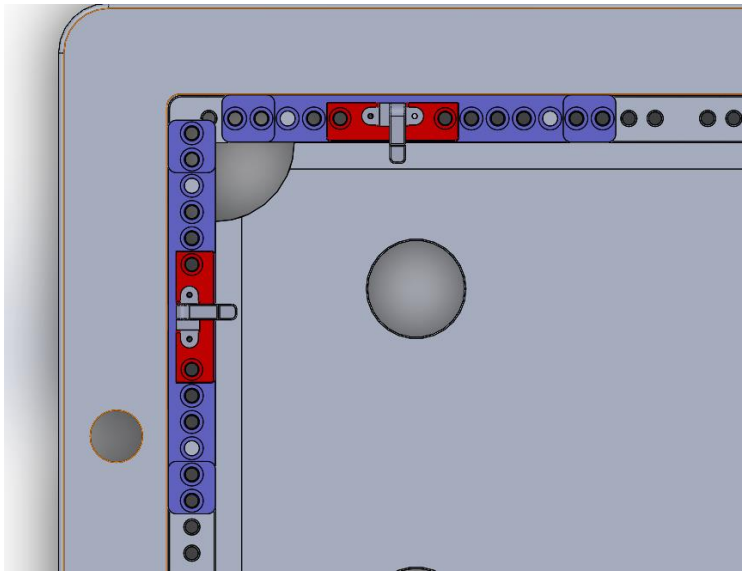
- Carrier frame
- Plate insert
- Datum (x2)
- Screen Holder (x2)
- Spring Bias (x4)



Universal Compatibility

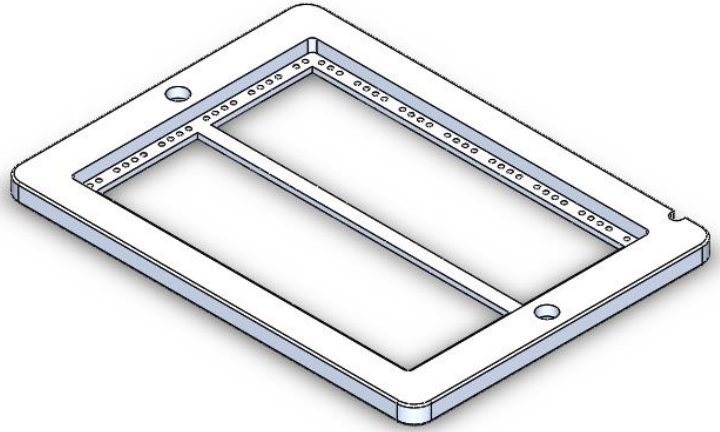
- Insert Plates have rotational symmetry and can rotate 180 degrees about the x-y axis if needed





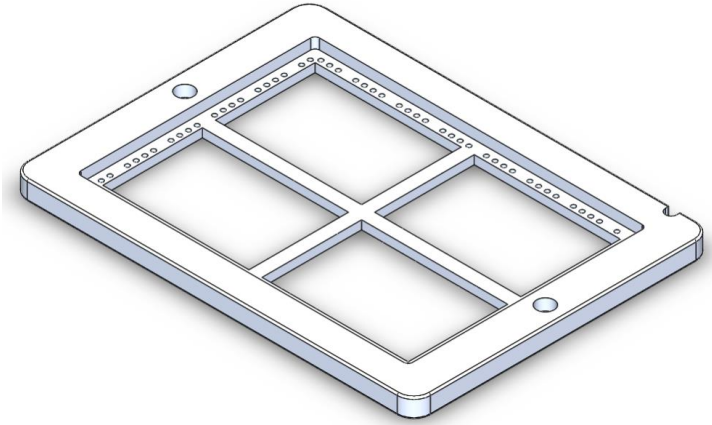
Components

Common Frame Options



Prototype 1

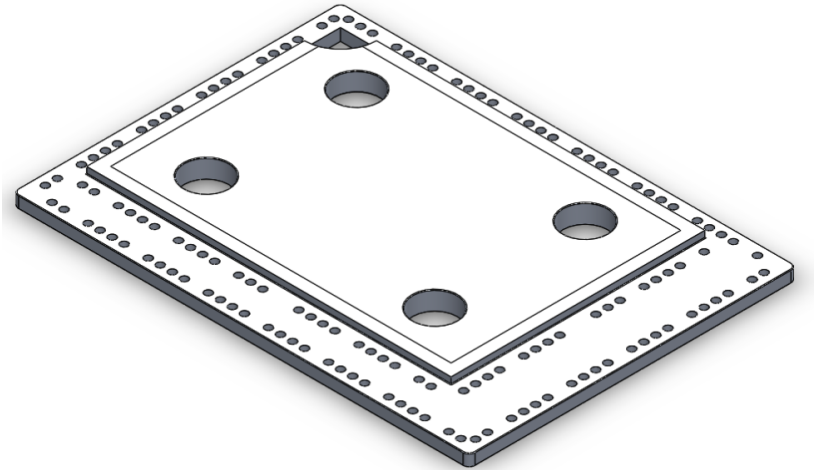
- Less machine time → Cheaper
- Larger Plate Deformation

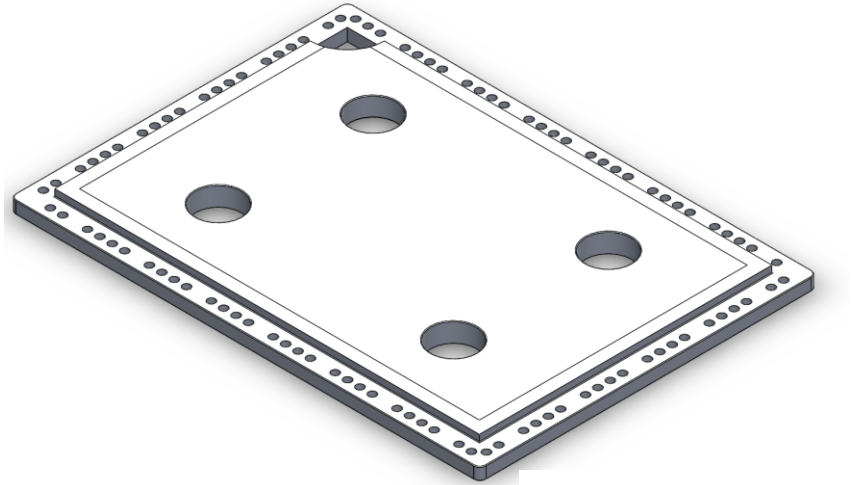


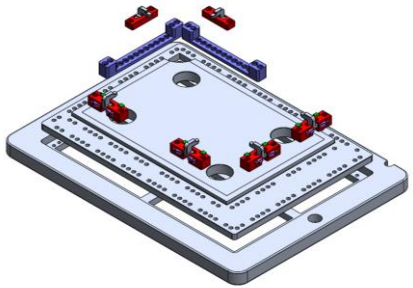
Prototype 2

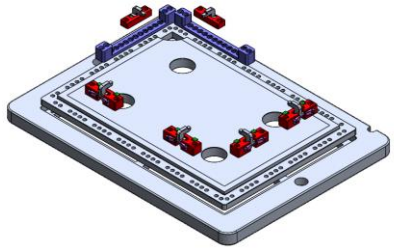
- Larger Pocket for Insert → Cost More
- Less insert deformation

Surface Book 13” and 15” Plate Inserts

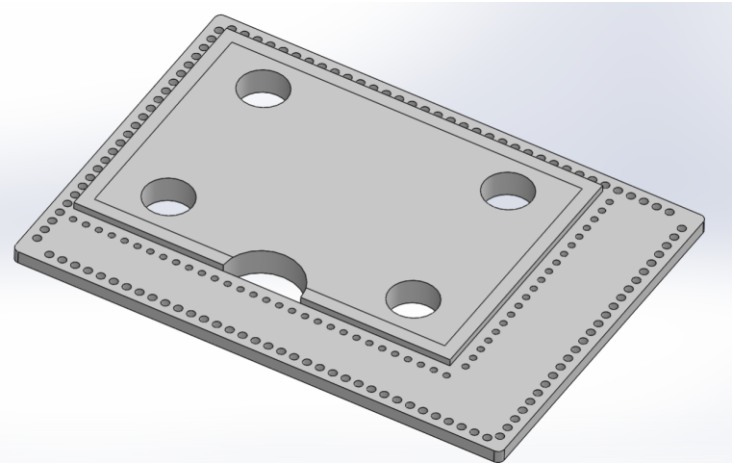




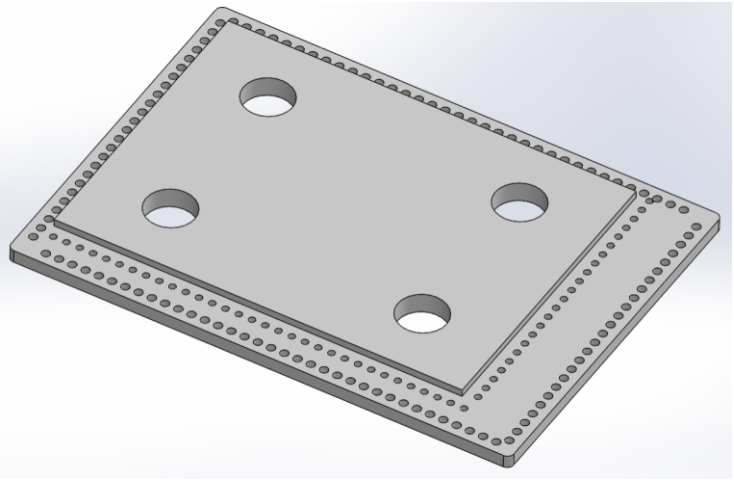




Surface Pro and Laptop Plate Insert

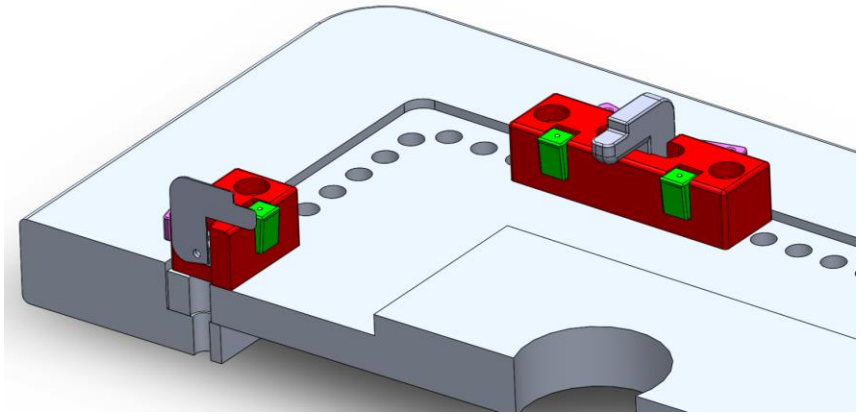


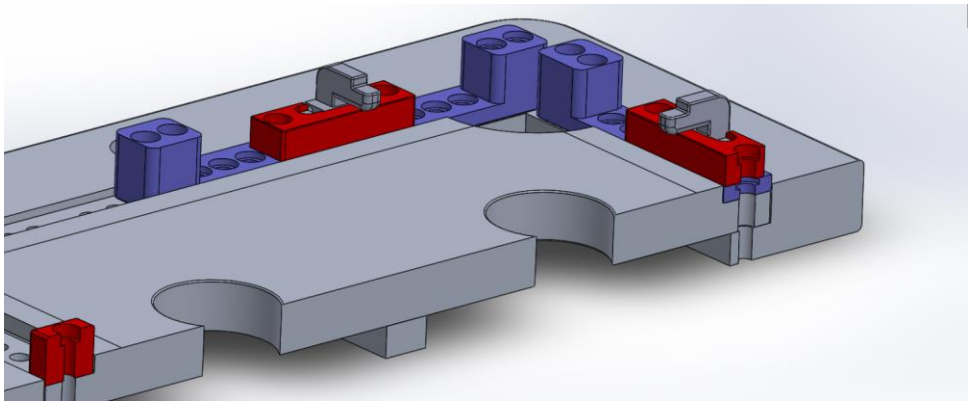
Surface Pro



Laptop

Screen Holder Assemblies



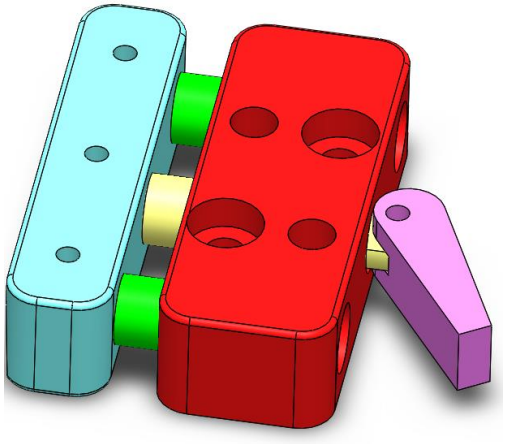


- M5 Screw
- 6.25 mm Diameter on plate
- 5.75 mm Diameter on datum bar
- 5.50 mm Diameter on screen holder

Spring Bias and Screen Holder Design

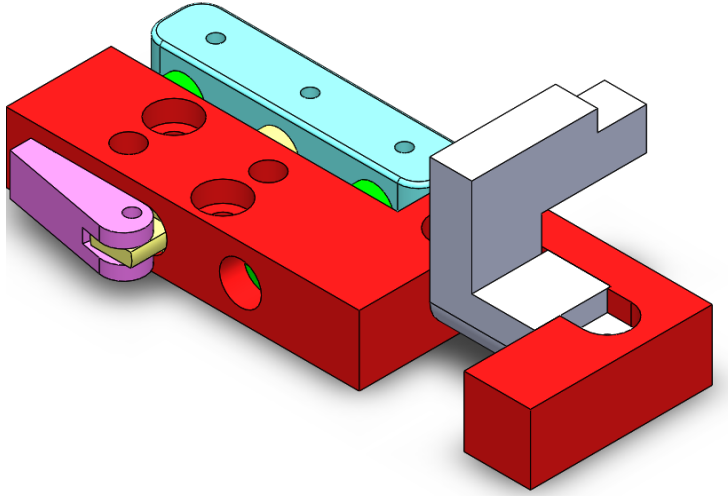
- Had to fulfill the requirements of the custom plate insert design for the carrier

- Initial model roughly reproduced one of the Microsoft Spring Biases
  - Separate screen holder
  - Too many rods and springs



Spring Bias and Screen Holder Design

- 2nd model combined 1st and screen holder to the side
  - Not space efficient
  - Non-symmetrical



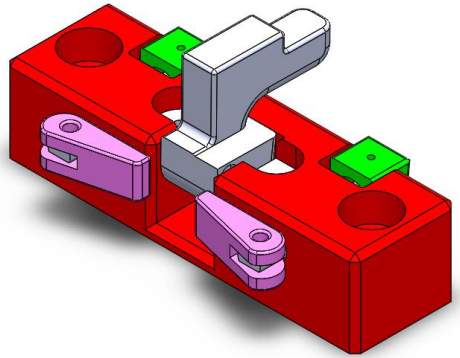
Spring Bias

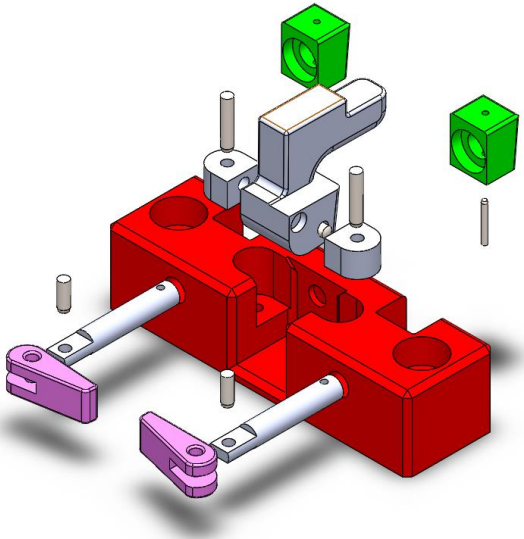
Pros:

- Interfaces with Insert Plate bolt pattern.
- Modular
- 100% commonality between product lines
- Combined bias and screen holder

Cons:

- Screen holder does not fully recede
- Requires custom plate to be slightly oversized



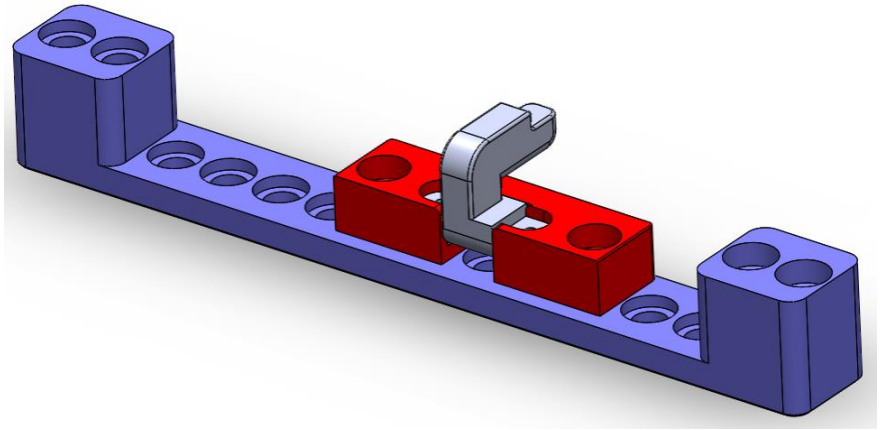


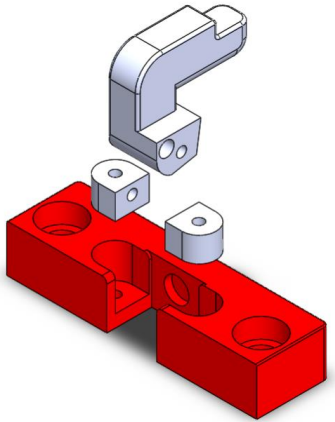
Datum Screen Holder

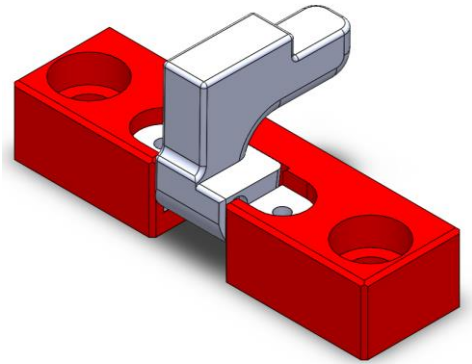
Assembly

Components:

- Core
- Screen holder mounts (x2)
- Screen holder
- Datum



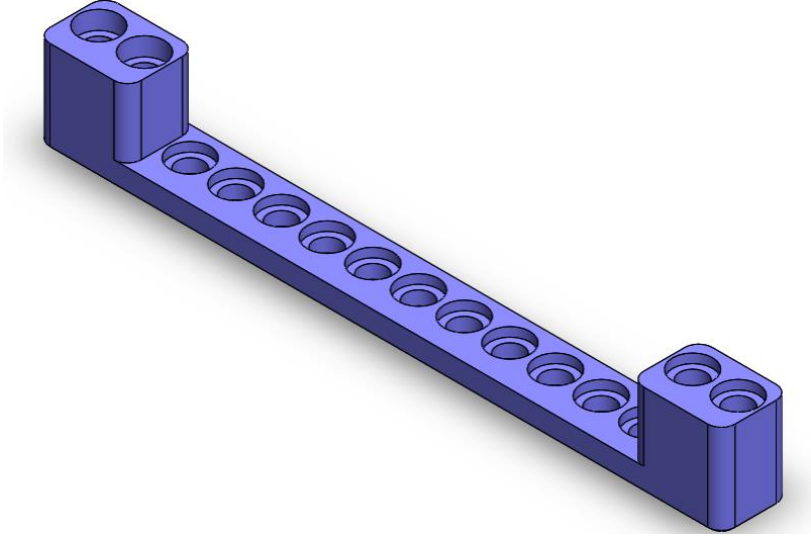


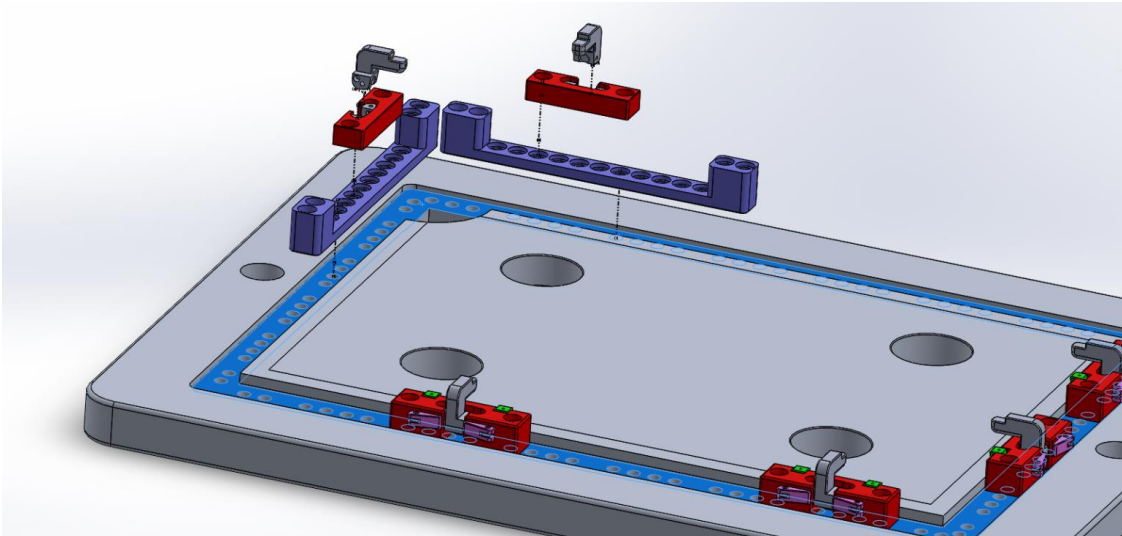


Datum Bar

Part
Function:

- To hold the datum screen holder
- Design and use identical in x and y directions
- Placeable anywhere along these axis





Materials and Machining Process

Part	Material	Process
Frame (# 1)	Aluminium	CNC Mill
Frame (# 2)	Aluminum	CNC Mill
13” Plate (# 1)	Delrin	CNC Mill
13” Plate (# 2)	Aluminum	CNC Mill
15” Plate (# 1)	Delrin	CNC Mill
15” Plate (# 2)	Aluminum	CNC Mill

Part	Material	Process
Pro Plate (# 1)	Delrin	CNC Mill
Pro Plate (# 2)	Aluminum	CNC Mill
Laptop Plate (# 1)	Delrin	CNC Mill
Laptop Plate (# 2)	Aluminum	CNC Mill
Screen Bias	PLA	3D printed
Datum screen holder	PLA	3D printed

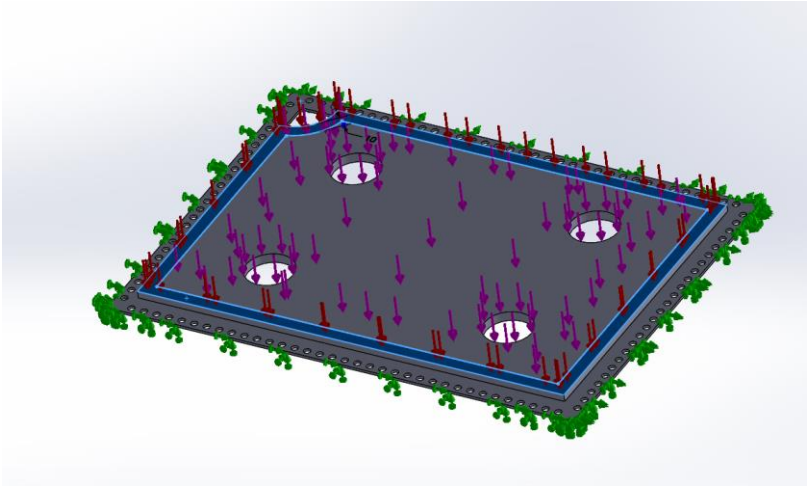
Materials and Machining Process

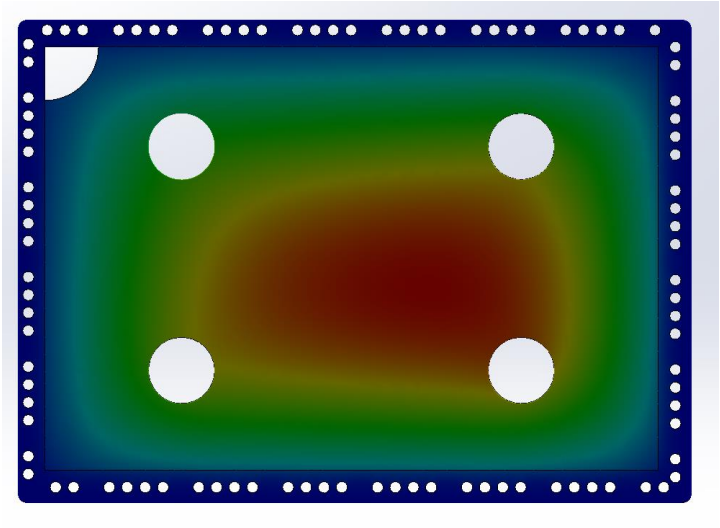
Part	Material	Process
Screen holder	PLA	3D printed
Datum	6061 T6 Aluminum	CNC Mill
Core (Bias/Datum)	6061 T6 Aluminum	CNC Mill
Mount	PLA	3D printed
Pad	PLA	Machiined
Bias Lever Corner	PLA	3D printed
Rod	12L14 Carbon Steel	Machined

Design Analysis

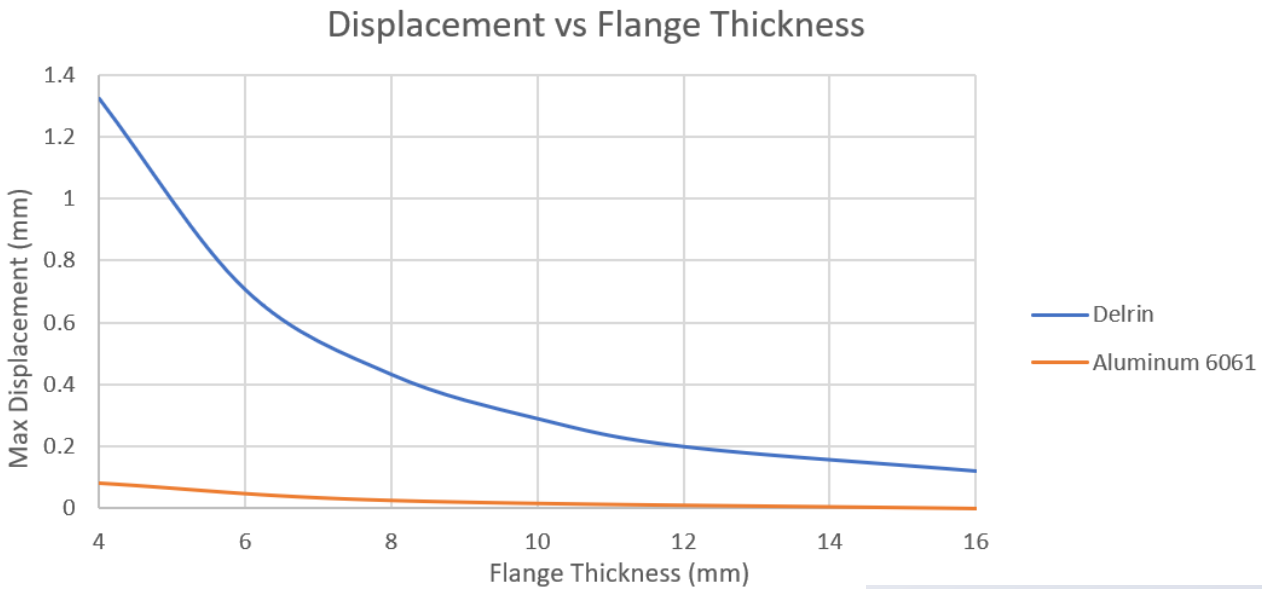
FEA of Plate Insert

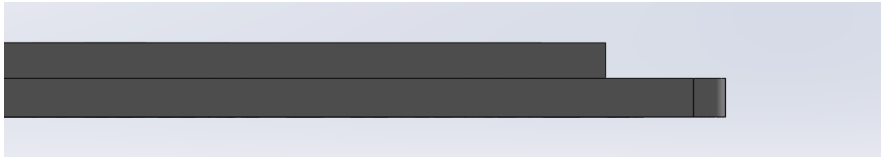
- Material: Delrin 500
- 60 PSI along top face to rep. bonding area
- Weight of Bucket uniformly distributed (~0.75 kg)
- Supported only by frame inner lip and crossbeam
- Max displacement of 1.25 mm





FEA - Displacement vs Insert Thickness





FEA - Insert for 15” SB

	Proto. 1 (Delrin)	10 mm Flange (Delrin)	Vert. CB 8mm (Delrin)	V. CB + 10mm (Delrin)	**Proto. 2** (Aluminum)
Plate	1.93 kg	2.23 kg	1.93 kg	2.23 kg	1.35 kg
Frame	3.62 kg	3.50 kg	3.69 kg	3.56 kg	3.56 kg
Tot. Weight	5.55 kg	5.73 kg	5.62 kg	5.79 kg	4.91 kg
Displacement	0.144 mm Max	0.0983mm Max	0.188 mm Max 0.093 mm Avg	0.165 mm Max 0.05 mm Avg	0.0927mm Max 0.05mm Avg

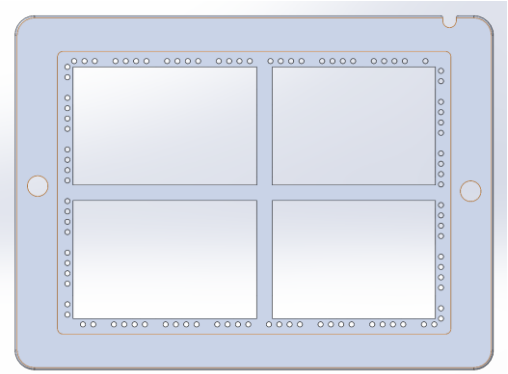
FEA - Insert 15’’

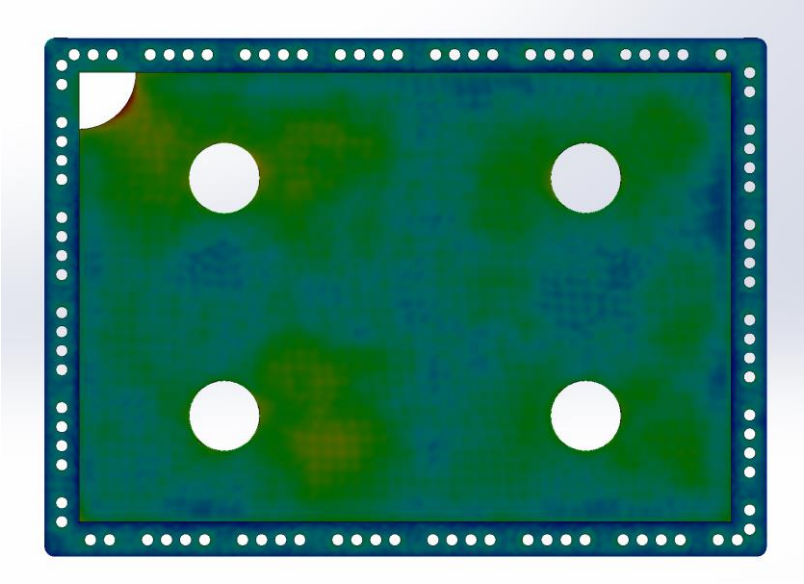
Prototype 1:

- 8 mm Flange with Frame Horizontal Crossbeam

Prototype 2 options:

- Flange increase to 10 mm.
- Added vertical crossbeam to frame.

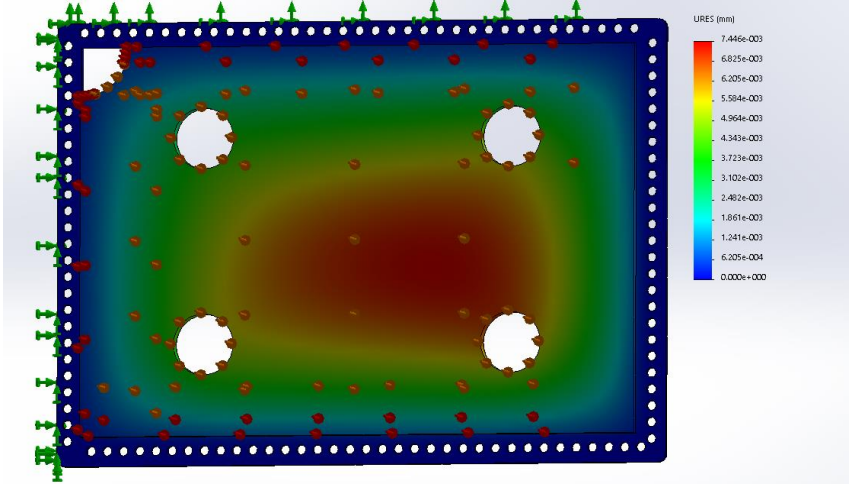




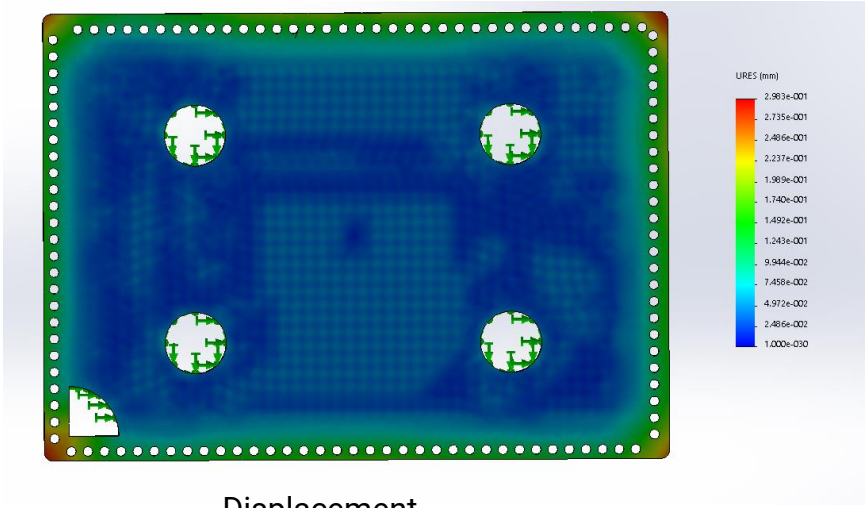
FEA for Proto. 2 w/ both crossbeams & 10mm flange

Thermal Analysis

	Delrin	Aluminum
Displacement	1.169 mm	0.007 mm
Thermal Expansion (100 C)	0.298 mm	.069mm
Cost	$39.37	$58.05



Stress



Displacement

Fatigue Analysis

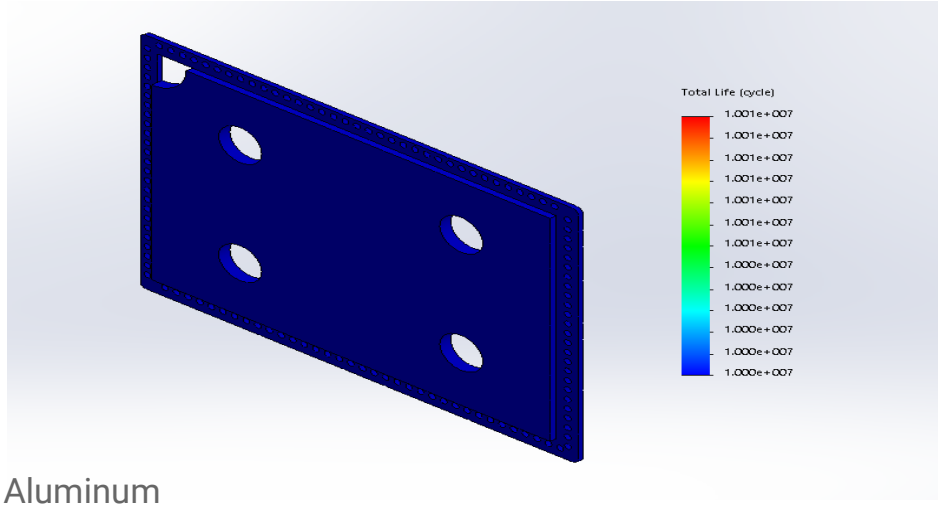
Delrin:

- Infinite fatigue life at 150 °C under given conditions

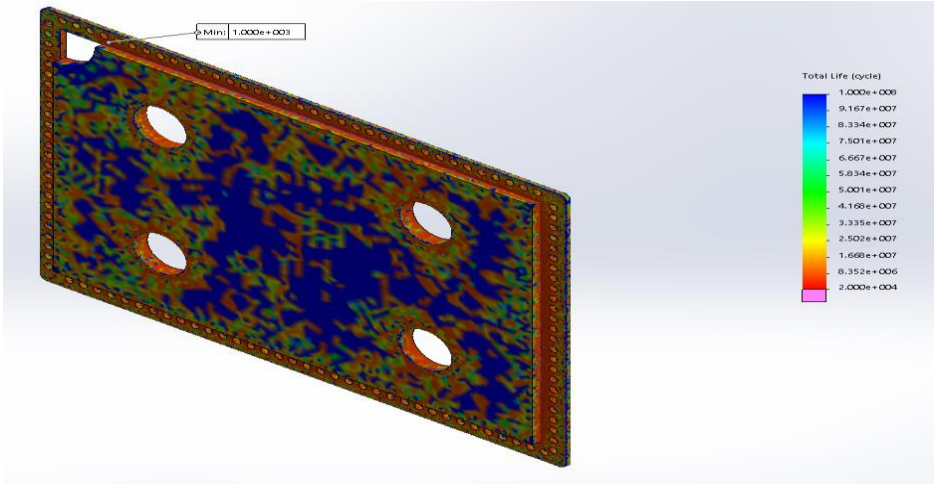
Aluminum:

- Max life of 100,000 cycles
- Minimum of 1,000 due to singularities and corners

Delrin

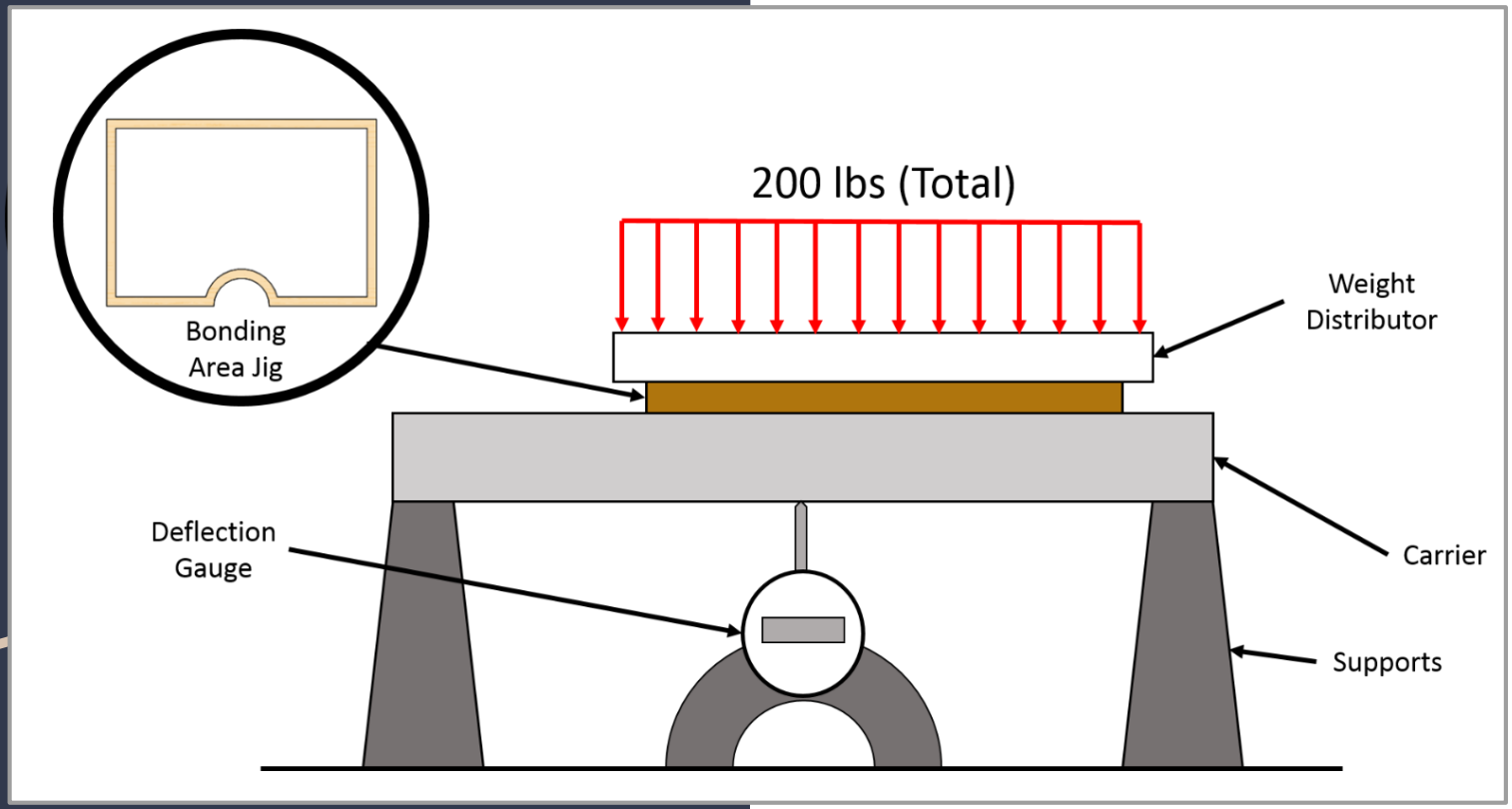


Aluminum



Validation Testing

Compression Test



Resultant Displacement

	Frame w/ Horizontal CB	Frame w/ Horizontal and Vertical CB
Surface Book 13”	0.219 mm	0.220 mm
Surface Pro	0.278 mm	0.269 mm

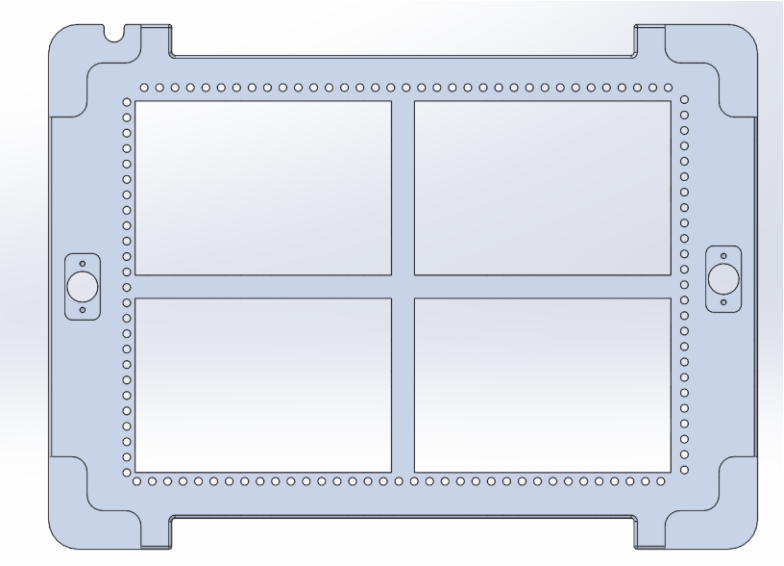
Project Review

Comparisons

Client Proposed Carrier Design	Prototype Carrier Designs
Budget: $600/carrier	$2,445
Weight: 5 kg	6.5-7 kg depending on frame/insert combination
10 minute changeover time	6-7 minutes
5 week fabrication lead time	Prototyped within 3 weeks

Possible Consideration

- Weight < 5 kg
- Honeycomb design?
- Material change (for tolerancing and weight difference)
- Threading the plate for all but 15 inch SB
- Injection molding of biases
- Less holes



Personal Experience

What we got out of this

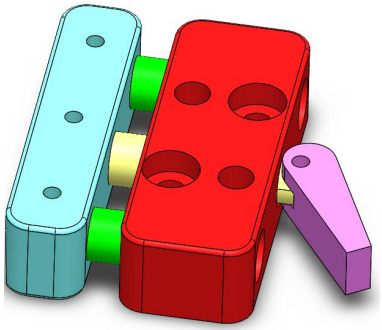
- Tolerancing and GD&T experience
- Analysis of design experience
- Manufacturing experience
- Project scheduling experience
- Engineering teamwork and work distribution
- Learned the importance of prototyping

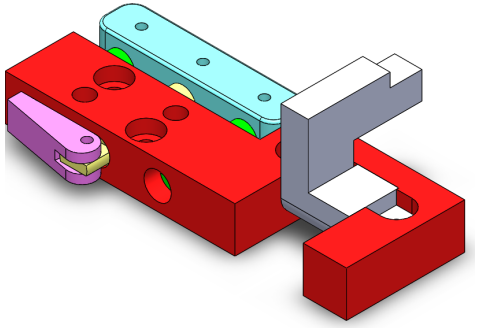
Appendix

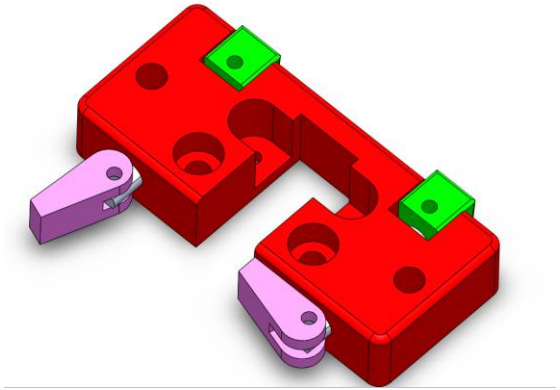
Additional materials for references and precision

Spring Bias and Screen Holder Design

- Had to fulfil the requirements of the custom plate insert design for the carrier
- Initial model roughly reproduced one of the Microsoft Spring Biases
  - Separate screen holder
  - Too many rods and springs
- 2nd model combined 1st and screen holder to the side
  - Not space efficient
  - Non-symmetrical
- 3rd model placed screen holder in the center.
  - Final design was based on it
  - Symmetrical
  - Smaller footprint



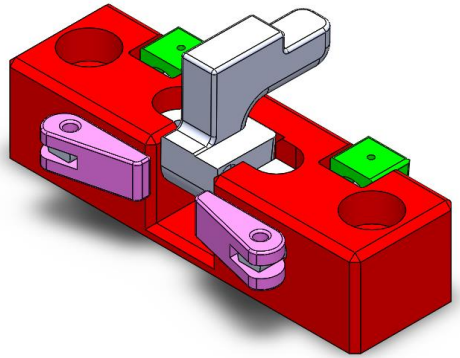


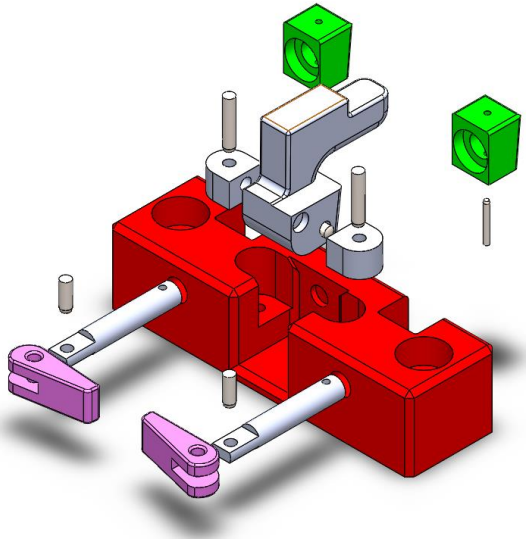


Spring Bias

Components

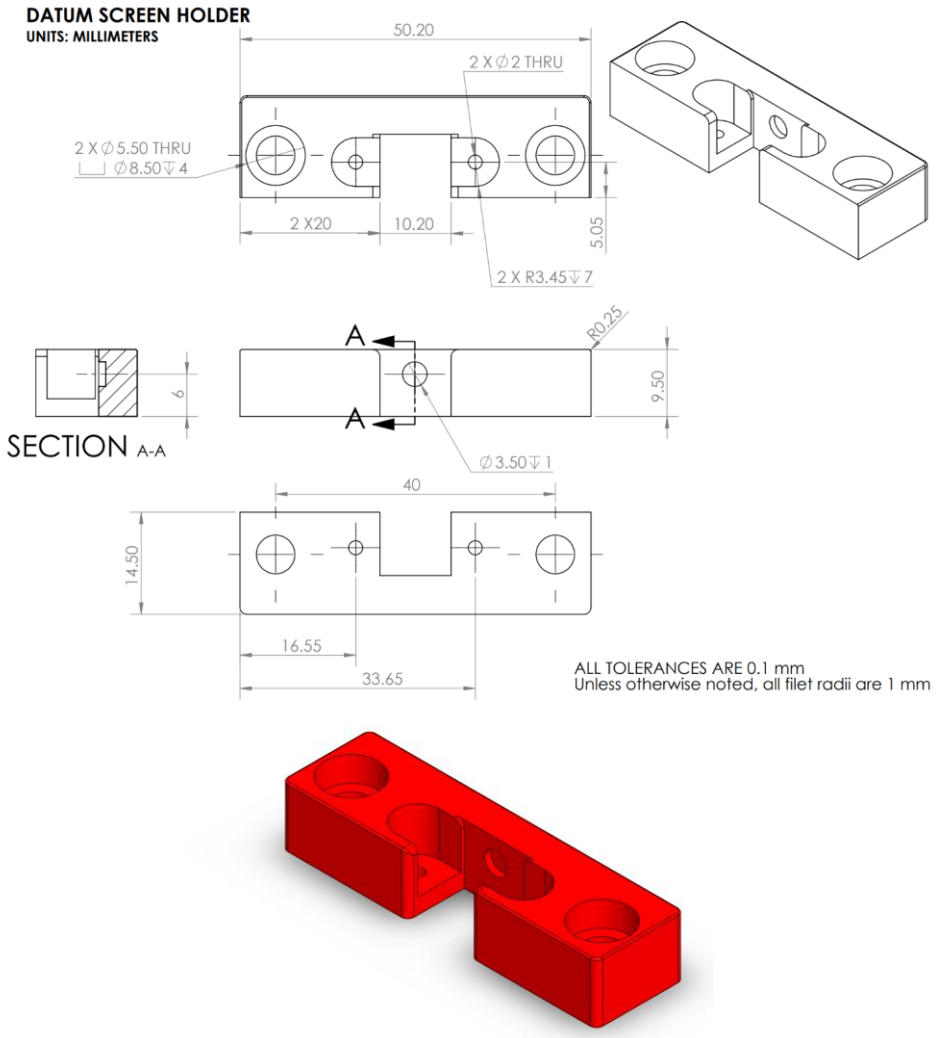
- Bias pad (x2)
- Bias lever (x2)
- Core
- Steel Push-rod (x2)
- Screen holder
- Screen holder mount (x2)
- 8mm x 1mm pin (x2)
- 6mm x 2mm pin (x4)
- 14mm x 2mm pin (x1)





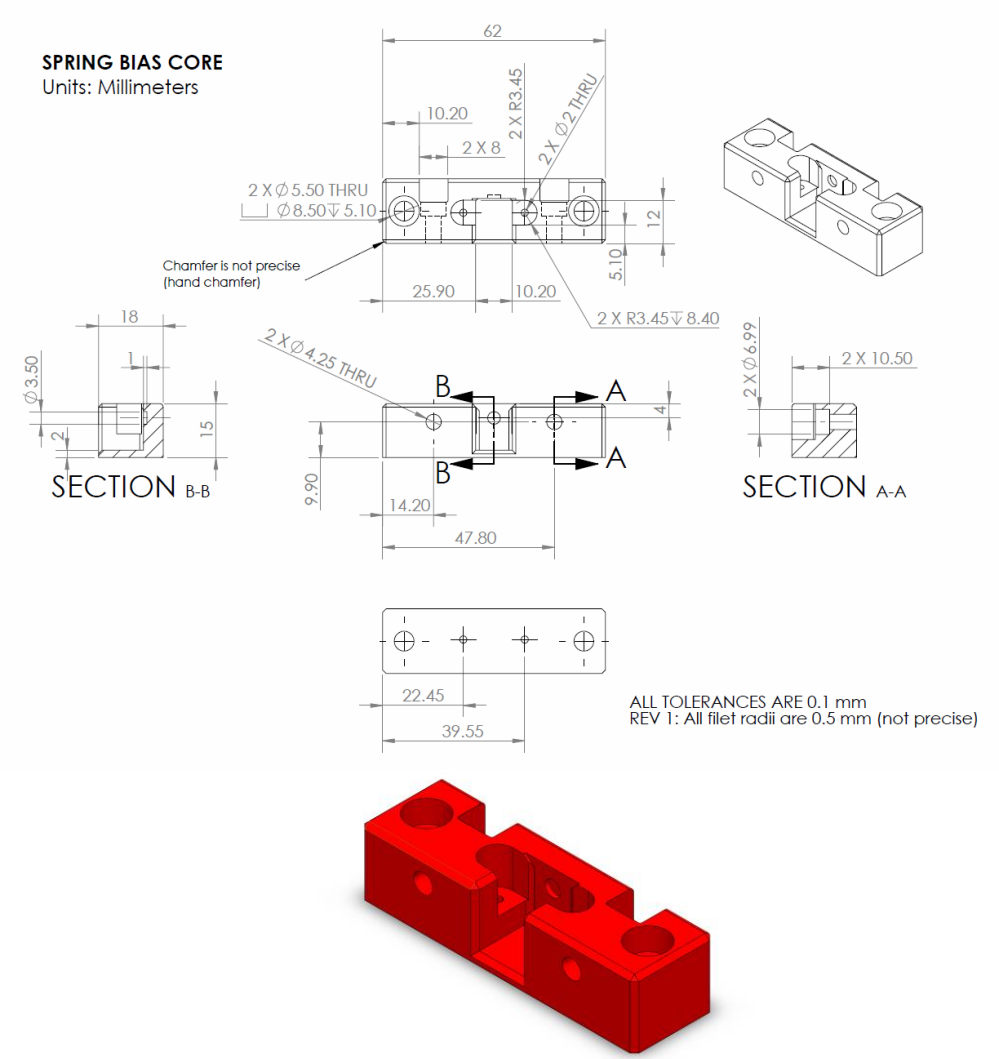
Core (Datum)

- Aluminum core for the Datum screen-holder



Core (Bias)

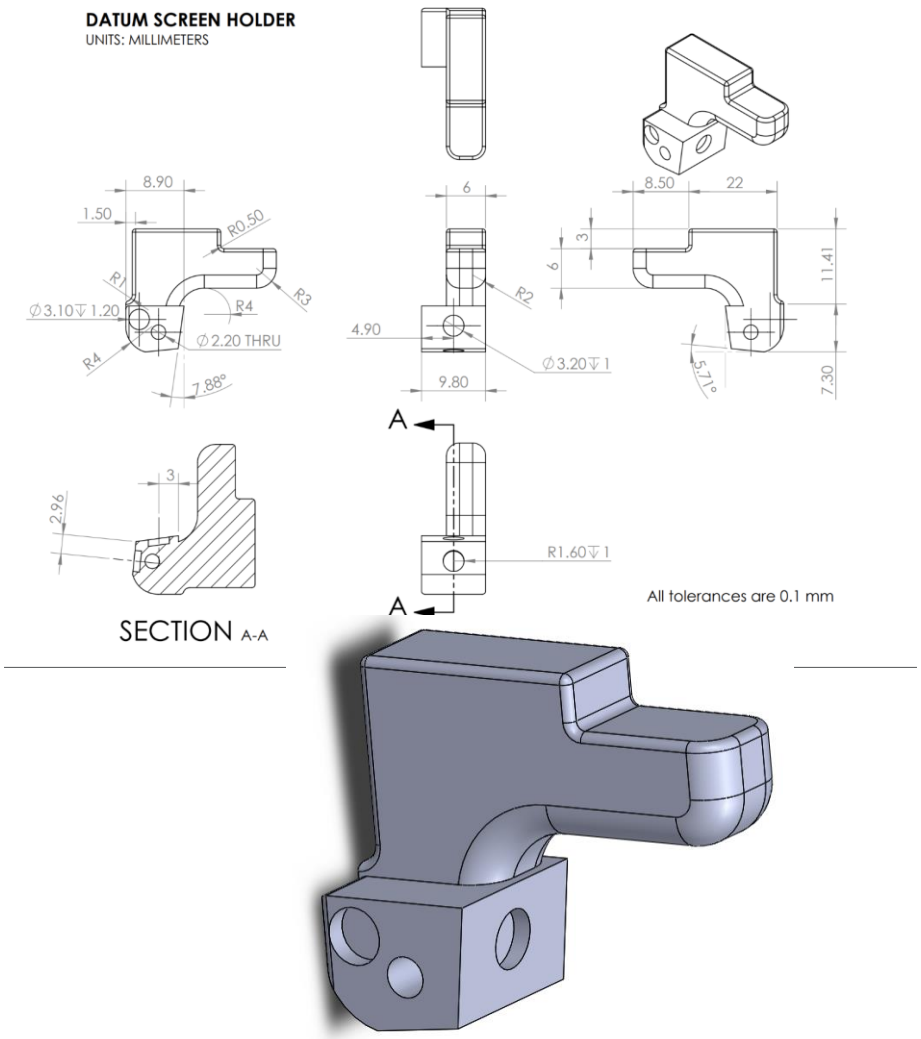
- Aluminum core for the spring bias



Screen holder (Datum)

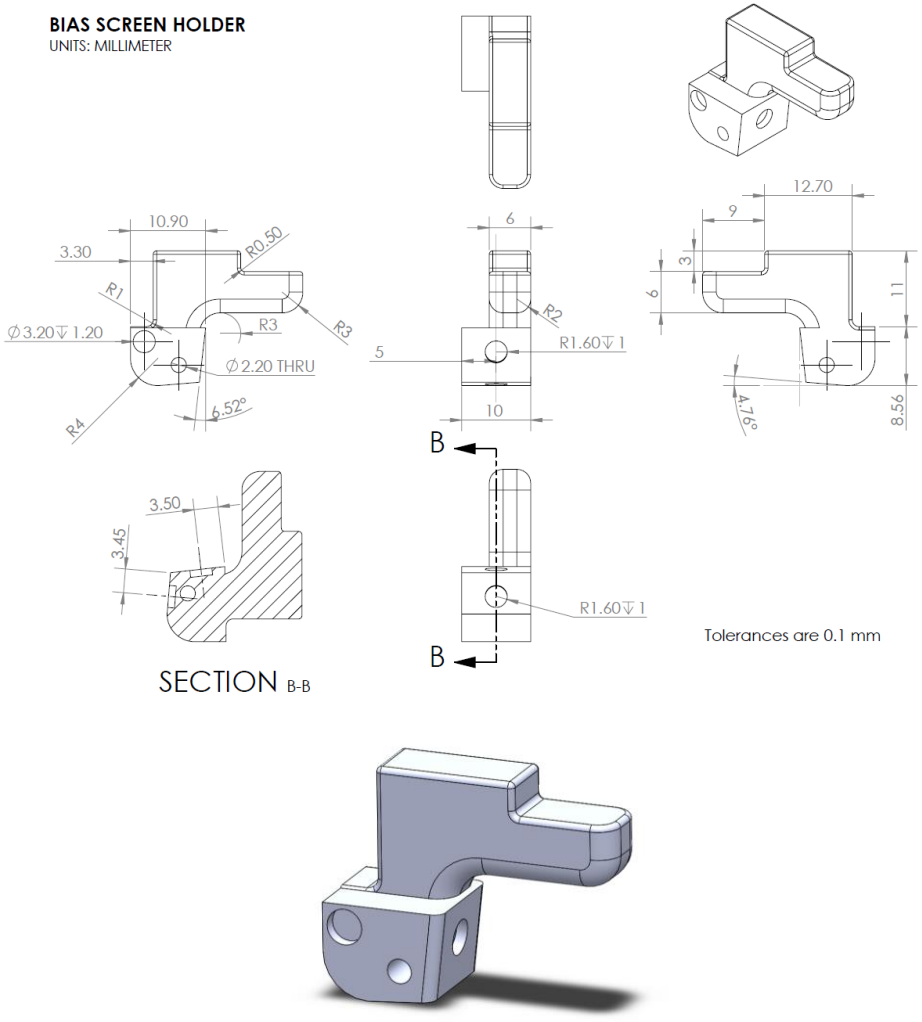
Part

- Used for the on datum screen holder assemblies
- Similar to bias version but shorter



Screen holder (Bias)

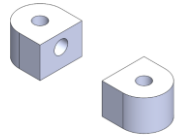
- Screen holder for the bias. Slightly taller than the datum version



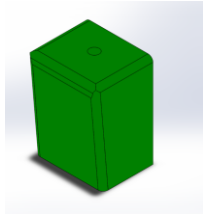
Additional Parts

- Common bias and datum screen holder parts

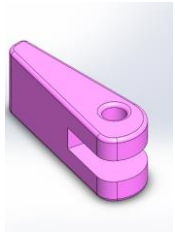
- Mounts
  - To hold screen holder



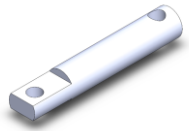
- Pad
  - Soft surface to avoid friction between screen holder and tablette



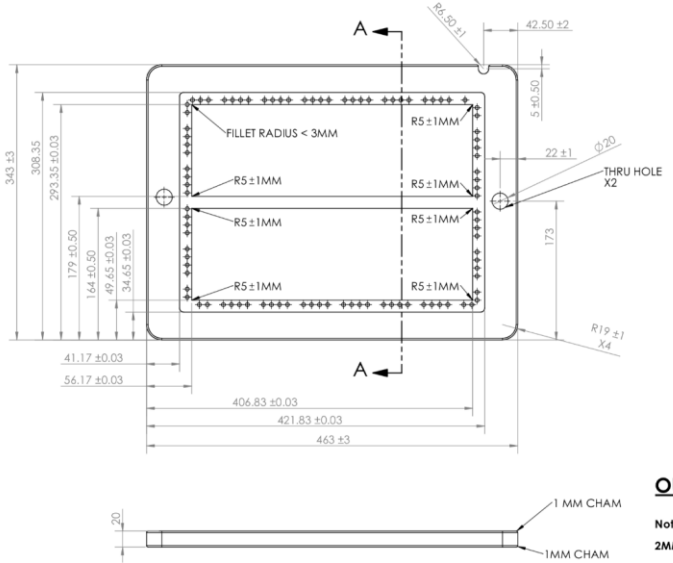
- Bias Lever
  - Used to compress the bias spring when device is unmounted

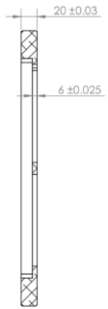


- Rod
  - Attaches between bias pad and lever. Surrounded by spring.



Frame Drawings





SECTION A-A
SCALE 1 : 3

OUTER FRAME 1

Notes:

2MM THINNER THAN OUTER FRAME 2

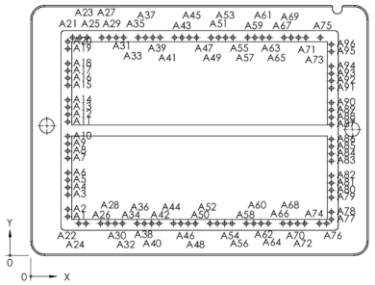
WATER JET FINISH IS OK ALONG OUTSIDE AND INNER PORCKETS IF MEETS TOLERANCE

TAG	X LOC	Y LOC	SIZE	TAG	X LOC	Y LOC	SIZE	TAG	X LOC	Y LOC	SIZE
A1	50.74	53.42	Ø5 ±0.05 THRU	A42	195.75	43.94	Ø5 ±0.05 THRU	A83	412.26	129.58	Ø5 ±0.05 THRU
A2	50.74	63.42	Ø5 ±0.05 THRU	A43	197.25	299.06	Ø5 ±0.05 THRU	A84	412.26	139.58	Ø5 ±0.05 THRU
A3	50.74	83.42	Ø5 ±0.05 THRU	A44	205.75	43.94	Ø5 ±0.05 THRU	A85	412.26	149.58	Ø5 ±0.05 THRU
A4	50.74	93.42	Ø5 ±0.05 THRU	A45	207.25	299.06	Ø5 ±0.05 THRU	A86	412.26	159.58	Ø5 ±0.05 THRU
A5	50.74	103.42	Ø5 ±0.05 THRU	A46	215.75	43.94	Ø5 ±0.05 THRU	A87	412.26	179.58	Ø5 ±0.05 THRU
A6	50.74	113.42	Ø5 ±0.05 THRU	A47	217.25	299.06	Ø5 ±0.05 THRU	A88	412.26	189.58	Ø5 ±0.05 THRU
A7	50.74	133.42	Ø5 ±0.05 THRU	A48	225.75	43.94	Ø5 ±0.05 THRU	A89	412.26	199.58	Ø5 ±0.05 THRU
A8	50.74	143.42	Ø5 ±0.05 THRU	A49	227.25	299.06	Ø5 ±0.05 THRU	A90	412.26	209.58	Ø5 ±0.05 THRU
A9	50.74	153.42	Ø5 ±0.05 THRU	A50	245.75	43.94	Ø5 ±0.05 THRU	A91	412.26	229.58	Ø5 ±0.05 THRU
A10	50.74	163.42	Ø5 ±0.05 THRU	A51	247.25	299.06	Ø5 ±0.05 THRU	A92	412.26	239.58	Ø5 ±0.05 THRU
A11	50.74	183.42	Ø5 ±0.05 THRU	A52	255.75	43.94	Ø5 ±0.05 THRU	A93	412.26	249.58	Ø5 ±0.05 THRU
A12	50.74	193.42	Ø5 ±0.05 THRU	A53	257.25	299.06	Ø5 ±0.05 THRU	A94	412.26	259.58	Ø5 ±0.05 THRU
A13	50.74	203.42	Ø5 ±0.05 THRU	A54	265.75	43.94	Ø5 ±0.05 THRU	A95	412.26	279.58	Ø5 ±0.05 THRU
A14	50.74	213.42	Ø5 ±0.05 THRU	A55	267.25	299.06	Ø5 ±0.05 THRU	A96	412.26	289.58	Ø5 ±0.05 THRU
A15	50.74	233.42	Ø5 ±0.05 THRU	A56	275.75	43.94	Ø5 ±0.05 THRU				
A16	50.74	243.42	Ø5 ±0.05 THRU	A57	277.25	299.06	Ø5 ±0.05 THRU				
A17	50.74	253.42	Ø5 ±0.05 THRU	A58	295.75	43.94	Ø5 ±0.05 THRU				
A18	50.74	263.42	Ø5 ±0.05 THRU	A59	297.25	299.06	Ø5 ±0.05 THRU				
A19	50.74	283.42	Ø5 ±0.05 THRU	A60	305.75	43.94	Ø5 ±0.05 THRU				
A20	50.74	293.42	Ø5 ±0.05 THRU	A61	307.25	299.06	Ø5 ±0.05 THRU				
A21	57.25	299.06	Ø5 ±0.05 THRU	A62	315.75	43.94	Ø5 ±0.05 THRU				
A22	65.75	43.94	Ø5 ±0.05 THRU	A63	317.25	299.06	Ø5 ±0.05 THRU				
A23	67.25	299.06	Ø5 ±0.05 THRU	A64	325.75	43.94	Ø5 ±0.05 THRU				
A24	75.75	43.94	Ø5 ±0.05 THRU	A65	327.25	299.06	Ø5 ±0.05 THRU				
A25	77.25	299.06	Ø5 ±0.05 THRU	A66	345.75	43.94	Ø5 ±0.05 THRU				
A26	95.75	43.94	Ø5 ±0.05 THRU	A67	347.25	299.06	Ø5 ±0.05 THRU				
A27	97.25	299.06	Ø5 ±0.05 THRU	A68	355.75	43.94	Ø5 ±0.05 THRU				
A28	105.75	43.94	Ø5 ±0.05 THRU	A69	357.25	299.06	Ø5 ±0.05 THRU				
A29	107.25	299.06	Ø5 ±0.05 THRU	A70	365.75	43.94	Ø5 ±0.05 THRU				
A30	115.75	43.94	Ø5 ±0.05 THRU	A71	367.25	299.06	Ø5 ±0.05 THRU				
A31	117.25	299.06	Ø5 ±0.05 THRU	A72	375.75	43.94	Ø5 ±0.05 THRU				
A32	125.75	43.94	Ø5 ±0.05 THRU	A73	377.25	299.06	Ø5 ±0.05 THRU				
A33	127.25	299.06	Ø5 ±0.05 THRU	A74	395.75	43.94	Ø5 ±0.05 THRU				
A34	145.75	43.94	Ø5 ±0.05 THRU	A75	397.25	299.06	Ø5 ±0.05 THRU				
A35	147.25	299.06	Ø5 ±0.05 THRU	A76	405.75	43.94	Ø5 ±0.05 THRU				
A36	155.75	43.94	Ø5 ±0.05 THRU	A77	412.26	49.58	Ø5 ±0.05 THRU				
A37	157.25	299.06	Ø5 ±0.05 THRU	A78	412.26	59.58	Ø5 ±0.05 THRU				
A38	165.75	43.94	Ø5 ±0.05 THRU	A79	412.26	79.58	Ø5 ±0.05 THRU				
A39	167.25	299.06	Ø5 ±0.05 THRU	A80	412.26	89.58	Ø5 ±0.05 THRU				
A40	175.75	43.94	Ø5 ±0.05 THRU	A81	412.26	99.58	Ø5 ±0.05 THRU				
A41	177.25	299.06	Ø5 ±0.05 THRU	A82	412.26	109.58	Ø5 ±0.05 THRU				

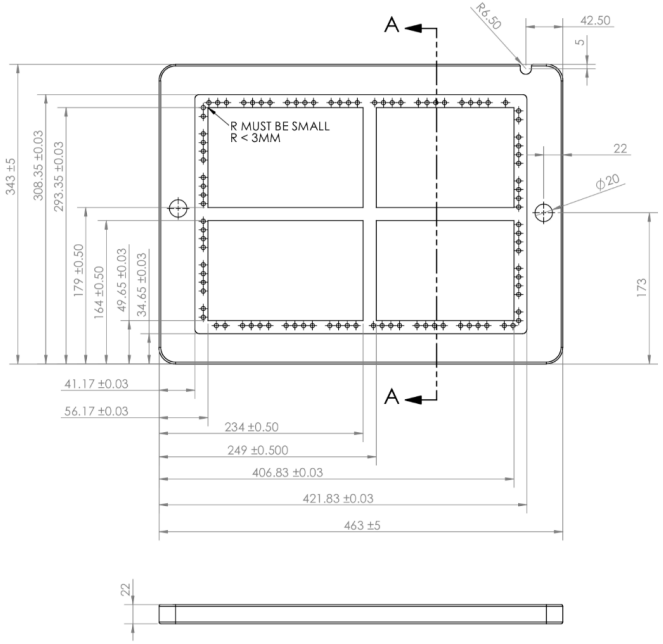
MICROSOFT COMMON CARRIER FRAME V7 HOLE PATTERN

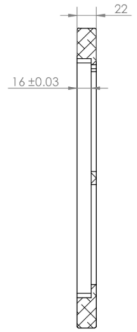
UNITS: MM
ALL TOLERANCES ARE ±0.05MM
ALL HOLES ARE THRU AND WILL BE M5 TAPPED

HOLES ARE POSITIONED INDEPENDENTLY TO AVOID TOLERANCE STACKING



Frame Drawings (Iteration 2)





SECTION A-A
SCALE 1 : 3

OUTER FRAME 2

Notes:

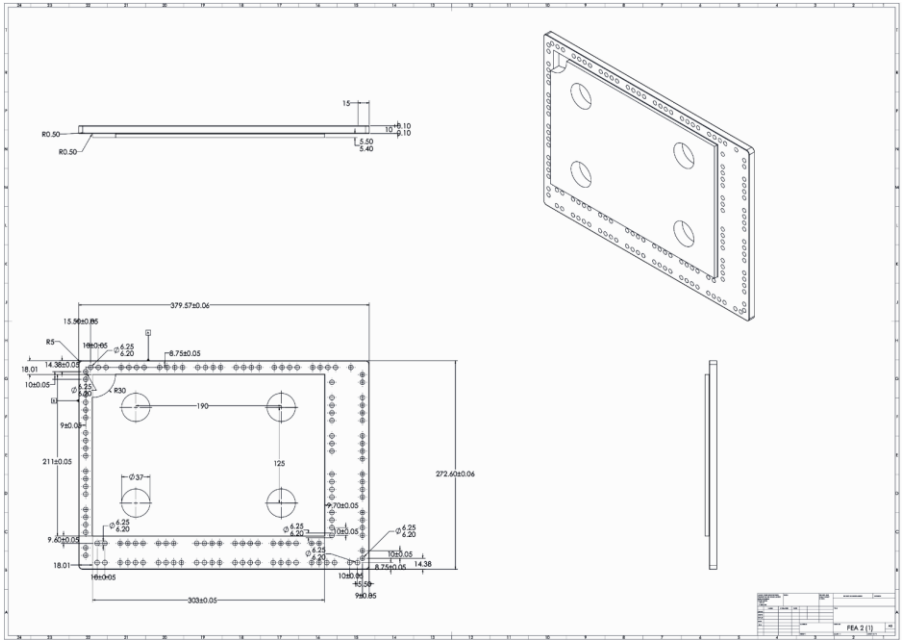
2MM THICKER THAN OUTER FRAME 1

HOLES ARE POSITIONED IDENTICAL TO OUTER FRAME 1

WATER JET FINISH IS OK ALONG OUTSIDE AND INNER PORCKETS IF MEETS TOLERANCE

BOTTOM FACE SAME AS OUTER 1 WITH POCKETS

Plate Insert 13”



TAG	X LOC	Y LOC	SIZE
A1	9	18.22	Ø6.20 THRU
A2	9	28.22	Ø6.20 THRU
A3	9	48.22	Ø6.20 THRU
A4	9	58.22	Ø6.20 THRU
A5	9	68.22	Ø6.20 THRU
A6	9	78.22	Ø6.20 THRU
A7	9	98.22	Ø6.20 THRU
A8	9	108.22	Ø6.20 THRU
A9	9	118.22	Ø6.20 THRU
A10	9	128.22	Ø6.20 THRU
A11	9	148.22	Ø6.20 THRU
A12	9	158.22	Ø6.20 THRU
A13	9	168.22	Ø6.20 THRU
A14	9	178.22	Ø6.20 THRU
A15	9	198.22	Ø6.20 THRU
A16	9	208.22	Ø6.20 THRU
A17	9	218.22	Ø6.20 THRU
A18	9	228.22	Ø6.20 THRU
A19	9	248.22	Ø6.20 THRU
A20	24.07	8.75	Ø6.20 THRU
A21	25.50	263.85	Ø6.20 THRU
A22	34.07	8.75	Ø6.20 THRU
A23	35.50	263.85	Ø6.20 THRU
A24	54.07	8.75	Ø6.20 THRU
A25	55.50	263.85	Ø6.20 THRU
A26	64.07	8.75	Ø6.20 THRU
A27	65.50	263.85	Ø6.20 THRU
A28	74.07	8.75	Ø6.20 THRU
A29	75.50	263.85	Ø6.20 THRU
A30	84.07	8.75	Ø6.20 THRU
A31	85.50	263.85	Ø6.20 THRU
A32	104.07	8.75	Ø6.20 THRU
A33	105.50	263.85	Ø6.20 THRU
A34	114.07	8.75	Ø6.20 THRU
A35	115.50	263.85	Ø6.20 THRU
A36	124.07	8.75	Ø6.20 THRU
A37	125.50	263.85	Ø6.20 THRU
A38	134.07	8.75	Ø6.20 THRU
A39	135.50	263.85	Ø6.20 THRU
A40	154.07	8.75	Ø6.20 THRU
A41	155.50	263.85	Ø6.20 THRU
A42	164.07	8.75	Ø6.20 THRU
A43	165.50	263.85	Ø6.20 THRU
A44	174.07	8.75	Ø6.20 THRU
A45	175.50	263.85	Ø6.20 THRU
A46	184.07	8.75	Ø6.20 THRU
A47	185.50	263.85	Ø6.20 THRU
A48	204.07	8.75	Ø6.20 THRU
A49	205.50	263.85	Ø6.20 THRU
A50	214.07	8.75	Ø6.20 THRU
A51	215.50	263.85	Ø6.20 THRU
A52	224.07	8.75	Ø6.20 THRU
A53	225.50	263.85	Ø6.20 THRU
A54	234.07	8.75	Ø6.20 THRU
A55	235.50	263.85	Ø6.20 THRU
A56	254.07	8.75	Ø6.20 THRU
A57	255.50	263.85	Ø6.20 THRU
A58	264.07	8.75	Ø6.20 THRU
A59	265.50	263.85	Ø6.20 THRU
A60	274.07	8.75	Ø6.20 THRU
A61	275.50	263.85	Ø6.20 THRU
A62	284.07	8.75	Ø6.20 THRU
A63	285.50	263.85	Ø6.20 THRU
A64	304.07	8.75	Ø6.20 THRU
A65	305.50	263.85	Ø6.20 THRU
A66	314.07	8.75	Ø6.20 THRU
A67	315.50	263.85	Ø6.20 THRU
A68	324.07	8.75	Ø6.20 THRU
A69	325.50	263.85	Ø6.20 THRU
A70	334.07	8.75	Ø6.20 THRU
A71	335.50	263.85	Ø6.20 THRU
A72	354.07	8.75	Ø6.20 THRU
A73	355.50	263.85	Ø6.20 THRU
A74	370.57	24.38	Ø6.20 THRU
A75	370.57	44.38	Ø6.20 THRU
A76	370.57	54.38	Ø6.20 THRU
A77	370.57	64.38	Ø6.20 THRU
A78	370.57	74.38	Ø6.20 THRU
A79	370.57	94.38	Ø6.20 THRU
A80	370.57	104.38	Ø6.20 THRU
A81	370.57	114.38	Ø6.20 THRU
A82	370.57	124.38	Ø6.20 THRU
A83	370.57	144.38	Ø6.20 THRU
A84	370.57	154.38	Ø6.20 THRU
A85	370.57	164.38	Ø6.20 THRU
A86	370.57	174.38	Ø6.20 THRU
A87	370.57	194.38	Ø6.20 THRU
A88	370.57	204.38	Ø6.20 THRU
A89	370.57	214.38	Ø6.20 THRU
A90	370.57	224.38	Ø6.20 THRU
A91	370.57	244.38	Ø6.20 THRU
A92	370.57	254.38	Ø6.20 THRU
B1	9	258.22	Ø6.25 Ø6.20 THRU
B2	15.50	263.85	Ø6.25 Ø6.20 THRU
B3	24.07	33.99	Ø6.25 Ø6.20 THRU
B4	34.07	33.99	Ø6.25 Ø6.20 THRU
B5	54.07	33.99	Ø6.25 Ø6.20 THRU
B6	64.07	33.99	Ø6.25 Ø6.20 THRU
B7	74.07	33.99	Ø6.25 Ø6.20 THRU
B8	84.07	33.99	Ø6.25 Ø6.20 THRU
B9	104.07	33.99	Ø6.25 Ø6.20 THRU
B10	114.07	33.99	Ø6.25 Ø6.20 THRU
B11	124.07	33.99	Ø6.25 Ø6.20 THRU
B12	154.07	33.99	Ø6.25 Ø6.20 THRU
B13	164.07	33.99	Ø6.25 Ø6.20 THRU
B14	174.07	33.99	Ø6.25 Ø6.20 THRU
B15	184.07	33.99	Ø6.25 Ø6.20 THRU
B16	204.07	33.99	Ø6.25 Ø6.20 THRU
B17	214.07	33.99	Ø6.25 Ø6.20 THRU
B18	224.07	33.99	Ø6.25 Ø6.20 THRU
B19	234.07	33.99	Ø6.25 Ø6.20 THRU
B20	254.07	33.99	Ø6.25 Ø6.20 THRU
B21	264.07	33.99	Ø6.25 Ø6.20 THRU
B22	274.07	33.99	Ø6.25 Ø6.20 THRU
B23	284.07	33.99	Ø6.25 Ø6.20 THRU
B24	304.07	33.99	Ø6.25 Ø6.20 THRU
B25	314.07	33.99	Ø6.25 Ø6.20 THRU
B26	330.71	44.38	Ø6.25 Ø6.20 THRU
B27	330.71	54.38	Ø6.25 Ø6.20 THRU
B28	330.71	64.38	Ø6.25 Ø6.20 THRU
B29	330.71	74.38	Ø6.25 Ø6.20 THRU
B30	330.71	94.38	Ø6.25 Ø6.20 THRU
B31	330.71	104.38	Ø6.25 Ø6.20 THRU
B32	330.71	114.38	Ø6.25 Ø6.20 THRU
B33	330.71	124.38	Ø6.25 Ø6.20 THRU
B34	330.71	154.38	Ø6.25 Ø6.20 THRU
B35	330.71	164.38	Ø6.25 Ø6.20 THRU
B36	330.71	174.38	Ø6.25 Ø6.20 THRU
B37	330.71	194.38	Ø6.25 Ø6.20 THRU
B38	330.71	204.38	Ø6.25 Ø6.20 THRU
B39	330.71	214.38	Ø6.25 Ø6.20 THRU
B40	330.71	224.38	Ø6.25 Ø6.20 THRU
B41	330.71	244.38	Ø6.25 Ø6.20 THRU
B42	364.07	8.75	Ø6.25 Ø6.20 THRU
B43	370.57	14.38	Ø6.25 Ø6.20 THRU

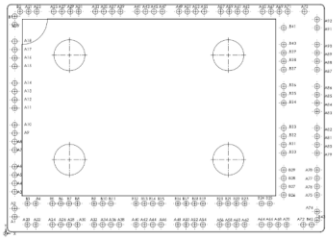


Plate Insert 15”

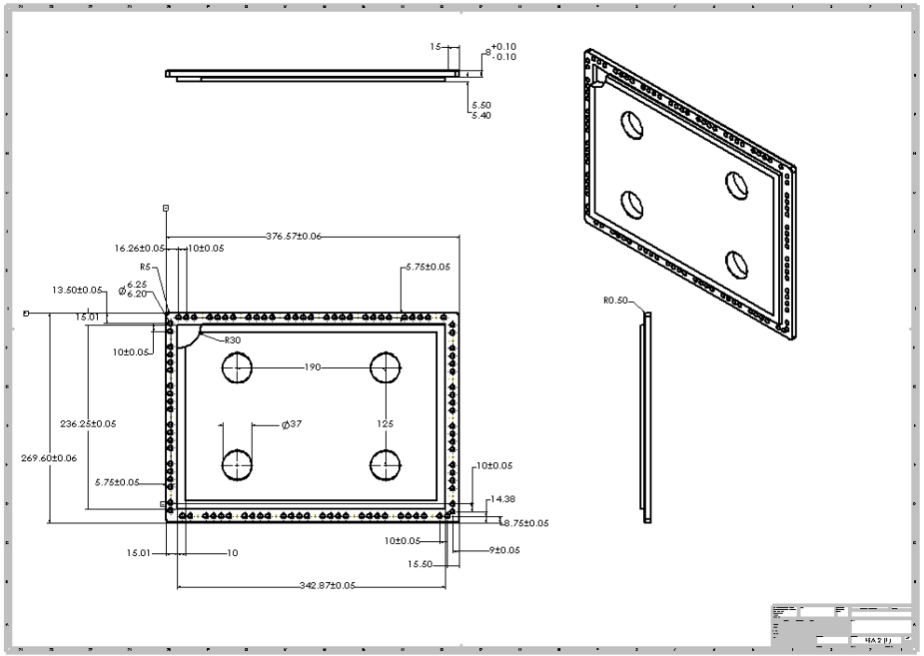
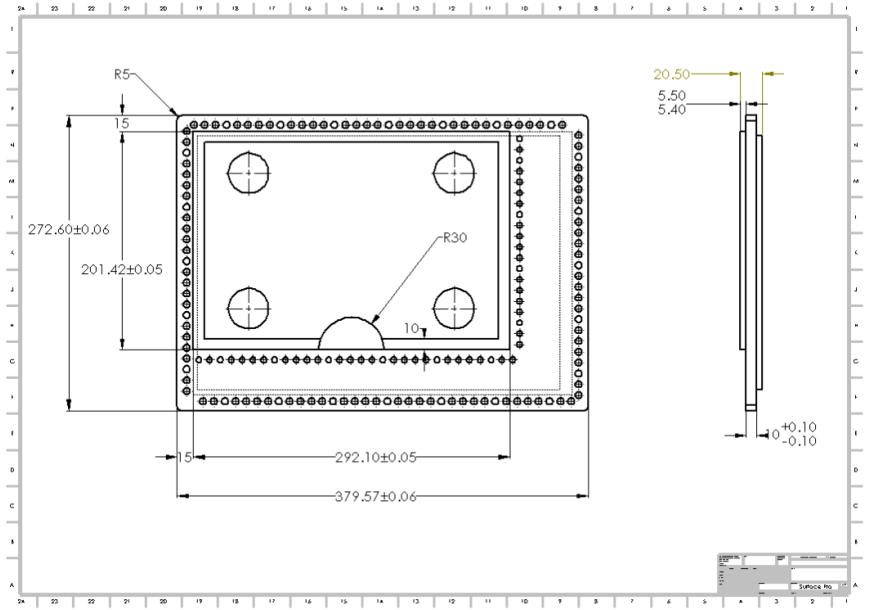


Plate Insert Surface Pro



TAG	X LOC	Y LOC	SIZE
A1	9	18.22	Ø 6.20 THRU
A2	9	28.22	Ø 6.20 THRU
A3	9	48.22	Ø 6.20 THRU
A4	9	58.22	Ø 6.20 THRU
A5	9	68.22	Ø 6.20 THRU
A6	9	78.22	Ø 6.20 THRU
A7	9	98.22	Ø 6.20 THRU
A8	9	108.22	Ø 6.20 THRU
A9	9	118.22	Ø 6.20 THRU
A10	9	128.22	Ø 6.20 THRU
A11	9	148.22	Ø 6.20 THRU
A12	9	158.22	Ø 6.20 THRU
A13	9	168.22	Ø 6.20 THRU
A14	9	178.22	Ø 6.20 THRU
A15	9	198.22	Ø 6.20 THRU
A16	9	208.22	Ø 6.20 THRU
A17	9	218.22	Ø 6.20 THRU
A18	9	228.22	Ø 6.20 THRU
A19	9	248.22	Ø 6.20 THRU
A20	24.07	8.75	Ø 6.20 THRU
A21	25.50	263.85	Ø 6.20 THRU
A22	34.07	8.75	Ø 6.20 THRU
A23	35.50	263.85	Ø 6.20 THRU
A24	54.07	8.75	Ø 6.20 THRU
A25	55.50	263.85	Ø 6.20 THRU
A26	64.07	8.75	Ø 6.20 THRU
A27	65.50	263.85	Ø 6.20 THRU
A28	74.07	8.75	Ø 6.20 THRU
A29	75.50	263.85	Ø 6.20 THRU
A30	84.07	8.75	Ø 6.20 THRU
A31	85.50	263.85	Ø 6.20 THRU
A32	104.07	8.75	Ø 6.20 THRU
A33	105.50	263.85	Ø 6.20 THRU
A34	114.07	8.75	Ø 6.20 THRU
A35	115.50	263.85	Ø 6.20 THRU
A36	124.07	8.75	Ø 6.20 THRU
A37	125.50	263.85	Ø 6.20 THRU
A38	134.07	8.75	Ø 6.20 THRU
A39	135.50	263.85	Ø 6.20 THRU
A40	154.07	8.75	Ø 6.20 THRU
A41	155.50	263.85	Ø 6.20 THRU
A42	164.07	8.75	Ø 6.20 THRU
A43	165.50	263.85	Ø 6.20 THRU
A44	174.07	8.75	Ø 6.20 THRU
A45	175.50	263.85	Ø 6.20 THRU
A46	184.07	8.75	Ø 6.20 THRU
A47	185.50	263.85	Ø 6.20 THRU
A48	204.07	8.75	Ø 6.20 THRU
A49	205.50	263.85	Ø 6.20 THRU
A50	214.07	8.75	Ø 6.20 THRU
A51	215.50	263.85	Ø 6.20 THRU
A52	224.07	8.75	Ø 6.20 THRU
A53	225.50	263.85	Ø 6.20 THRU
A54	234.07	8.75	Ø 6.20 THRU
A55	235.50	263.85	Ø 6.20 THRU
A56	254.07	8.75	Ø 6.20 THRU
A57	255.50	263.85	Ø 6.20 THRU
A58	264.07	8.75	Ø 6.20 THRU
A59	265.50	263.85	Ø 6.20 THRU
A60	274.07	8.75	Ø 6.20 THRU
A61	275.50	263.85	Ø 6.20 THRU
A62	284.07	8.75	Ø 6.20 THRU
A63	285.50	263.85	Ø 6.20 THRU
A64	304.07	8.75	Ø 6.20 THRU
A65	305.50	263.85	Ø 6.20 THRU
A66	314.07	8.75	Ø 6.20 THRU
A67	315.50	263.85	Ø 6.20 THRU
A68	324.07	8.75	Ø 6.20 THRU
A69	325.50	263.85	Ø 6.20 THRU
A70	334.07	8.75	Ø 6.20 THRU
A71	335.50	263.85	Ø 6.20 THRU
A72	354.07	8.75	Ø 6.20 THRU
A73	355.50	263.85	Ø 6.20 THRU
A74	370.57	24.38	Ø 6.20 THRU
A75	370.57	44.38	Ø 6.20 THRU
A76	370.57	54.38	Ø 6.20 THRU
A77	370.57	64.38	Ø 6.20 THRU
A78	370.57	74.38	Ø 6.20 THRU
A79	370.57	94.38	Ø 6.20 THRU
A80	370.57	104.38	Ø 6.20 THRU
A81	370.57	114.38	Ø 6.20 THRU
A82	370.57	124.38	Ø 6.20 THRU
A83	370.57	144.38	Ø 6.20 THRU
A84	370.57	154.38	Ø 6.20 THRU
A85	370.57	164.38	Ø 6.20 THRU
A86	370.57	174.38	Ø 6.20 THRU
A87	370.57	194.38	Ø 6.20 THRU
A88	370.57	204.38	Ø 6.20 THRU
A89	370.57	214.38	Ø 6.20 THRU
A90	370.57	224.38	Ø 6.20 THRU
A91	370.57	244.38	Ø 6.20 THRU
A92	370.57	254.38	Ø 6.20 THRU
B1	9	258.22	Ø 6.25 Ø 6.20 THRU
B2	15.50	263.85	Ø 6.25 Ø 6.20 THRU
B3	30	46.93	Ø 6.25 Ø 6.20 THRU
B4	50	46.93	Ø 6.25 Ø 6.20 THRU
B5	60	46.93	Ø 6.25 Ø 6.20 THRU
B6	70	46.93	Ø 6.25 Ø 6.20 THRU
B7	80	46.93	Ø 6.25 Ø 6.20 THRU
B8	100	46.93	Ø 6.25 Ø 6.20 THRU
B9	110	46.93	Ø 6.25 Ø 6.20 THRU
B10	120	46.93	Ø 6.25 Ø 6.20 THRU
B11	130	46.93	Ø 6.25 Ø 6.20 THRU
B12	150	46.93	Ø 6.25 Ø 6.20 THRU
B13	160	46.93	Ø 6.25 Ø 6.20 THRU
B14	170	46.93	Ø 6.25 Ø 6.20 THRU
B15	180	46.93	Ø 6.25 Ø 6.20 THRU
B16	200	46.93	Ø 6.25 Ø 6.20 THRU
B17	210	46.93	Ø 6.25 Ø 6.20 THRU
B18	220	46.93	Ø 6.25 Ø 6.20 THRU
B19	230	46.93	Ø 6.25 Ø 6.20 THRU
B20	250	46.93	Ø 6.25 Ø 6.20 THRU
B21	260	46.93	Ø 6.25 Ø 6.20 THRU
B22	270	46.93	Ø 6.25 Ø 6.20 THRU
B23	280	46.93	Ø 6.25 Ø 6.20 THRU
B24	300	46.93	Ø 6.25 Ø 6.20 THRU
B25	310	46.93	Ø 6.25 Ø 6.20 THRU
B26	316.35	61.18	Ø 6.25 Ø 6.20 THRU
B27	316.35	71.18	Ø 6.25 Ø 6.20 THRU
B28	316.35	91.18	Ø 6.25 Ø 6.20 THRU
B29	316.35	101.18	Ø 6.25 Ø 6.20 THRU
B30	316.35	111.18	Ø 6.25 Ø 6.20 THRU
B31	316.35	121.18	Ø 6.25 Ø 6.20 THRU
B32	316.35	141.18	Ø 6.25 Ø 6.20 THRU
B33	316.35	151.18	Ø 6.25 Ø 6.20 THRU
B34	316.35	161.18	Ø 6.25 Ø 6.20 THRU
B35	316.35	171.18	Ø 6.25 Ø 6.20 THRU
B36	316.35	191.18	Ø 6.25 Ø 6.20 THRU
B37	316.35	201.18	Ø 6.25 Ø 6.20 THRU
B38	316.35	211.18	Ø 6.25 Ø 6.20 THRU
B39	316.35	221.18	Ø 6.25 Ø 6.20 THRU
B40	316.35	241.18	Ø 6.25 Ø 6.20 THRU
B41	364.07	8.75	Ø 6.25 Ø 6.20 THRU
B42	370.57	14.38	Ø 6.25 Ø 6.20 THRU
C1	66.05	94.39	Ø 37 THRU
C2	66.05	219.39	Ø 37 THRU
C3	256.05	94.39	Ø 37 THRU
C4	256.05	219.39	Ø 37 THRU

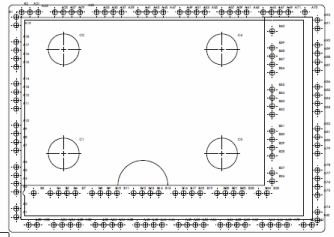
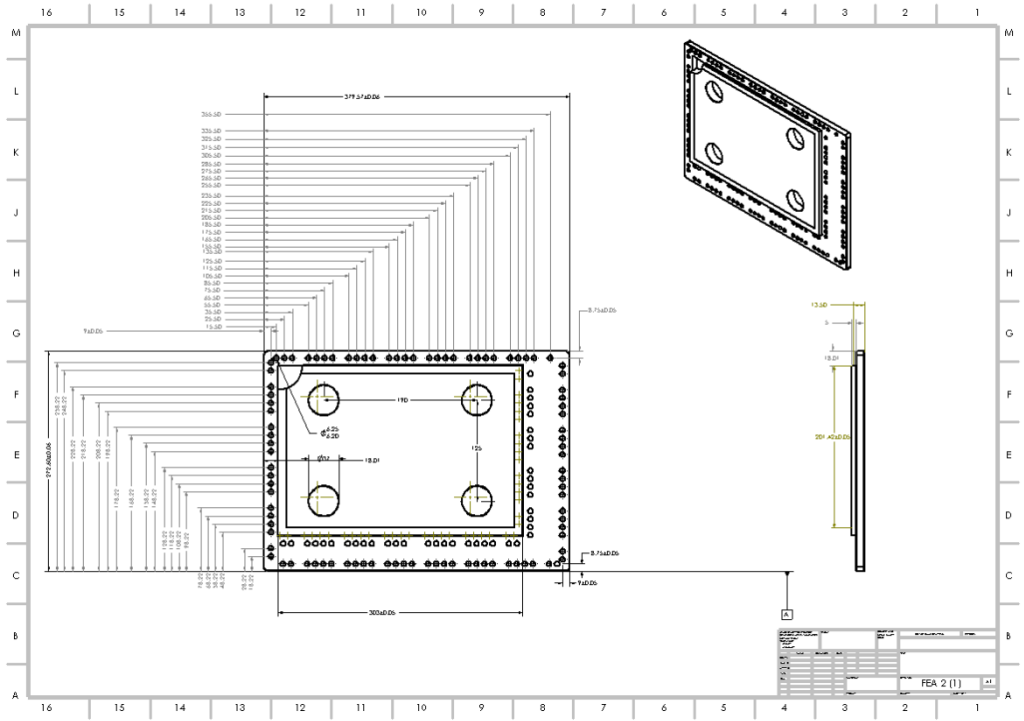


Plate Insert Laptop



Machining Process of Assemblies (Details)

Part	Material	Process	Time (hour)
Screen holder	PLA	3D Print	
Datum	6061 T6 Aluminum	CNC Mill	
Core (Datum)	6061 T6 Aluminum	CNC Mill	
Core (Bias)	6061 T6 Aluminum	CNC Mill	
Mount	PLA	3D Print	
Pad	PLA	3D Print	
Bias Lever Corner	PLA	3D Print	
Rod	12L14 Carbon Steel	Mill and Lathe	

Cost Analysis

Part	Handling		Machining	
	Time (hr)	Price ($)	Time (hr)	Price ($)
Frame (option 1)				
Frame (option 2)				
13” Plate (option 1)				
13” Plate (option 2)				
15” Plate (option 1)				
15” Plate (option 2)				

Part	Process		Machining	
	Time (hr)	Price ($)	Time (hr)	Price ($)
Pro Plate (option 1)				
Pro Plate (option 2)				
Laptop Plate (option 1)				
Laptop Plate (option 2)				
Spring Bias *Assembly*		20.55		
Datum Screen Holder *Assembly*		5.09		

Cost analysis per carrier per option

	Frame 1		Frame 2	
Plate Insert 13’’	Price ($)	*Time (hr)*	Price ($)	*Time (hr)*
Plastic				
Aluminum				
Plate Insert 15’’	Price ($)	*Time (hr)*	Price ($)	*Time (hr)*
Plastic				
Aluminum				