Flywheel Mechanism-Based Human-Mounted Fixed-Wing Unmanned Aerial Vehicle Launch Platform

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Background

- Small yet capable UAVs have become increasingly vital in both civil and military applications.
- The Russo-Ukrainian War exemplifies this trend, with both sides deploying large numbers of small UAVs for reconnaissance, surveillance, and strikes [1,2]
- This strategy enables rapid, low-cost deployment, replacing traditional high-cost aerial assets and ground-based artillery [3,4]
- Drones have limited **range** and **endurance**
- A **portable launcher** capable of deploying UAVs from any location could greatly extend their operational range and endurance
  - Conserving energy required for takeoff
  - No requirement for runway
- Could decrease set up and deployment time and increase adaptability

Previous Solutions

- Militaries have developed tube and catapult-based systems for launching drones from ground vehicles and other stationary locations

AeroVironment Switchblade 300: $80,000 (Figure 1):

- Takes several minutes to set up before launching
- UAV itself is also proprietary, being fragile and complex due to its foldability, being limited to just 20 minutes of endurance [5,6]

The Rafael SkyLite: $150,000 (Figure 2):

a. Launches the UAV to an altitude of about 80 meters in just a few seconds
b. The system requires two individuals for transportation [7,8]

Previous Solutions (Continued)

- No existing system allows drones to be deployed while being carried by an individual

Figure 1: Switchblade 300

Figure 2: Rafael SkyLite

Research Question and Objectives

- Evaluate the feasibility of a **flywheel-based propulsion system** as an efficient and effective solution **deploying fixed-wing UAVs from a human-mounted launch platform** through the development of a conceptual design and prototype build
- Assess the platform's potential to enhance endurance, range, and energy efficiency using computer-based alongside the construction of a test bed to evaluate and test performance as well as the number of flywheels, launch velocity, and material cost

Launch Platform Benchmarks

- Launch a commercially available fixed-wing UAV to an altitude of 75 feet (22.86 meters)
- UAV to reach apogee within four seconds
- Support a maximum payload of 75 pounds

Launch Platform Design

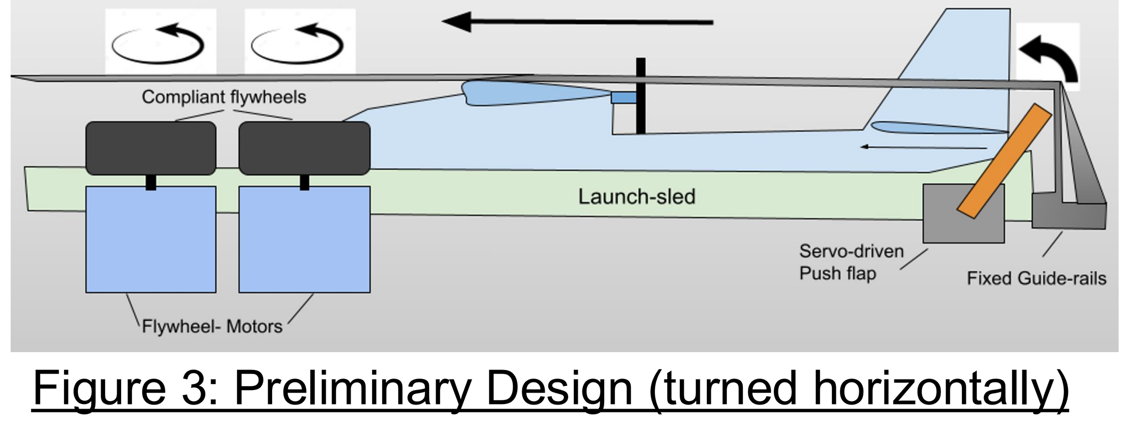

Figure 3: Preliminary Design (turned horizontally)

Launch Platform Design (Continued)

- UAV to be launched using one or two sets of 12/24V 10,000 rpm motors
- 3D-printed flywheels using TPU for flexibility
- Stainless-steel guide rails and launch sled guide the projectile into flywheels to ensure consistent feeding

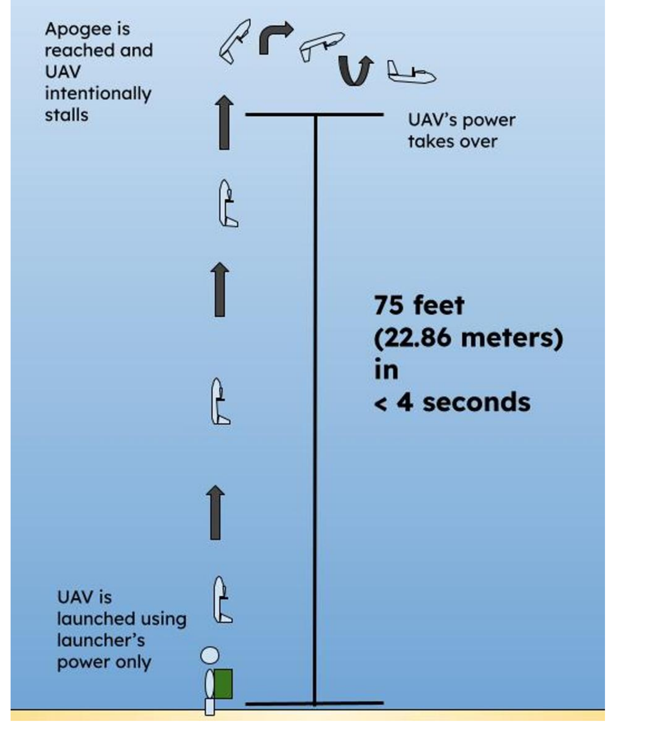

Figure 4: Launch Process

- High-torque servomotor driving pusher flap pushed projectile into the flywheels
- UAV is launched vertically before intentionally stalling (Figure 4)

Kinematics

- Launch velocity can be calculated with mass of the UAV, the coefficient of static friction, flywheel radius, length, and angular velocity

$$v_{final} = m_{projectile}^{-1} \cdot \sum_{i=1}^{n} \frac{4\mu F_n d}{r_{flywheel}\omega_{flywheel}}$$

- There is a lower limit to angular velocity, as with too low of a velocity, not enough kinetic energy will be transferred from the flywheels to the projectile

$$\sum_{i=1}^{n} \frac{1}{2} I_{i,\,flywheels}\,\omega_{i,\,flywheels}^{2} \geq \frac{1}{2} m_{projectile}\, v_{launch}^{2}$$

- The energy transfer from rotational kinetic energy to linear kinetic transfer will not be 100%
- Therefore, we must first test for kinetic energy transfer before proceeding with further development of the prototype

Flywheel Testbed

- Designed to test kinetic energy loss between the flywheels and projectile
- Constructed upon a wooden board
- Custom 3D-printed guide-rail towers and motor mounts are affixed to said board
- Powered via a 6s high-voltage Li-Po
- Power to motor is controlled by two BTS 7960 motor driver modules, connected to an Arduino

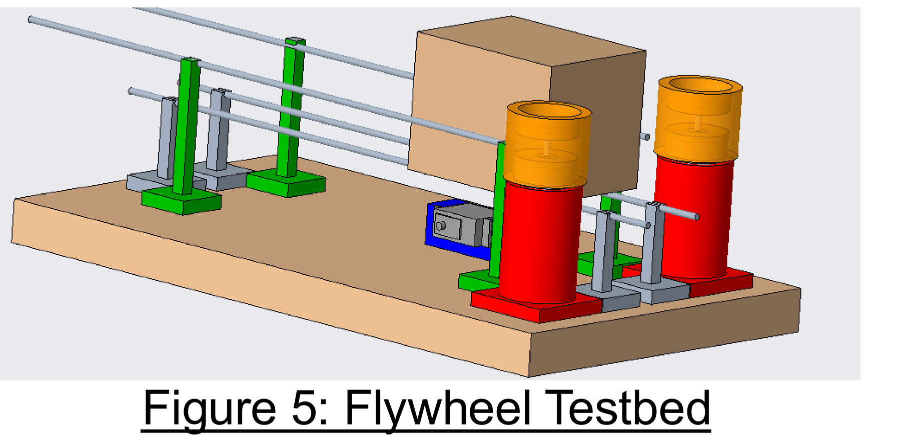

Figure 5: Flywheel Testbed

Fixed-Wing UAV Candidate

- Chosen for small wingspan and optimal propeller placement and contact area between UAV and flywheels (Figure 6)

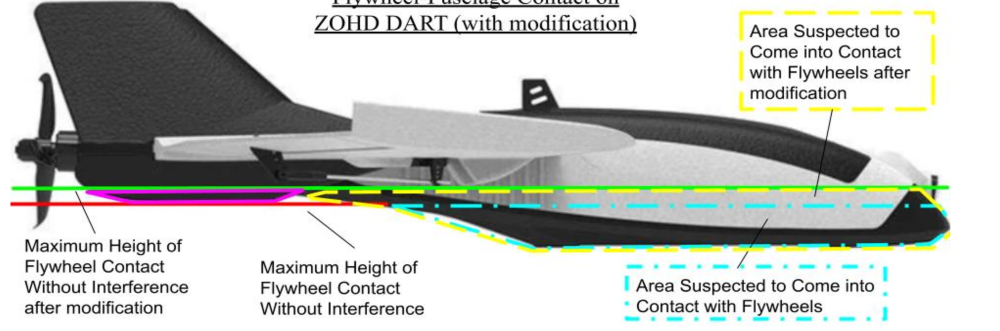

Figure 6: ZOHD Dart and Contact Area

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UNDERGRAD RESEARCH

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