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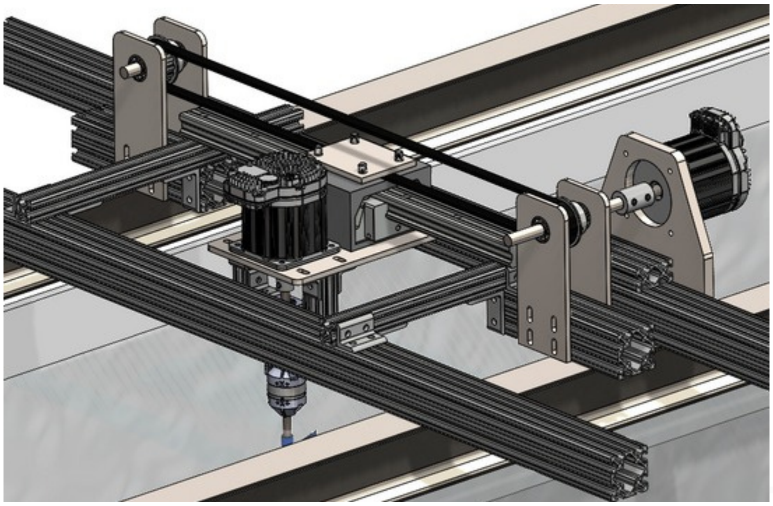
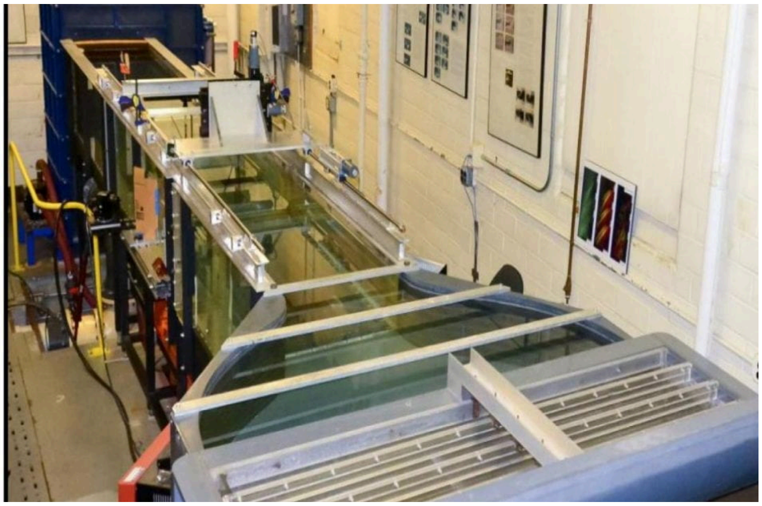
PITCH AND HEAVE SETUP FOR BIO-PROPULSION STUDIES





What?

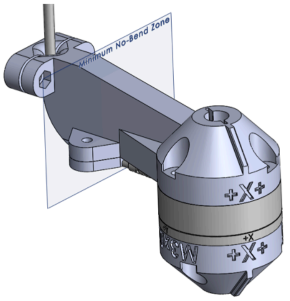
- **Design a setup to mimic robotic swimmers**, leading investigations into their hydrodynamic performance and development of **quiet underwater vehicles**, a part of a **$7.5M U.S. DOD-funded MURI project.**

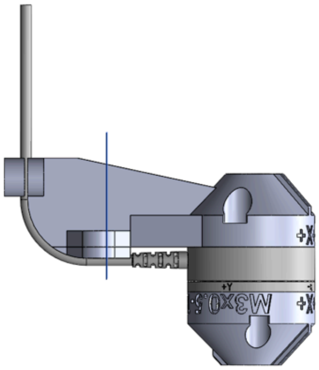
How?

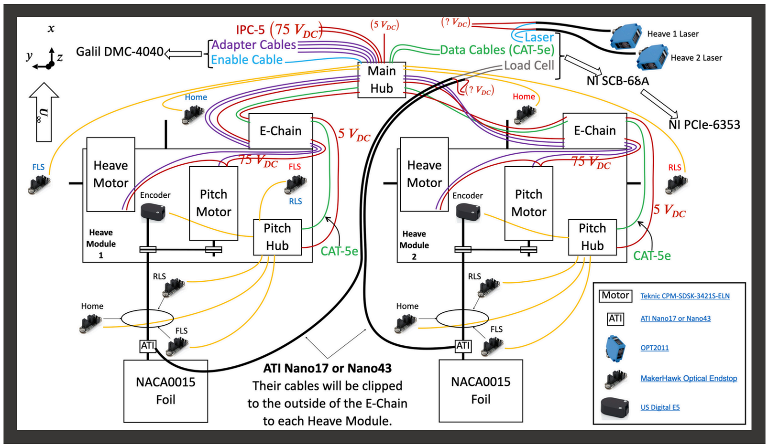
- Designed and built the setup using **SOLIDWORKS, CNC, waterjet cutting, and 3D printing.**
- **Applied GD&T** to all drawings.
- **Integrated systems** such as PIV system, 6-axis force sensor, NI DAQ data acquisition card, high-torque motors.

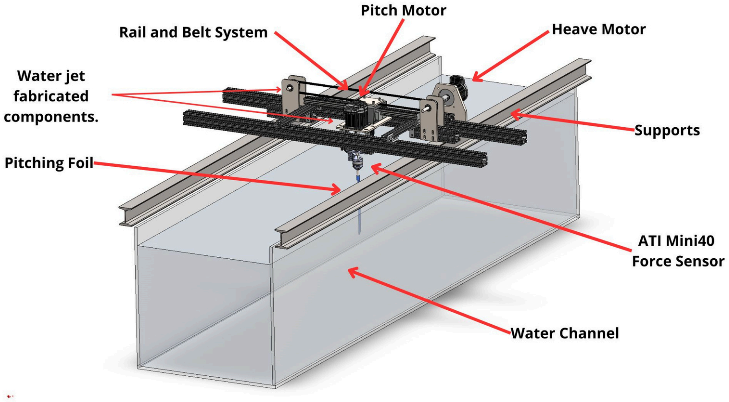
Results

- Gathered and analyzed **35 data sets** using **MATLAB** and NI DAQ for tests.
- Improved movement **accuracy to 98.2%, a 1.75x increase** over previous designs.
- **Reduced operational noise by 32%** through optimized control systems.









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RESEARCH POSTER FOR THE MOUNTAIN TOP RESEARCH CONFERENCE

Design and Implementation of a Dual-Axis Pitch and Heave Setup for Bio-Propulsion Studies

Abylaikhan Mukhamejanov, Keith Moored, Matt Stasolla, Ali S. Sarraf

Department of Mechanical Engineering and Mechanics, Lehigh University

Background

- Bio-inspiration has improved underwater vehicle design by mimicking natural propulsion systems.
- Aquatic creatures often use flapping fins or jets to achieve efficient movement, offering benefits like reduced cavitation and better maneuverability (Figure 1).
- This research focuses on developing a dual-axis pitch and heave setup to simulate these complex motion patterns accurately and enhance our understanding of bio-inspired propulsion systems.

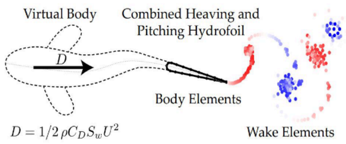

Figure 1. Schematic of the idealized self-propelled swimmer with a combined heaving and pitching hydrofoil [1].

Sinusoidal Motion Experiments

- System achieves smooth motion by starting the motor at zero speed at the peak of the sine wave. This avoids issues related to starting from equilibrium where velocity is at its maximum, thus preventing infinite acceleration.
- Provides options for automatic fault handling, manual intervention, emergency stop, safe homing.
- Utilizes external encoders and end-stop sensors to set a precise reference point and ensure accurate positioning of the motor.

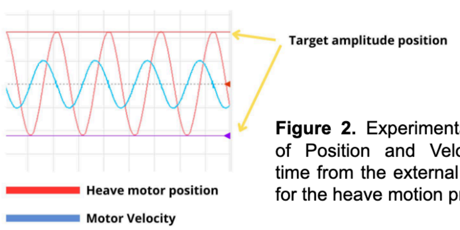

Figure 2. Experimental graph of Position and Velocity vs. time from the external encoder for the heave motion profile.

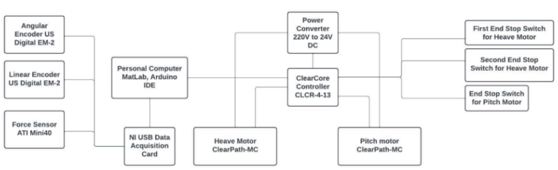

Figure 3. Data Acquisition and Hardware connection block diagram

Improved Experimental Design

- The improved design features high-torque, high-feedback motors for precise testing minimizing the vibration effects.
- Optical end-stop switches were added to conduct high accuracy homing solving issue of hard stop, unlimited rotation and emergency prevention.
- Motors are controlled by the ClearCore controller, configured for specific counts per revolution, velocity limits, and signal counts, achieving over 99% accuracy for amplitude, frequency, and phase shift.
- The system uses a smooth rail and belt heave motion mechanism and has been improved with the attachment of external digital encoders (EM2) for data acquisition via an NI DAQ.
- The ATI Mini40 sensor can measure all 6-degrees of freedom force and moments.

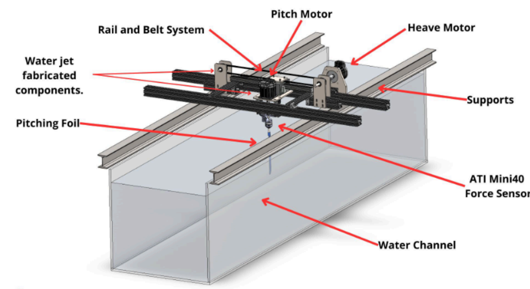

Figure 4. The mechanical CAD design of the improved pitch and heave setup in the water channel.

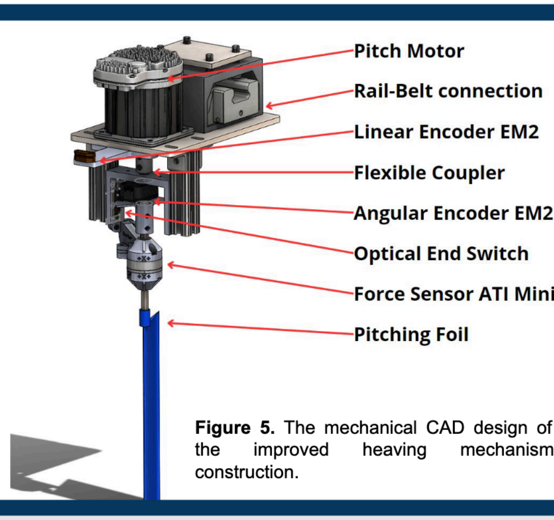

Figure 5. The mechanical CAD design of the improved heaving mechanism construction.

Acknowledgements:

[1] Akoz, E., Mivehchi, A., & Moored, K. (2021). Intermittent unsteady propulsion with a combined heaving and pitching foil. Physical Review Fluids, 6(4), 043101.

This work was supported by the Office of Naval Research under Program Director Dr. R. Brizzolara through MURI grant no. N00014-08-1-0642, and by the National Science Foundation under Program Director Dr. R. Joslin in Fluid Dynamics within CBET, through NSF CAREER award no. 1653181.

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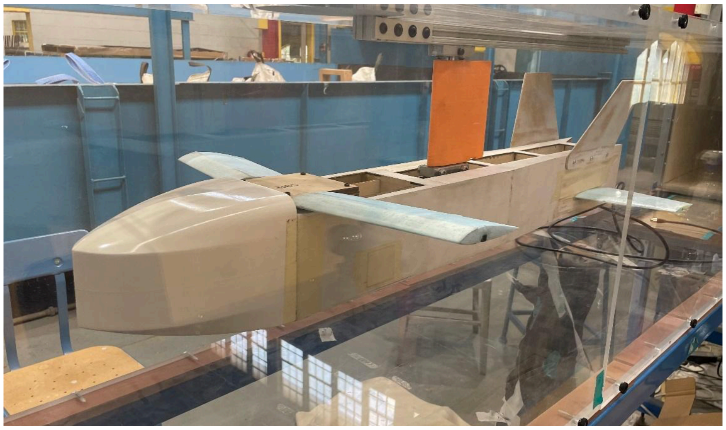
WIND TUNNEL DRONE TESTING - AEROTARGETS INTERNATIONAL



What?

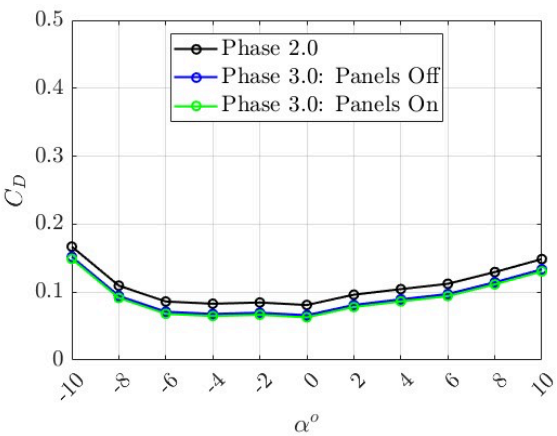
- **Scaled down a military-use drone** to perform **tests in a wind tunnel** to evaluate performance characteristics.
- Splited experiment into 3 phases focusing on (1) preliminary **aerodynamic stability** studies, (2) a scaled up model at a higher Re used for extensive drag tests with panels off and (3) with panels on.

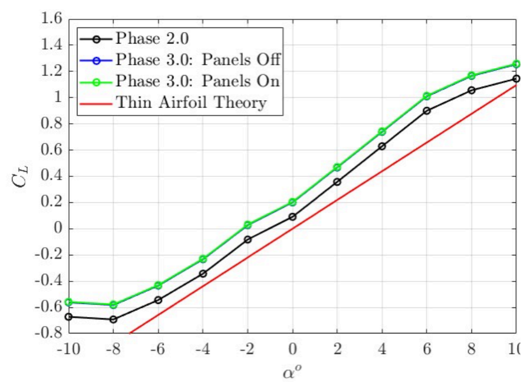
How?

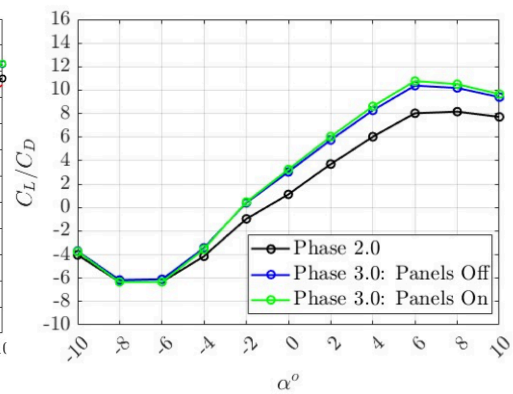
- **Build a 4-bar linkage structure** that allows change to all angles needed.
- Used **SolidWorks** to scale down and alter model for **compatibility** with force sensor / wind tunnel.
- Utilized an NI DAQ card and **MATLAB** to **acquire and process data.**

Results

- Phase 1 revealed that the model is **dynamically stable** in both pitch and roll motions around its CG and weakly stable in yaw.
- Phase 2 and 3 showed a **lower drag coefficient**, increasing its L/D ratio.
- Communicated with AeroTargets engineers to recommend fuselage design modifications, **achieving a 10% drag reduction.**







AEROTARGETS INTERNATIONAL

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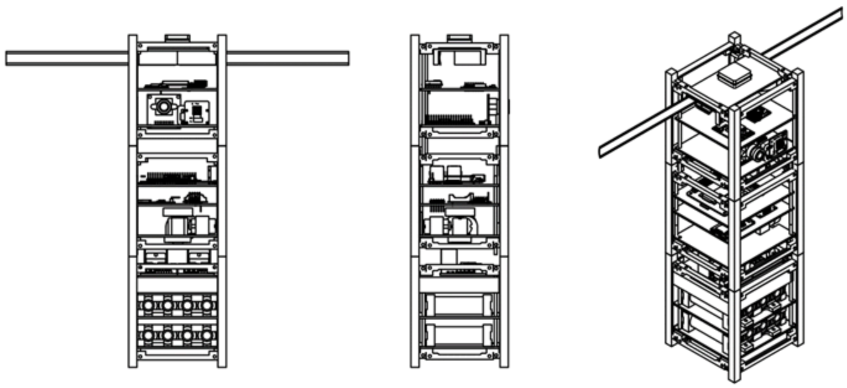
SKILLSAT STARTUP



What?

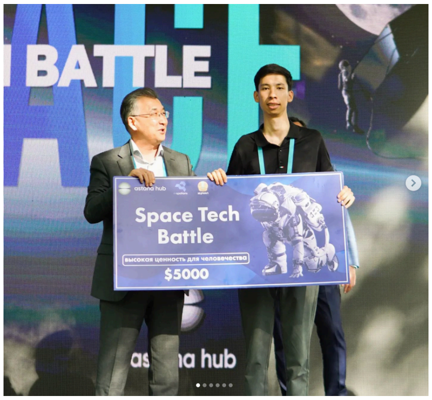
- **Founded SkillSat**, an EdTech startup to **manufacture STEM kits** that teach students to build stratospheric satellites.

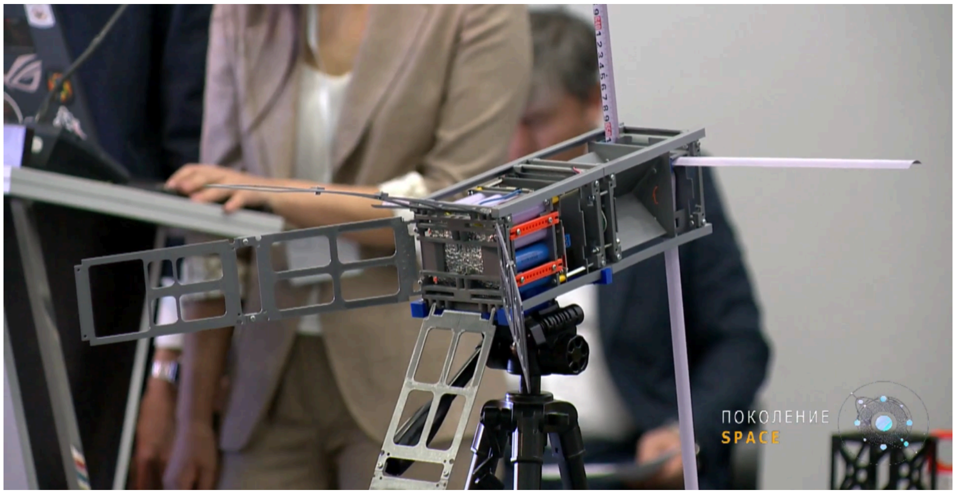
How?

- Used **Arduino and Raspberry P**i as the base for satellite systems.
- Utilized **additive manufacturing** to prototype 25+ designs.
- Applied **DFA and DFM** principles to **reduce production costs by 44%**.
- **Tested prototypes** at the National Space Center of Kazakhstan.

Results

- **Launched satellites to Near Space** (40 km+) via stratospheric balloons.
- **Raised $15K** in funding and distributed 80+ kits to 240+ students across 25+ schools.
- Recognized as a **Top-3 SpaceTech** and Top-15 EdTech Startup by **Forbes Kazakhstan**.





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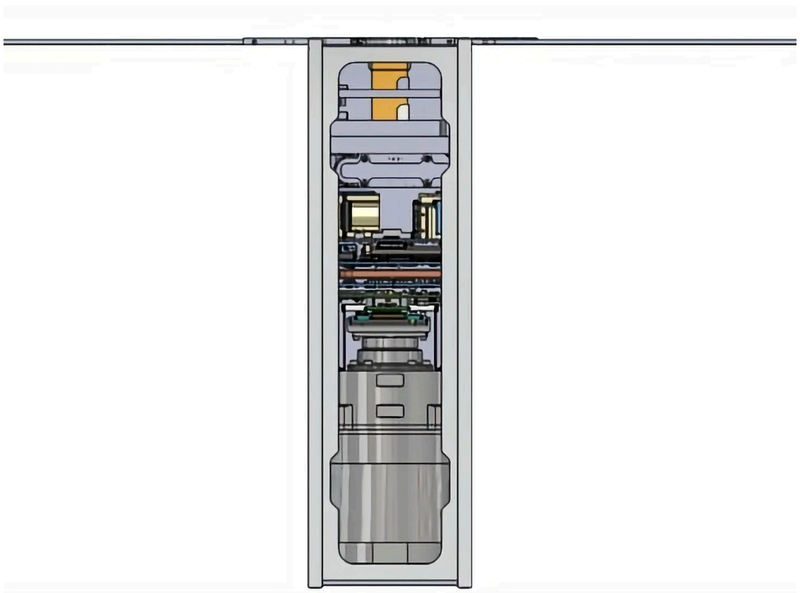
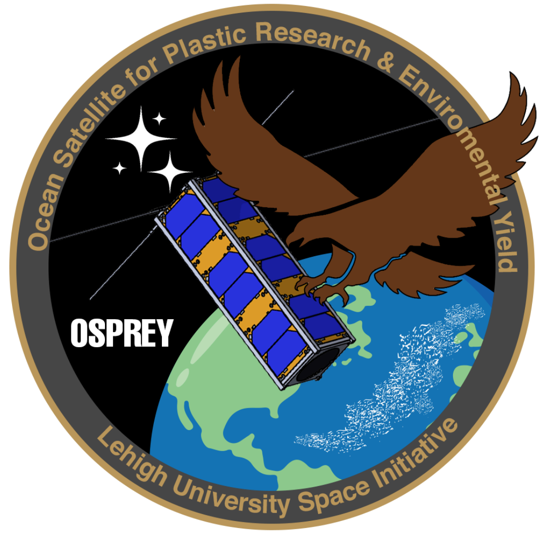
OSPREY CUBESAT - LEHIGH UNIVERSITY'S FIRST NANOSATELLITE





What?

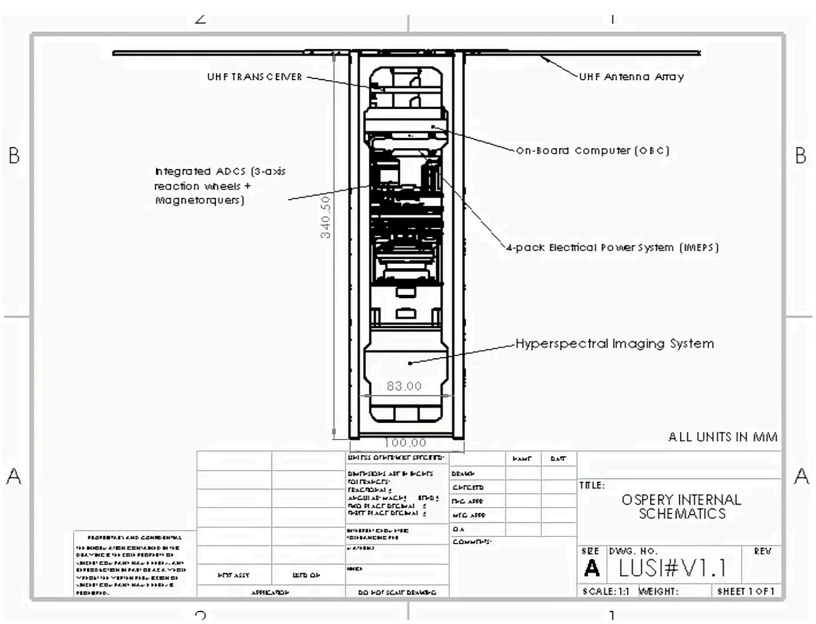
- Designed and led the development of **Lehigh University's first CubeSat**, OSPREY, a 3U satellite using a VS/SWIR camera system to detect ocean plastic within a 1-square-meter area for ocean trash monitoring.

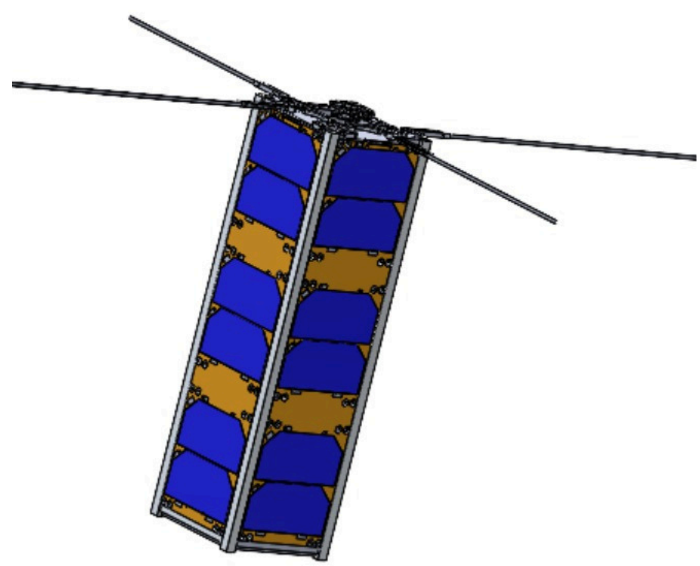
How?

- **Lead CAD modelling in SolidWorks**, optimizing the center of mass and moments of inertia.
- **Used GD&T principles**, applied material selection, mass budgeting, to ensure tolerance and compliance with NASA standards.
- **Managed a team** of 6 students and **coordinated with other sub-teams** to integrate deployable solar cells and antenna systems

Results

- **Raised $150,000** in funding from Lehigh alumni and sponsors.
- **Optimized the mass budget** by 23% and **increased payload volume** by 33%.
- **Successfully submitted a proposal** for NASA's 2024 CubeSat Student Launch Initiative.





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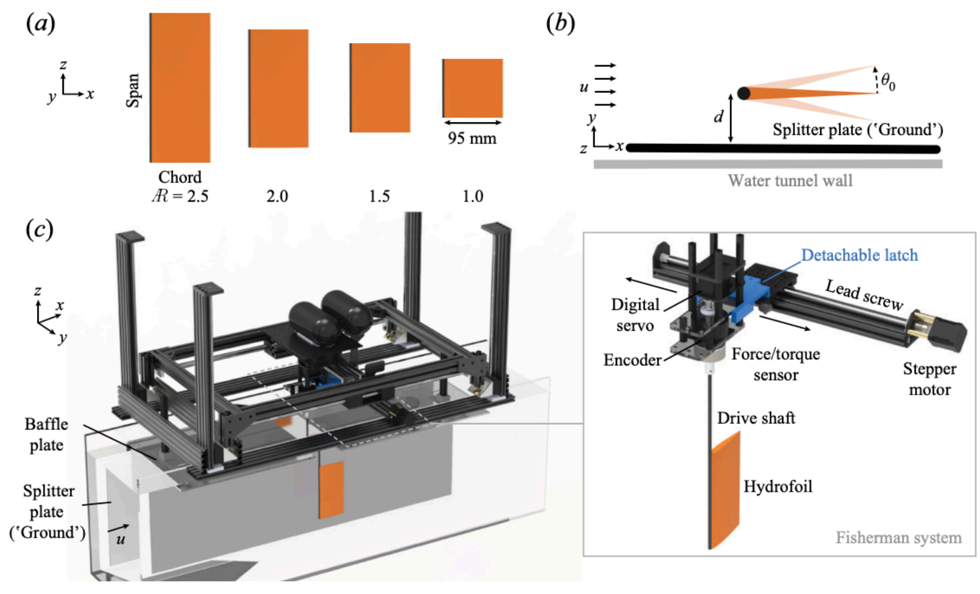
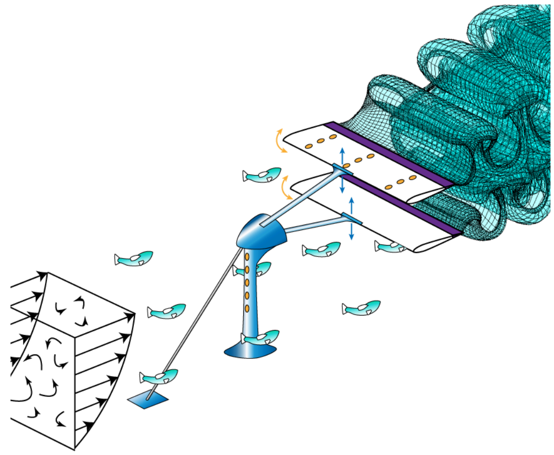
BIO-INSPIRED RIVERINE POWER GENERATION





What?

- Contribute to the design of a **$7.5M U.S. DoD, DoE funded project** to develop a hydrokinetic turbine, which uses bio-inspired hydrofoils oscillating in water flow to **convert motion into electricity**, suitable for remote villages and large cities.

How?

- Used **SolidWorks** to upgrade the design.
- **Wired and troubleshooted** motors, angular encoders, torque sensors, laser distance sensors, etc.
- Utilized a DAQ card, LabVIEW, and MATLAB for **data acquisition and processing.**
- Used optical encoders to **track exact positioning.**

Results

- **Boosted power generation output by 57%** by designing and implementing a **wireless communication system** for the closed-loop control and data acquisition that utilizes **real-time data analysis** to optimize energy extraction efficiency.