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UAV Forge

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FORGE

https://sites.uci.edu/uavforgeuci/

PROJECT DESCRIPTION

ABOUT US

UAV Forge is a multidisciplinary engineering team that focuses on the design, manufacturing, programming, and testing of autonomous aerial vehicles.

The design aims to fulfill the constraints that allow the team to participate in the AUVSI SUAS 2024 - 2025 competition season.

PAYLOAD MECHANISM

OVERVIEW

Our payload module utilizes two winch systems to meet SUAS requirements for controlled descent. Each payload, a GP908 strobing beacon, must drop from a minimum of 50 ft AGL and land within a 25 ft target radius. Each winch uses a rotary speed limiter, drastically decreasing the speed from freefall to account for safety and target accuracy. Winches replace our previous parachute deployment method to prioritize power efficiency and ease of design.

PAYLOAD RELEASE AND DESCENT

A sliding key mechanism secures two payload capsules to the module and is driven by a pinion gear. A FEETECH FS90R continuous servo drives the pinion in intervals of 65 degrees that release one capsule per turn. Gravity induces the payload to drop while the rotary speed limiter dampens its descent to ~1.8 ft/s. Servo power consumption during flight is zero as it only draws power when a drop is required. The module and mechanism parts are printed from PLA and the capsules are from PETG. The total subsystem mass is 160 g. Vibrations are dampened with foam tape placed between the capsule and the module.

OUR MISSION

MISSION REQUIREMENTS

The competition focuses on Unmanned Aerial Systems (UAS) performing autonomous missions. These tasks include:

- Autonomous Flight** - The UAS must take off, fly within boundaries, navigate a series of waypoints, and land.
- Obstacle Avoidance** - The UAS must avoid other aircrafts sharing the airspace through sense-detect-avoid.
- Object Detection, Classification, Localization** - The UAS takes pictures of a search area, detects objects of interest, classifies its characteristics, and provides a GPS position.
- Air Delivery** - The UAS autonomously drops a GP908 strobing beacon so that it lands undamaged at the target GPS position.

COMPETITION

- SUAS 2025
- June 24 - 26, 2025
- St. Mary's County Regional Airport
- California, MD

PRIMARY OBJECTIVE

Although our annual emphasis is to outperform in a competition setting, the primary objective is to ensure that undergraduate students participating in the project apply their engineering and computer science skills to a compelling real-world problem.

Design and iteration of autonomous systems require a wide variety of skills and knowledge to plan and execute. As such, UAV Forge is composed of students from all engineering disciplines.

FINANCIAL BREAKDOWN

Total cost\$6,500

MAE24%

Competition23%

EECS53%

MAE Subsystem Teams:

- Airfract
- Payload

EECS Subsystem Teams:

- Perception
- GN&C
- Avionics

NAVIGATION CONTROLS

AUTONOMOUS FLIGHT

The core autonomous functionality includes flying a waypoint lap, scanning a drop zone for targets, flying to detected targets, mapping the competition area, and returning to home to land. This year we refactored our control code to shift from PX4 to ArduPilot flight control firmware.

We achieve this using ROS (Robot Operating System) based control code running the onboard Jetson Orin Computer that sends MAVLINK to the flight controller.

CUSTOM GROUND CONTROL STATION

This year we've renewed our effort to develop a custom web-based ground control station. Current functionality includes sending multiple custom waypoints to the drone's onboard computer over Wi-Fi. The drone's onboard computer will then generate a flight plan with the custom waypoints.

Digital Twin of Competition Airfield

SOFTWARE IN THE LOOP TESTING

In order to safely test and debug flight behaviors before actual deployment, the team heavily used Software-in-the-Loop (SITL) Simulation. This allows us to simulate both the drone and environment, as well as the flight control firmware and our ROS control code. This setup, which incorporated ArduPilot flight firmware with a detailed virtual model of the competition area using Gazebo, allows us to test and verify our autonomous functionality before deploying to the test drone for real world flight testing.

PERCEPTION

TARGET DETECTION

We used a custom Ultralytics Yolo11n deep learning model trained on synthetic data from the Godot game engine to detect targets.

CAMERA

The camera chosen for this season was the SIYI A8 Mini, a gimbal-stabilized camera. The camera shoots in 1080p and the gimbal ensures clear and directed images regardless of the drones orientation.

MAPPING

Due to an additional mapping requirement this season, we run a custom image-stitching algorithm based on SIFT keypoints to generate a map of the competition area asynchronously.

OBSTACLE AVOIDANCE

Using another Yolo11n model with two wide-angle cameras for a full 170-degree view, we can detect obstacles and if nonstationary, predict their locations using a model-based particle filter.

AIRCRAFT DESIGN

SUAS competition rules have specific aircraft performance requirements that must be met. Our UAV must be able to deliver a payload while flying at least two 3-mile laps in a single trip, resulting in a UAV design that needs to be optimized for range rather than speed. Along with these baseline performance requirements, the 2025 SUAS competition requires the system to fit within a 9in. x 14in. x 22in. volume to maximize points. To deliver on the competition mission requirements, the team has designed a high-efficiency quadcopter capable of carrying two payloads simultaneously for over 7 miles. Our airframe has been created to carry out this strategy.

Custom Machined Carbon Fiber Chassis

- Utilized CAD software to optimize the weight and to tailor the design for a quadcopter frame that emphasizes maximum weight reduction while still preserving structure rigidity during flight.

3D Printed Carbon Fiber PETG Mounts

- 3D printed solutions are easy to manufacture, cheap, and practical.
- All structural components on the new quadcopter will be manufactured by the aircraft team while utilizing Finite Element Analysis (FEA) to quickly iterate proposed designs and optimize their performance under load.
- Carbon Fiber PETG is a lightweight material and has been tested in a lab to be able to handle all loads with a safety factor of at least 2.

Payload Hot-Swap Design

- The competition quadcopter design includes a robust rail system below the chassis to minimize time needed to switch out UAV payloads for testing.

from left to right:
upper plate, lower plate, battery plate

AVIONICS

POWER DISTRIBUTION

The drone is powered by a custom 6S8P Li-ion battery pack comprising 48 Molicel P45Bs spot welded with 0.2mm pure nickel strips. 2 custom PCBs combine battery power flow and cell management, as well as low power distribution.

PROPULSION

4 KDE 465 KV motors power the drone paired with Tarot 15in x 6.5 pitch bi-blade propellers. On our custom built thrust stand, they achieved hover at 61% @ ~13A each and peak thrust of 13.78kg @ 164A combined, putting our T/W ratio at around 2.0.

RTK GPS

A Here4 RTK GPS & Here+ ground station lets us achieve cm-level accuracy, a leap over the traditional meter-level accuracy from typical GPS systems.

COMMUNICATION

Our UAV employs a dual radio setup: an ELRS 2.4 GHz radio for RC control and an RFD 900x 915 MHz telemetry radio for data transmission between the drone and the ground station. We carry out extensive testing to optimize antenna placement and frequency selection to mitigate interference.

CUSTOM PCB SOLUTIONS

We employ a custom low-power electronics PCB to centralize 5V and 12V power for all the drone electronics such as the flight controller, telemetry radio, cameras, payload mechanisms, NVIDIA Jetson, etc. The PCB is capable of 5V @ 5.5A and 12V @ 4.5A, along with an ESP32-S3 allowing for wireless monitoring of our custom battery pack. To increase safety and ease of use, a custom PCB links all eight 6S packs together into a singular parallel output and is capable of 80A continuous and 220A burst current.