

# Going for Gold: How To Win an Olympic Medal With Autodesk Software

Richard Didham

Design/Analysis Engineer – US Olympic Sailing Innovation, Research, & Development







# About the speaker

## Richard Didham

- Design/Analysis Engineer for US Olympic Sailing IR&D
- Works jointly between Autodesk's Pier 9 rapid prototyping facility and US Sailing's FAST USA technology center
- Design and prototype advanced composite structures for Olympic sailing equipment
- B.S. in Mechanical Engineering from UC Berkeley
- Former athlete in the US Sailing Olympic Development Program (ODP)



# Overview

- Introduction to the US Olympic Sailing Program**
- Design Project: Moth Hydrofoil**
- Future Development Plans with Autodesk**



# Our World

THESE BOATS:



NOT THESE  
BOATS:





# Our World – Key Distinctions

## OTHER HIGH PERFORMANCE SAILING

- Large Teams – 5 ~ 10 sailors per boat
- “Box Rule” classes
  - Designs need to fit within specific parameters
  - Minimal design constraints



## OLYMPIC SAILING

- “single-handed” or “double-handed” disciplines
- “One Design” classes
  - Certain equipment can only be made by licensed manufacturers
  - Strict design constraints on other equipment



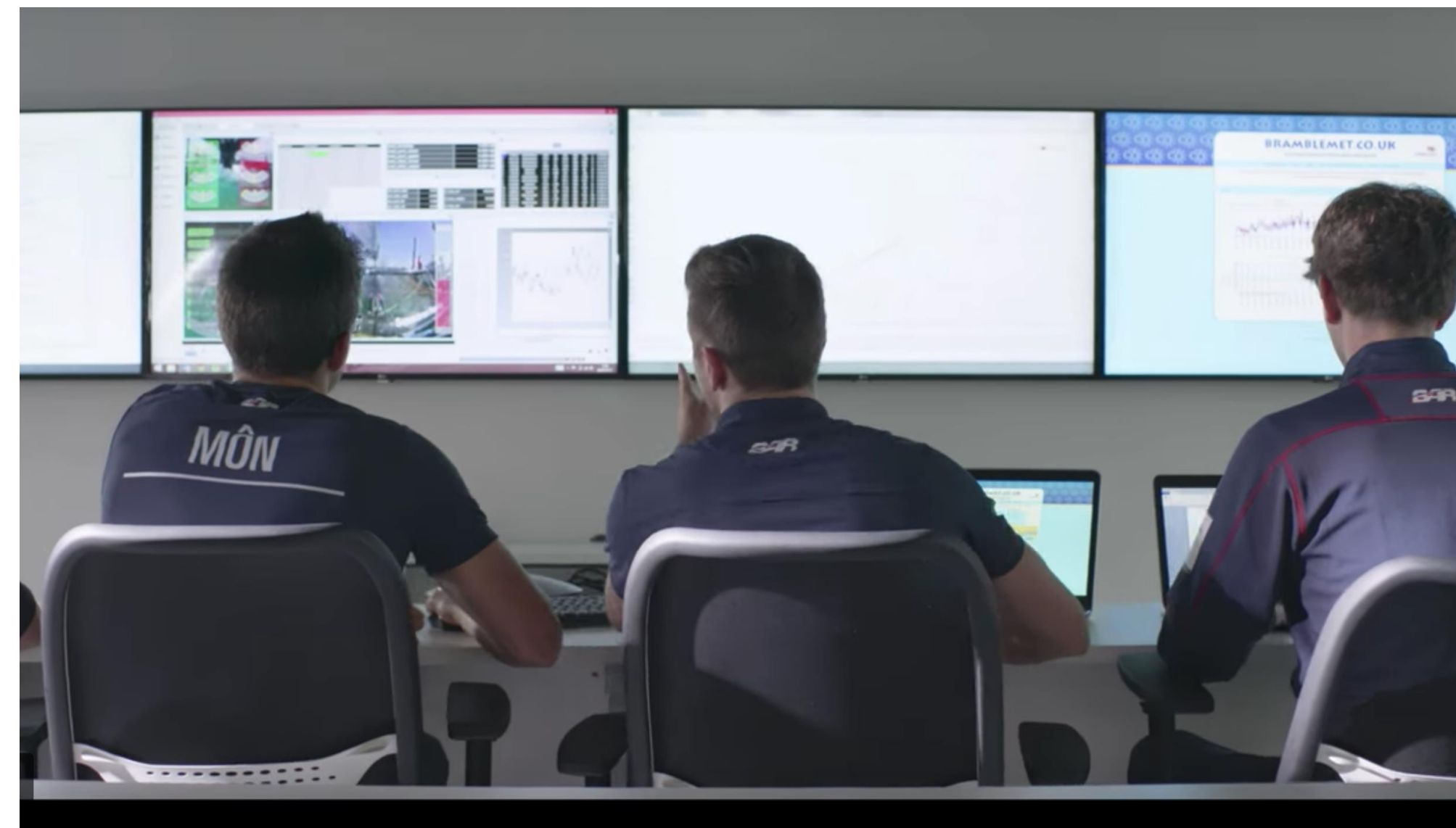


# IR&D within the US Sailing Team

Primary Goal – improve equipment where there is room for refinement, profile anything we can't change (other equipment, race venues, weather)

Small team dedicated to pushing the envelope as far as we can within the limited windows of opportunity afforded us by the Olympic rules

- Complete 'system' modelling
- Mast/foil design and manufacture
- Equipment 'performance' assessment
- Advanced performance analytics
  - Incorporating environmental analysis/predictive models
  - Tactical analysis
  - Race simulation using Machine learning/VR



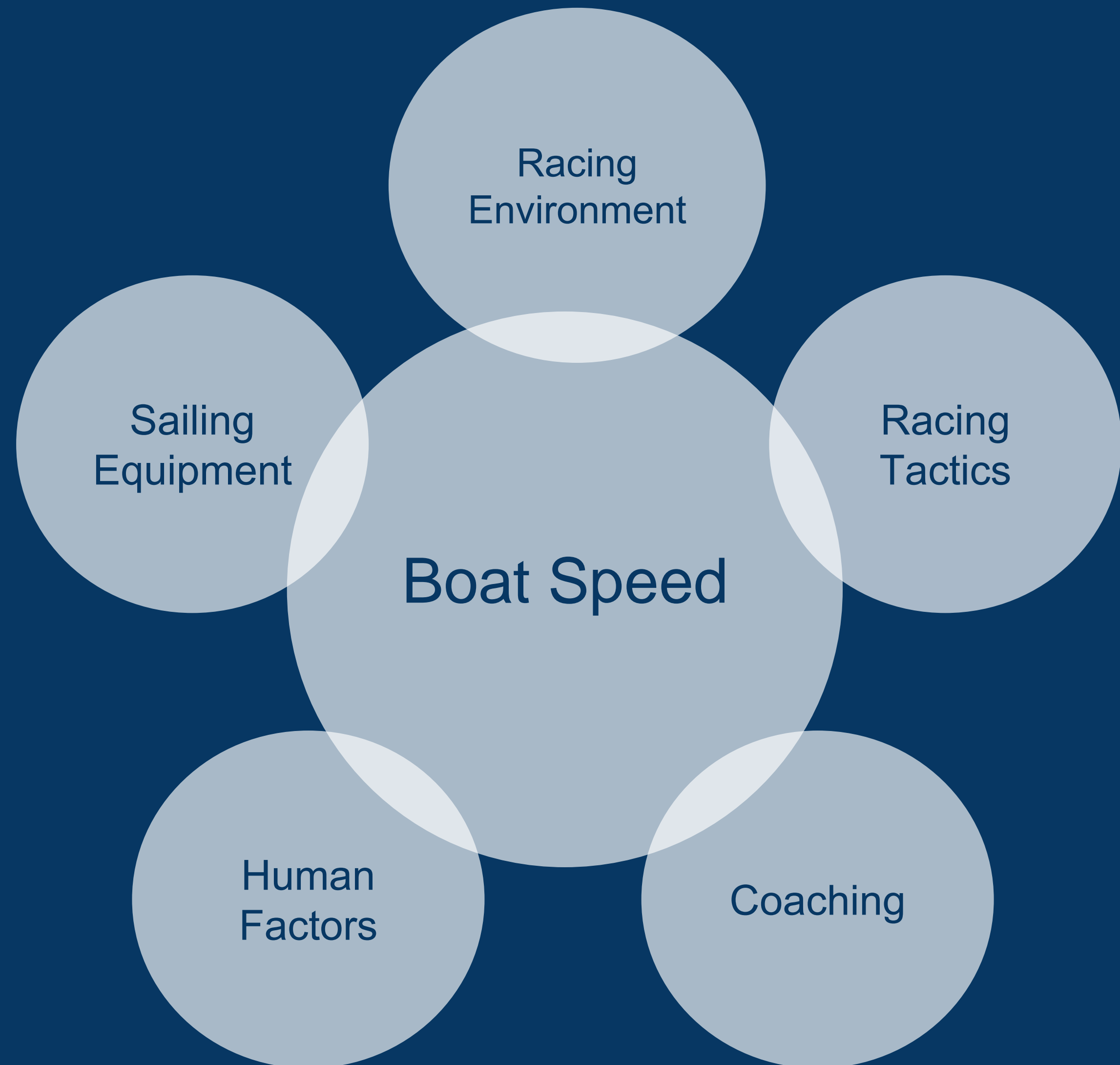




470 class

# USST IR&D – Data Driven Preparation Model

IR&D initiatives to improve performance via 5 key areas





# 1. Human Factors

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- Fitness of the body: stamina, fatigue resistance, strength, power, agility
- Fitness of the mind: mental toughness, alertness
- Biometric Analysis tools
  - Technique and Movement efficiency

Laser Radial Class



## 2. Racing Environment

- Improve understanding of racing environment
- High resolution modeling and simulation
- Utilize accurate real time measurement tools
  - Wind gear
  - Current measurement tools

Nacra 17 class



### 3. Racing Tactics

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- Improve understanding of winning tactics/strategies
- Info & learnings routinely captured and curated (database)
- Race Simulation – to ‘condition’ winning tactics
  - Machine learning algorithms combine competition data with weather forecasting models

49er FX class



## 4. Coaching

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- Give coaches better insight to training performance
- Data acquisition platform (DAP)
- Instrumented boat and appendages
  - human sensory data
  - Equipment sensory data
  - specific/comprehensive video footage
- **Make coaching more efficient!**

49er FX class





## 5. Sailing Equipment

- Design and prototype – molds, foils, masts
- Measure - sail, mast and foil performance
- Model - structural, aerodynamic and hydrodynamic performance simulations

Nacra 17 class



# Current Partners

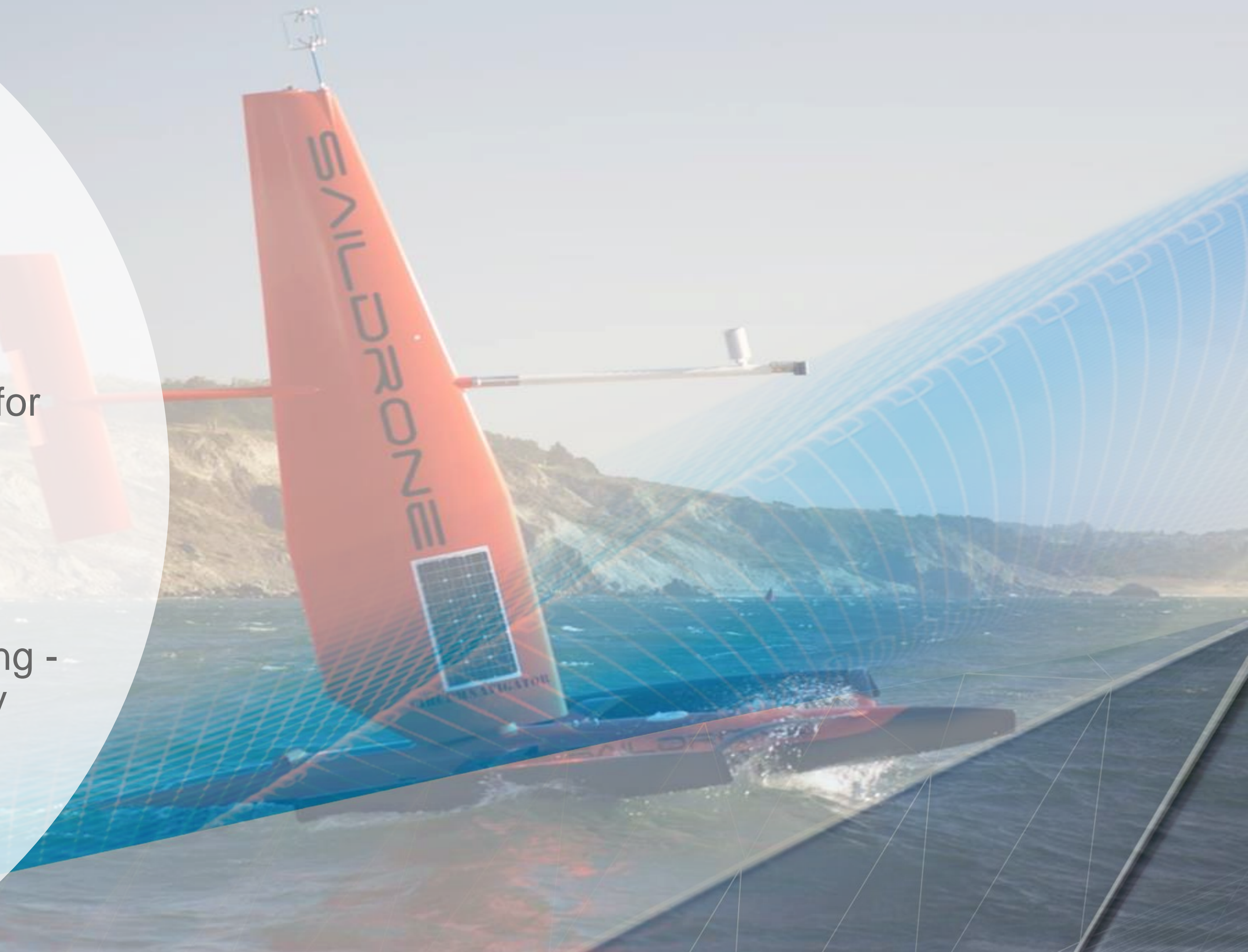
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**Autodesk Pier 9** (& Boston Build Space) - innovative design and build of componentry (for coach-boats and sailboats)

**Saildrone** - environmental reconnaissance

**University of Miami** – mechanical engineering - masts/boards bend & twist profiles, metrology

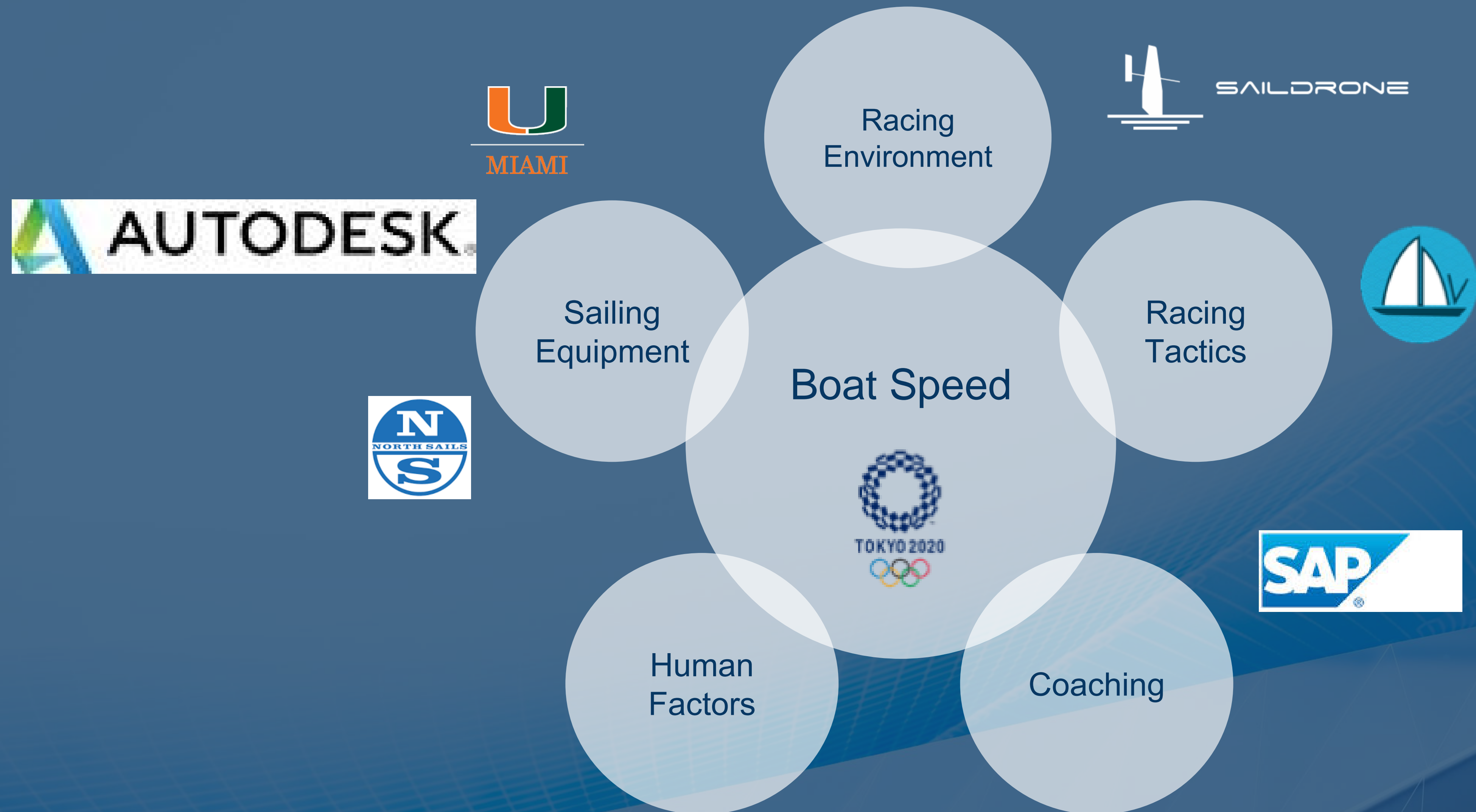
**SAP** – Performance analytics in competition





# USST IR&D – Data Driven Preparation Model

Where current partnerships fit the 5 key areas





# Overview

- Introduction to the US Olympic Sailing Program
- Design Project: Moth Hydrofoil**
- Future Development Plans with Autodesk



# The Moth Sailboat

High performance, Hydro-foiling, sailing discipline that's **NOT** in the Olympics but has several key attributes:

- Relaxed “Box-Rule” encourages development
- No longer a “game of inches”
  - Easier to quantify results / models
- Allows us to test a technology or approach before applying it to an Olympic discipline
- Many US Sailing Team athletes race moths as a supplement to their Olympic discipline
- Projects can be shared with the public!







# DAY 2 HIGHLIGHTS





# The Moth Hydrofoil

- “Wing like” structure that lifts the boat out of the water while sailing
- Goal: design and build prototype to test capabilities in 2 fields of interest
  - Hydro-dynamic design optimization
  - Carbon fiber reinforced composite fabrication



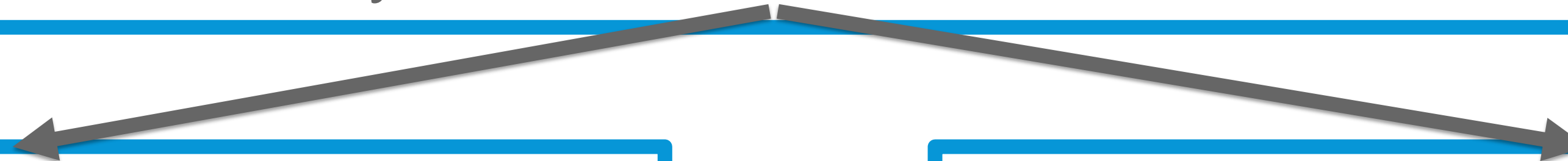


# Workflow Overview:

**Design optimal profiles for hydrofoil using  
Computational Fluid Dynamics (CFD) software**

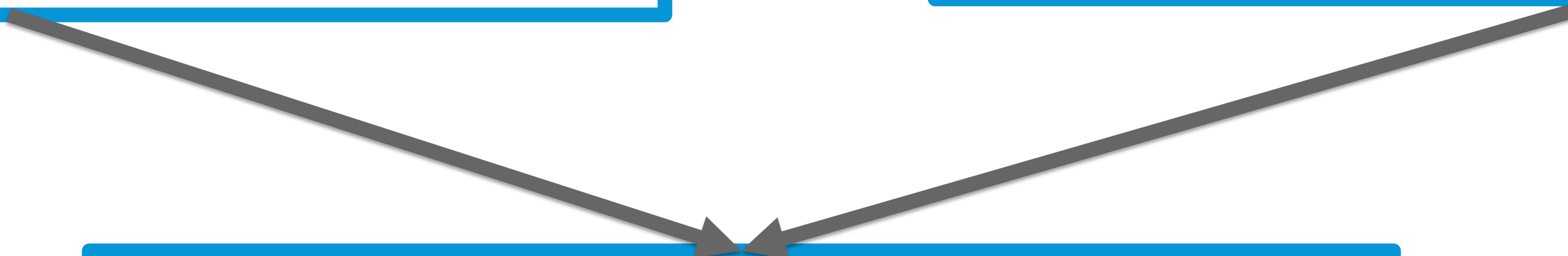


Work on 3D body within Fusion 360 CAD/CAM environment



Program CNC router to machine molds  
using Fusion 360 CAM

Define Layup scheme using Autodesk  
Tru-Composites



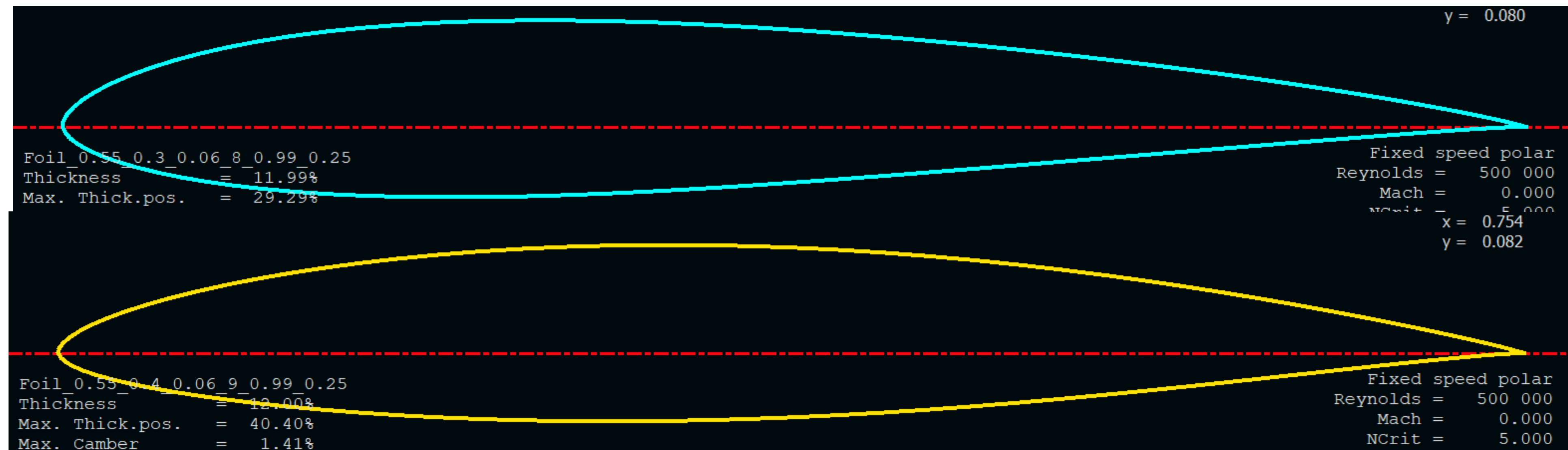
Fabricate Hydrofoil



# Shape Parametrization

- Created formula to parametrize important characteristics of airfoil shapes
  - Bluntness of leading edge
  - Location of max thickness
  - Value of max thickness
  - Sharpness of trailing edge
  - Chamber-line

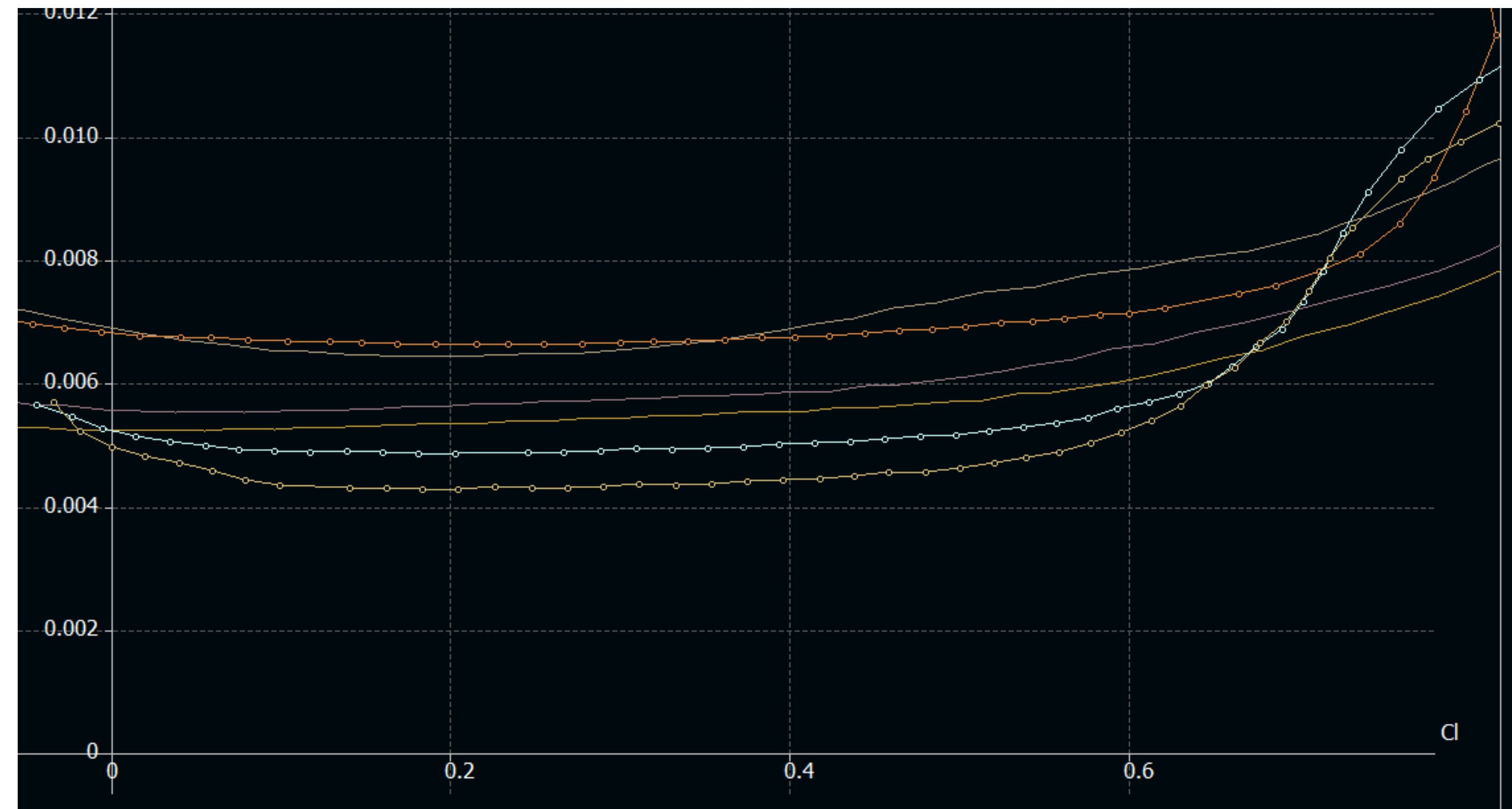
Example: the top foil has max thickness closer to leading edge than bottom foil





# Design Optimization using CFD Simulation

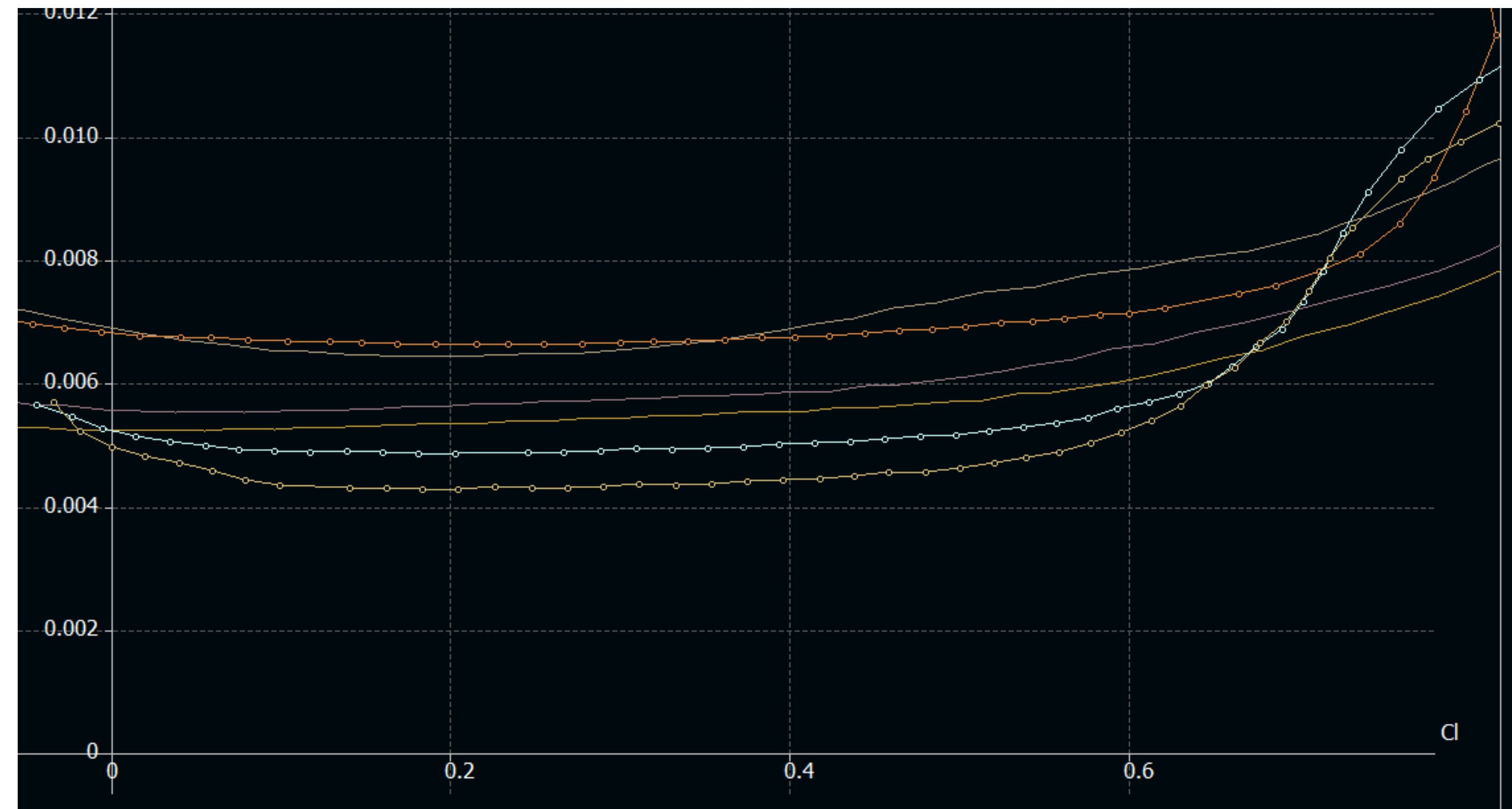
- Performance metric: Lift vs Drag across a wide range of operating conditions
- How does one design the “perfect” hydrofoil shape?
  - Option 1: analyze every possible hydrofoil shape and pick the one that performs best





# Design Optimization using CFD Simulation

- Performance metric: Lift vs Drag across a wide range of operating conditions
- How does one design the “perfect” hydrofoil shape?
  - ⊖ Option 1: analyze every possible hydrofoil shape and pick the one that performs best
  - Option 2: Analyze a batch of foils, pick shape that performs best, generate a bunch of new shapes that are similar, repeat process many times



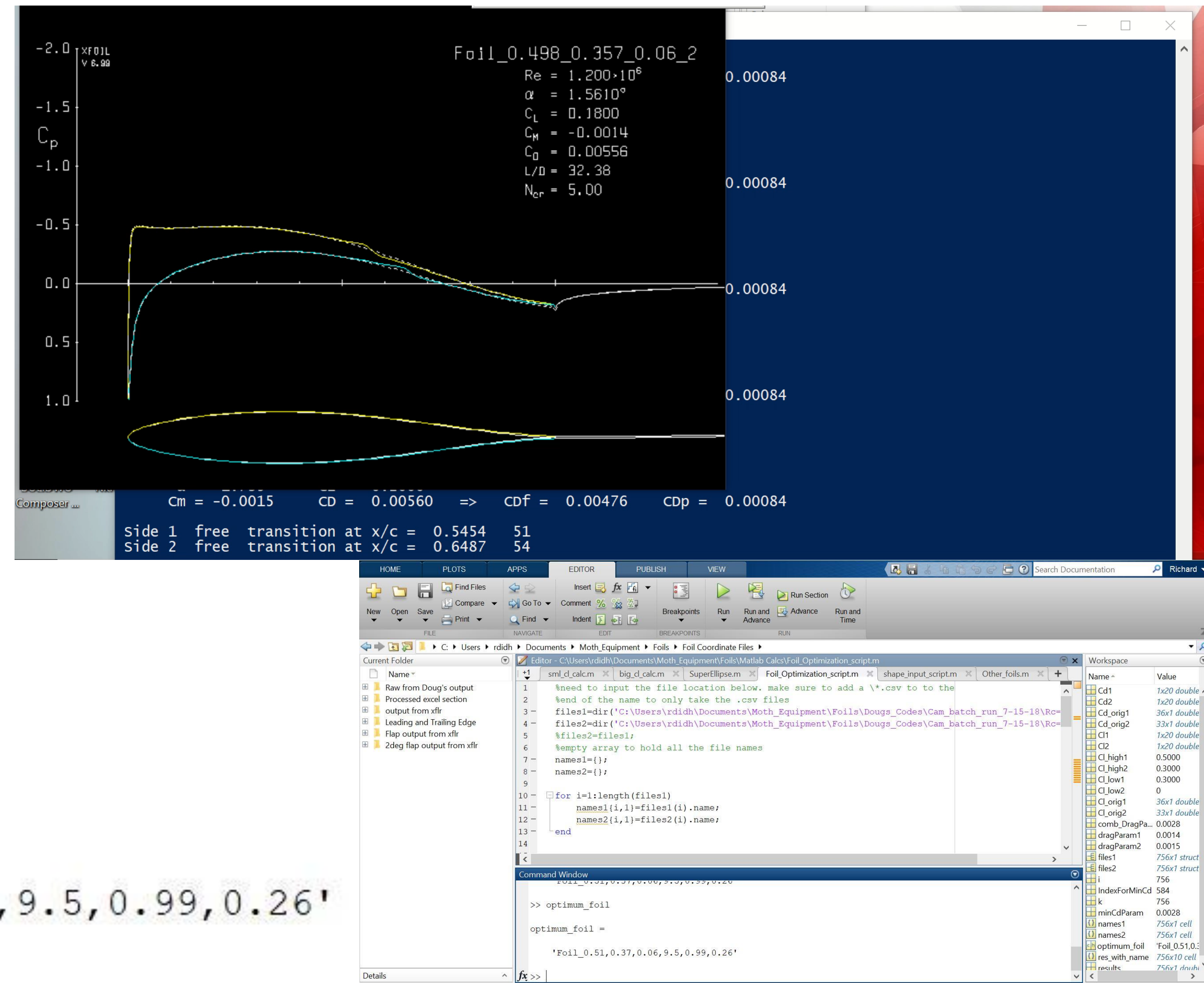


# Design Optimization using CFD Simulation

- Used Xfoil 2D CFD software to optimize shapes
- Why Xfoil?
  - Very quick to run analysis
  - Lends itself to large batches of simulations
  - Allows us to automate option 2 using MATLAB or similar programming environment

optimum\_foil =

'Foil\_0.51,0.37,0.06,9.5,0.99,0.26'



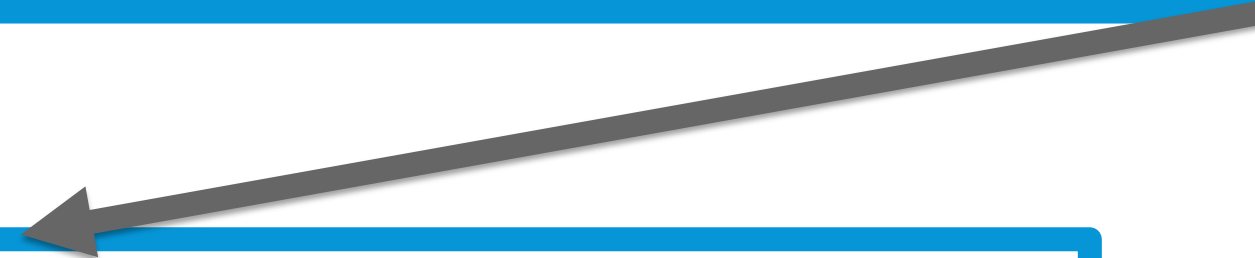


# Workflow Overview:

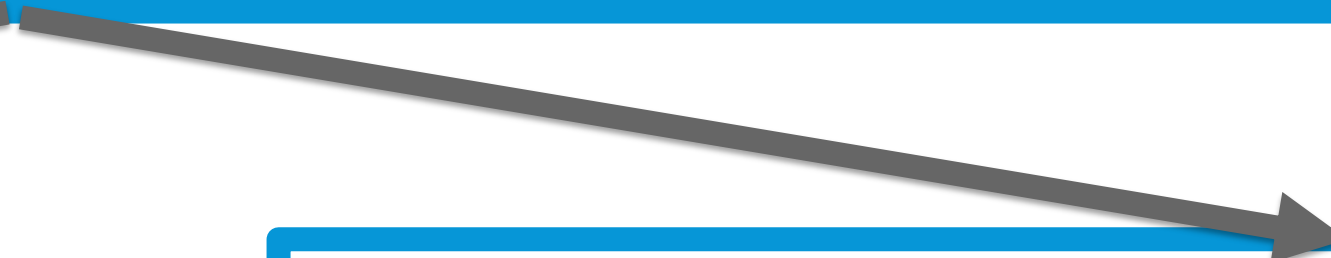
Design optimal profiles for hydrofoil using Computational Fluid Dynamics (CFD) software



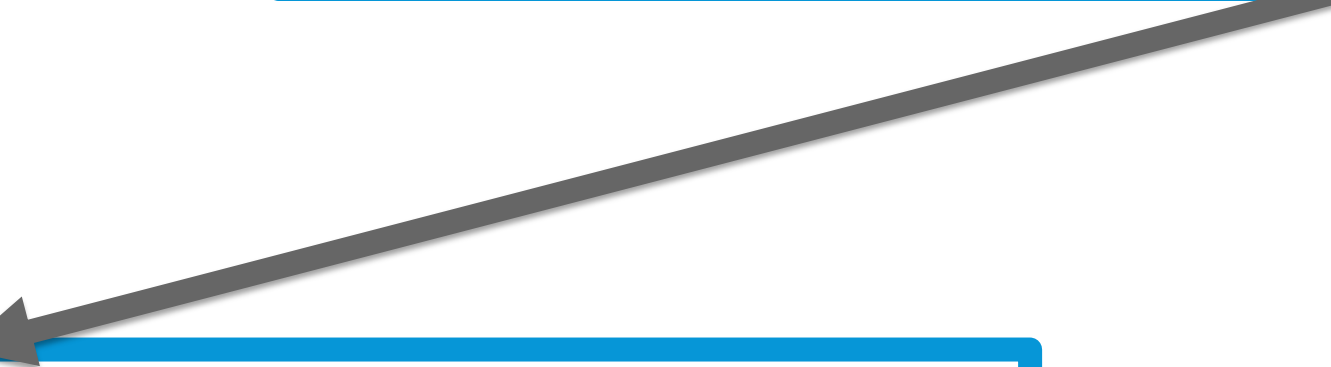
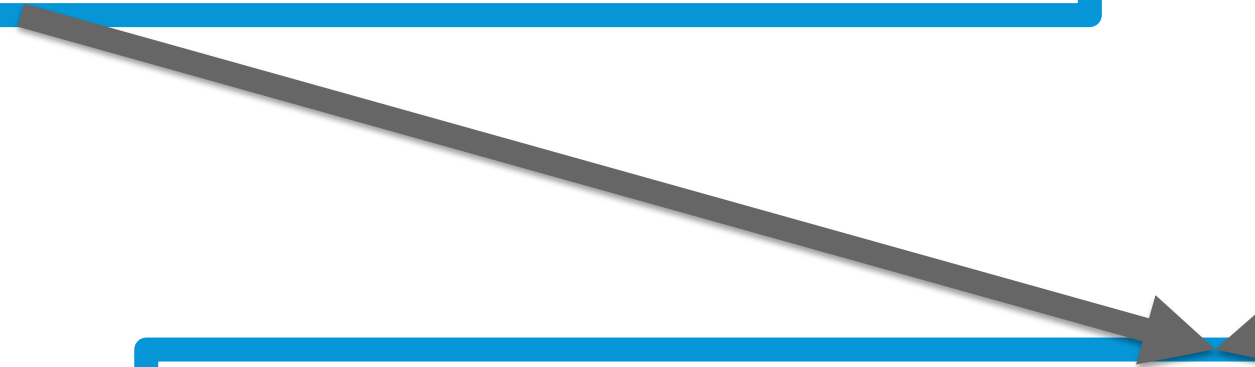
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Program CNC router to machine molds  
using Fusion 360 CAM



Define Layup scheme using Autodesk  
Tru-Composites

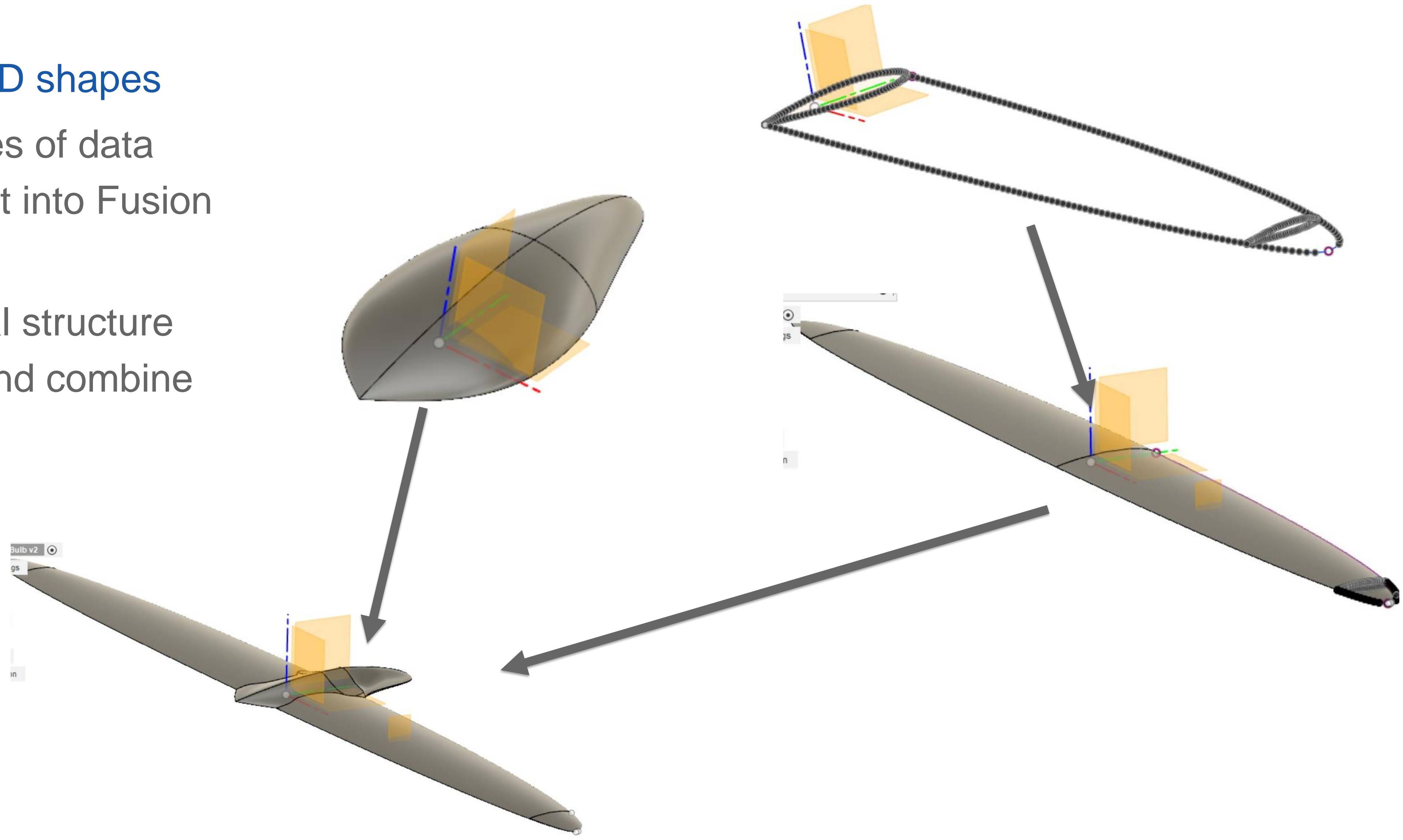


Fabricate Hydrofoil



# 3D Modeling in Fusion 360

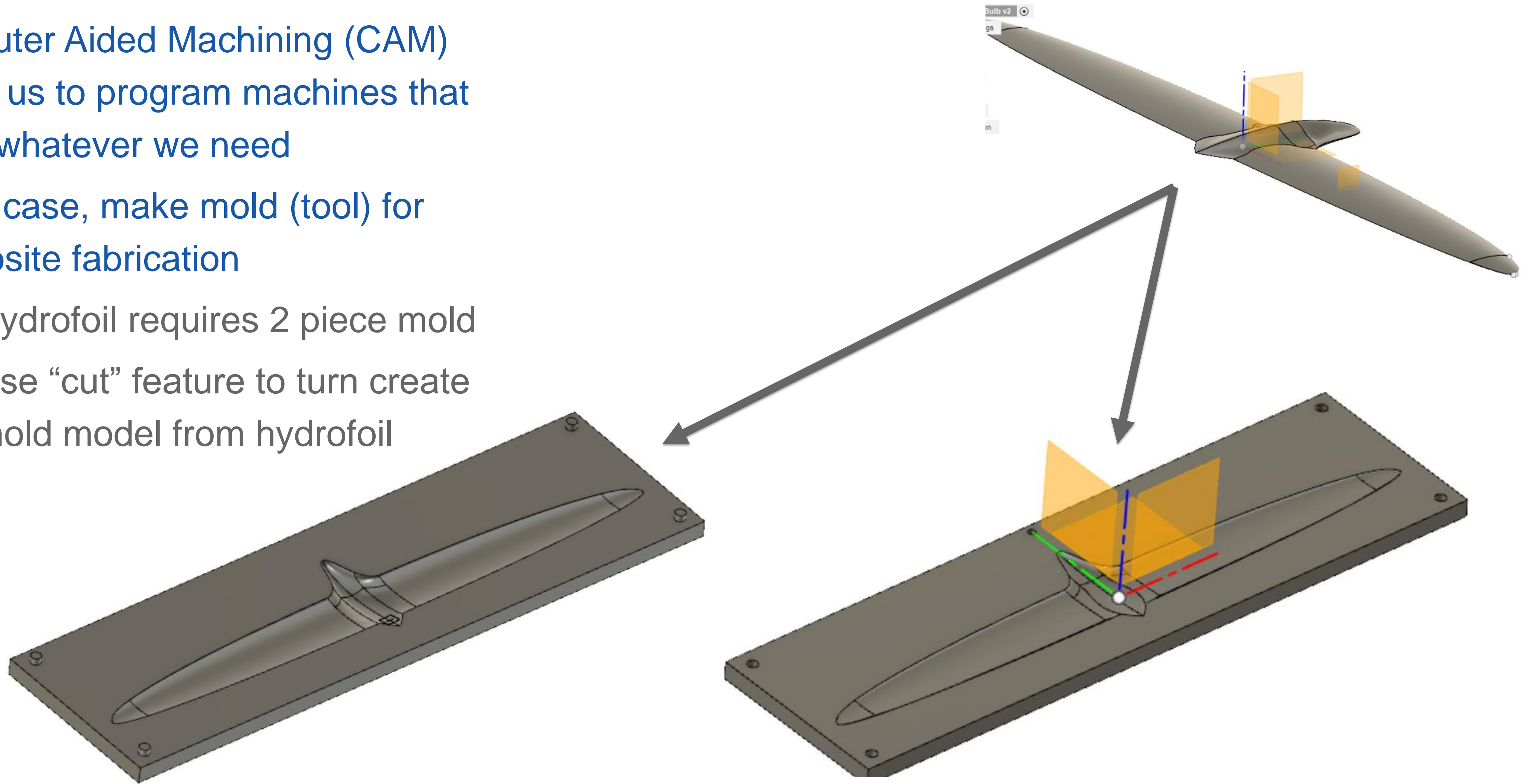
- Loft 2D profiles into 3D shapes
  - Start with csv files of data points and import into Fusion 360
  - Design additional structure where needed and combine bodies





# Prep for CAM in Fusion 360

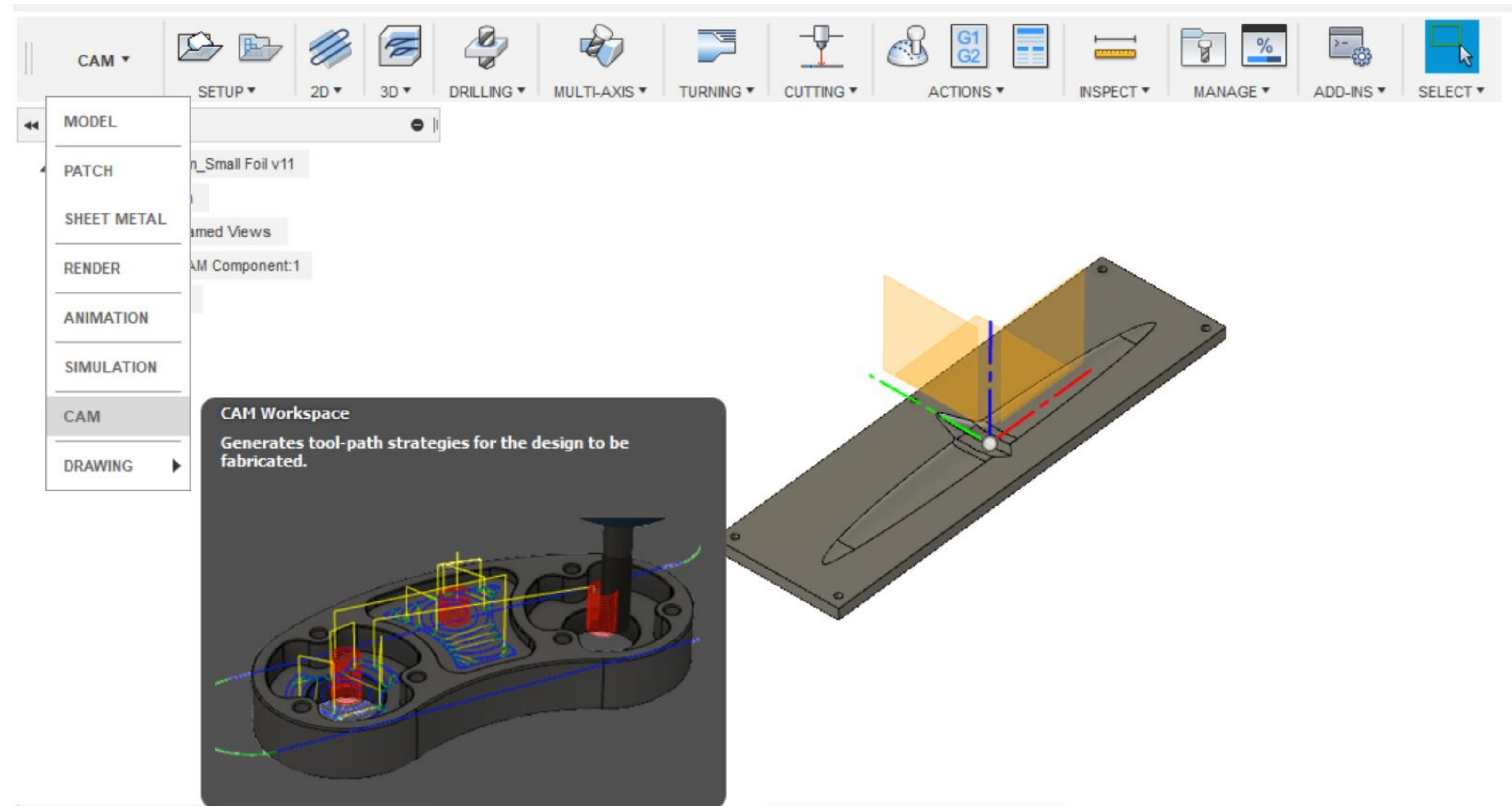
- Computer Aided Machining (CAM) allows us to program machines that make whatever we need
- In this case, make mold (tool) for composite fabrication
  - Hydrofoil requires 2 piece mold
  - Use “cut” feature to turn create mold model from hydrofoil





# CAM Workspace in Fusion 360

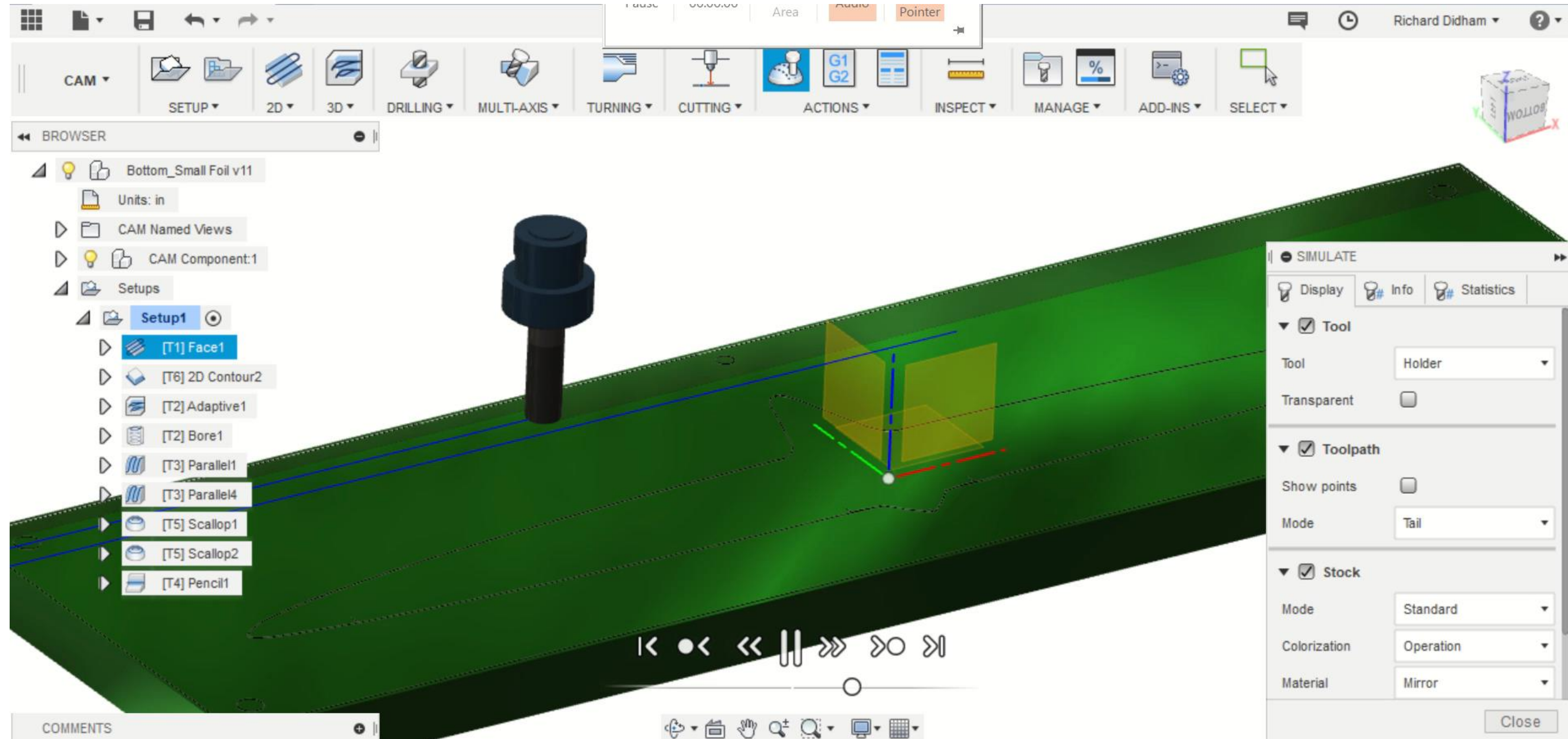
- Switch to CAM workspace with a simple click
- Traditionally CAM would require separate software environment or additional packages to





# CAM Programming in Fusion 360

- Allows us to specify machining process
- Allows us to simulate machining process





# Workflow Overview:

Design optimal profiles for hydrofoil using Computational Fluid Dynamics (CFD) software

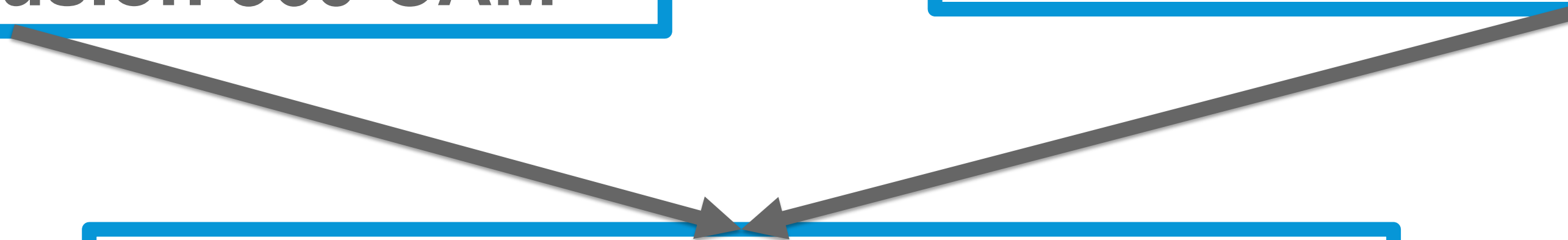


Work on 3D body within Fusion 360 CAD/CAM environment



**Program CNC router to machine molds using Fusion 360 CAM**

Define Layup scheme using Autodesk Tru-Composites



Fabricate Hydrofoil



# CNC Machining

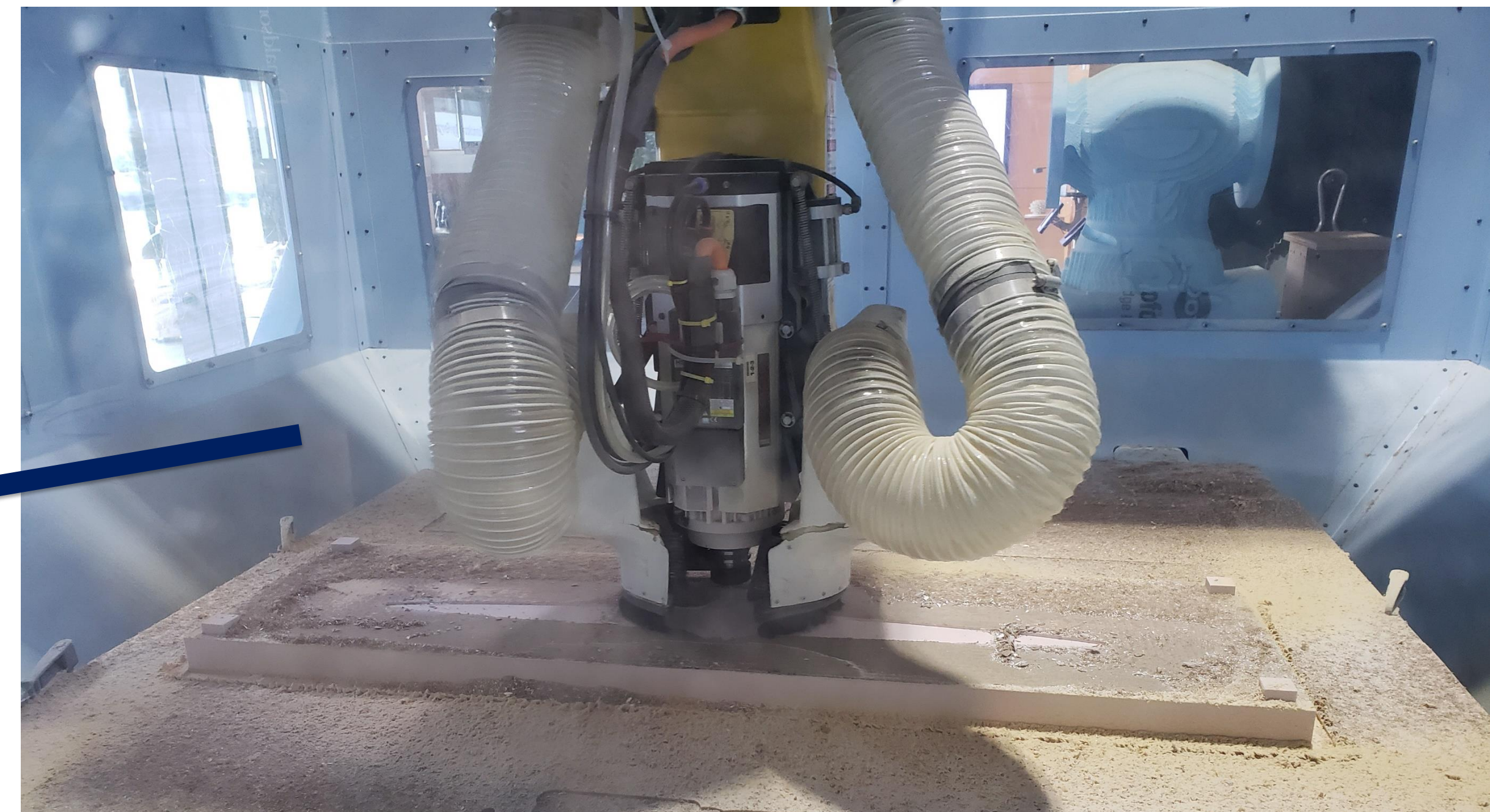
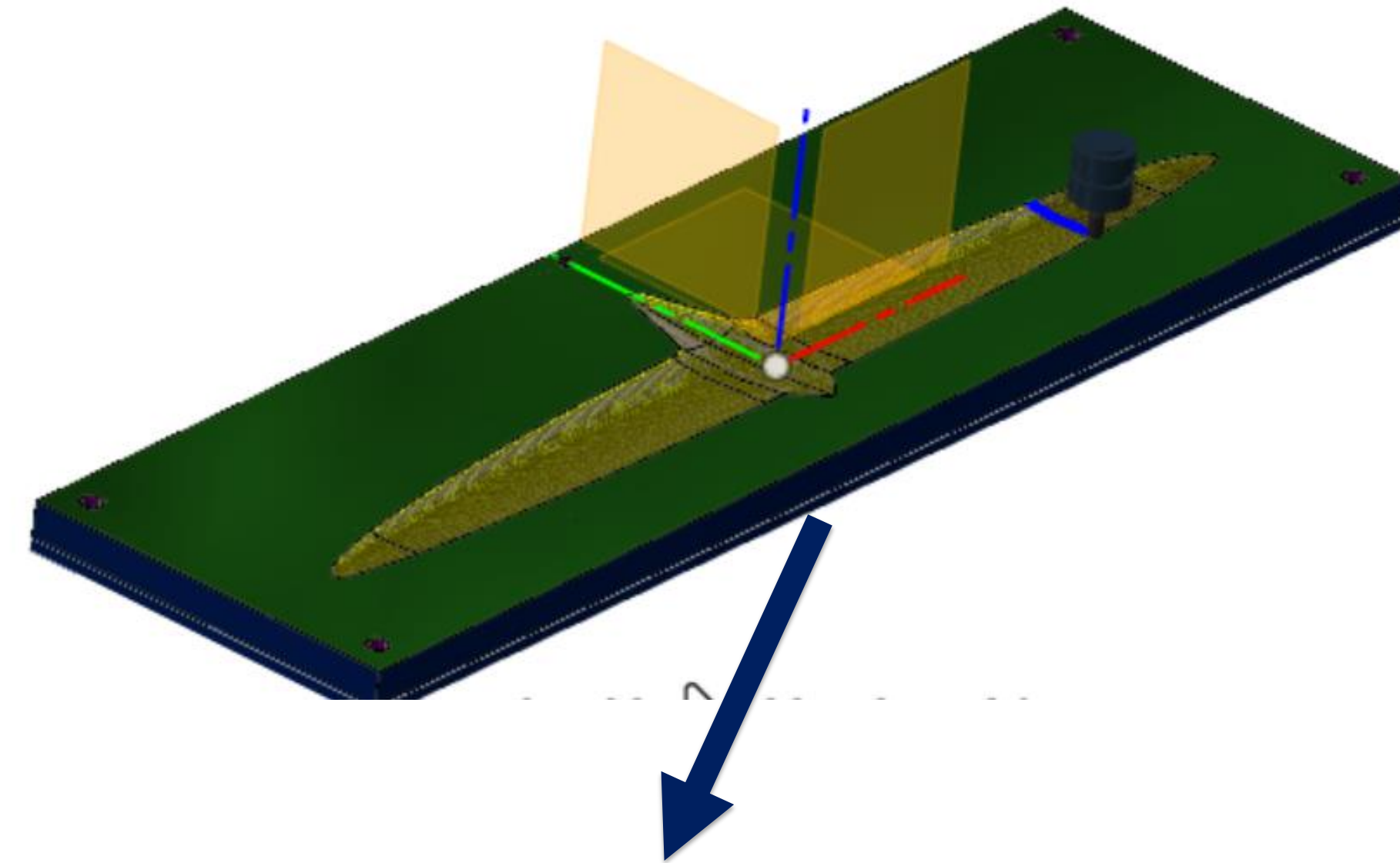
- CAM program from Fusion 360 uploaded to a Computer Numeric Control (CNC) router
  - Giant robot with a variety of cutting tools on the end of it
- Used the DMS 5 axis router at Autodesk's Pier 9 Workshop





# CNC Machining

- Machines material according to our Fusion 360 CAM programming
- Virtual World >> Real World!!



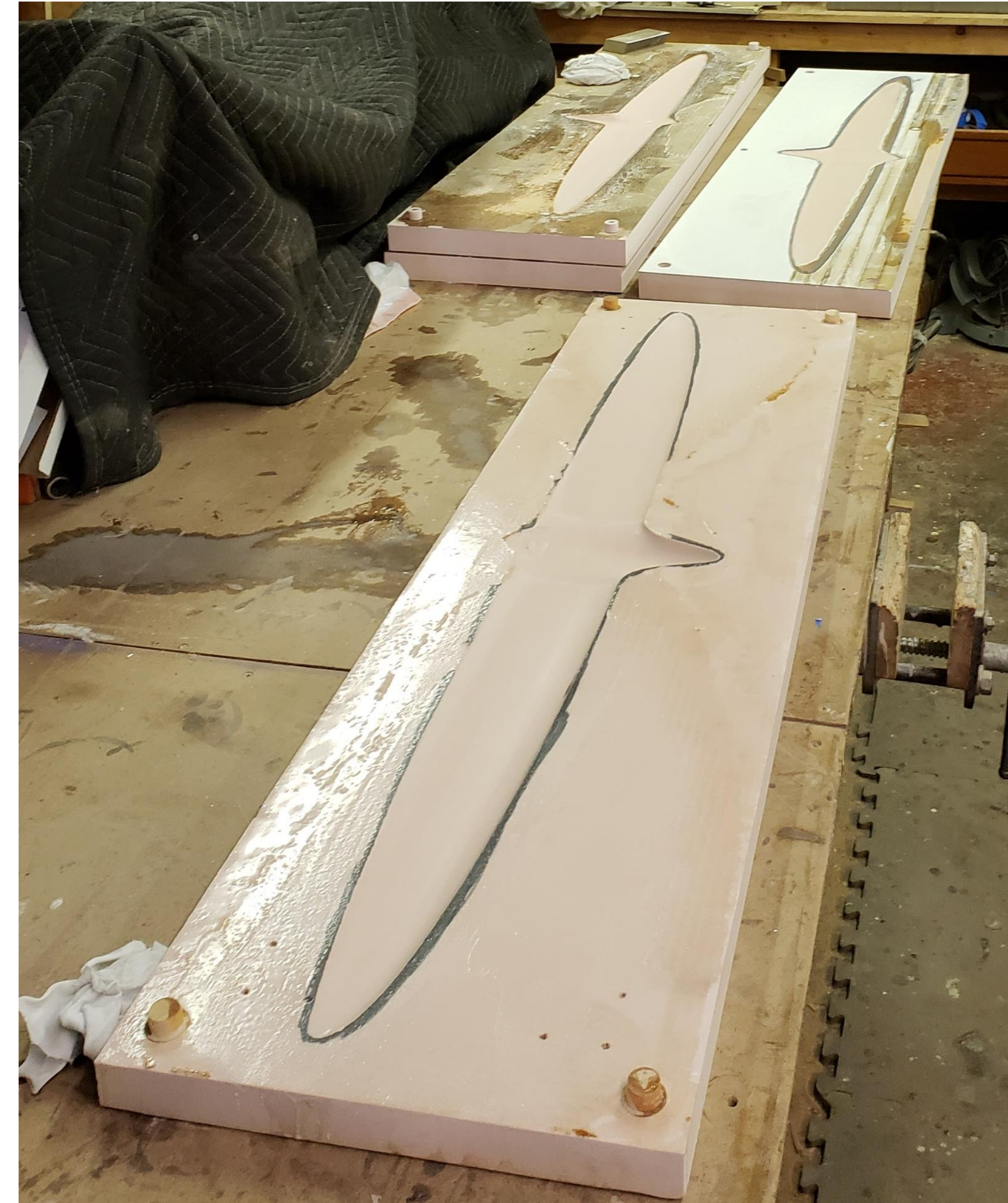






# Post Machining

- Minor post processing needed
- Then molds are ready for use





# Workflow Overview:

Design optimal profiles for hydrofoil using Computational Fluid Dynamics (CFD) software

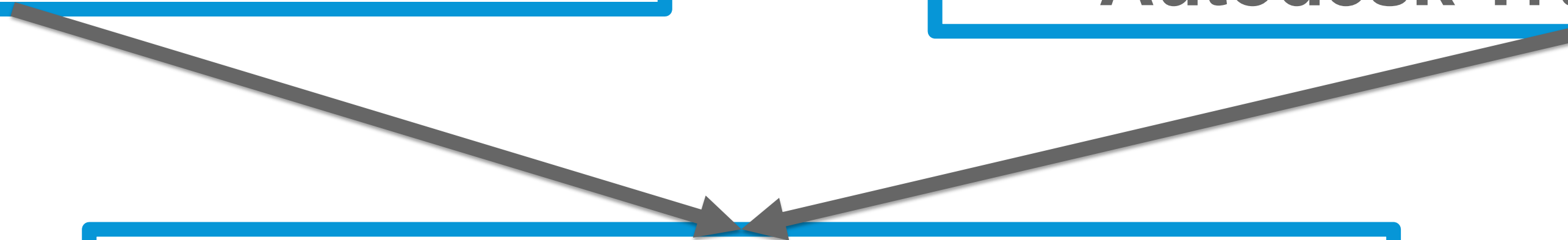


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Program CNC router to machine molds using Fusion 360 CAM

**Define Layup scheme using Autodesk Tru-Composites**

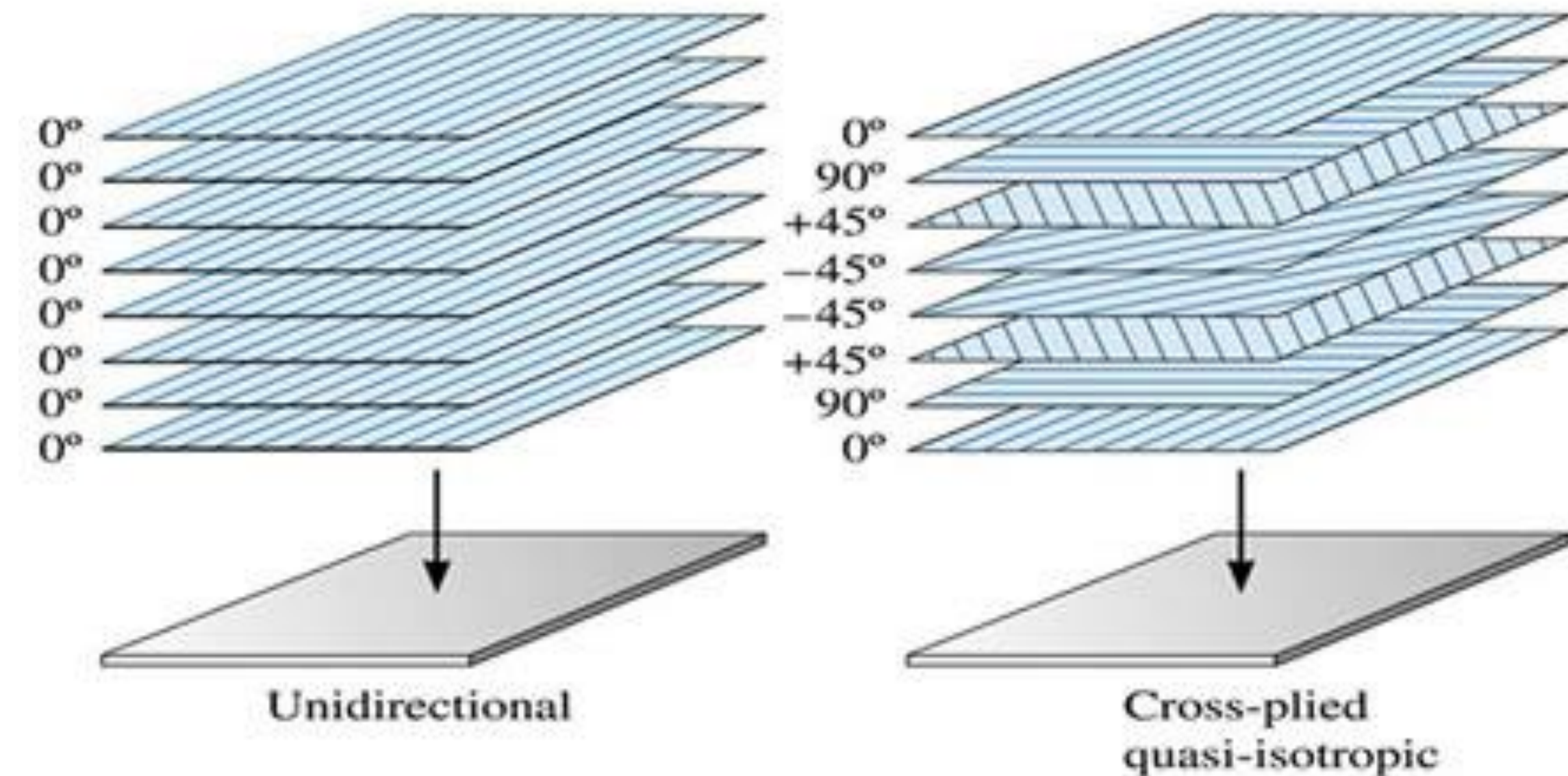
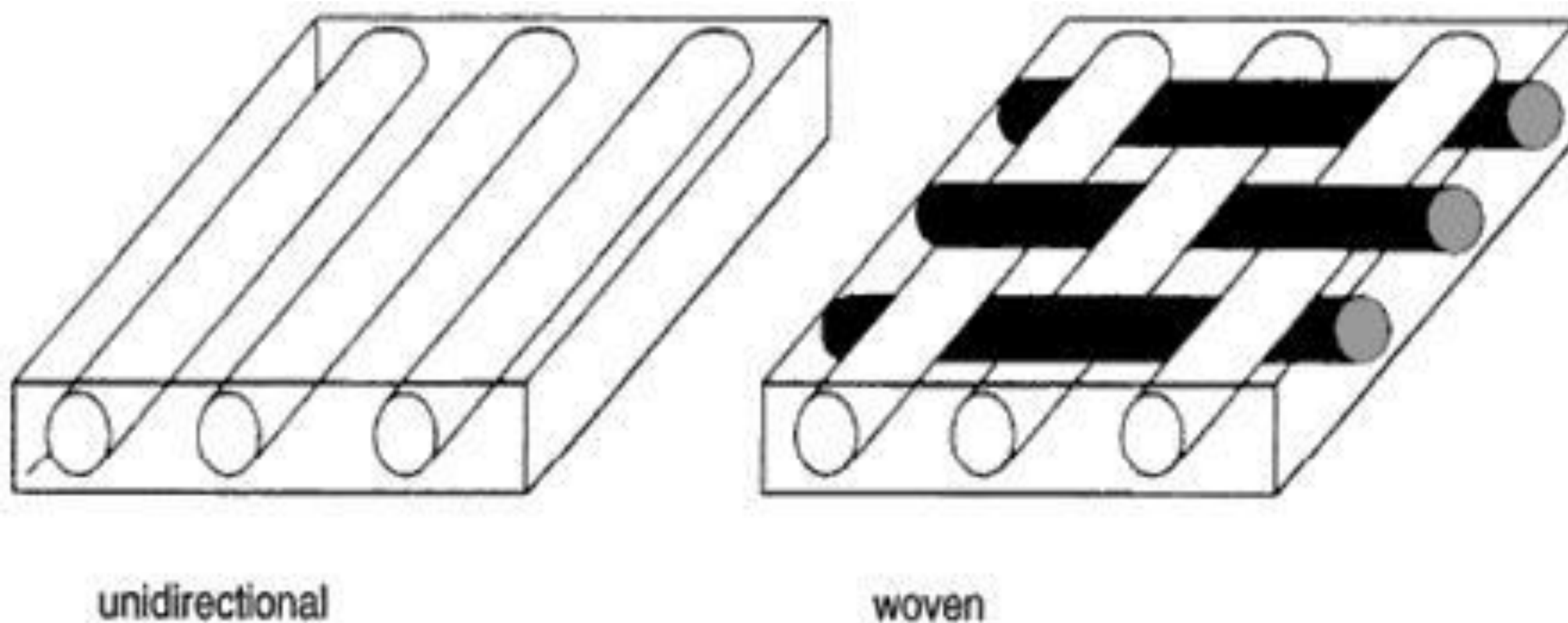
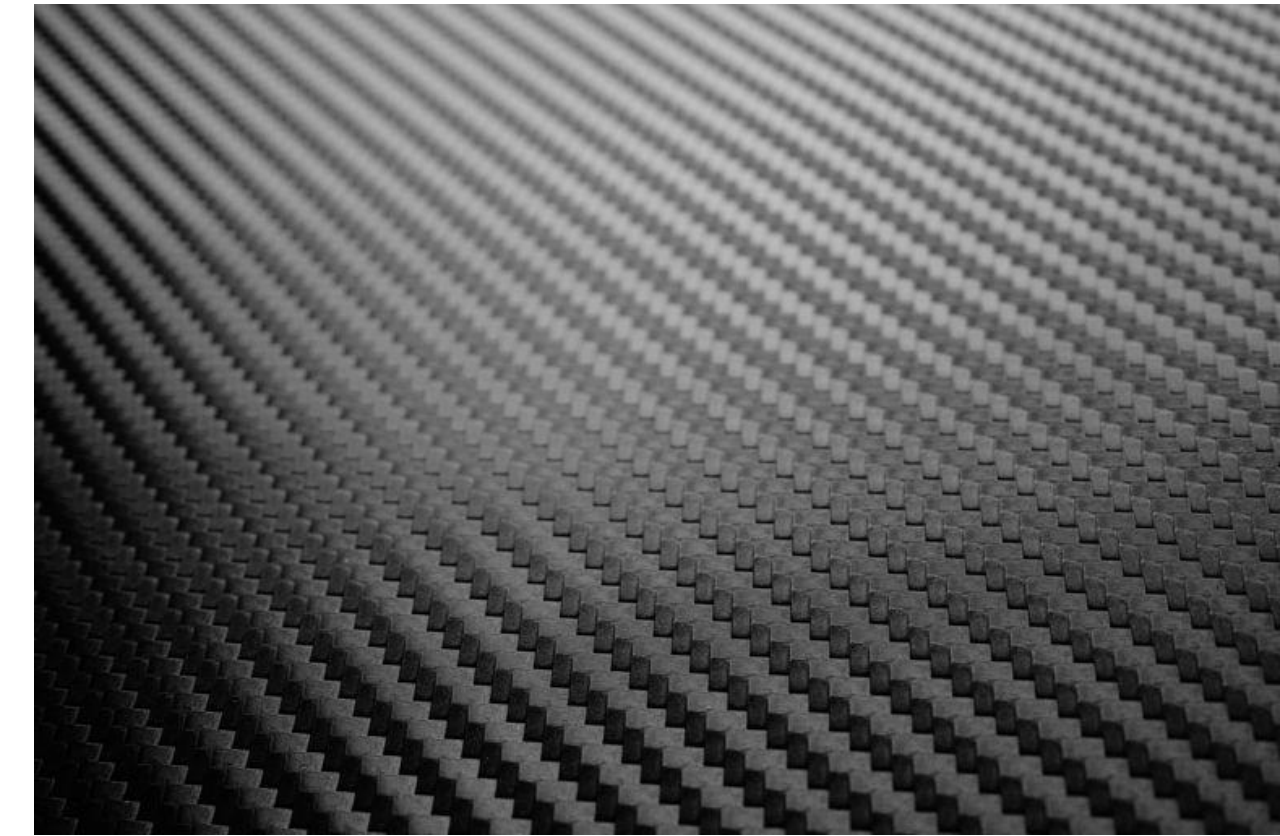


Fabricate Hydrofoil



# Composite Lay-ups

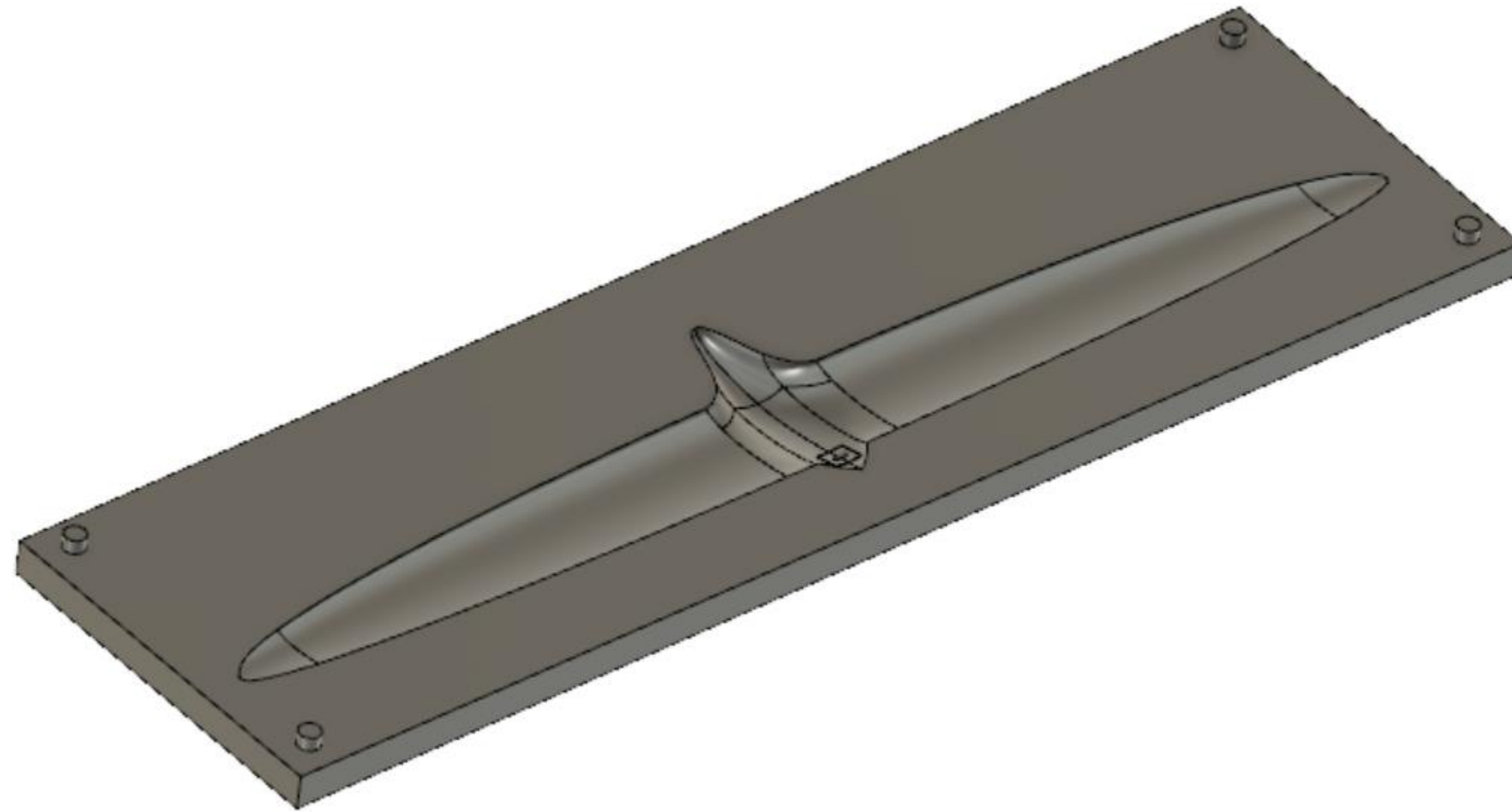
- AKA: Carbon fiber reinforced plastics (CFRP)
  - Never just carbon fiber: always carbon fiber + matrix material
- Illustration below:
  - rods = carbon fiber
  - surrounding volume = matrix material (usually thermoset polymer)
- Sheets of CFRP stacked to form Lay-up





# Composite Lay-ups

- Big Question 1: How many layers are needed for this complex geometry?
  - Complex contours
  - Want to avoid wasting material where possible

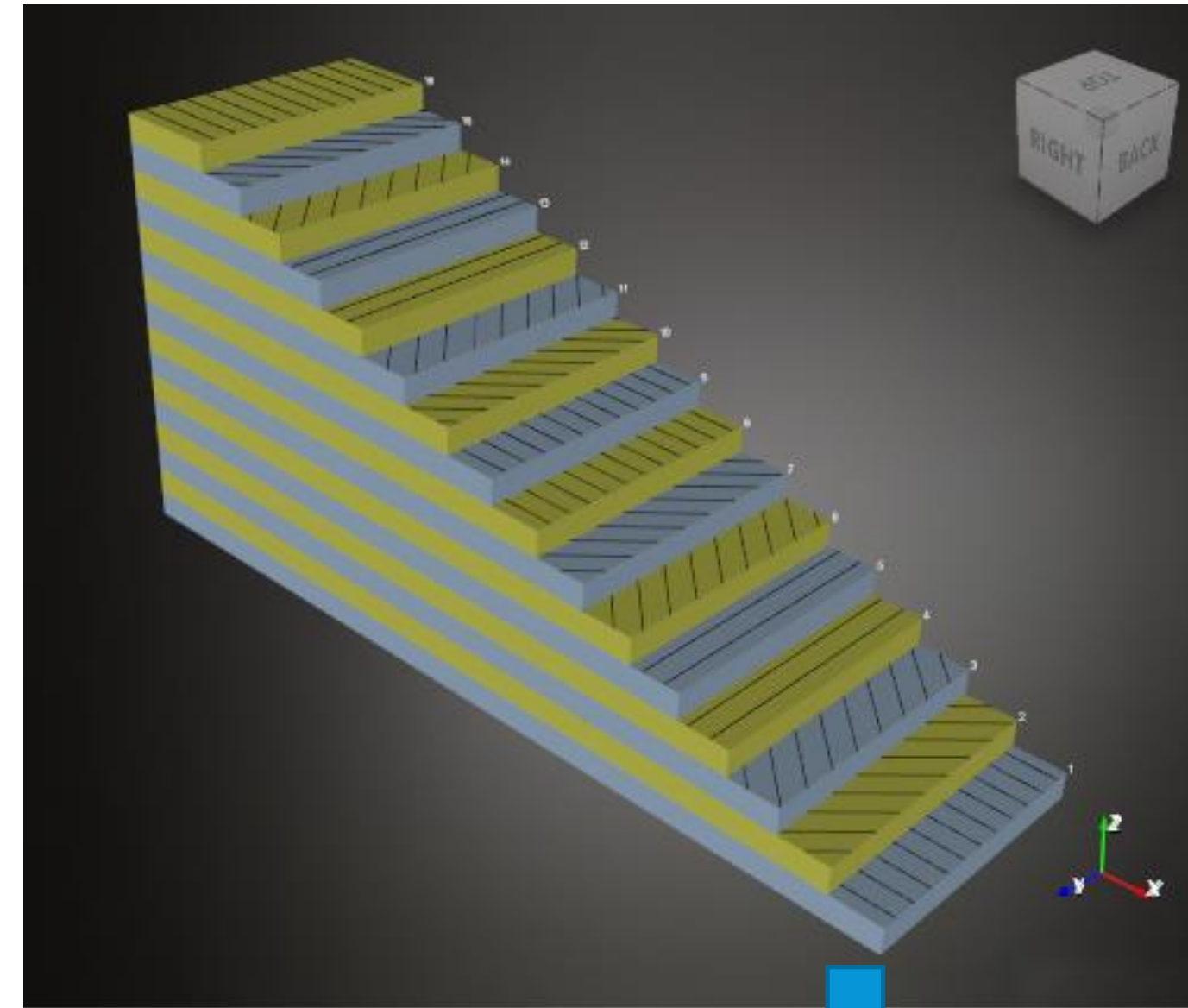




# Solution: Autodesk Tru Composites

## Laminate Survey

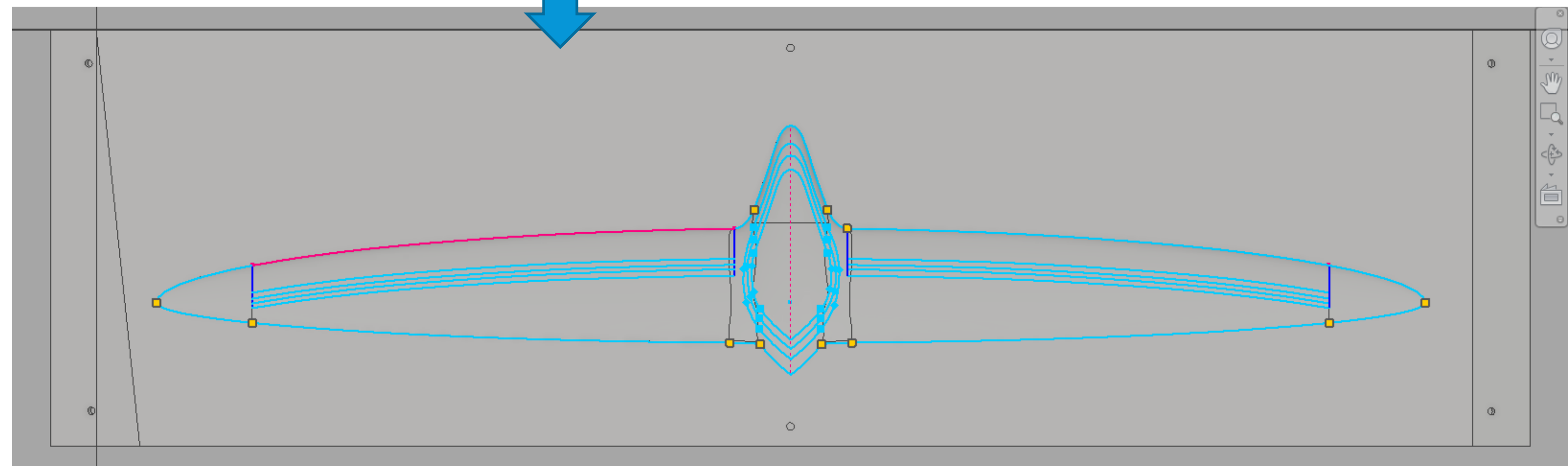
- Determine necessary layup thickness and orientation
- Calculates laminate material stiffness from shear strength, compressive/tensile strengths, and Young's modulus.



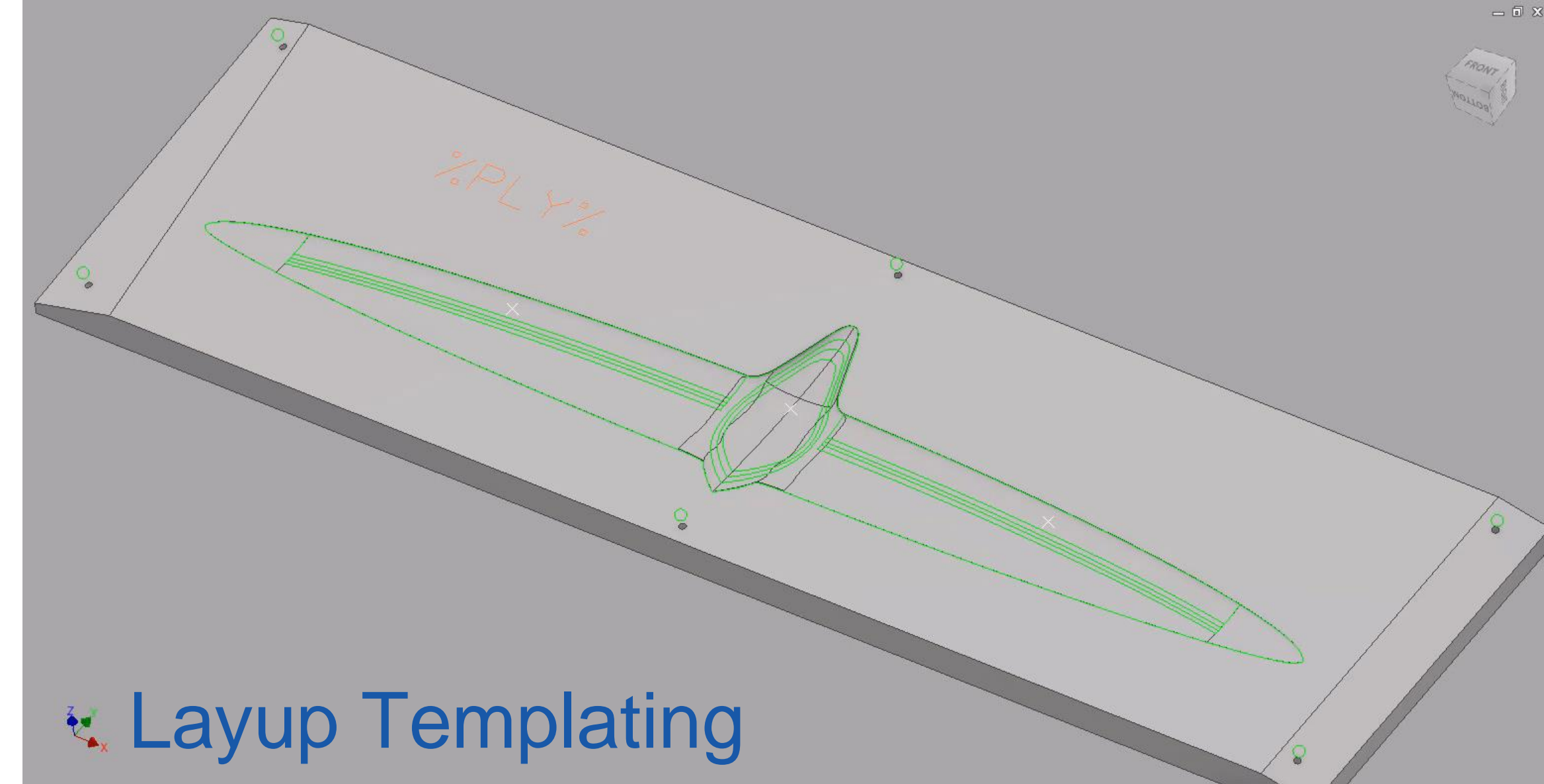
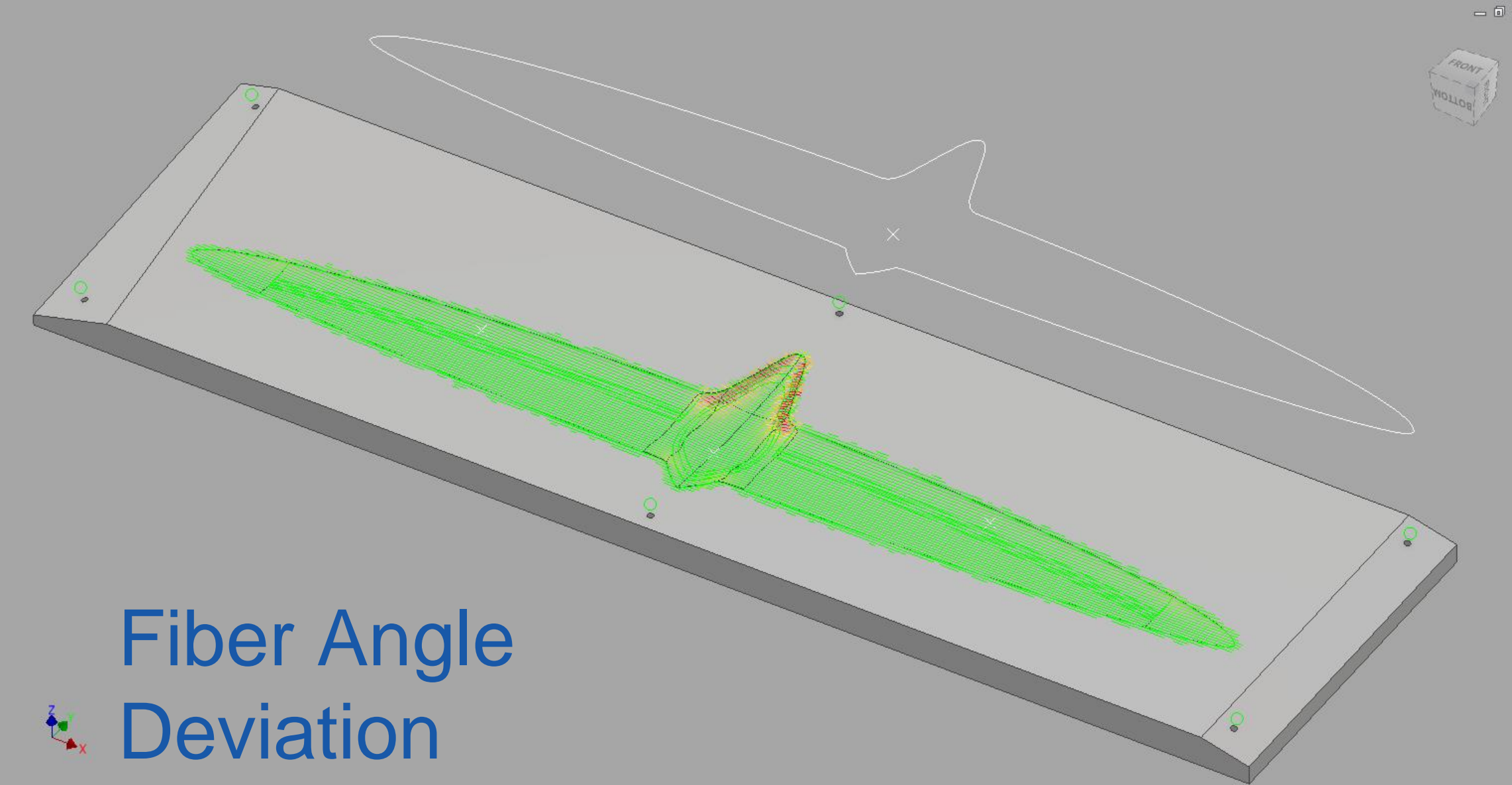
Laminate Survey Results								
Layup	%+0	%+90	%+45	Ex (psi)	Ey (psi)	Gxy (psi)	NUxy	
1	100	0	0	2.34961e+0...	1.40469e+0...	850066	0.3183	
2	95	5	0	2.24478e+0...	2.51557e+0...	850066	0.178185	
3	95	0	5	2.253e+007	1.68745e+0...	1.10947e+0...	0.414886	
4	90	10	0	2.1361e+007	3.62641e+0...	850066	0.123723	
5	90	5	5	2.15346e+0...	2.79763e+0...	1.10947e+0...	0.251434	
6	90	0	10	2.15414e+0...	1.96311e+0...	1.36888e+0...	0.482941	
7	85	15	0	2.02628e+0...	4.73719e+0...	850066	0.0947594	
8	85	10	5	2.04737e+0...	3.90768e+0...	1.10947e+0...	0.180373	
9	85	5	10	2.05969e+0...	3.07214e+0...	1.36888e+0...	0.31076	
10	85	0	15	2.0539e+007	2.23082e+0...	1.62829e+0...	0.53348	
11	80	20	0	1.91595e+0...	5.84792e+0...	850066	0.0767843	
12	80	15	5	1.93906e+0...	5.01759e+0...	1.10947e+0...	0.140628	
13	80	10	10	1.95647e+0...	4.18092e+0...	1.36888e+0...	0.229086	
14	80	5	15	1.9641e+007	3.33819e+0...	1.62829e+0...	0.359789	
15	80	0	20	1.95275e+0...	2.48965e+0...	1.8877e+006	0.572494	
16	75	25	0	1.80538e+0...	6.95857e+0...	850066	0.0645413	
17	75	20	5	1.82973e+0...	6.12733e+0...	1.10947e+0...	0.115236	

## Detailed Ply Design

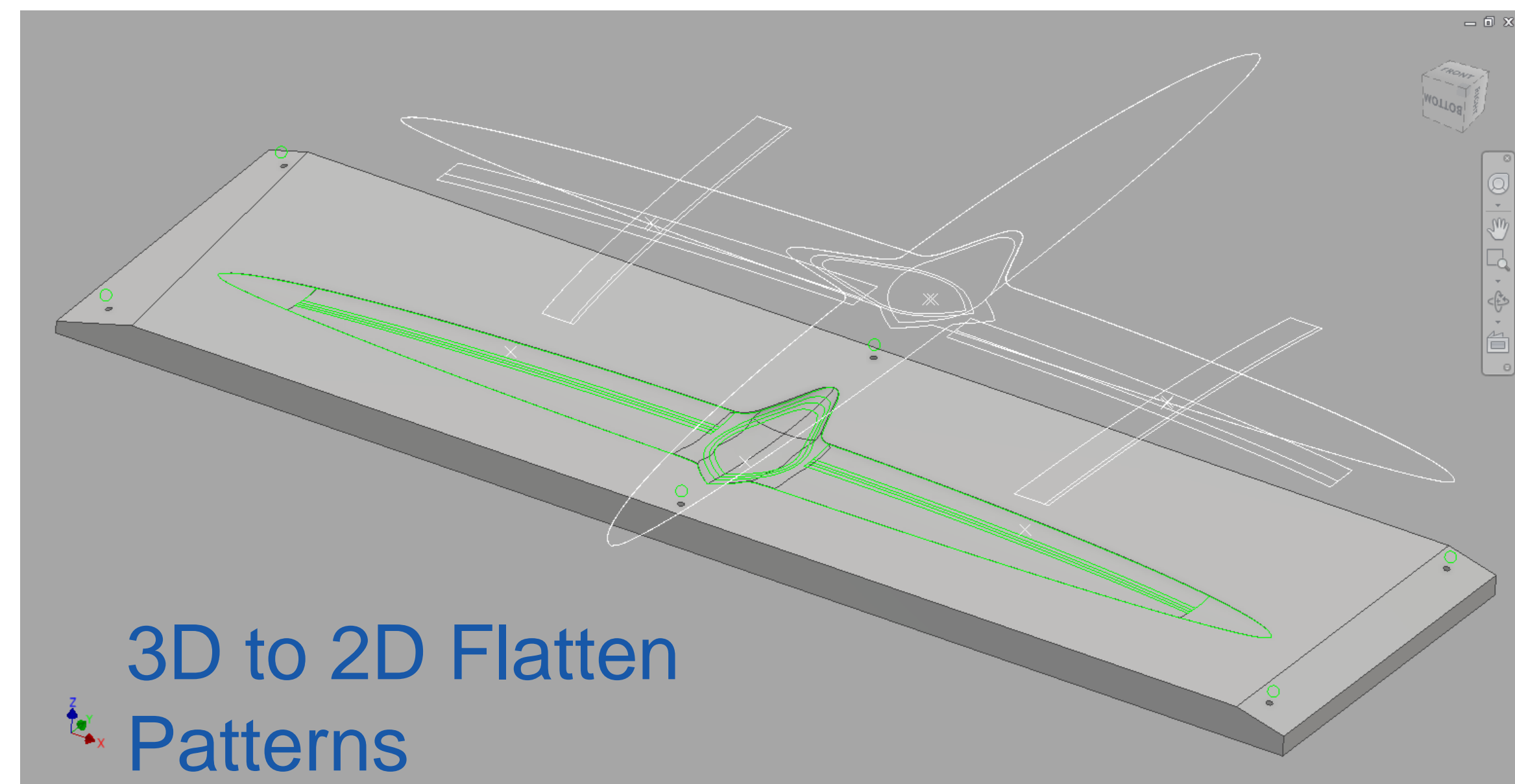
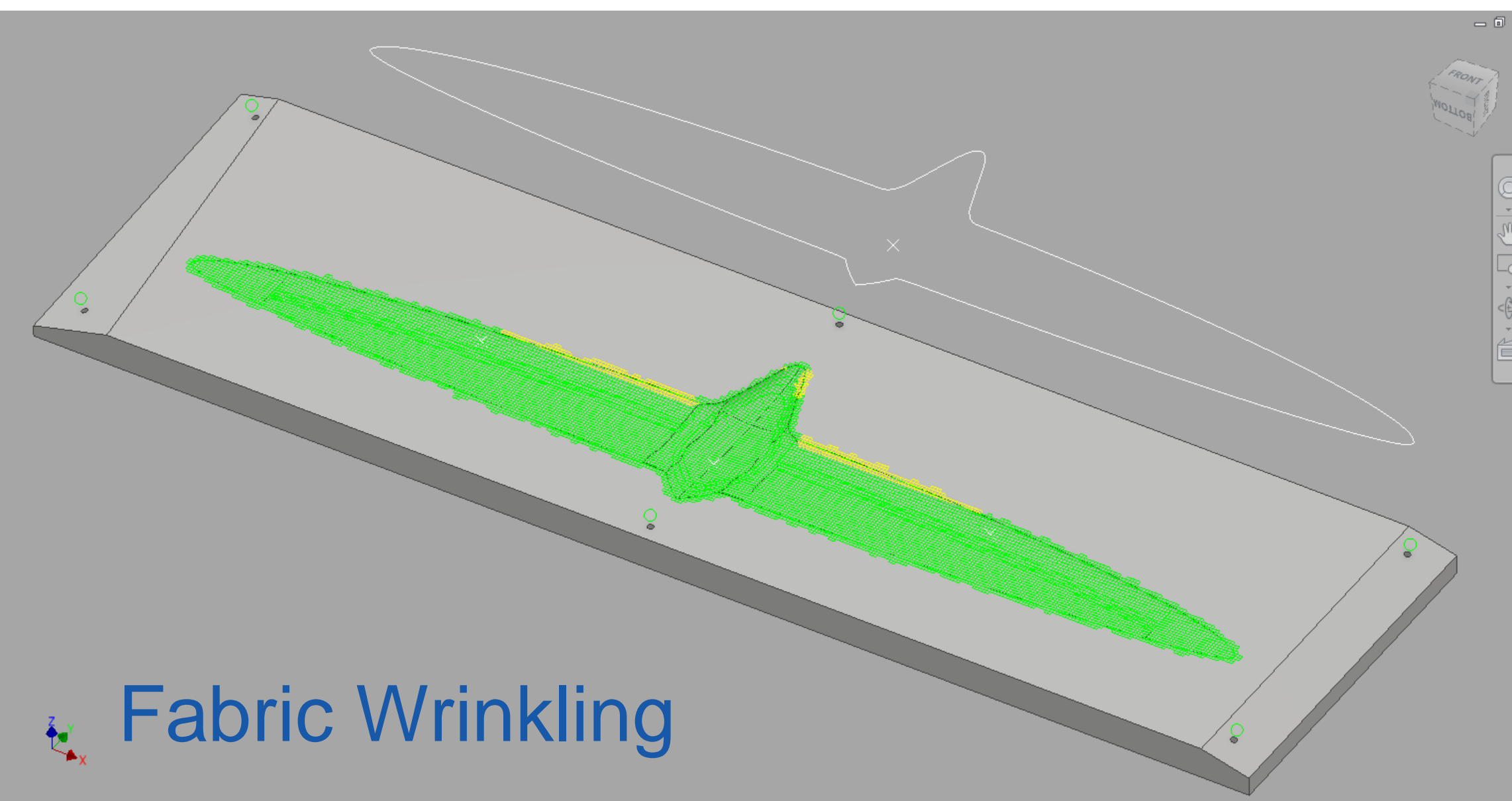
- Associate wireframe geometry to define each layer
- Create ply drop-offs for smooth transitions between varied thicknesses







## Manufacturing Analysis, Flat Patterning, and Laser Projection



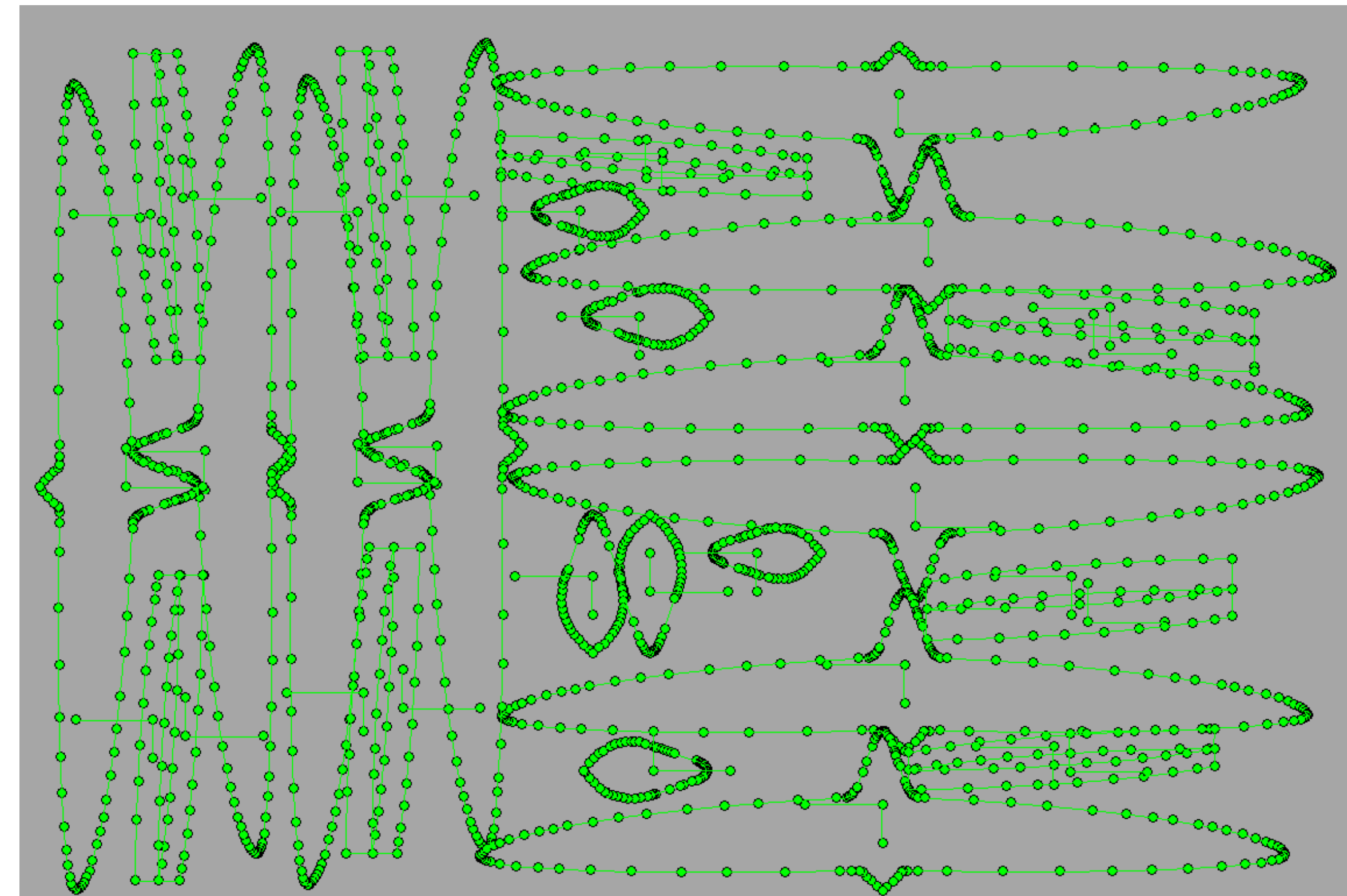
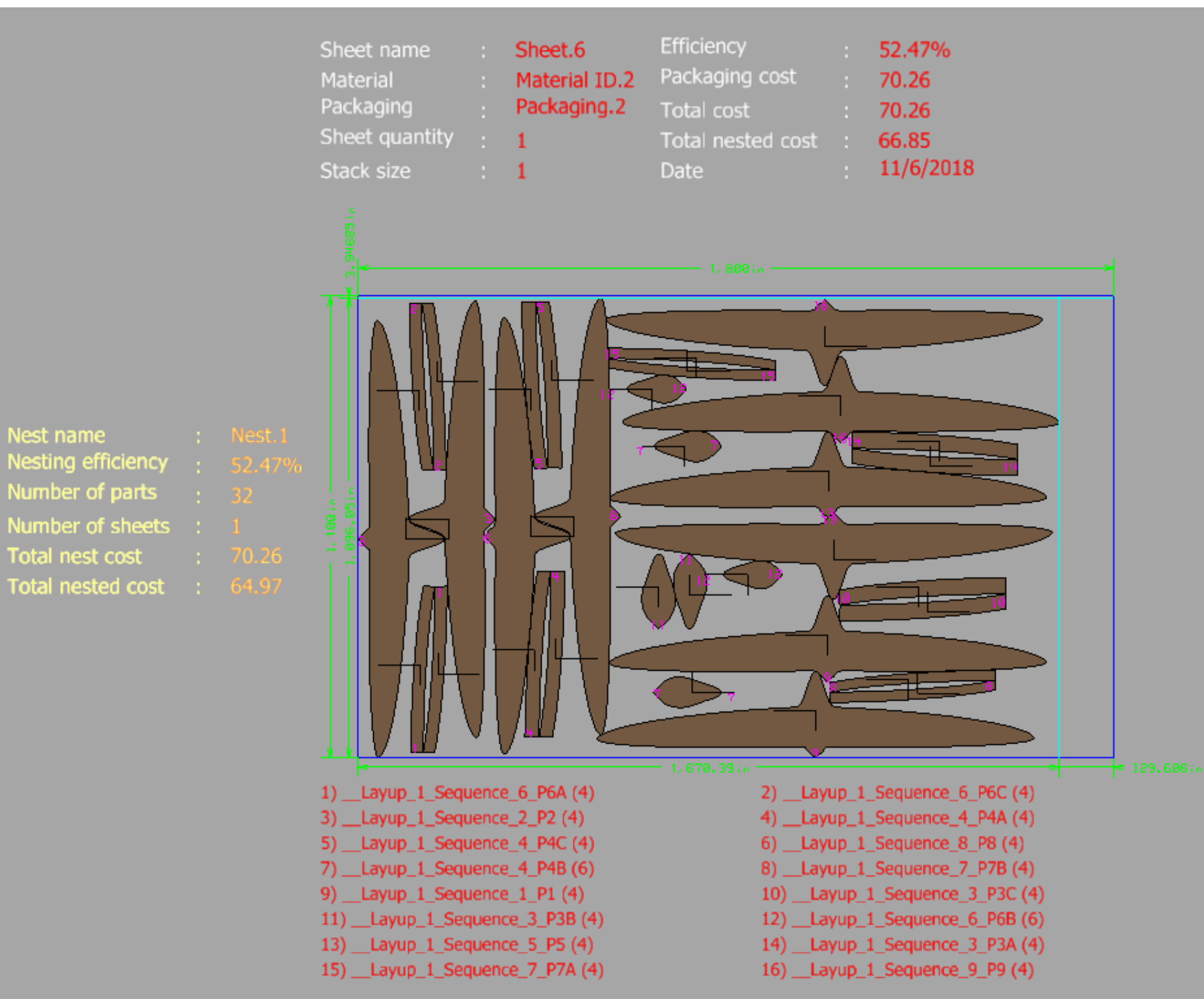


# Autodesk Tru Composites

## Flat Patterns sent directly to Nesting Environment

- Fully associative
- Ply Orientations are maintained
- Shape information is maintained

Export DXF file for CNC cutting machine or for use as a template





# Workflow Overview:

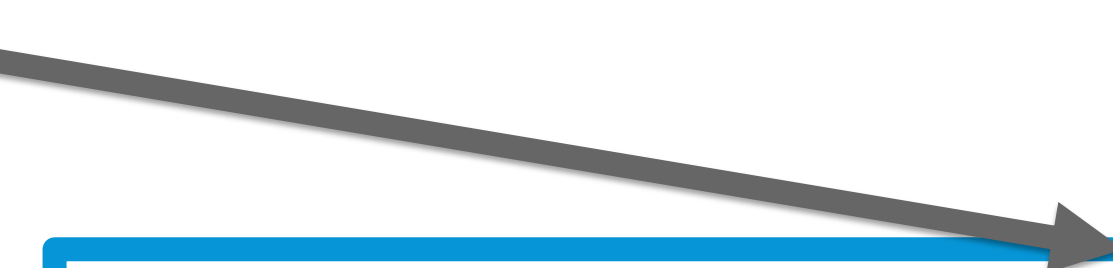
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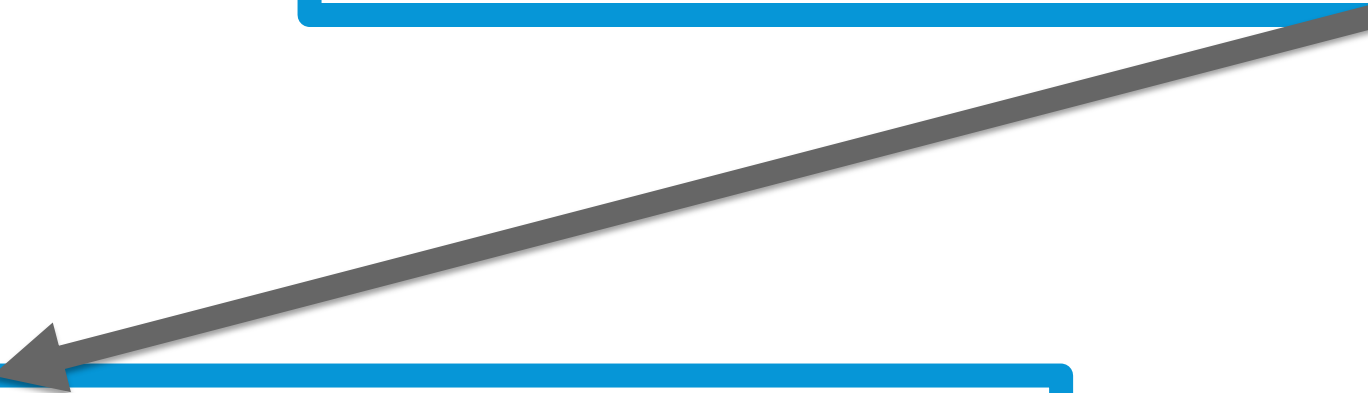
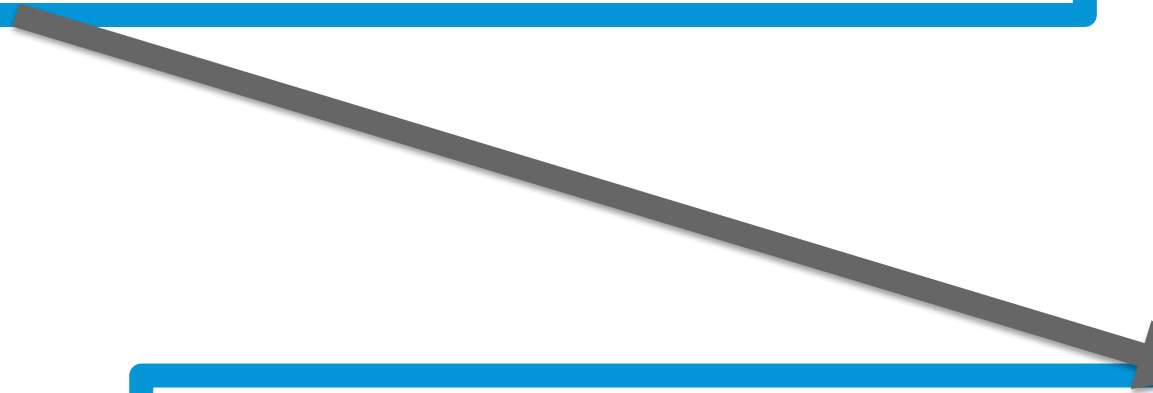
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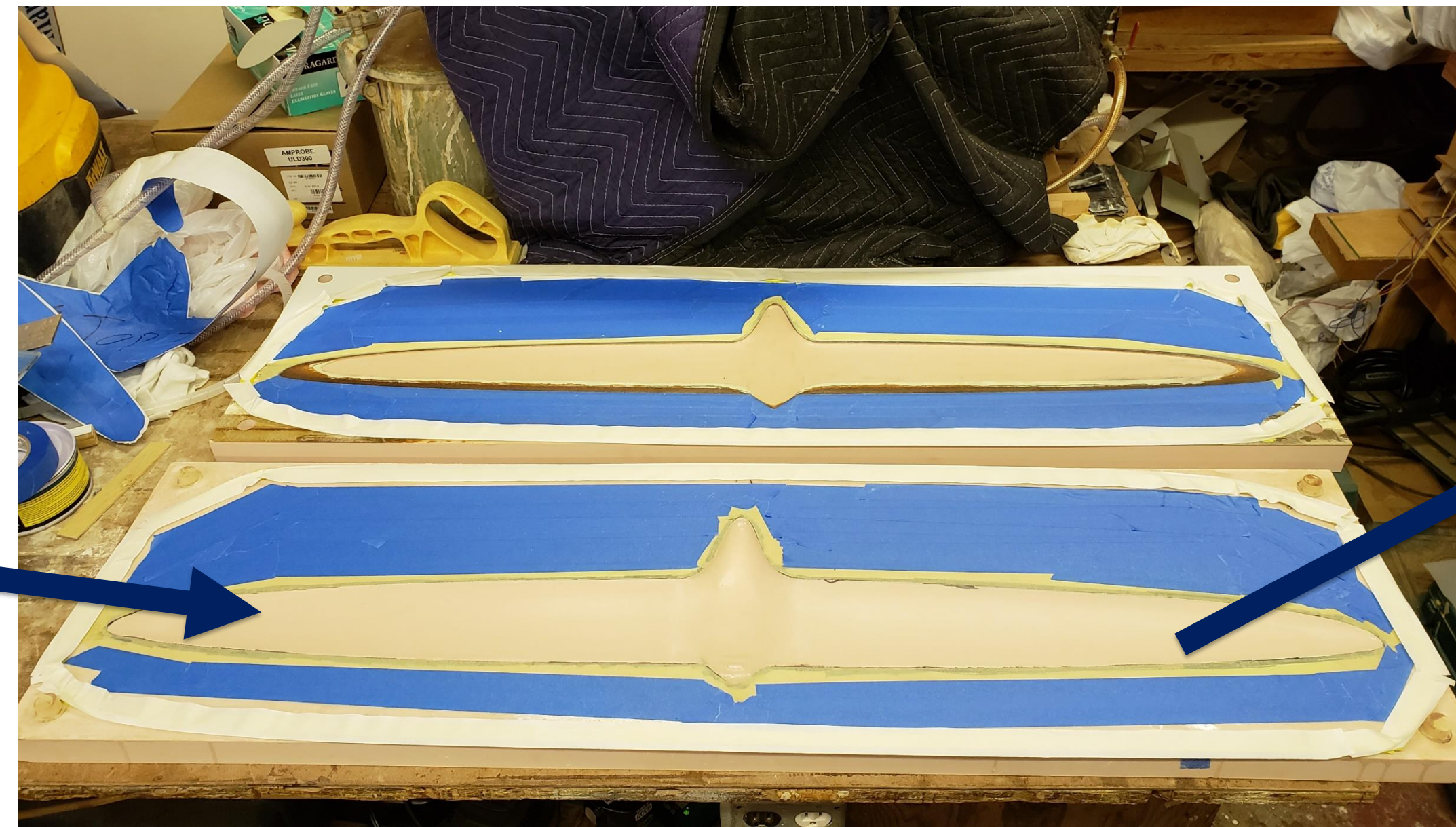
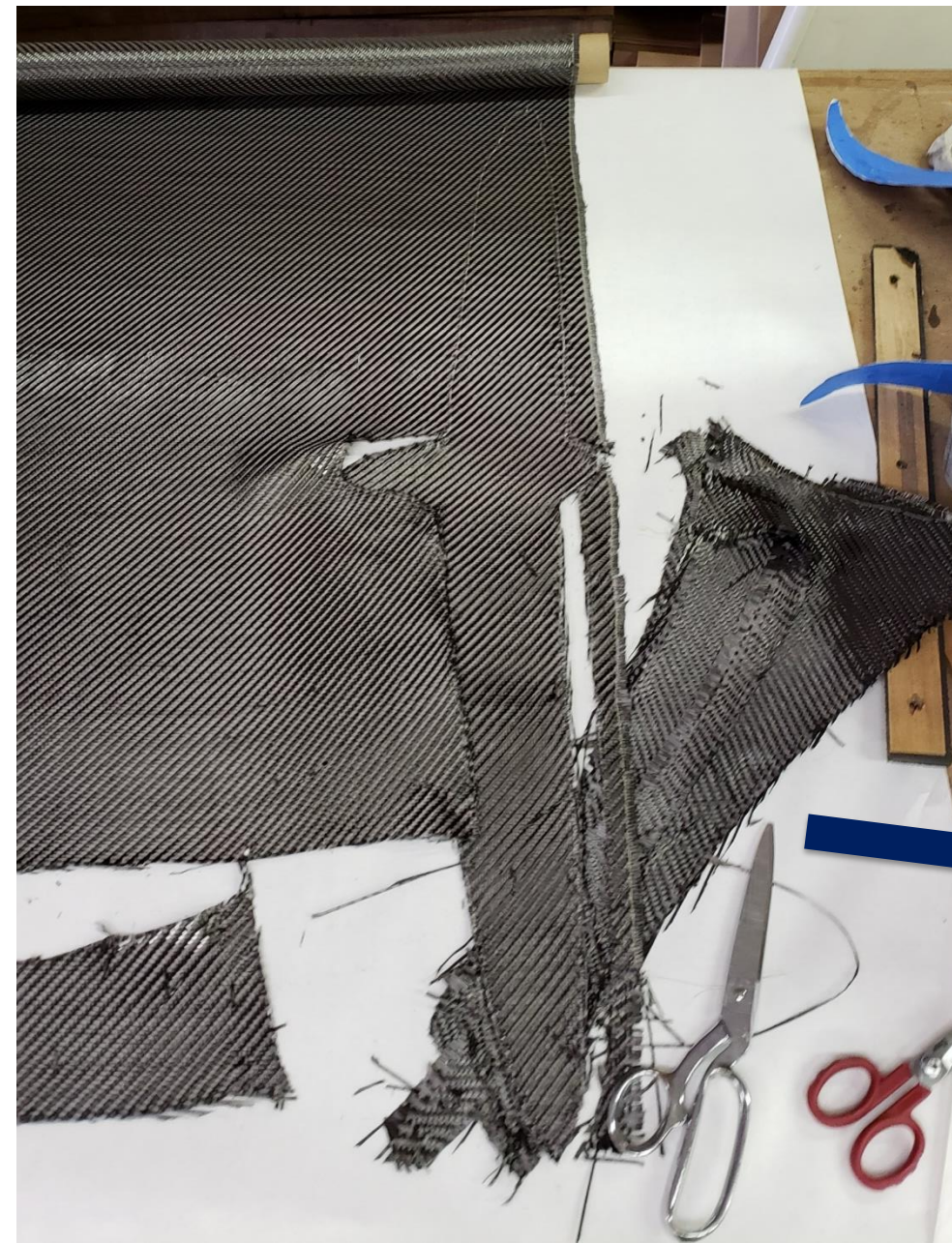


**Fabricate Hydrofoil**



# Resin Infusion Manufacturing

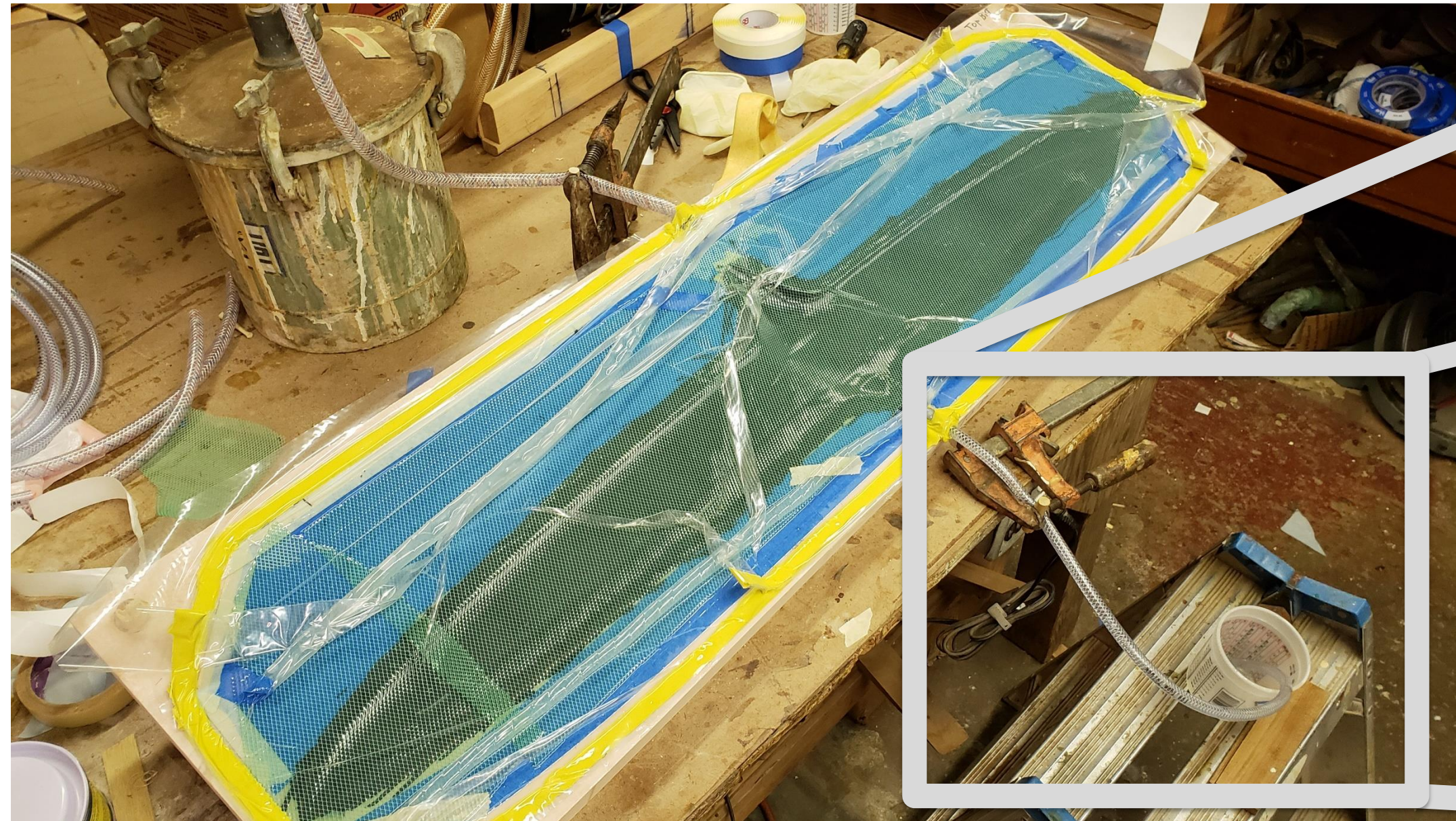
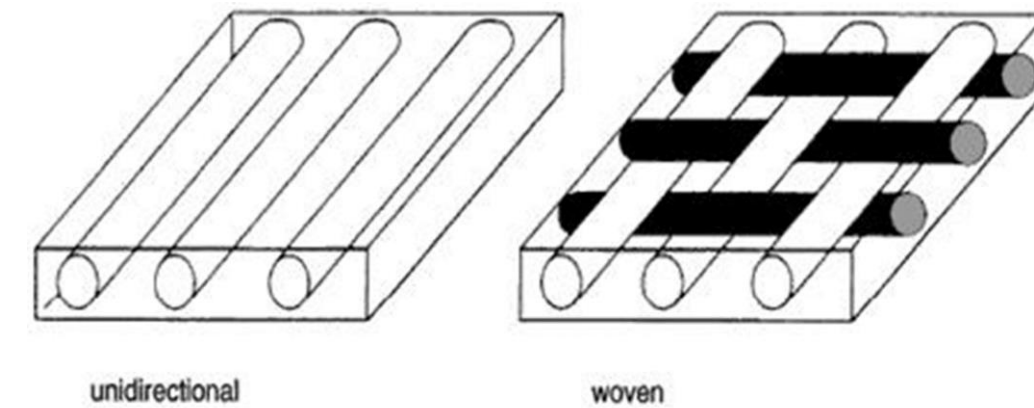
- AKA: vacuum assisted resin transfer molding (VARTM)
  - Thermoset polymer known as “resin” in its liquid state
- 1. Cut out dry carbon fiber fabric – No matrix at this stage
- 2. Lay fabric in mold in desired orientation
- 3. Seal the perimeter of the mold using vacuum bag





# Resin Infusion Manufacturing

4. Pull a vacuum down onto the part to compress the layup (leads to better mechanical properties)
5. Open one end of the vacuum - use pressure differential to suck resin (liquid state polymer) into carbon fabric
6. Resin fills voids and uniformly distributes itself throughout carbon fiber fabric





# Resin Infusion Manufacturing

- 7. Seal the environment while the resin hardens
- 8. Remove vacuum bag and demold part
- 9. Process part before usage





# Final Product





# Overview

- Introduction to the US Olympic Sailing Program
- Design Project: Moth Hydrofoil
- Future Development Plans with Autodesk



# Future Development: Finn Rudder

Apply what we learned to from the moth foil to Olympic equipment

## Finn Rudder:

- Open to development
- Few constraints to design
- Design can be optimized for application





# Future Development: Finn Rudder

## Performance Goals:

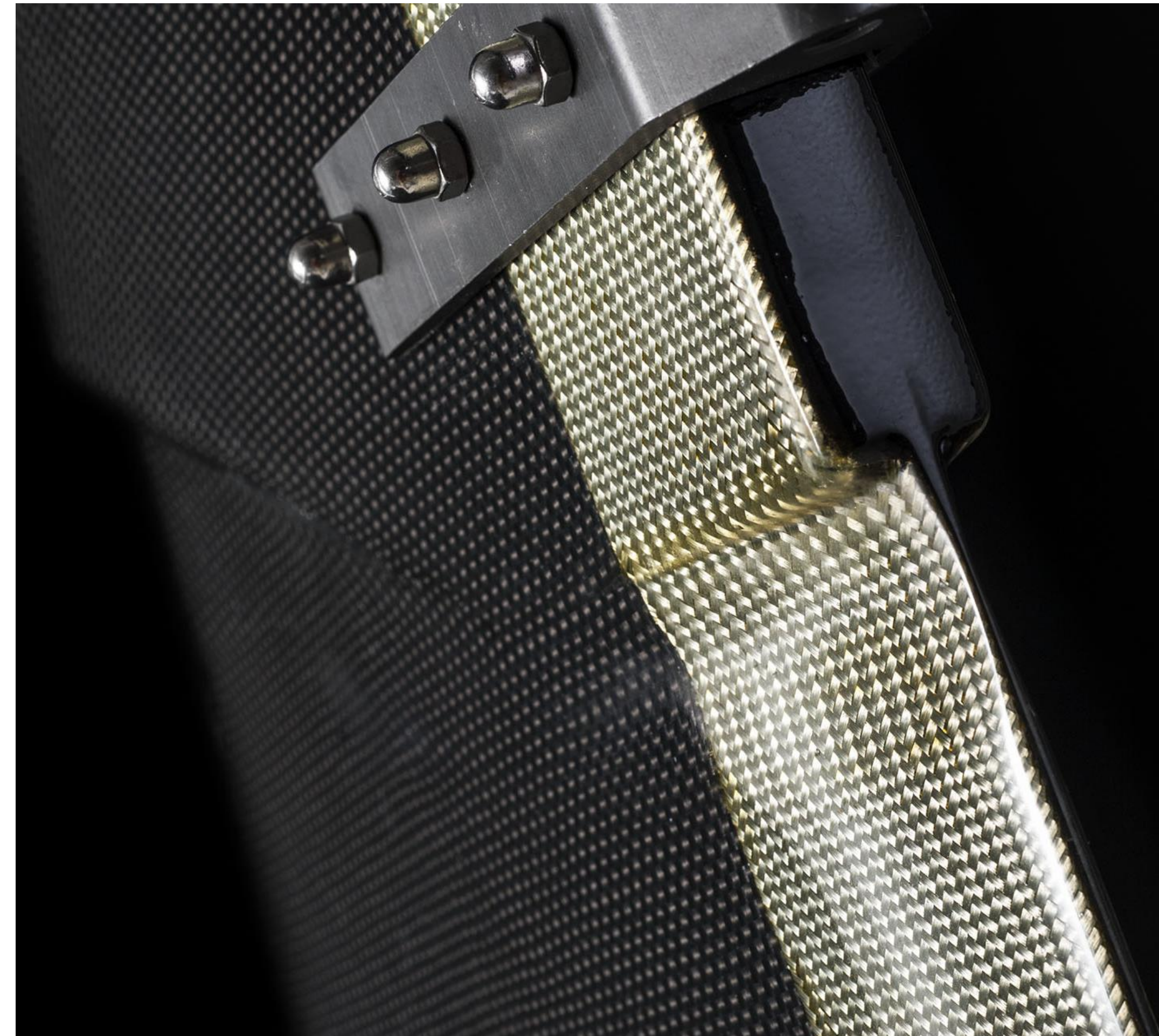
- Optimize for Tokyo 2020 Olympic venue
- Optimize for particular athlete(s)
- Improve on current designs

## Design Constraints:

- Physical shape needs to conform to certain parameters

## Performance Constraints:

- Produce low drag across wide range of flow conditions
- Structurally sound subjected to variable loading

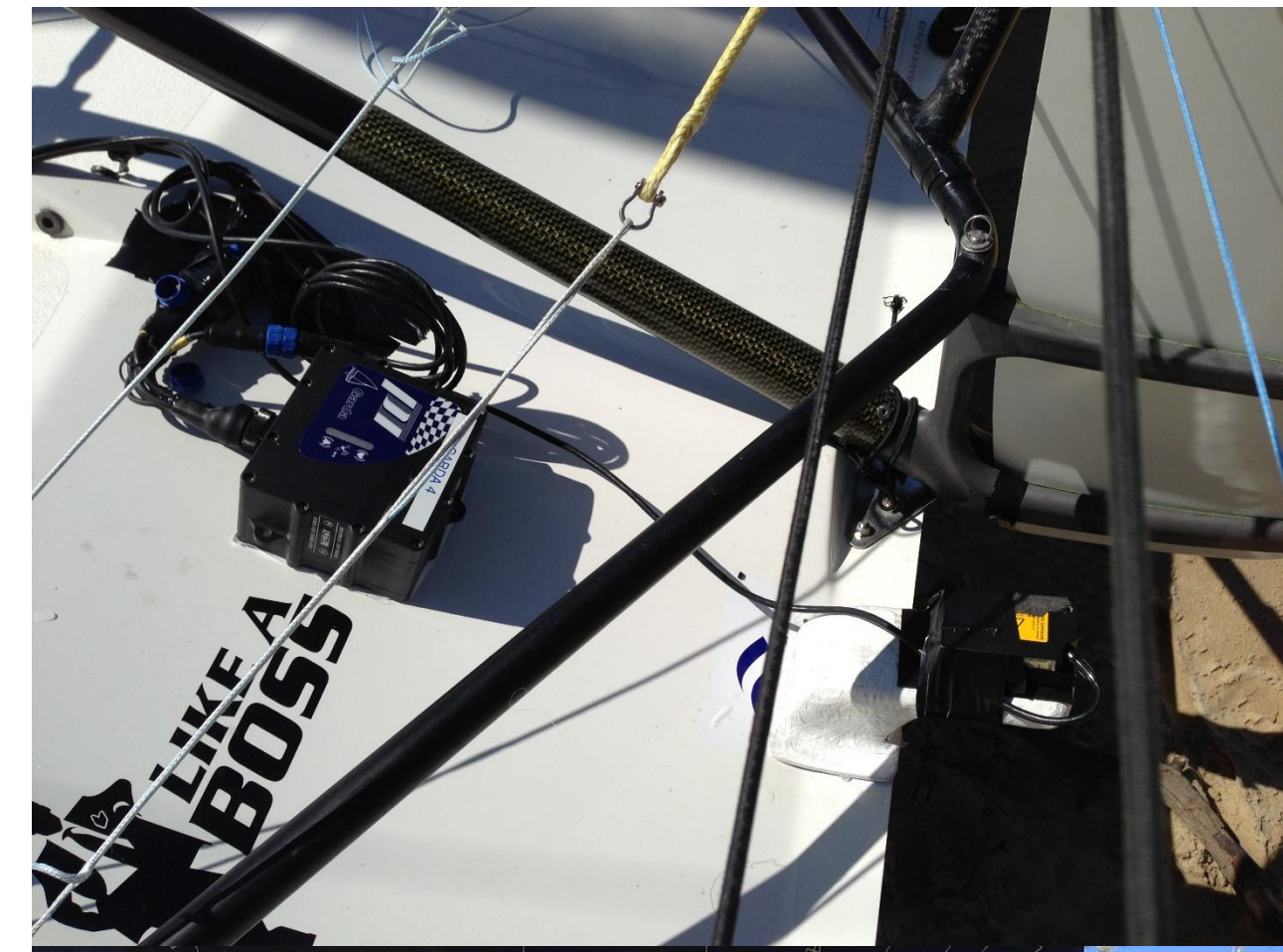




# Finn Rudder & Autodesk

## Performance Goals:

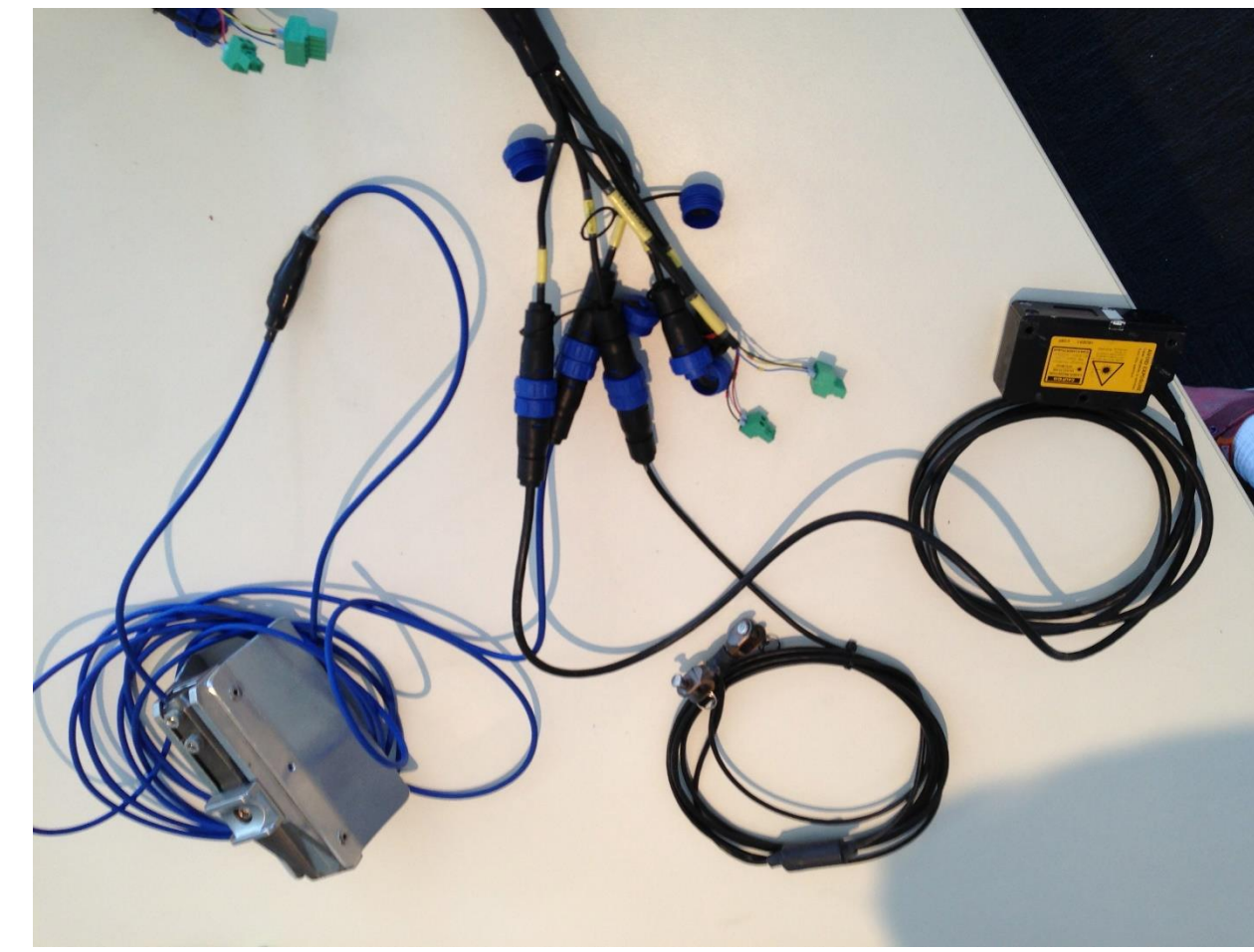
- Optimize for Tokyo 2020 Olympic venue – Data Acquisition Platform (DAP)
- Optimize for particular athlete(s) – Data Acquisition Platform (DAP)
- Improve on current designs – Laser scan existing equipment-> CFD Simulations



DAP electronics  
prototyped @ Autodesk  
Pier 9 Facility



FARO Laser  
Scanner @  
Autodesk BUILD  
Space





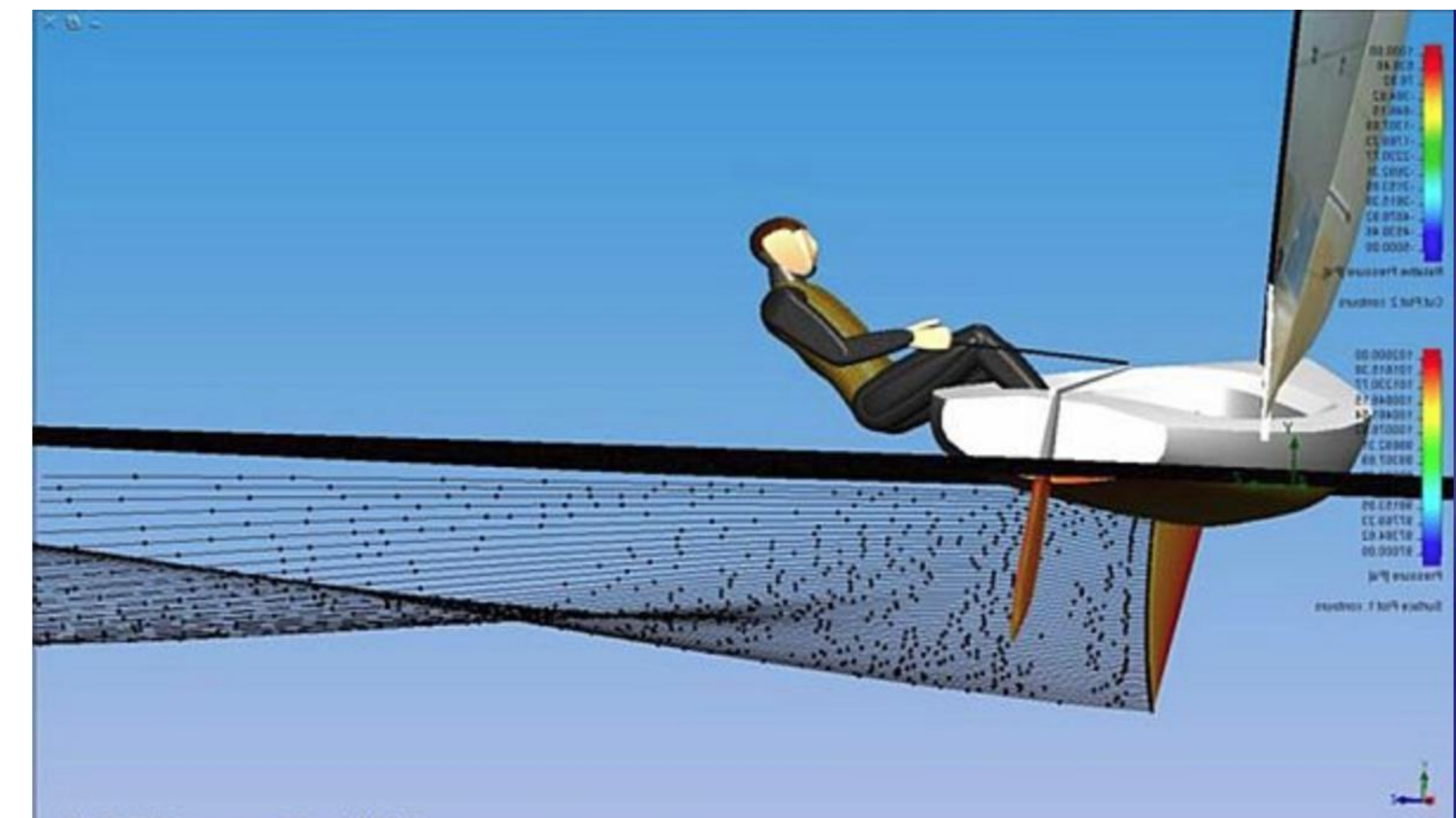
# Finn Rudder & Autodesk

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# Questions?





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