CUSTOM COMPOSITE ROAD CYCLING SHOES

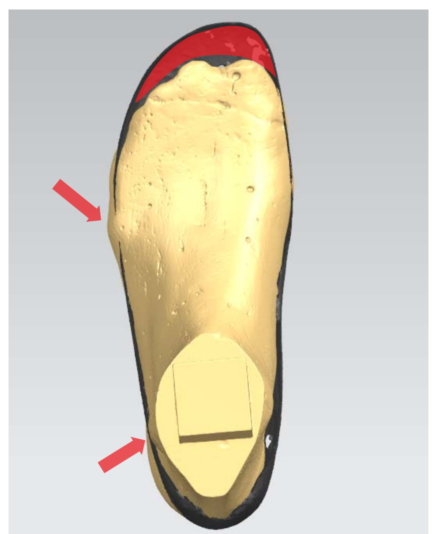
CONNOR SHIMAMOTO | SHERPA DESIGN

Sherpa Design presents an innovative process for **designing** and **manufacturing** a custom composite cycling shoe. This white paper offers an exclusive glimpse into our groundbreaking product creation journey, emphasizing our diverse capabilities in design, 3D scanning, 3D printing, advanced NX CAD, laser cutting, and more.

At the heart of this innovation lies the extraordinary potential of our **Carbon 3D** printing services, with a focus on applications in the realm of custom footwear. Manufacturing custom cycling shoes is typically a manual process that relies on manual labor and physical record keeping. With our use of **digitization** and **additive manufacturing**, we condensed the design and manufacturing process to a few weeks.

Why make a custom cycling shoe?

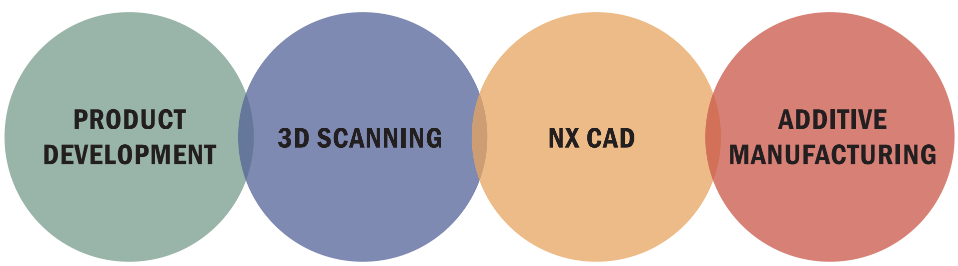
Commercially available shoes are often designed for the masses and for ease of manufacturing. Connor Shimamoto, Sherpa Design's Additive Manufacturing Manager, has feet that fall outside of the "average" shape and often has difficulty finding comfortable shoes. He often sizes up to compensate for lack of width. Improper fit leads to discomfort and negatively impacts perfomance.



This image shows the discrepancy in fit between Connor's foot(yellow) and his previous cycling shoe sole(black). His foot measures up to 10mm too wide and 15mm too short.

Leveraging Our Toolsets

Designing and manufacturing a custom composite cycling shoe was a great way to leverage many of Sherpa Design's current tools and skillsets. It was an opportunity to learn new skills such as carbon fiber manufacturing and footwear manufacturing.



Research

Making an entire shoe from the ground up was completely new to us. Before starting any design work, we researched custom shoe design, cycling shoe anatomy, and prepreg carbon fiber manufacturing.

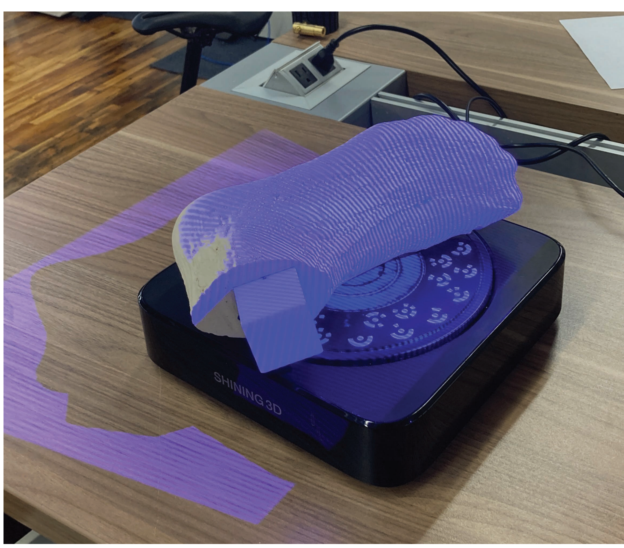
This composite cycling shoe was dessicted to learn more about construction and materials.

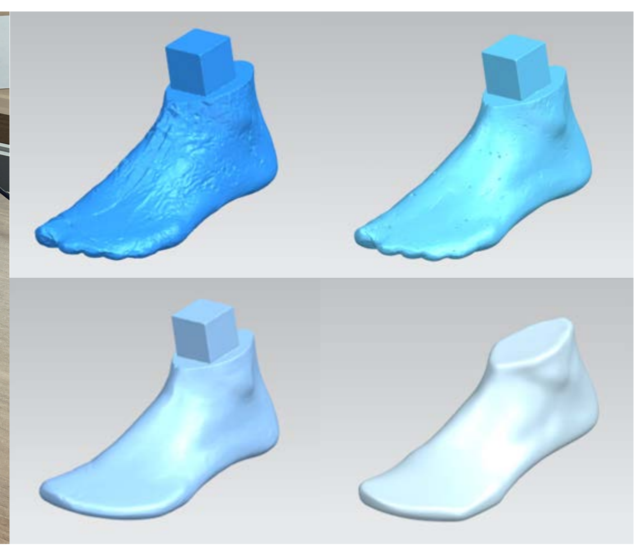
Life Casting

Connor's feet were cast using polymer embedded casting socks. 3D printed blocks and memory foam helped keep the feet in a comfortable, partial weight bearing posture. The casting socks were filled with plaster to make foot model positives.

Digital Record Keeping

In-house 3D scanning served as record keeping between each stage of hand finishing the plaster foot models.





Manual Sculpting vs Digital Sculpting

Manually sculpting the plaster casting into usable lasts was a slow process and presented a few challenges. Instead, we decided to use NX to digitally sculpt the scan data into unique lasts for the left and right foot.

MANUAL PLASTER SCULPTING

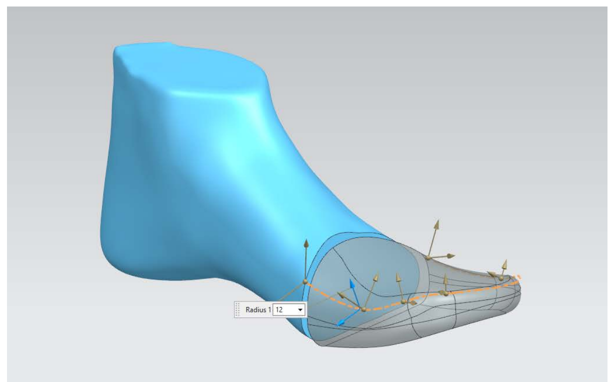
- Time consuming
- Lack of control
- Lack of continuity
- Messy process
- Challenging to repeat

The first manually sculpted shapes did not fit well.

NX DIGITAL SCULPTING

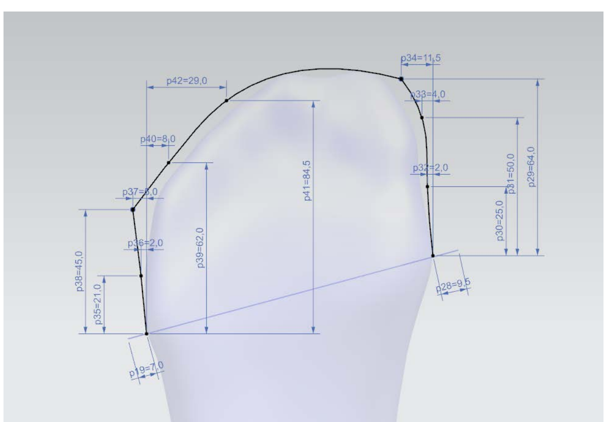
+ Fast
+ Great control
+ Partially parametric
+ Zero mess
+ Repeatability

The digitally sculpted shape fit well and allowed for easy adjustments.

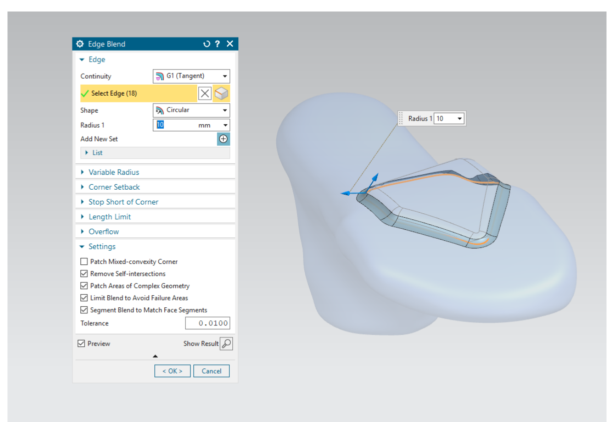


Convergent Modeling

NX Convergent modeling allowed us to work seamlessly between facet and B-Rep geometry. Most features made between the two geometry types became editable in the feature tree.



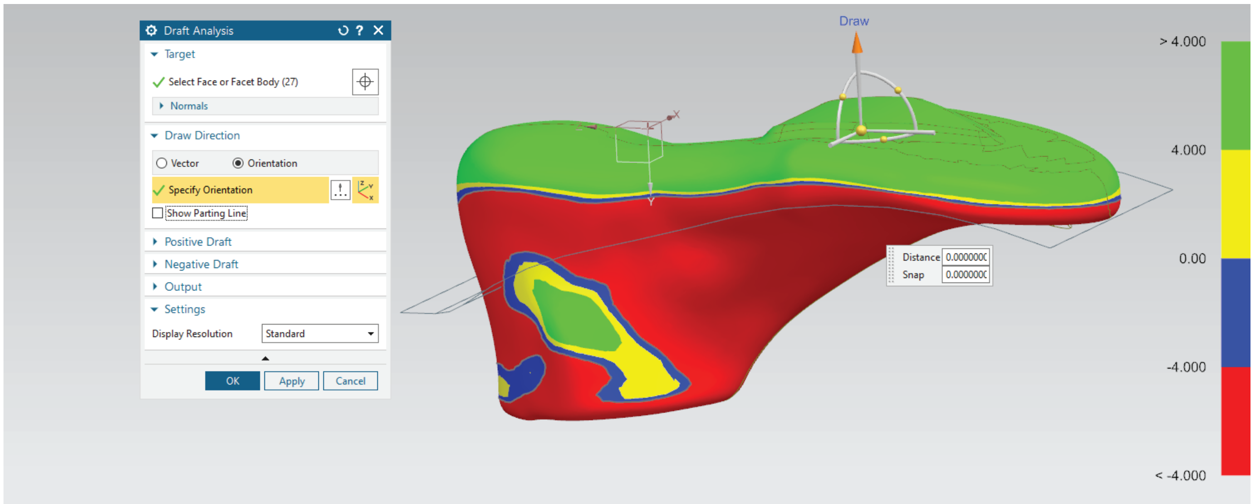
Shaping the toe box with a dimension driven sketch.



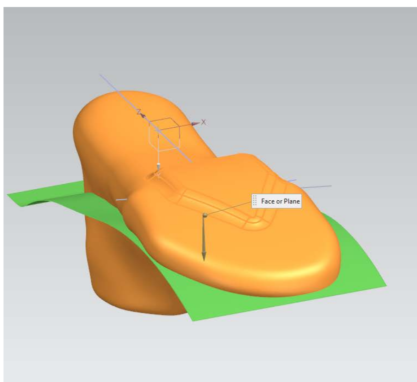
Placing an editable fillet between a facet body and B-Rep body.

Composite Sole Tool Design

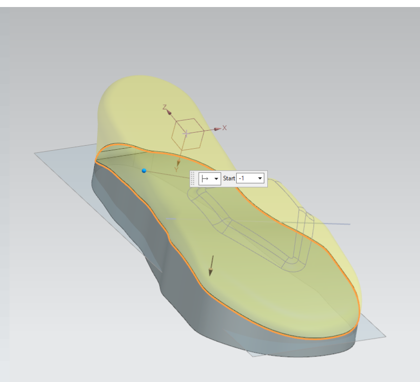
Initial Draft Analysis showed that it would be impossible to pull the composite sole off a single part mold. To get around these overhangs, we decide to design a multi-part tool. Each part would have a unique draw direction.



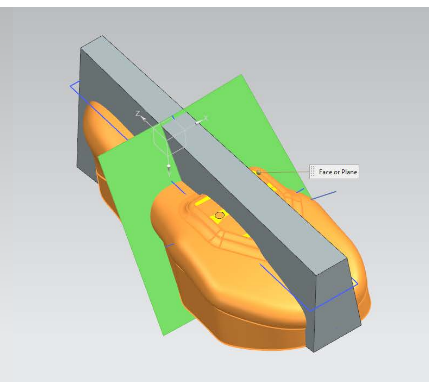
NX draft analysis can interpret B-Rep data, facet data, and convergent data.



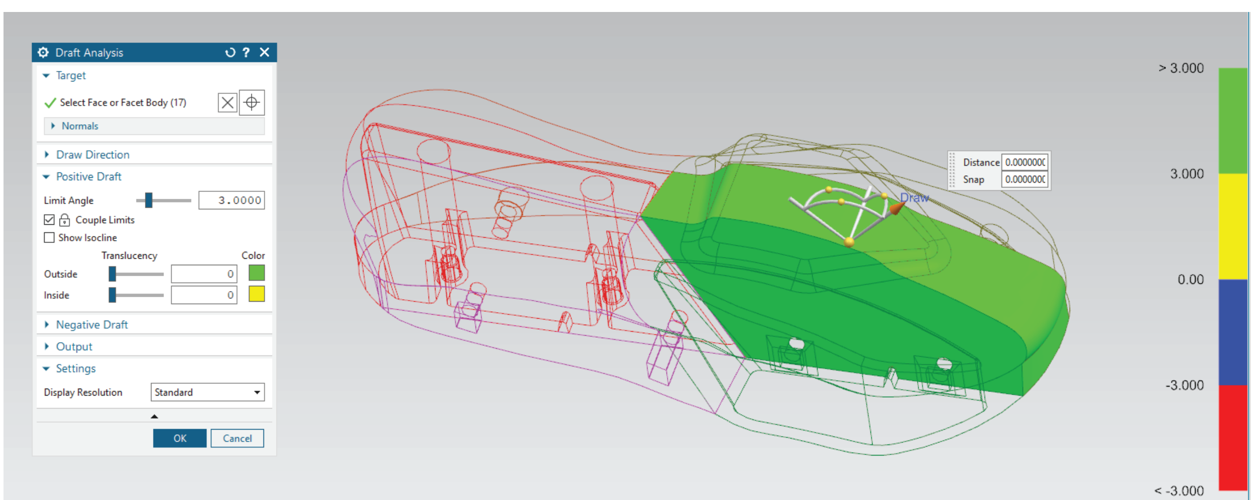
A surface is used to trim away the upper and isolate the sole.



Convergent modeling allowed us to extrude a trimmed facet region.



The mold is split into six parts with drafted faces.



We used draft analysis to validate the six parts of the mold with unique pull vectors.

Material Selection

LAMINATING MOLD: CARBON EPX 82

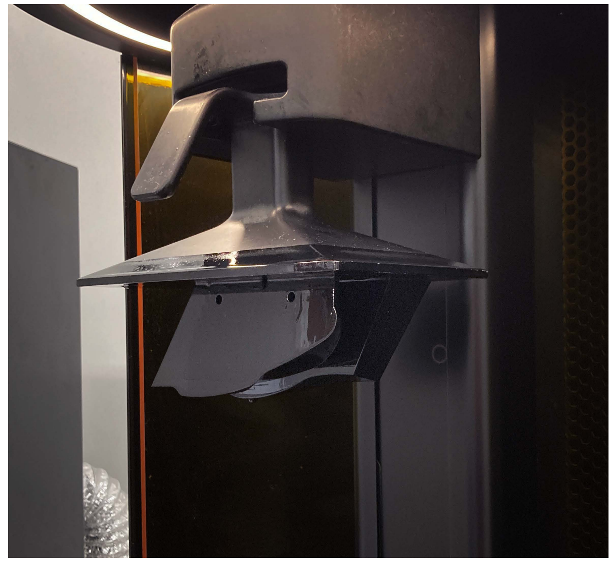
Carbon printing enabled us to manufacture the tools quickly and affordably. The current revision was printed with **EPX 82** on a Carbon M2 printer.

- 3D printing was a fast alternative to CNC machining.

- Carbon 3D printing has a smooth, non-porous surface finish allowing us to pull the part off with ease.

- EPX 82 heat deflection temperature withstood the minimum temperature requirement for baking the prepreg carbon fiber.

- EPX 82 has great chemical compatibility. It did not absorb the petroleum based mold wax or PVA mold release.

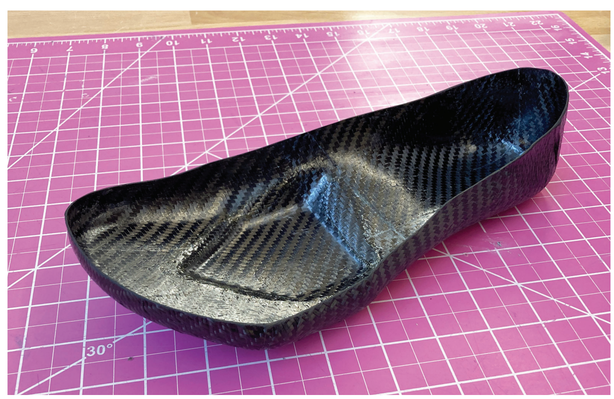


The **Henkel Loctite 3D IND 147** is being evaluated for the next revision of the tool. The higher HDT of the IND 147 would allow us to bake the prepreg carbon fiber for a shorter duration at a higher temperature.

RIGID SOLE: PREPREG CARBON FIBER

The full length of the rigid sole was constructed with prepreg 3k, 2x2 twill weave carbon fiber.

- A prepreg layup is cleaner and more consistent compared to wet layup.



OUTSOLE PADS: CARBON EPU 40

The toe and heel outsole pads were Carbon 3D printed with **EPU 40**.

- 3D printing saved on labor and time compared to urethane casting.

- Carbon 3D printing was capable of creating deep textures on all cosmetic surfaces. Additional texture designs did not increase costs.

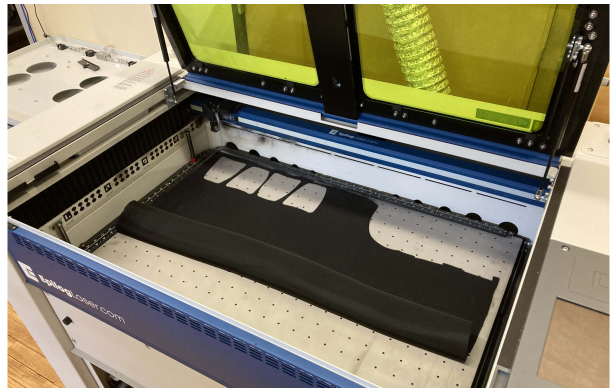
Upper Prototyping

The upper pattern design started with traditional taping and sketching. Panels were individually cut and flatbed scanned.

We used Rhino to make digital copies of the flat patterns. Multiple revisions were made to compensate for the expansion and compression rates of different fabrics.

Our in-house Epilog Fusion Pro laser cutter made mesh fabric cutting fast and accurate. Cardboard stencils were cut for materials that were incompatible with the laser cutter.

The panels of fabric were hand stitched or by a hand crank cobbler sewing machine.



Mesh panels laser cut in-house

Uppers patterns fitted to FDM printed lasts

Carbon Fiber Manufacturing

The 6 parts of the tool were fastened to each other with shoulder screws then fastened to a slotted plate.

Prepreg 2x2 carbon fiber was trimmed by hand and laid over the tool.

The tool was vacuum bagged and placed into a thermal oven.

The first prototype had 4x plys laid in alternating 45°. It was too flexy, and the cleat holes were difficult to drill out cleanly.

The second prototype had 5x plys plus 1x ply over the cleat holes laid in alternating 45°.

Part under vacuum and placed in an oven

Removal of the multipart tool

First Prototype

An initial prototype was built to validate fit and assembly process.

LASER CUT MESH

Our in-house laser cutter allowed us to make fabric panels directly from CAD without the need for hand cutting.

HENKEL LOCTITE 3D 3843

Carbon 3D printed Loctite 3843 served as a great interface between the carbon fiber shell and threaded steel plate. It is extremely quick to print and great for mild impact applications.

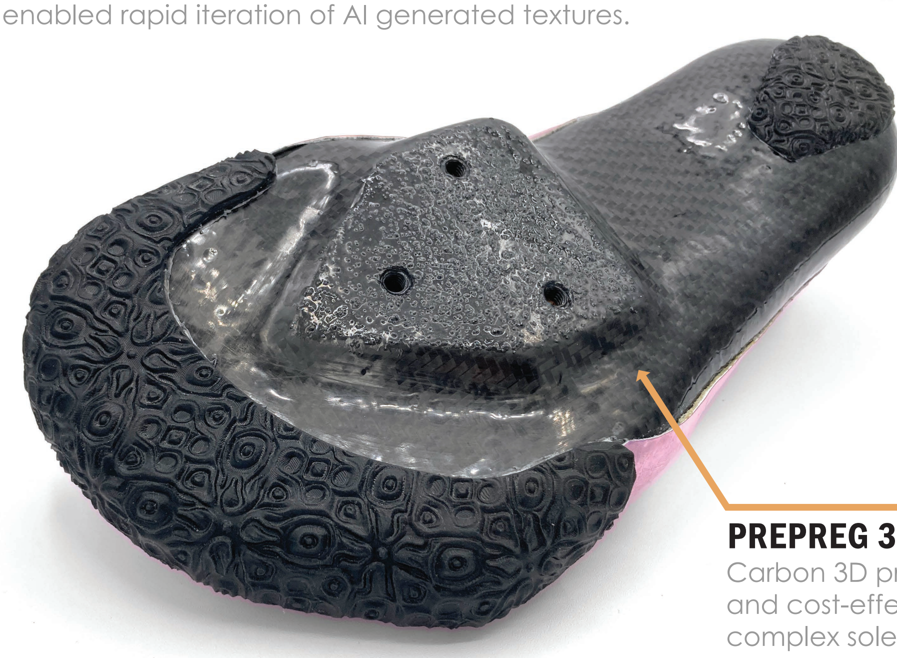
Fit check outsole pads were printed in Loctite 3843 for time and cost savings.

Second Prototype

The second prototype was built with alterations to the upper and more layers in the carbon fiber sole.

CARBON EPU 40

Toe and heel outsole pads were Carbon 3D printed in EPU 40. Toolless manufacturing enabled rapid iteration of AI generated textures.



PREPREG 3K 2X2 TWILL

Carbon 3D printed EPX 82 made quick and cost-effective tooling for this complex sole part. EPX 82 was resistant to the constant raised temperature and vacuum pressure of the prepreg carbon fiber molding process.

Mass manufactured shoe with an over-the-counter orthodic.

Custom shoe with 3mm insole.

Conclusion

The project was a success thanks to the wide variety of services at Sherpa Design. Learning to make a shoe from the ground up was a daunting task, but with our talented engineers and access to in-house tools like our Epilog laser cutter and Carbon 3D printers, we were able to push through challenges rather than compromising. With the correct resources, we could push through challenges rather than compromising.

Connor thinks these are the single best investment out of all his cycling gear. The shoes' comfort was far beyond anything he could achieve through off-the-shelf products. He used the shoes daily for training and racing during his 2023 road racing season.

What is next?

Even though a successful pair of shoes was built, there is much more to explore.

- Explore Sub-D modeling to reduce file sizes and speed up computation time.
- Switch our carbon fiber manufacturing tools from EPX 82 to Loctite 3D IND147.
- Source higher quality footwear specific fabrics.

The custom shoes in use during a local criterium race.