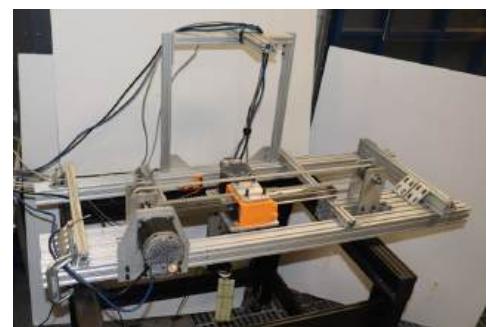
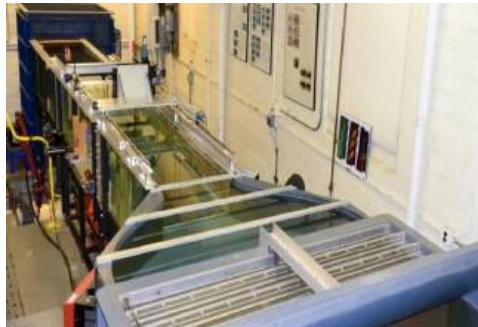
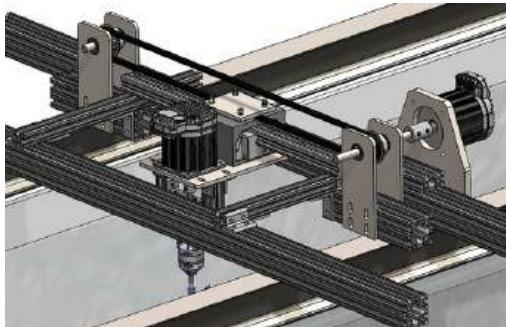


PITCH AND HEAVE SETUP FOR BIO-PROPULSION STUDIES



What?

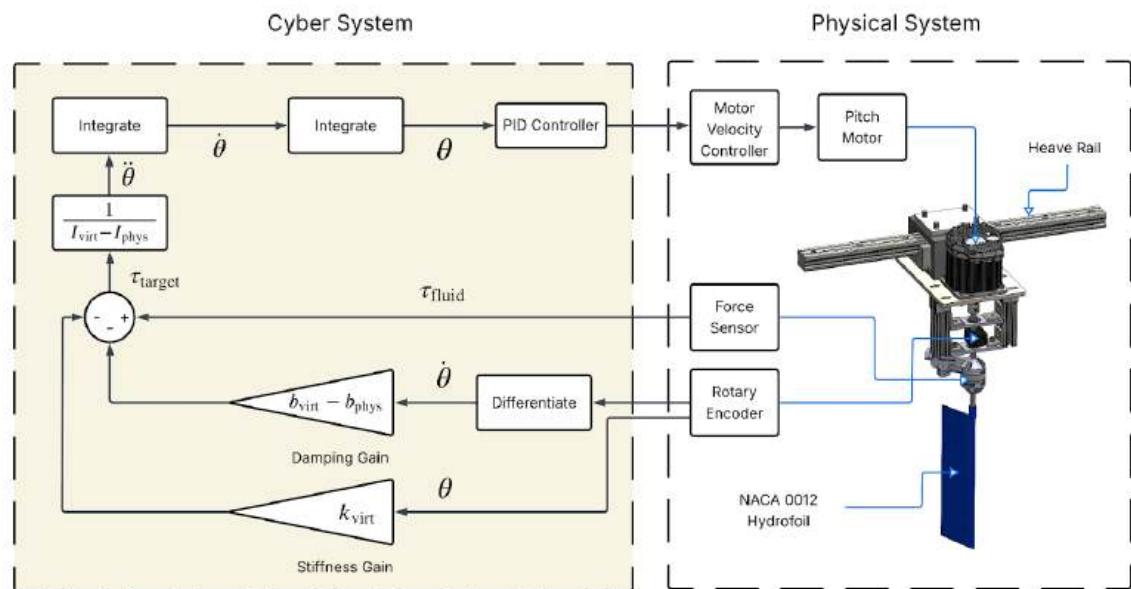
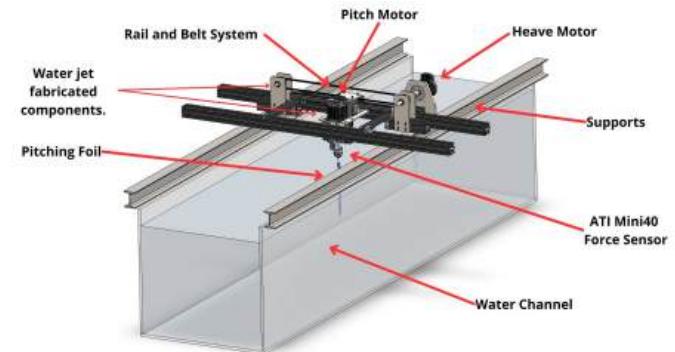
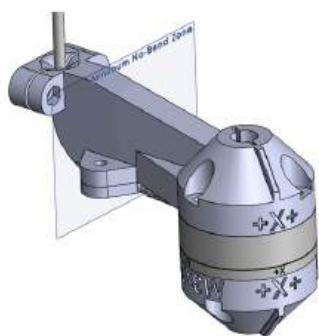
- Design a setup to mimic robotic swimmers, leading investigations into their hydrodynamic performance and development of quiet underwater vehicles, a part of a \$7.5M U.S. DOD-funded MURI project.

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.



CARBON FIBER SUSPENSION SYSTEM FOR FORMULA SAE



What?

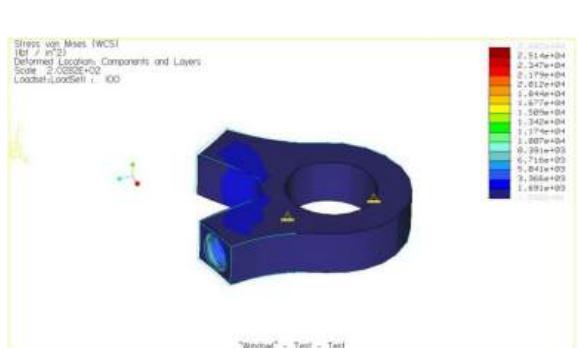
- Designed and manufactured a carbon fiber-aluminum hybrid suspension control arm for a Formula SAE vehicle.
- Replaced steel members to reduce mass while maintaining required load capacity.

How?

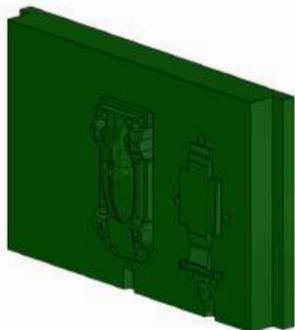
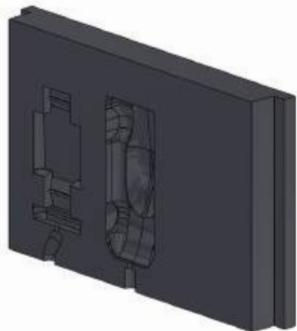
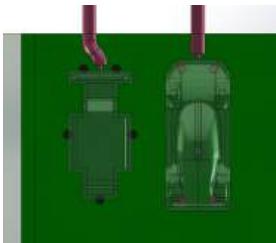
- Modeled geometry in SolidWorks and conducted FEA to evaluate stress and deflection under braking and cornering loads.
- Machined aluminum end joints and bonded them to carbon fiber tubes using structural epoxy.

Results

- Reduced component mass compared to steel baseline.
- Measured strain and load response were consistent with FEA predictions.
- Component sustained expected loads without material failure or joint separation.



RACE CAR INJECTION MOLDING PROJECT



What?

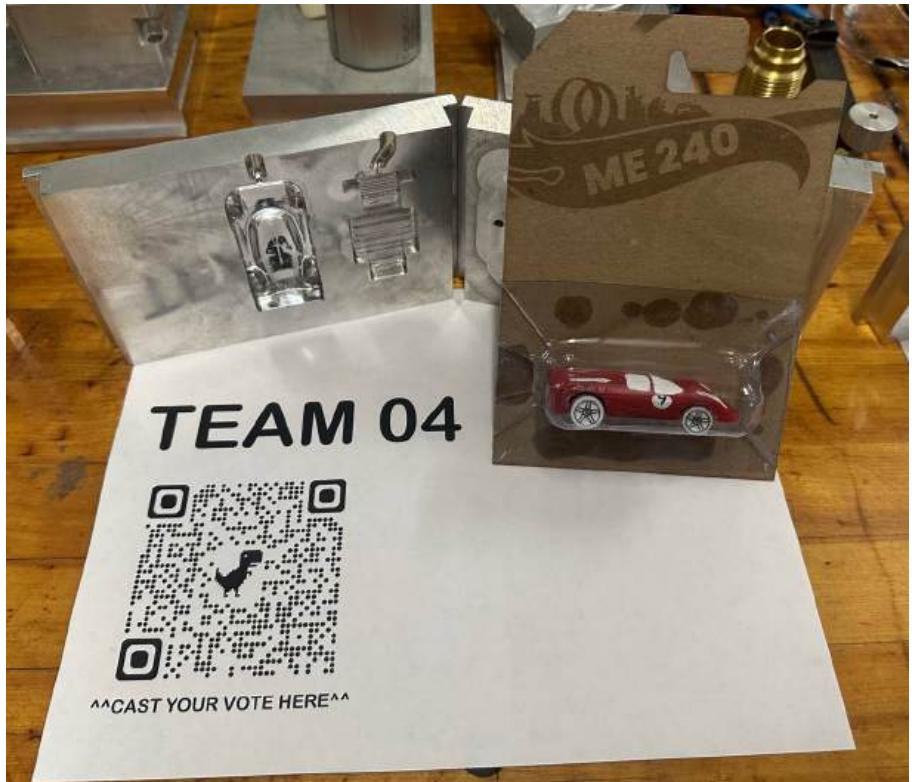
- Designed and manufactured a two-part aluminum injection mold for a race car body component.
- Developed a complete molding workflow including part design, gating, and runner system.

How?

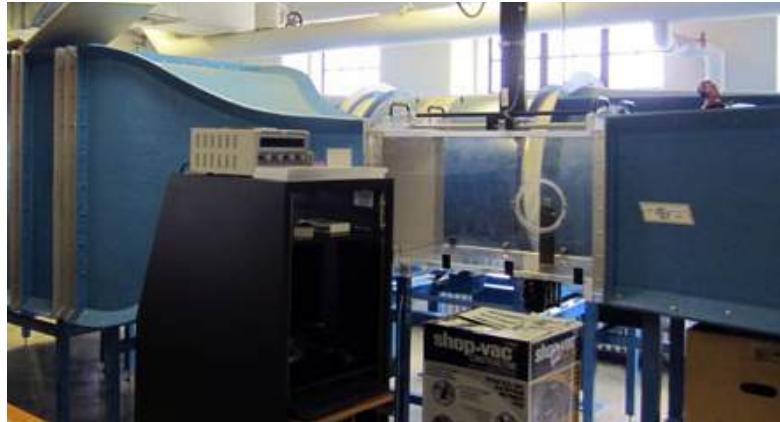
- Modeled part and mold assembly in SolidWorks.
- Fabricated mold using CNC machining and waterjet cutting.
- Applied GD&T to ensure dimensional accuracy and proper part ejection.
- Conducted molding trials and evaluated part quality and repeatability.

Results

- Successfully produced molded race car components with consistent geometry and surface finish.
- Achieved proper mold alignment and clean part release.
- Validated manufacturability through multiple successful production cycles.



WIND TUNNEL DRONE TESTING - AEROTARGETS INTERNATIONAL



What?

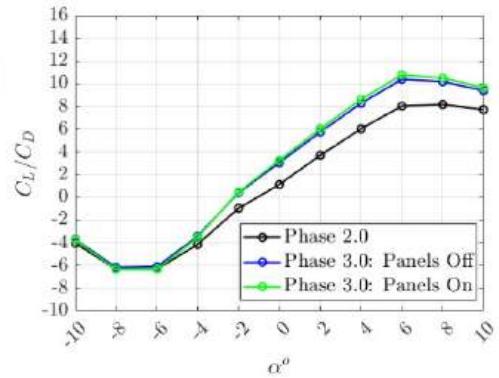
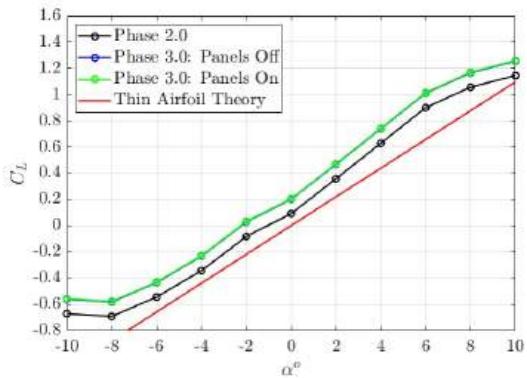
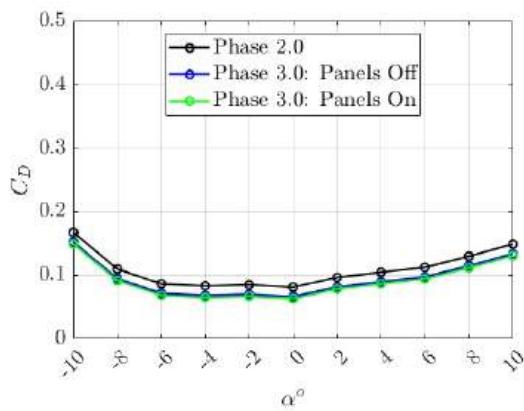
- Scaled down a military-use drone to perform tests in a wind tunnel to evaluate performance characteristics.
- Spliced experiment into 3 phases focusing on (1) preliminary aerodynamic stability studies, (2) a scaled up model at a higher Re used for extensive drag tests with panels off and (3) with panels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

How?

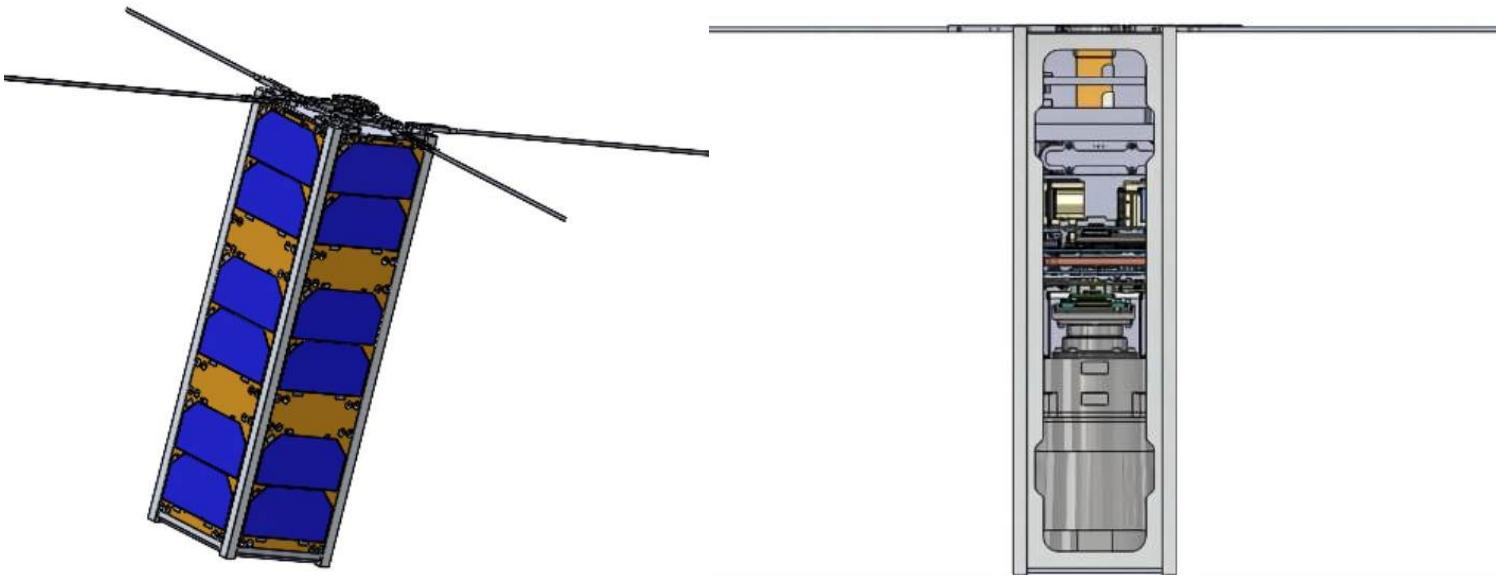
- Build a 4-bar linkage structure that allows change to all angles needed.
- Used SolidWorks to scale down and alter model for compatibility with force sensor / wind tunnel.
- Utilized an NI DAQ card and MATLAB to acquire and process data.

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.



OSPREY CUBESAT - LEHIGH UNIVERSITY'S FIRST NANOSATELLITE



What?

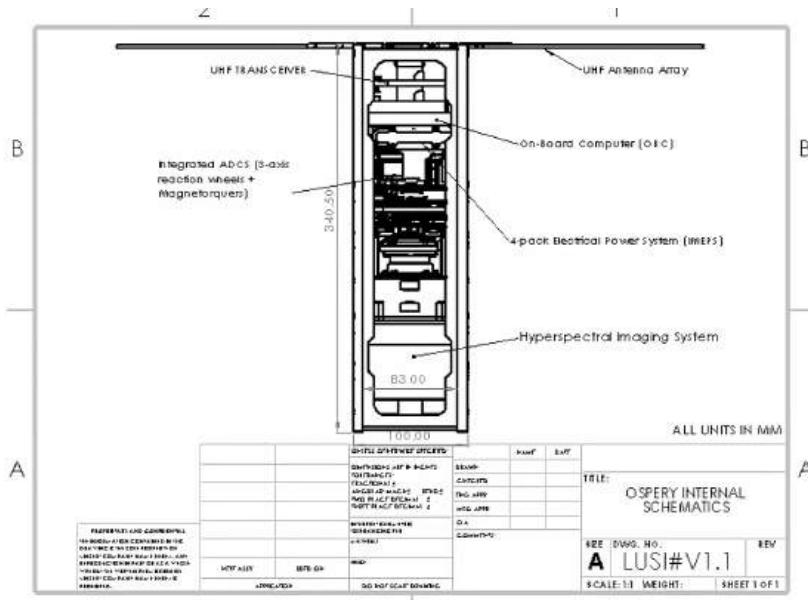
- Designed and led the development of Lehigh University's first CubeSat, OSPREY, a 3U satellite using a VS/SWIR camera system to detect ocean plastic within a 1-square-meter area for ocean trash monitoring.

How?

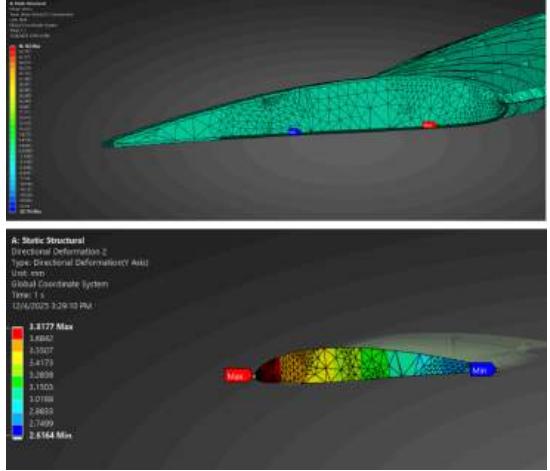
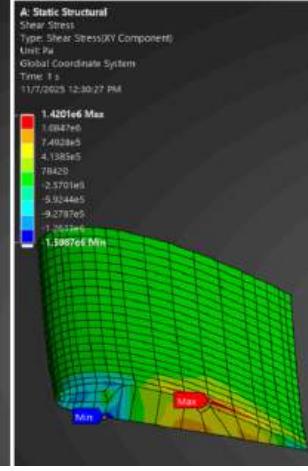
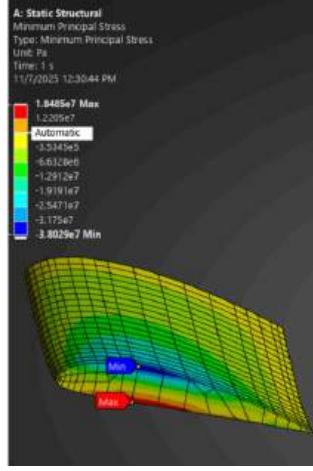
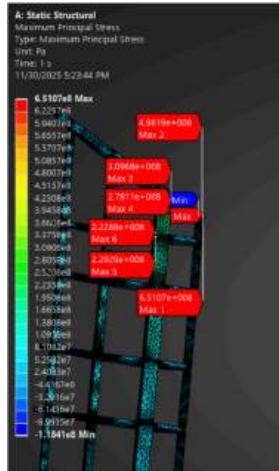
- Lead CAD modelling in SolidWorks, optimizing the center of mass and moments of inertia.
- Used GD&T principles, applied material selection, mass budgeting, to ensure tolerance and compliance with NASA standards.
- Managed a team of 6 students and coordinated with other sub-teams to integrate deployable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



AEROELASTIC WING DESIGN - LEHIGH UNIVERSITY



What?

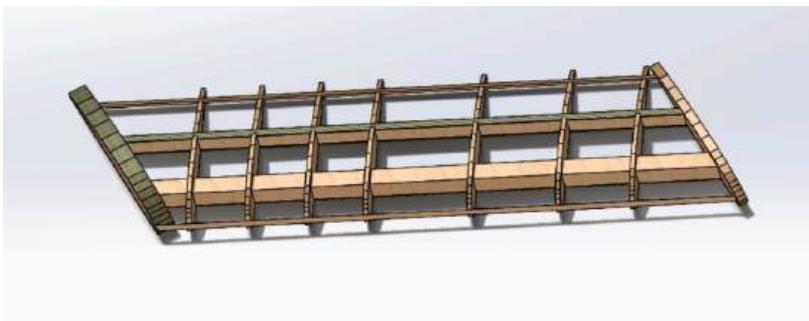
- Designed and analyzed three Gottingen 398 balsa wood wing models (straight, swept-forward, rib & strut).
- Evaluated torsional stiffness, aeroelastic coupling, and divergence speed under a 100 N/m distributed lift load.
- Fabricated rib-strut structure using a laser cutter and reinforced critical regions with carbon fiber epoxy.

How?

- Modeled geometry in SolidWorks.
- Performed structural analysis using ANSYS Workbench FEA to extract deflections and stresses.
- Computed twist, torsional stiffness, shear center, and divergence speed in MATLAB.
- Conducted wind tunnel testing.

Results

- Showed that aggressive weight reduction (to 0.247 N) led to a ~98% stiffness drop, lowering divergence speed to 26.2 m/s.
- Identified the base shear interface as the critical failure location during wind tunnel testing (~90 mph).
- Established quantitative relationship between mass reduction, stiffness penalty, and aeroelastic stability.



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SKILLSAT STARTUP



What?

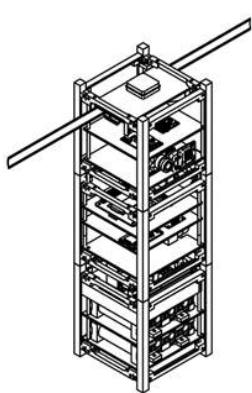
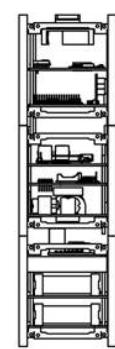
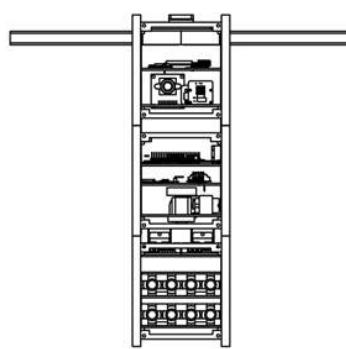
- Founded SkillSat, an EdTech startup to manufacture STEM kits that teach students to build stratospheric satellites.

How?

- Used Arduino and Raspberry Pi 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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Uncovering the Fluid-Structure Interactions of Wave-Assisted Propulsion via Cyber-Physical Fluid Dynamics



Division of
Fluid Dynamics
DFD

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78th Annual Meeting APS DFD

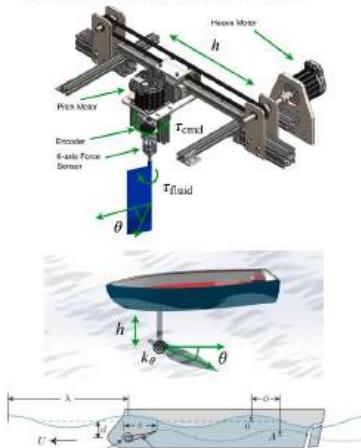
Nov. 23–25, 2025, Houston, TX

Project Objectives and Goals

- Investigate wave-assisted propulsion (WAP) using controlled heave and passive pitch to transform wave energy into forward thrust and improve stability.
- Develop and validate a cyber-physical testbed that couples a flapping hydrofoil with virtual mass-spring-damper dynamics.
- Implement real-time control of virtual stiffness, damping, and inertia to emulate passive pitching behavior.

Motivation

- Wave-assisted propulsion (WAP) uses oscillating hydrofoils to extract energy from waves and generate forward thrust.
- The flapping motion can also reduce vessel oscillations, improving stability and efficiency in marine systems.
- Studying these fluid-structure interactions (FSI) requires precise control of mass, stiffness, and damping parameters.
- Traditional experiments fix mass, stiffness, and damping through mechanical design, limiting flexibility in studying dynamic behavior.

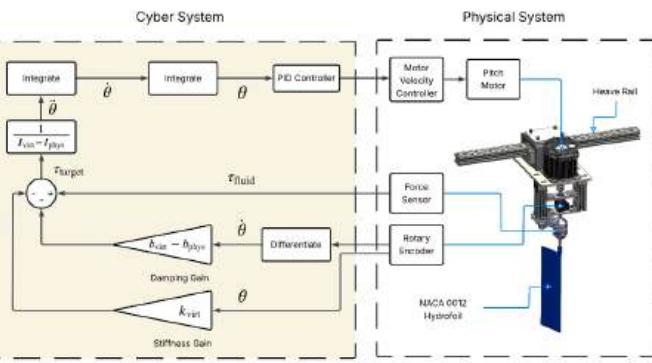


Methods & Procedures

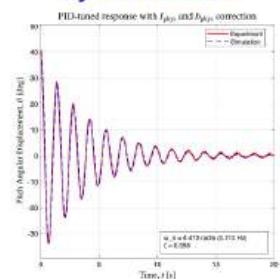
- A cyber-physical system [1] couples the physical actuator-fluid testbed with a computer-based controller that enforces a virtual dynamic model in real time.
- Command signal cancels physical inertia and damping to match desired virtual parameters.
- Physical inertia and damping identified via ring-down experiment.
- Double integration [2] of force/torque removes filtering need and enables stable 4 kHz Simulink Real-Time control loop.

$$\begin{aligned}\tau &= I \ddot{\theta} + b_v \dot{\theta} + k_v \theta \\ \tau_{\text{virt}} &= - (I_v \ddot{\theta} + b_v \dot{\theta} + k_v \theta) \\ J_p \ddot{\theta} &= \tau_{\text{fluid}} + \tau_{\text{virt}} \\ (I_p + I_v) \ddot{\theta} + (b_p + b_v) \dot{\theta} + k_v \theta &= \tau_{\text{fluid}}\end{aligned}$$

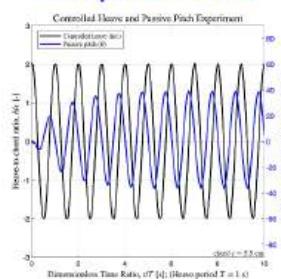
Cyber System



System Validation



Air Experiment Results



Experimental Setup



Conclusions

- Developed a working cyber-physical system mimicking passive pitching.
- Any structural parameters can be virtually assigned to the system, including nonlinear stiffness elements and damping characteristics.
- The system accepts real heave motion inputs from naval vessels, enabling experimental investigation and optimization of Wave-Assisted Propulsion (WAP).

Future Studies / Recommendations

- Evaluate propulsion efficiency and stability under varying environmental and structural parameters in the water channel.
- Recreate natural sea-state conditions by coupling heave-wave excitation with vessel motions across multiple degrees of freedom.

Acknowledgments

This research was supported by the Lehigh Opportunity Fund and Rossin Research Scholars Program (2025), managed by Prof. Mark Snyder, Associate Dean for Graduate Education, Lehigh University.

References

- [1] Matenewski, A. M., and Williamson, C. H. K., 2011, "Developing a Cyber-Physical Fluid Dynamics Facility for Fluid-Structure Interaction Studies," *J. Fluid Struct.*, 27 (5–6), pp. 749–757.
- [2] Zhu, Y., Su, Y., and Breuer, K., 2020, "Nonlinear Flow-Induced Instability of an Elastically Mounted Pitching Wing," *J. Fluid Mech.*, 899, A35.