PART

Purdue Aerial Robotics Team

Annual Report 2021 - 2022

Developing Principled Industry Leaders

PURDUE UNIVERSITY

Written March 7, 2022
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Team Purpose

Mature students into principled industry leaders for their post-undergraduate careers by executing a comprehensive industry standard approach to interdisciplinary design, prototyping, and systems engineering.

What We Do

PART designs, builds, and tests a two-vehicle system from the ground up each year to compete in an international competition. PART's Uninhabited Aerial System (UAS) air-drops an Uninhabited Ground Vehicle (UGV), both of which will complete a series of tasks demonstrating their ability to operate and navigate autonomously while performing remote sensing missions representative of real-world problems.

Team Composition

PART is an interdisciplinary engineering team comprised of 71 undergraduate students studying computer science and various engineering disciplines. The team has three technical branches bound by a leadership team and a systems engineer.

- Leadership, 7 Team Members
- Aeromechanical, 40 Team Members
- Electrical, 15 Team Members
- Software, 10 Team Members

The Competition

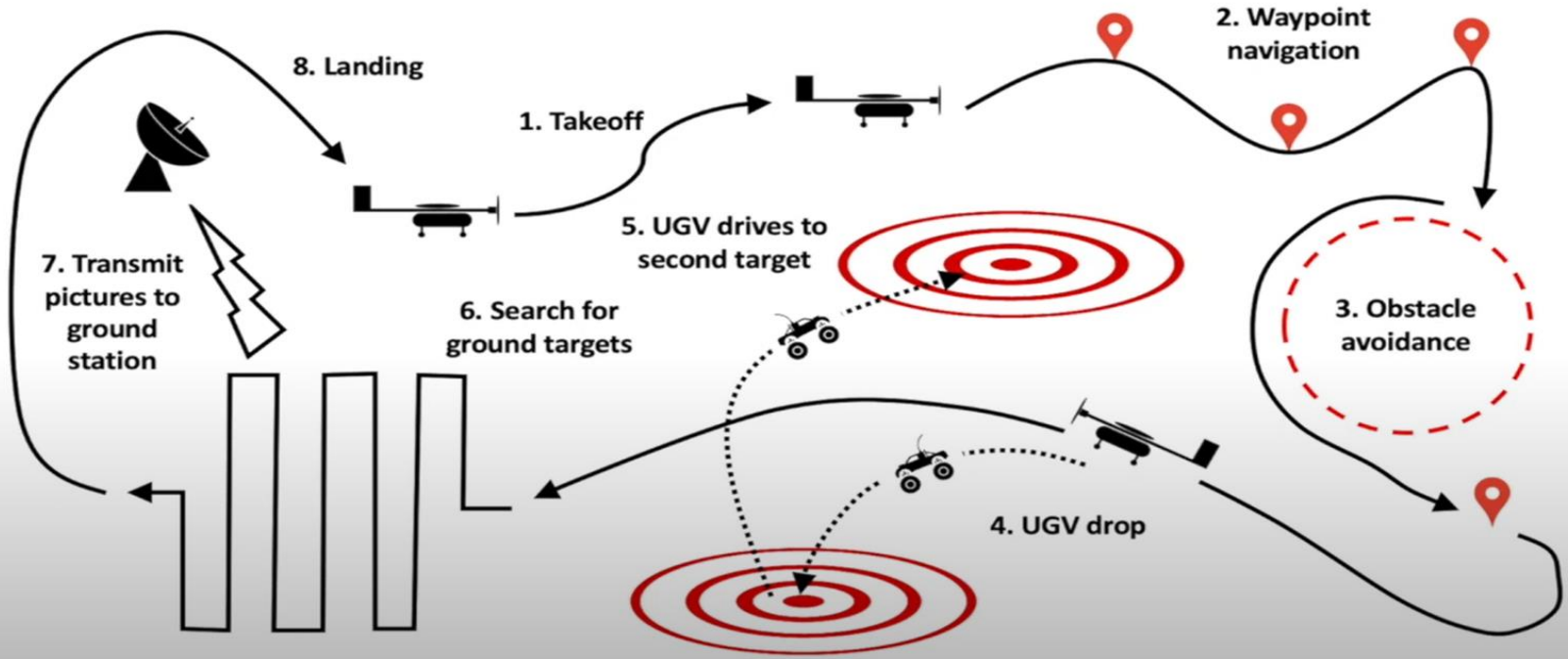
The competition is held annually at Webster Field in southern Maryland by the Association for Unmanned Vehicle Systems International (AUVSI). Teams travel from around the world to represent their school, state, and country with a demonstration of their aircraft's capabilities.

The competition rules are released in September with three main categories, each scored with different weights: (1) the technical design paper (TDP) (20%), (2) the flight readiness review (FRR) (20%), and (3) the mission demonstration (60%).

The TDP is due in February. This gives the team five and a half months to design a mission capable drone start to finish, including passing a preliminary design review with our advisors, and documenting our process.

The FRR is due June 1st. It is 10-minute video submission to the competition judges that proves the team's system is safe to fly.

The Mission Demonstration takes place between June 16th and 18th. The mission consists of 8 separate functions representative of real-world applications; these functions are shown below. The drone completes these tasks autonomously with a human safety pilot on standby in the event of a systems failure.

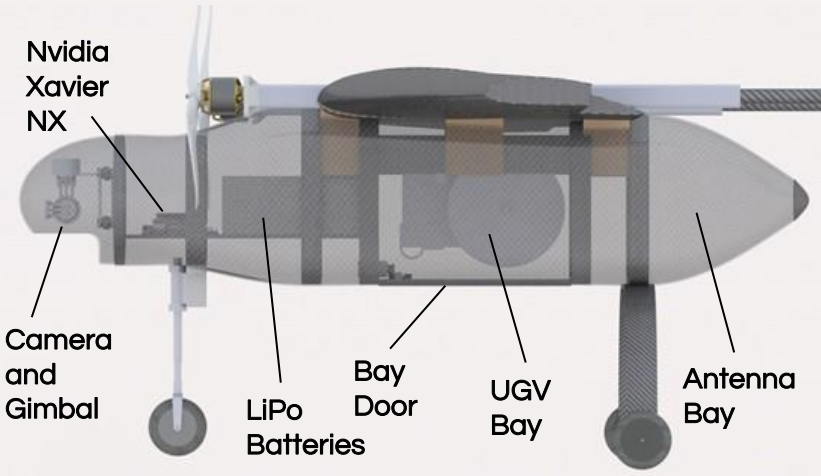


2022 Design

Performance Specs

Specification	Metric
Gross Takeoff Weight	15 kg
Max Takeoff Weight	20 kg
Stall Speed	13 m/s
Cruise Speed	17 m/s
Takeoff Distance	30 m
Aircraft Endurance	25 minutes

Internal Components



Design Description

Object classification and UGV deployment are critical, high value requirements necessitating stability at low speeds and appropriate payload placement within the airframe. Therefore, the aircraft configuration (1) places the camera in the nose of the aircraft to prevent damage during takeoffs and landings, (2) places the UGV at the center of gravity to maintain stability after release, and (3) has a large wing area and aspect ratio for slow and efficient flight. The design exhibits a high wing, twin tail configuration with an internally housed UGV to minimize drag before release. Twin motors provide thrust for safe flight sporting a 25-minute endurance. Fixed landing gear increase the designs simplicity and reliability.

The main wing's NACA 4415 airfoil provides a max lift coefficient of 1.5, a low drag coefficient 0.01 under cruise conditions at 17 m/s, and a 15:100 thickness to chord ratio which provides predictable stall behavior due to trailing edge boundary layer separation. The wing exhibits a 0.5 taper ratio to achieve 97% aerodynamic efficiency relative to the elliptical lift distribution.

The tail's NACA 64(1)-012 symmetric airfoil provides internal housing of control surface servos due to its large geometric volume.

A HolyBro Pixhawk 5X flight controller provides robust obstacle avoidance and it's numerous communication ports and redundant sensors ensure reliable autonomous flight capabilities. ProfiCNC Here2 GPS/Compass communicates with the Pixhawk to provide accurate UAS position data. A custom printed circuit board with mid-level voting firmware provides for the fusion of three I^2C airspeed sensors to measure accurate airspeed data. The autopilot integrates directly with the flight computer and antenna tracking hardware to transfer telemetry data between the UAV and Ground Control Station (GCS).

The onboard imaging system consists of a 2-axis gimbal and an Onsemi AR0820AT camera. The image sensor delivers 3848 x 2168 resolution in 4 exposure HDR mode at 30 frames per second, enough information to resolve targets one foot wide and color characterization. Gimbal positioning provides sharp images for map stitching and target geolocation.

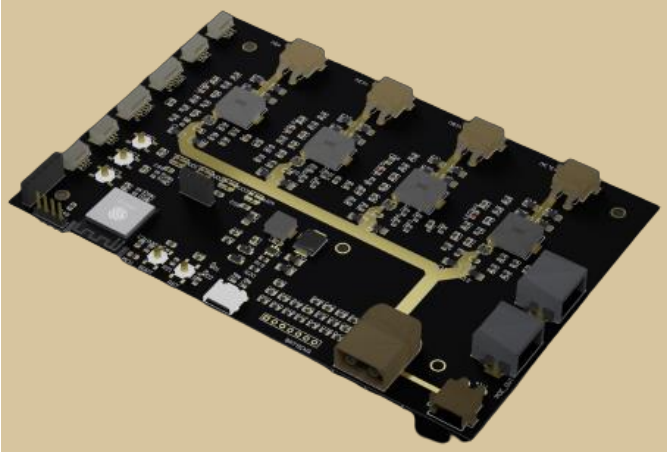
The UGV has a framed chassis with two independently driven wheels to minimizes weight and volume. An airdrop delivery system with a parachute and shock absorbent wheels prevent damage to the UGV upon landing. An 800 mAh battery and pixracer flight controller power the UGV and provide capabilities necessary to complete the mission. A payload compartment houses an 8 oz water bottle and vehicle electronics. The UGV weighs 0.75 kg with ground range of 500 meters at 0.5 m/s.

Construction

Aeromechanical Team

The aeromechanical team constructs the UAS fuselage, wings, tail, and internal structures, primarily using carbon fiber and 3D printed PLA. The aeromechanical team construction process is highly hands-on, providing members with experience using a variety of machine shop tools as well as advanced industry standard carbon layup techniques. In constructing the UAS subassemblies, the team considers refinements to design factors such as transportability, assemblability, and maintainability.

The aeromechanical team is continuously iterating upon subassembly designs and advancing their manufacturing techniques to improve the airframe as they learn through test driven development. The UGV in particular was a target of rapid prototyping via laser cutting to arrive at a final design made of carbon fiber that is lightweight, rugged, and efficient.



Electrical Team

The electrical covers a breadth of topics that primarily deal with UAS power, autonomy, and communication. This year's team built two isolated avionics systems: one manages the electric propulsion system, and the other manages the auxiliary systems including the flight computer, Pixhawk 5X flight controller, gimbal, camera, and transmission antennas.

The electrical team quantifies uninstalled motor thrust and endurance limits subject to their avionics system, develops and tests custom waypoint obstacle avoidance algorithms, develops and tests search grid algorithms, wires the interior of the aircraft, and builds a ground-based antenna tracker to transmit information between the ground station and the UAS.

Software Team

The software team develops algorithms that locate, identify, and classify targets on the ground, and stitch individual images together into full orthomosaics. This year, the team used artificial intelligence and machine learning (AI/ML) algorithms to detect targets in images taken by the UAV's camera. Their algorithms identify the shape of the target, its color, and the alpha-numeric symbol painted on the target.

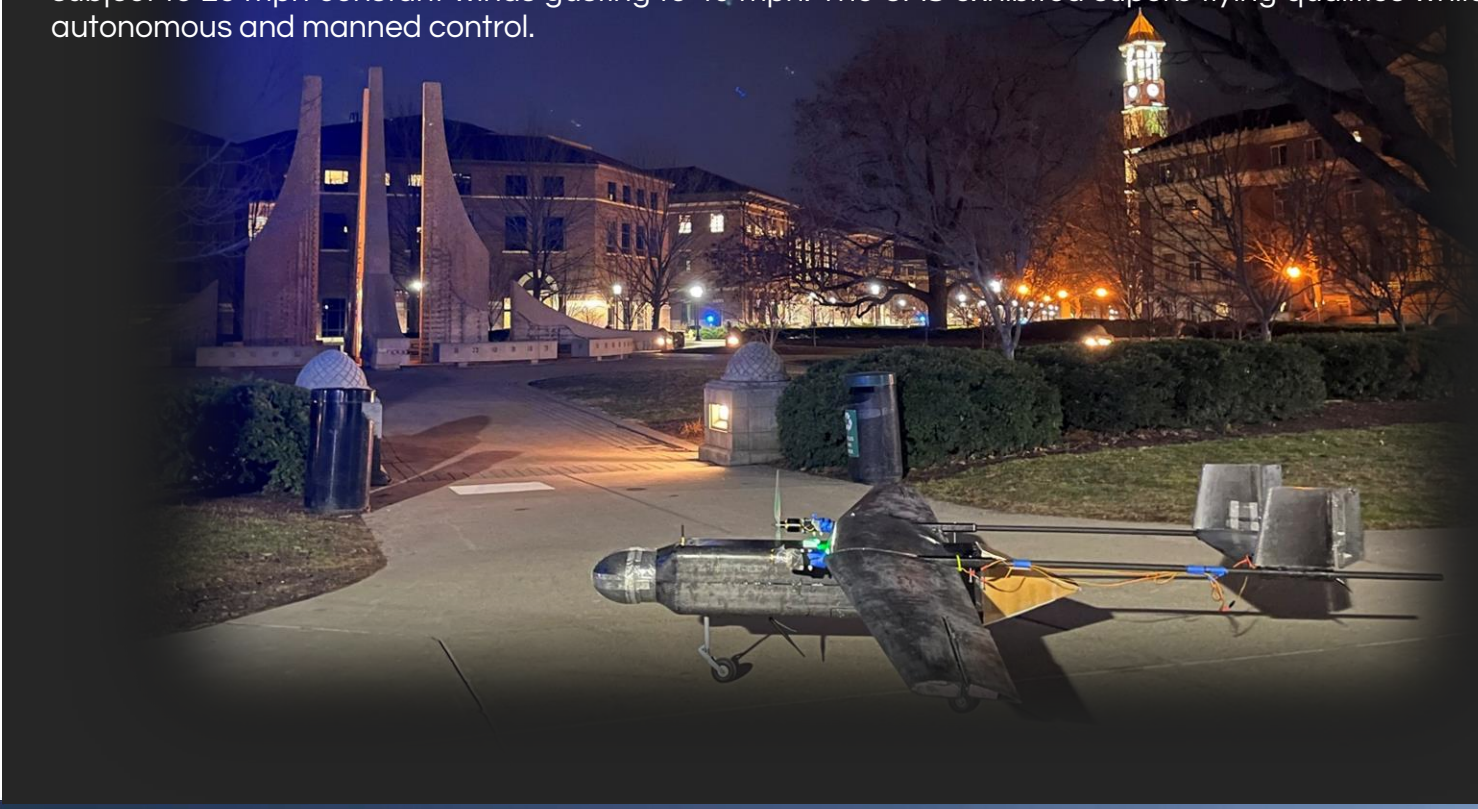
The software team trained their AI/ML algorithms using a combination of real targets and synthetically generated targets housed in a virtual environment.

The software team also utilizes state-of-the art edge computing devices to host their algorithms on-wing, and they developed a graphical user interface where ground station operators can review the UAS's target identification, localization, and classification performance.

The 2022 Competition Ready UAS

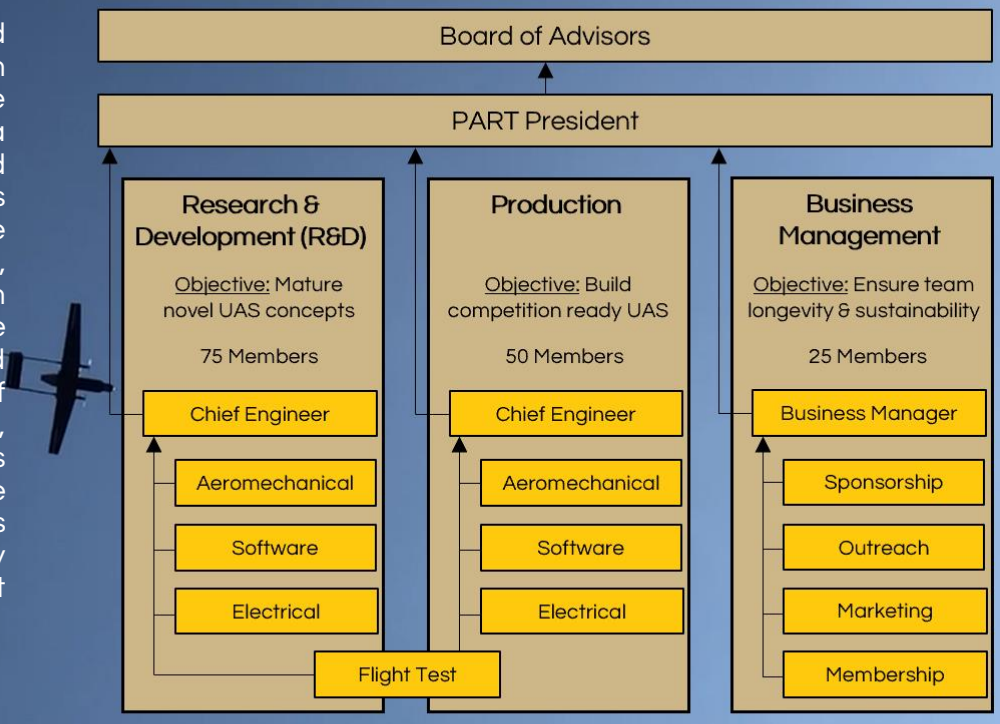
Maiden Flight: March 5th 2022

On March 5th the team conducted three successful test flights at Staggerwing Field in Lauramie Township IN. The UAS flew for a total of 15 minutes, and demonstrated its design performance by flying a mission subject to 25 mph constant winds gusting to 40 mph. The UAS exhibited superb flying qualities while under autonomous and manned control.



PART 2022 - 2023 Vision

PART's 1-year goal is to restructure and double the size of the team. The new team structure will include three divisions: (1) the production division, which builds a competition ready UAS; (2) the research and development (R&D) division, which matures technology for next year's UAS; and (3) the business management division (BMD), which works to ensure the long-term organizational sustainability of PART. These three divisions are linked by a student led leadership team advised by a Board of Advisors (BOA) that consists of industry, government, and academic sponsors. This new team structure will help PART achieve its defining goal, to mature undergraduates into principled industry leaders, by implementing an organizational layout similar to that of industry.



Leadership Team

President: Matthieu Opdyke
BS Aerospace Engineering
Class of 2023

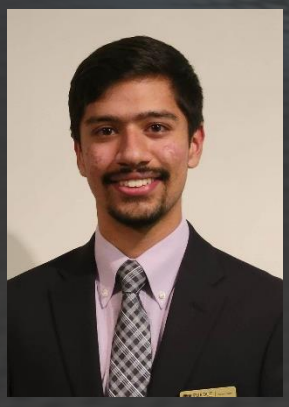
Matthieu is junior studying aerospace engineering and minoring in mathematics and management. He has a background in manufacturing and structural analysis of composite airframes, the application of high-lift devices for STOL aircraft, and systems engineering within the aerospace field. As President of PART, Matthieu has improved workflow structures and team dynamics, growing membership from 20 to 65+ students within a year. His vision for the team is to place in the top three in the AUVSI competition each year.

Systems Integration Lead: Andrew Swanback
BS Mechanical Engineering
BS Computer Engineering
Class of 2023

Andrew is a junior dual-majoring in mechanical and computer engineering. His interests lie at the intersection of aerospace, autonomy, and artificial intelligence. While serving as PART's systems integrator, Andrew has followed INCOSE's systems engineering process to generate system requirements, and tracking. He has also overseen interface requirements and system verification and validation. His vision for the team is to implement a proceduralized industry standard systems engineering process.

Aeromechanical Lead: Eric O'Keefe
BS Mechanical Engineering
Class of 2023

Eric is a junior studying mechanical engineering. His interests lie in mechatronics -- a subject related to the interdisciplinary integration of mechanical, electronic, and electrical engineering -- and fluid mechanics. He exemplifies his time management and leadership abilities by serving as the Captain of the Purdue Water Ski Team while also leading the aeromechanical team. Eric enjoys hands-on engineering and seeks to narrow in his career path search into positions that involve working directly with mechanical systems.



Electrical Lead: Hadi Ahmed
BS Computer Engineering
Class of 2022

Hadi is a junior studying computer engineering. He is fascinated with all types of technology, ranging from large machine learning models to mm-scale microchips. Hadi is working on learning about digital hardware design and plans to pursue a career in creating new computing circuits. His course work is preparing him for such a role as his course work spans all aspects of computing, including network infrastructure, digital design, and embedded systems. In addition to leading PART's electrical team, Hadi serves as the chair of IEEE's Software Saturday's, teaching Purdue engineers web development skills, and as the IEEE infrastructure head, maintaining and updating critical web services.

Software Lead: Diego Montes
BS Computer Engineering
Class of 2022

Diego is a junior studying computer engineering and minoring in artificial intelligence. His background is in deep learning and software engineering, having applied both to his former work in industry at Ford Motor Company and Cummins Inc. Diego plans to build a career pushing the boundaries of what artificial intelligence can do on-the-edge through research and practical applications. He is excited for the future of PART's software team, having made strides in developing the team's computer vision system over the last eight months.

Sponsorship Coordinator: Charles D'Onofrio
MS Aerospace Engineering
Class of 2024

Charles is a graduate student studying aerospace engineering focusing on dynamics and control, and systems engineering. He intends to add an MBA focusing on finance before leaving Purdue. Charles, having worked in NAVAIR's Propulsion and Power division prior to attending Purdue, sees tremendous potential in PART's ability to provide team members with tangible and highly sought-after expertise in engineering design and leadership not typically found in undergraduates. His vision for PART is to transform the team from a club to a renowned Purdue student-led organization.

Membership Director: Romy Kim
BS Electrical Engineering
Class of 2024

Romy is a sophomore in electrical engineering. She enjoys coding, designing DIY circuits for room decor, and learning how to use machining tools. Romy plans on launching a career in the integrated circuit and semiconductor industry, where she aspires to work in a clean room building and testing IC chips. Her long-term goal is to start her own company manufacturing custom built ICs. She is excited to steer the direction of PART's 2022-2023 vision through her role as the membership director, where her primary duty is to recruit new team members and interview leadership applicants.

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