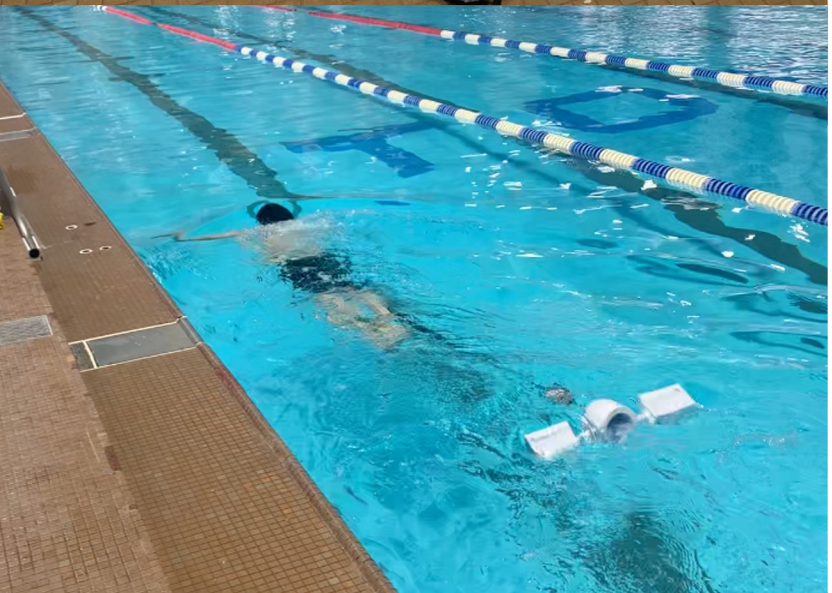
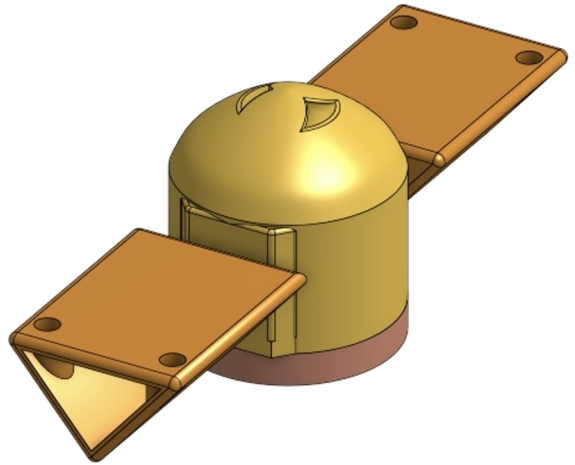
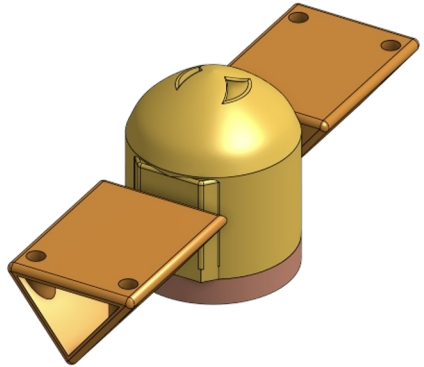




Praxis II
Fin-Drag Design

Isaac, Ezgi, Bobby, Alessandra

Table of **Contents**



The Opportunity

Community Overview

- **Our Community:**
  - **MSSAC** is a high-performance competitive swim club in Mississauga.

- **Crucial Stakeholders:**
  - High Performance Team (competitive swimmers ages 14-18)
  - The coaching team

- **Key Values**:
  - A portable design → the team travels frequently
  - More resistance levels → Current designs are insufficient

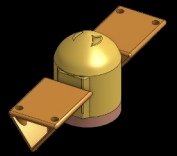
Need

Resistance training equipment that allows for **highly variable** resistance while **remaining portable**.

Our Team Values

Team Values:

- **Inclusivity**
- **Human Centric Design**
- **Sustainability**



2026 Feb

Jan 13 — Establish **Individual Position Statement**

Jan 18 — Start **RFP**

Feb 13 — Receive new **RFP**

Team Values:

- Inclusivity

→ Value designs that are highly **customizable/easy to personalize**

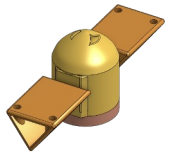
- Human-Centric Design

→Value **maintaining technique and comfort** of the swimmer
→Value a usable design, quick to switch between levels

- Sustainability

→ Prioritize **durability and resource conservation**

Our Team Limitations/Biases



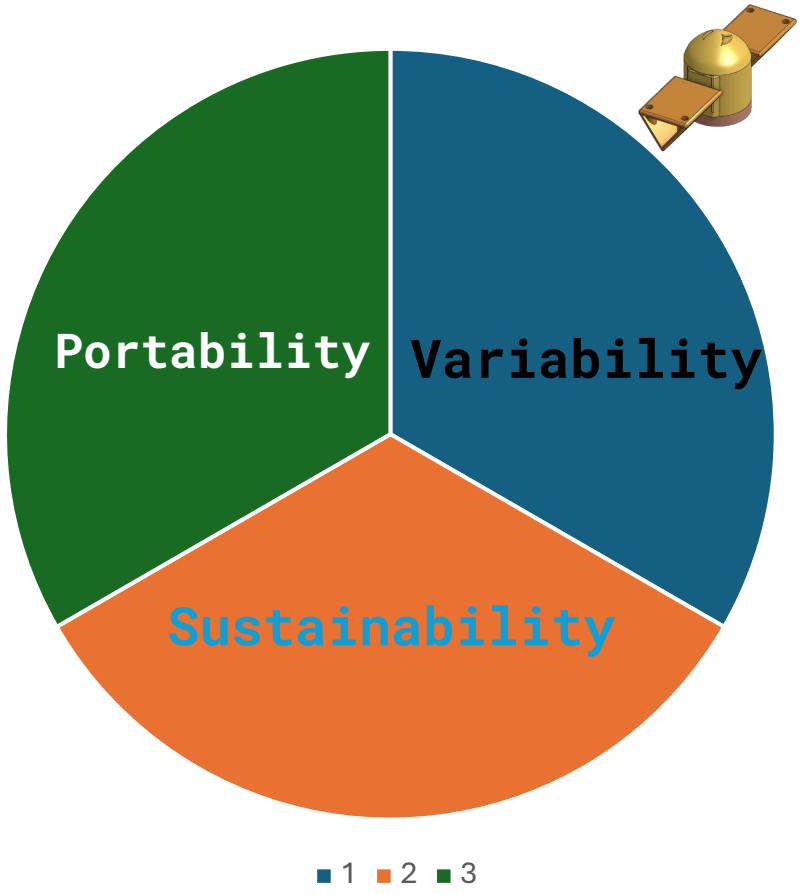
Team members **lack experience** with competitive swim training

Limited contact with community

Designed for averages (**16 y/o**)

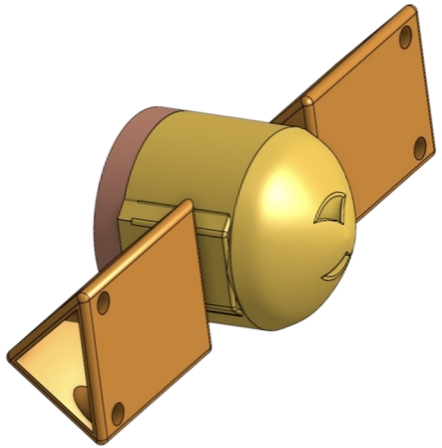
What does a good design seek?

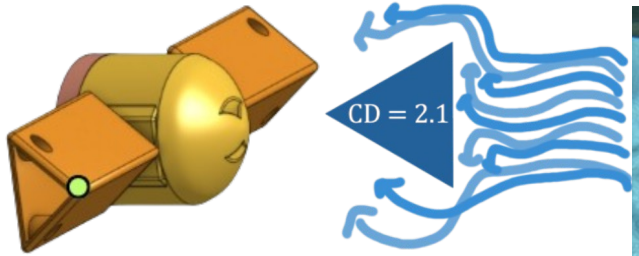
- Highly variable resistance
- A small size
- Maintenance of swimming technique and comfort
- High sustainability

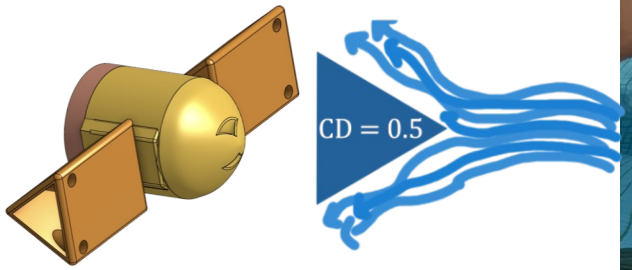


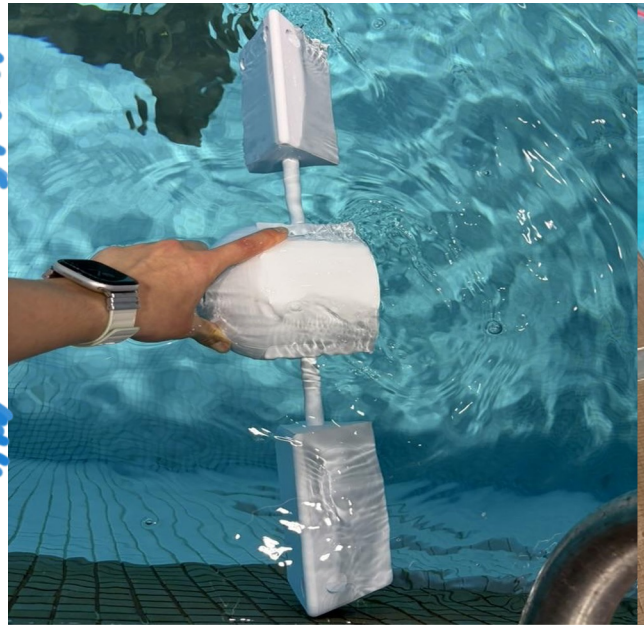
Recommended Design:

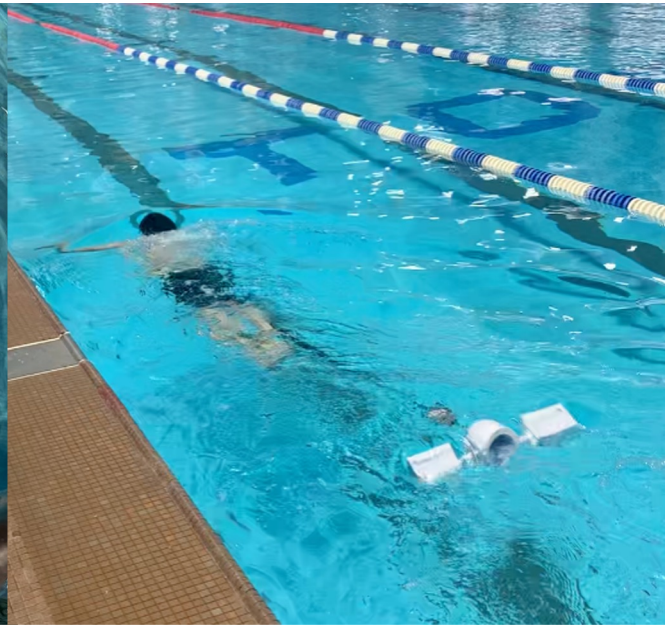
Fin-drag











20-95.6N

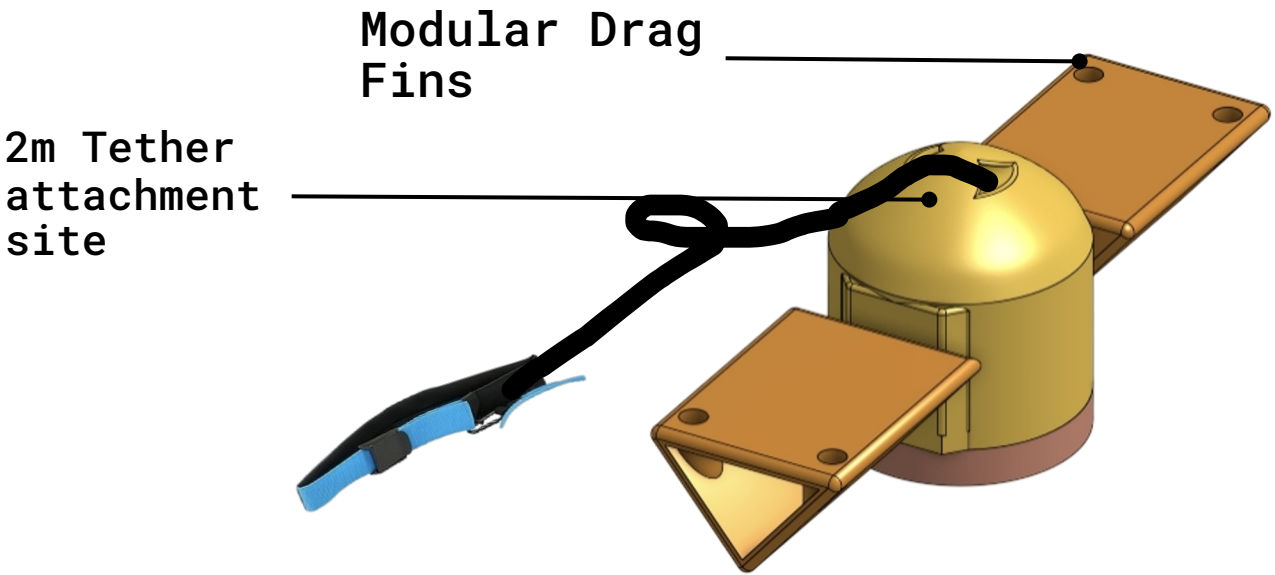
Provides variable force by changing fin angle

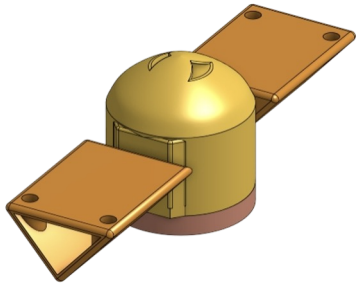
3s

Rapid transition between resistance levels

2m

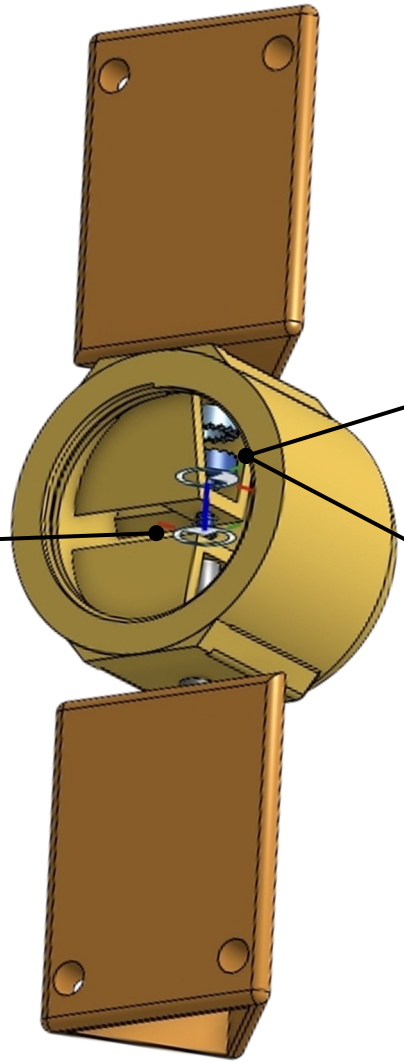
Waist-strap tether preserves stroke technique

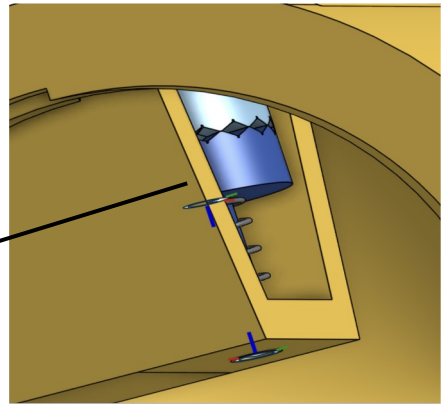

Modular Drag Fins
2m Tether attachment site

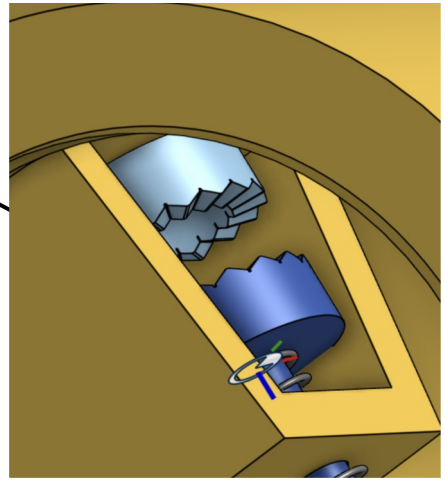


8

resistance levels



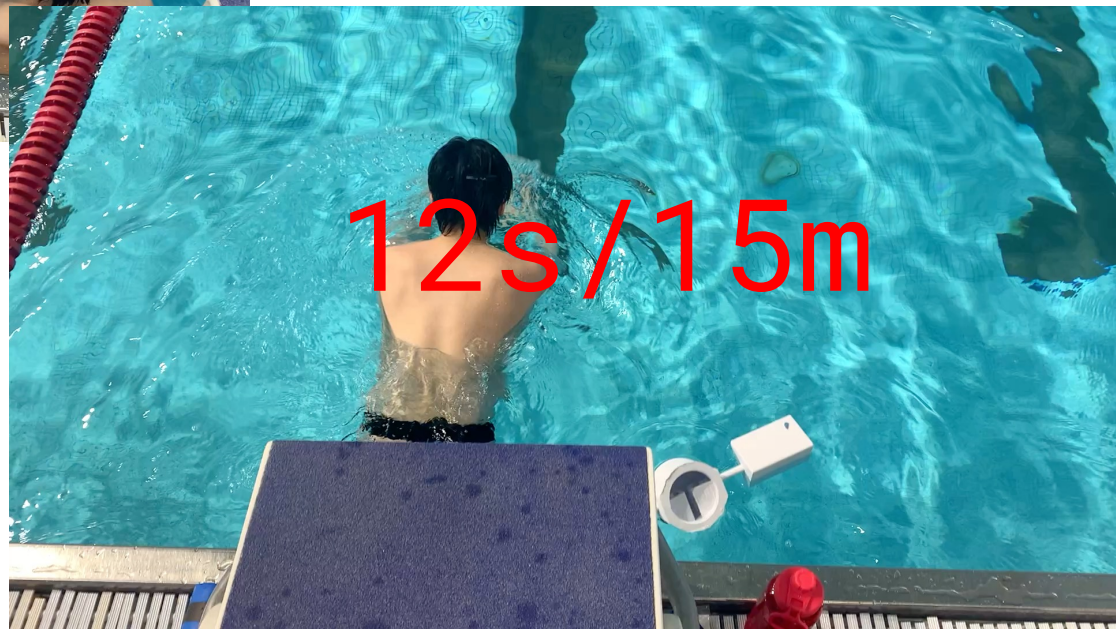




Lock Down Mechanism

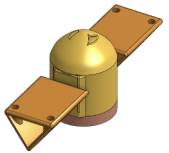
Video Demonstration
Without Design

Video Demonstration
With Design



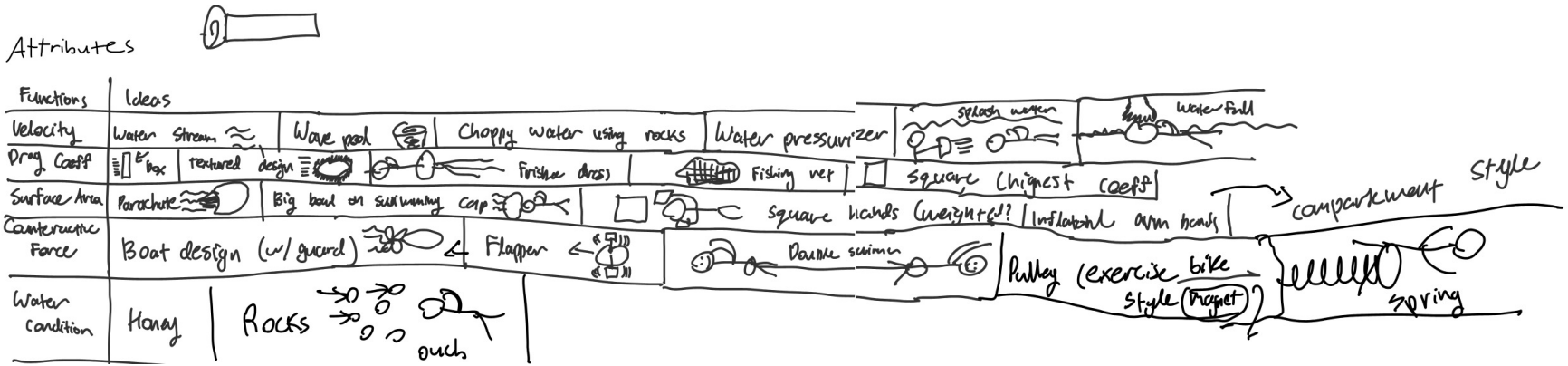
Engineering Design Tools

Engineering Design Tools



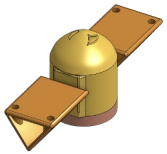
Attribute Listing

Determine factors contributing to resistance.



Diverging

Engineering Design Tools

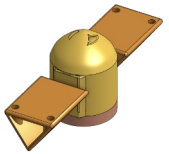


Biomimicry

Minimize anchoring bias
towards reference designs.

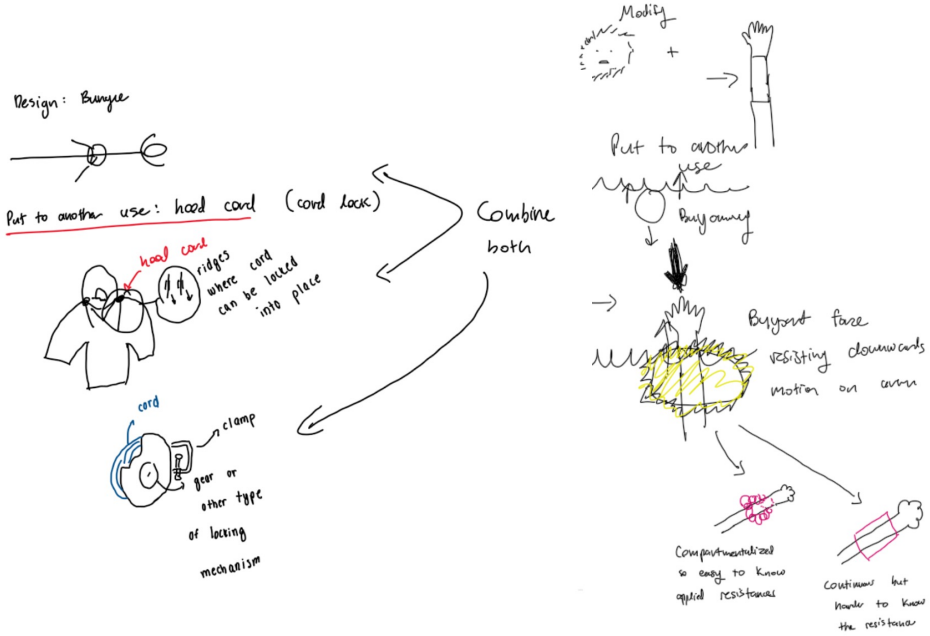
Diverging

Engineering Design Tools



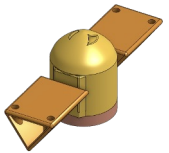
SCAMPER

Enabled **nuanced iterations** upon existing designs.



Diverging

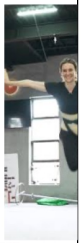
Engineering Design Tools



Morph Chart

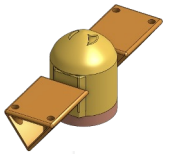
Combine functions across different designs

Morphological Chart

Function/It	1	2	3	4	
Underwater Drag/Resistance	 Water Parachute	 Water socks	 Water ball		
Variable Drag/ Rotation	 Airplane flaps	 Solar Panel	 Starship Fins	 Dragon boat machine	 Boat propeller
Connecting to people	 Wire connection for drama	 Waist Belt for lifting	Water parachute waist connection 		
Resistance to Chlorine	 ABS material	 ASA material			

Diverging

Engineering Design Tools



Pairwise Comparison

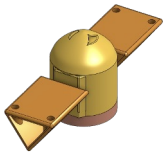
Determine our priorities prior to converging.

Pre-Converging

Pairwise Comparison for Evaluation Criteria

Evaluation Criteria	EC 1.1	EC 1.2	EC 1.3	EC 1.4	EC 2.4	EC 3.1	EC 3.4	EC 4.1	EC 5.1
EC 1.1 A better design is one which can provide more than 5 distinct levels of resistance, or a continuous range of resistance values.	-	0	0	0	0	0	0	0	0
EC 1.2 A better design has a smaller difference between resistance levels.	1	-	1	1	0	1	0	0	0
EC 1.3 Duration of Resistance: A better design is one which provides continuous resistance for more than 25m (length of pool lane). (Metric: metres)	1	0	-	0	0	1	0	0	0
EC 1.4 Speed-Independent Resistance: A better design is one which provides constant resistance that is independent of the swimmer's speed. (Metric...)	1	0	1	-	0	1	0	0	0
EC2.4 A better design is one which can withstand a greater amount of force without failure.	1	1	1	1	-	1	1	0	1
EC3.1 The less the effect on range of motion the better. (aka. Impact on technique)	1	0	0	0	0	-	1	1	1
EC3.4 A better design is one which requires less than 30 seconds to change between two resistance levels.	1	1	1	1	0	1	-	0	0
EC 4.1 A better design is one which can be stored in a space smaller than 13 x 13 x 11 inches.	1	1	1	1	0	1	1	-	0
EC 5.1 A better design can withstand more than 18400 use cycles without failure.	1	1	1	1	0	1	1	1	-
Sum	9	5	7	6	1	8	5	3	3

Engineering Design Tools



Measurement Matrix

Organize data for reference during PUGH chart relation.

Table1: Viability Testing of R1.1

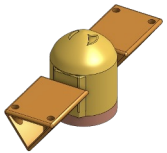
Theoretical Range of Resistance (N)	120.0-273.0	50.0-300.0	0.0-36.0	104.38-404.8
Proxy Range of Resistance (N)	139.32-275.32	115.8 (64N of normal force) - 305.0 (168.5N of normal force)	20.0-36.01	20.0-95.57N

Table 2: Measurement Matrix for Critical EC's

	Design 1: Variable Slack	Design 2: Friction Spool	Design 3: Armband Floatie	Design 4: Fin-Drag
Number of Resistance Levels (#)	10	Continuous	Continuous	8 for physical prototype, but the potential to be continuous
Duration of Resistance (provides continuous resistance for more than 25m) (m)	No	No	Yes	Yes
Kinematic Range Performance (Flexion / Total Rotational Arc / Horizontal Abduction) (°)	180.5 / 158.0 / 45.0	179.0 / 152.0 / 42.0	176.5 / 150.2 / 39.5	180.0 / 152.5 / 42.0

Converging

Engineering Design Tools



Pugh Charts

Make **relative comparisons** between designs across key ECs.

Table 1: Pugh Chart with Fin-Drag as Baseline Design

	Design			
Evaluation Criteria	Variable Slack	Friction Spool	Armband Floatie	Fin-Drag
EC 1.1 A better design is one which can provide more than 5 distinct levels of resistance.	Better	Same	Same	
EC 1.3 Duration of Resistance: A better design is one which provides continuous resistance for more than 25m (length of pool lane). (Metric: metres)	Better	Better	Same	
EC3.1 The less the effect on range of motion, the better (aka. Impact on technique)	Same	Same	Better	

Converging

Requirements & Evaluation Criteria

Key Requirement

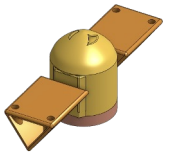
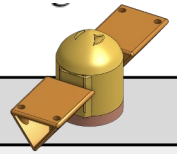


Table 1: Requirements for Personalization

Requirements for Personalization (R1):			
Requirement	***Metric***	***Evaluation Criteria***	***Justification***
R1.1 Levels of Resistance: The design shall provide at least 5 levels of resistance greater than 36.75N.	N	EC 1.1 A better design is one which can provide more than 5 distinct levels of resistance between 36.75N and the upper bound of resistive force provided.	The lower bound of resistive force provided by reference designs considered was 36.75N[5], with designs generally providing three to four discrete levels of resistance[1][2][3], with only the power tower providing a continuous range of resistances. The design should hence at a minimum be able to provide 36.75N of resistive force to be consistent with existing alternatives. Each design will have its own inherent maximum possible resistive force it can provide. Between 36.75N and this upper bound, the design should provide at least 5 intermediate resistance levels to provide greater personalization of resistance than existing alternatives. *A requirement for an upper bound resistive force was not imposed as while some designs may provide greater force than others, the need identified was a lack of variability in resistive force, rather than existing designs providing insufficient resistive force. Each design may provide unique merits which should not be immediately eliminated solely because it provides less force than an alternative.



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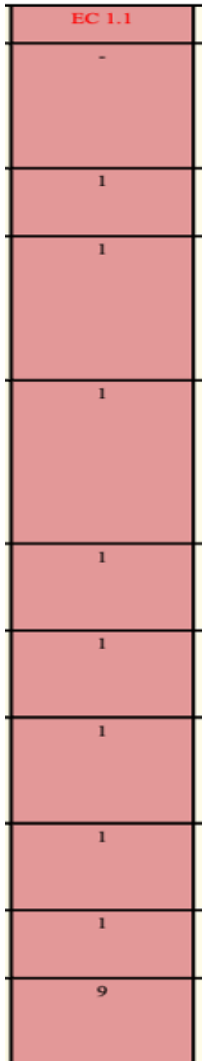
Pairwise Comparison

&

Evaluation Criteria

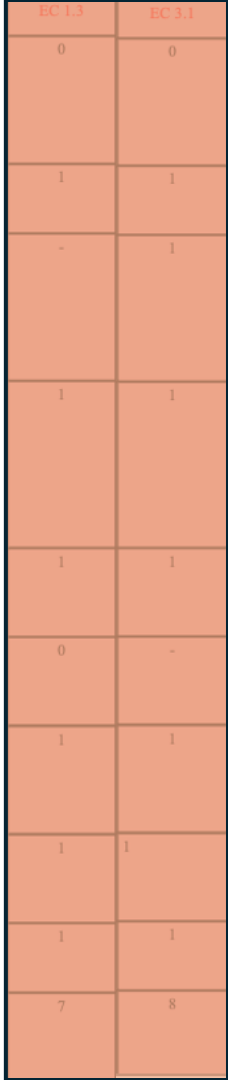
Evaluation Criteria	EC 1.1	EC 1.2	EC 1.3	EC 2.4	EC 3.1	EC 3.4	EC 4.1	EC 5.1
EC 1.1 A better design is one which can provide more than 5 distinct levels of resistance, or a continuous range of resistance values.	-	0	0	0	0	0	0	0
EC 1.2 A better design has a smaller difference between resistance levels.	1	-	1	0	1	0	0	0
EC 1.3 Duration of Resistance: A better design is one which provides continuous resistance for more than 25m (length of pool lane). (Metric: metres)	1	0	-	0	1	0	0	0
EC 1.4 Speed-Independent Resistance: A better design is one which provides constant resistance that is independent of the swimmer's speed. (Metric...)	1	0	1	0	1	0	0	0
EC2.4 A better design is one which can withstand a greater amount of force without failure.	1	1	1	-	1	1	0	1
EC3.1 The less the effect on range of motion the better. (aka. Impact on technique)	1	0	0	0	-	1	1	1
EC3.4 A better design is one which requires less than 30 seconds to change between two resistance levels.	1	1	1	0	1	-	0	0
EC 4.1 A better design is one which can be stored in a space smaller than 13 x 13 x 11 inches.	1	1	1	0	1	1	-	0
EC 5.1 A better design can withstand more than 1840(use cycles without failure.	1	1	1	0	1	1	1	-
Sum	9	5	7	1	8	5	3	3



EC 1.1

A better design is one which can provide **more than 5 distinct levels** of resistance, or a continuous range of resistance values.
Metric: levels of resistance

Reason: The community wants more adjustable resistance, so designs with more distinct resistance levels should be prioritized.

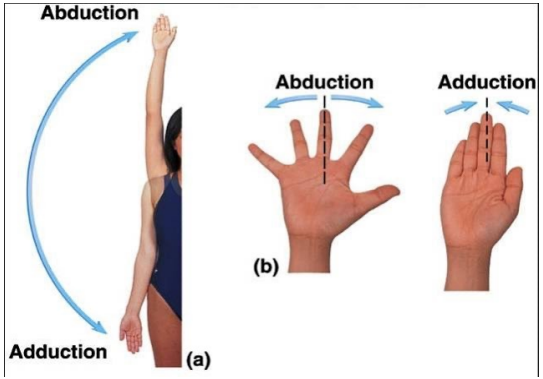


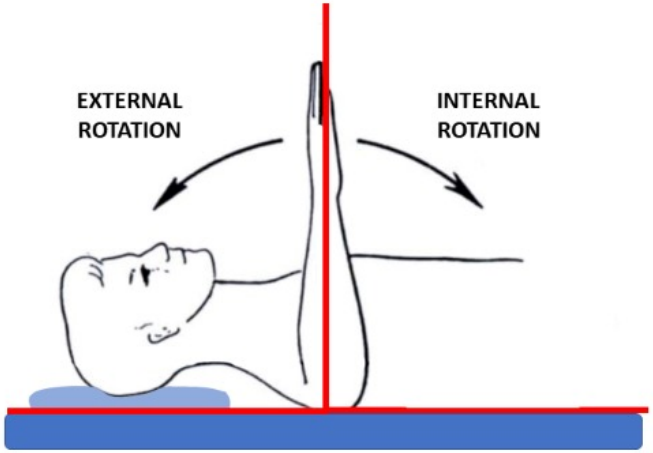
EC 3.1 

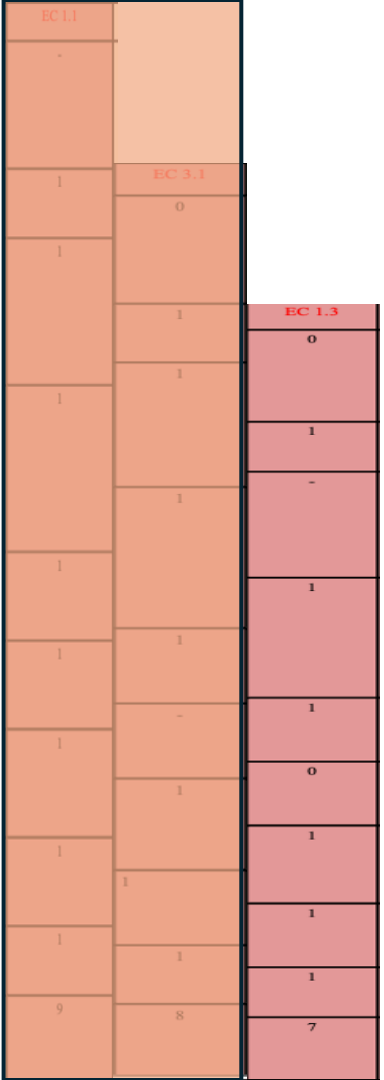
The **less the effect on range of motion** the better. (aka. Impact on technique)
Metric: angle in degrees

Reason: A better design has less impact on range of motion, since reduced motion can harm swimming technique and performance.


Elbow Extension
(opening the joint, joint angle is large)
Elbow Flexion
(closing the joint, joint angle is small)


Abduction
Adduction
(a)
Abduction
Adduction
(b)


EXTERNAL ROTATION
INTERNAL ROTATION



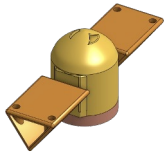
EC 1.3

Duration of Resistance:
A better design is one which **provides continuous resistance** for more than 25m (length of pool lane).
Metric: metres

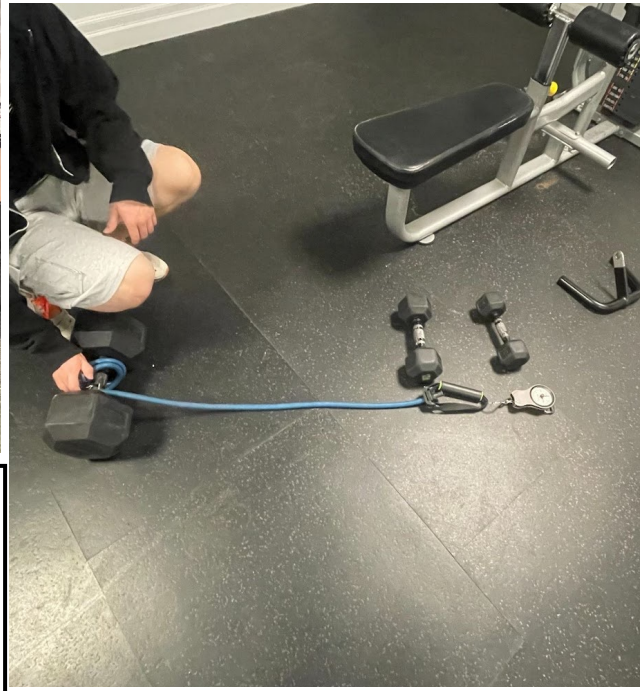
Reason: Competitions lengths span longer than 25m. Designs that simulate race conditions more accurately and provide continuous resistance for more than 25m are preferred.

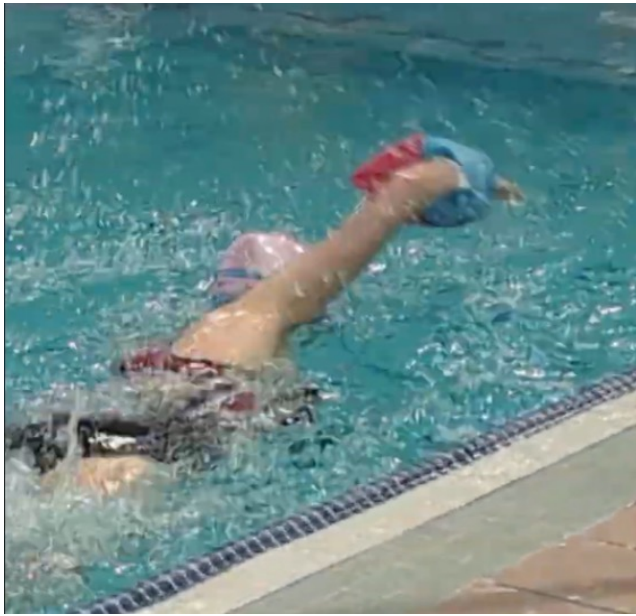
Prototypes & Verification

Other Prototypes



Variable Slack
-Mechanism: Changes in elastic force via change in original length
-Material: Silicon

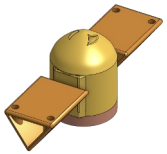




Friction-Based Resistance
-Mechanism: Change in normal force results in increased friction
-Material: Polyester, ABS, Nickle

Inflatable Armband
-Mechanism: Increased buoyancy of the floatie results in increased resistance
-Material: PVC

Testing Limitations



Proxy hard to standardize

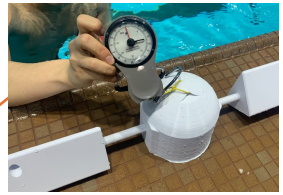
Extrapolation, Scaling

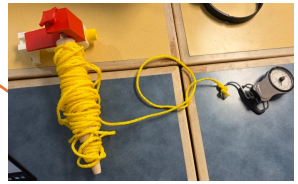
Relative comparison

Inability to simulate long tether with multiple swimmers in lane

Proxy Tests

- Resistance Level
- Range of Motion
- Duration of Resistance





Inflatable Armband

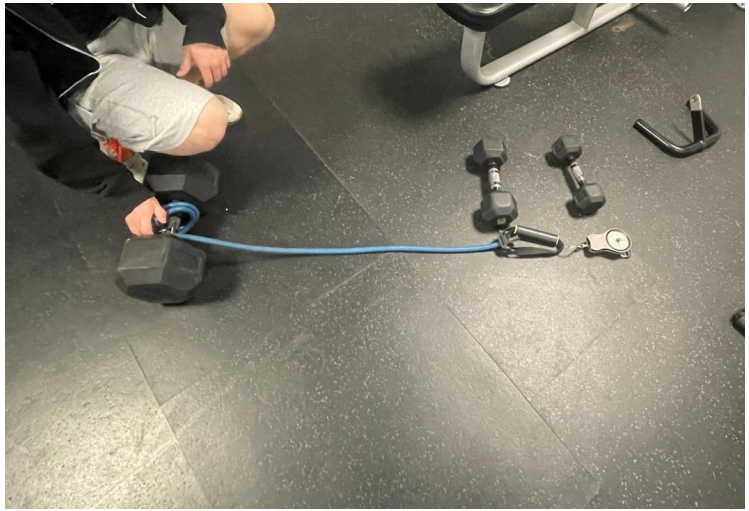
Experimental Resistance: **20-36.01N**

Proxy	Resistance Level	Range of Motion	Duration of Resistance
	Continuous	Flexion / Total Rotational Arc / Horizontal Abduction 176.5/150.2/39.5	25m+

Showing you in person!

Variable Slack

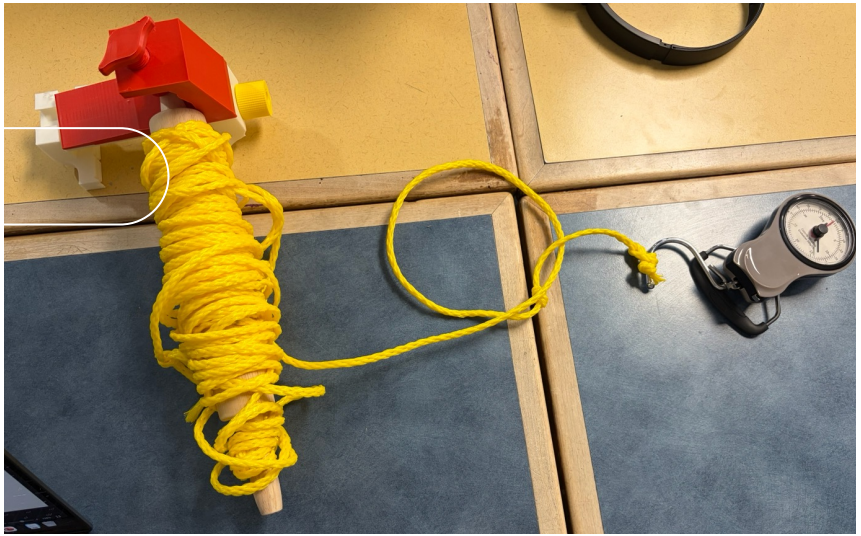
Experimental Resistance:
139.32-275.32N



Proxy	Resistance Level	Range of Motion	Duration of Resistance
	10	Flexion / Total Rotational Arc / Horizontal Abduction 180.5/158.0/45.0	≤ 25m

Friction-Based Resistance Spool

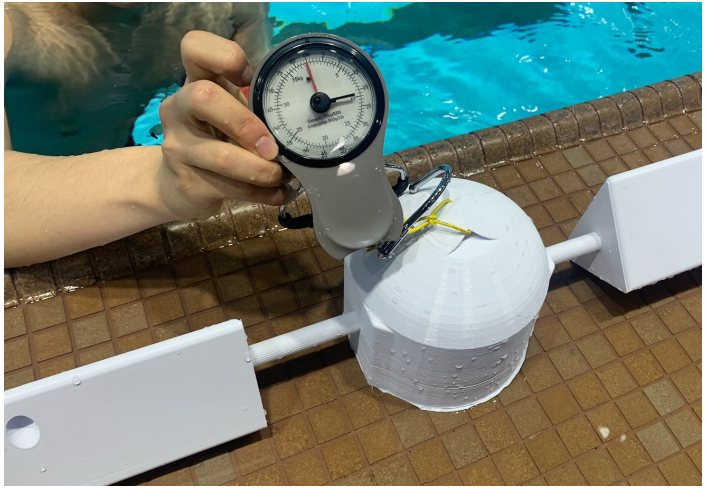
Experimental Resistance:
115.8- 305.0N



Proxy	Resistance Level	Range of Motion	Duration of Resistance
	Continuous	Flexion / Total Rotational Arc / Horizontal Abduction 179.0/152.0/42.0	≤ 25m

Fin-Drag

Theoretical Resistance:**104.4-404.8N**
Experimental Resistance: **20-95.6N**



Proxy	Resistance Level	Range of Motion	Duration of Resistance
	8 levels/ Continuous	**Flexion / Total Rotational Arc / Horizontal Abduction** **180.0/152.5/42.0**	**25m+**

Converging to Fin Drag

Constructing Measurement Matrix

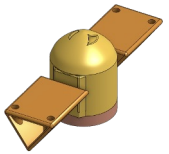


Table 2: Measurement Matrix for Critical EC's

	Design 1: Variable Slack	Design 2: Friction Spool	Design 3: Armband Floatie	Design 4: Fin-Drag
Number of Resistance Levels (#)	10	Continuous	Continuous	8 for physical prototype, but the potential to be continuous
Duration of Resistance (provides continuous resistance for more than 25m) (m)	No	No	Yes	Yes
Kinematic Range Performance (Flexion / Total Rotational Arc / Horizontal Abduction) (°)	180.5 / 158.0 / 45.0	179.0 / 152.0 / 42.0	176.5 / 150.2 / 39.5	180.0 / 152.5 / 42.0

Constructing Pugh Charts

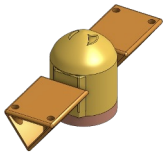
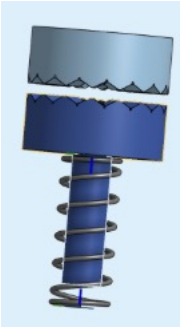


Table 1: Pugh Chart with Fin-Drag as Baseline Design

	Design			
Evaluation Criteria	Variable Slack	Friction Spool	Armband Floatie	Fin-Drag
EC 1.1 A better design is one which can provide more than 5 distinct levels of resistance.	Better	Same	Same	
EC 1.3 Duration of Resistance: A better design is one which provides continuous resistance for more than 25m (length of pool lane). (Metric: metres)	Better	Better	Same	
EC3.1 The less the effect on range of motion, the better (aka. Impact on technique)	Same	Same	Better	

Key Design Decisions



Tether + Waist Harness

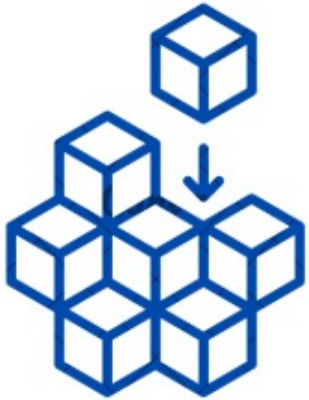
- **Maintain technique** by having waist harness, has limited effect on range of motion
- Permits **flip turns** (though not as smooth)

Rotating, Triangular Fins

- Triangular fins **can rotate 360º**
- Each angle results in different coefficient of drag
- Currently **8 levels**, next steps is continuous

Showing you in person!





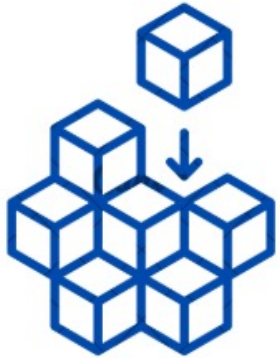
Sustainability Considerations

Sustainability Considerations

ASA has excellent **chlorine resistance**.

UV resistance reduces the likelihood of fracture.

High impact strength to withstand falls on deck, rough handling



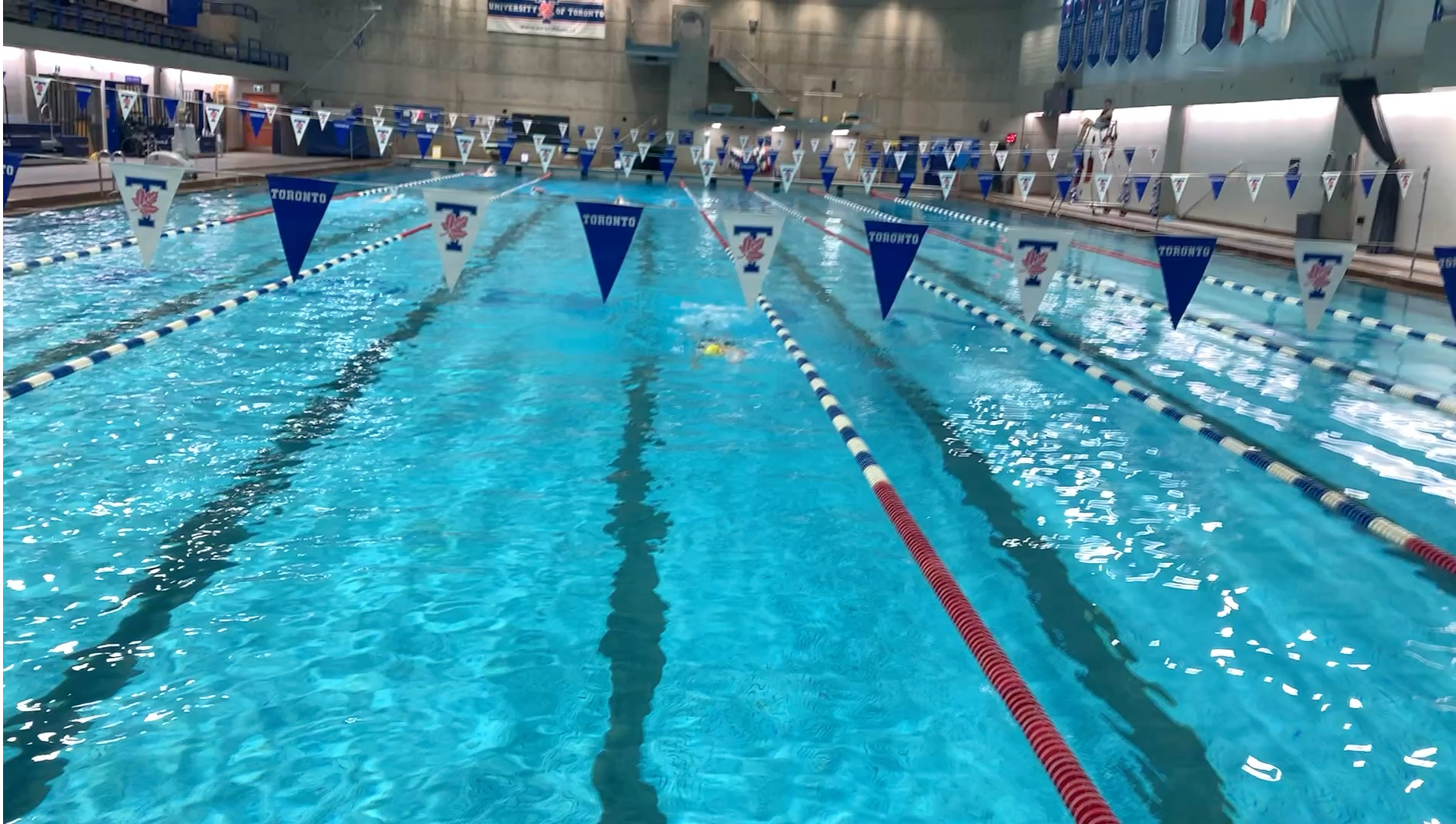
Modular fins for component replacement

Limitations & Next Steps

Athletic Centre, UofT

UofT Masters Swim Club team member

Two former competitive swimmers


TORONTO
TORONTO
TORONTO
TORONTO

Coach Aris

Us: Do **rope based or tethered systems ever tangle** or obstruct the swimmers?

Coach: **Yes**, especially if the belt is not positioned at the center of the body.

Limitations

Prototype is floating (not as much resistance)

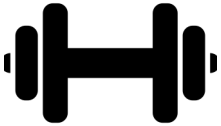
Tether tangling

Resistance range is not continuous

Relies on friction to hold fins

Next Steps

Prototype is floating → Increase Density



Tether tangling → Provide a flexible tether

Resistance range is not continuous → Increase resistance levels

Relies on friction to hold fins → Screw in design/locking mechanism

Recommended Design:

Fin-drag