Additive Manufacturing of Grenade Launchable Aerial Sensor Platform

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Introduction

Advanced 40mm grenade rounds with integrated electronics are being investigated as future military devices. These devices can integrate easily into existing weapons systems and have a form-factor that is both durable and compatible with conventional storage and transport solutions (Figure 1). There is particular interest in using additive manufacturing to create an ecosystem of inexpensive and easily manufacturable devices that can be fired from a standard 40mm grenade launcher. Such devices can be produced without dedicated manufacturing facilities and can be modularly designed such that non-printable components are efficient to transport. The capabilities of these devices include chemical sensors, optical observation equipment, and autonomous vehicles. This project aimed to design and test a new addition to this family of a devices: an autonomous aerial drone.


Figure 1: Standard 40mm Grenade Round

Problem Specification

The purpose of this drone is to provide easy access to a multipurpose aerial tool without requiring military personnel to carry additional equipment. Thus, the drone must fulfill the following constraints:

- It must be 35.5mm in diameter and 150mm or less in height, in order to interface with existing non-lethal grenade technology.
- It must survive launch stresses, self-stabilize, and fly unaided with

a high degree of control and navigational capabilities.

- Battery life must be two minutes or longer.

Problem Specification (cont.)

Besides these requirements, there are several desired properties that make up the following design goals:

- Full self-navigation, with both pre-recorded GPS waypoints and

real-time editing of GPS waypoints.

- Complete 3D-printed construction.
- Relatively inexpensive components and manufacturing process.
- Highly configurable features with modular equipment bay.

Hardware

A winged design was initially explored, but it proved to be too heavy when printed, while the minimum feature size of printed objects led to bulky joints and poor volume efficiency.

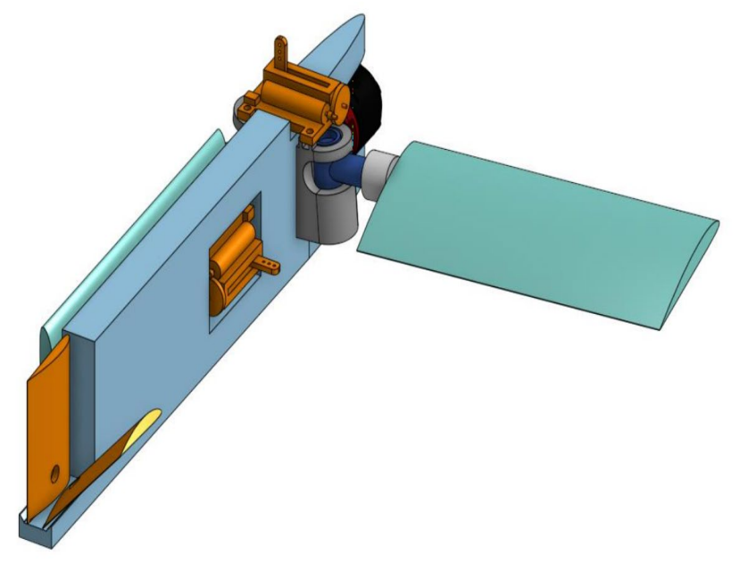
Figure 2: Proposed winged design.

A quadrotor topology was instead selected (Figure 3). This topology provides excellent flight characteristics with significantly more room for error in construction than a winged craft. This design uses spring-loaded staggered arms to extend four small but powerful motors. Figures 3 demonstrate the core components of the design: the motors (teal), the arms (purple), the flight controller electronics (red), and the cap (blue).

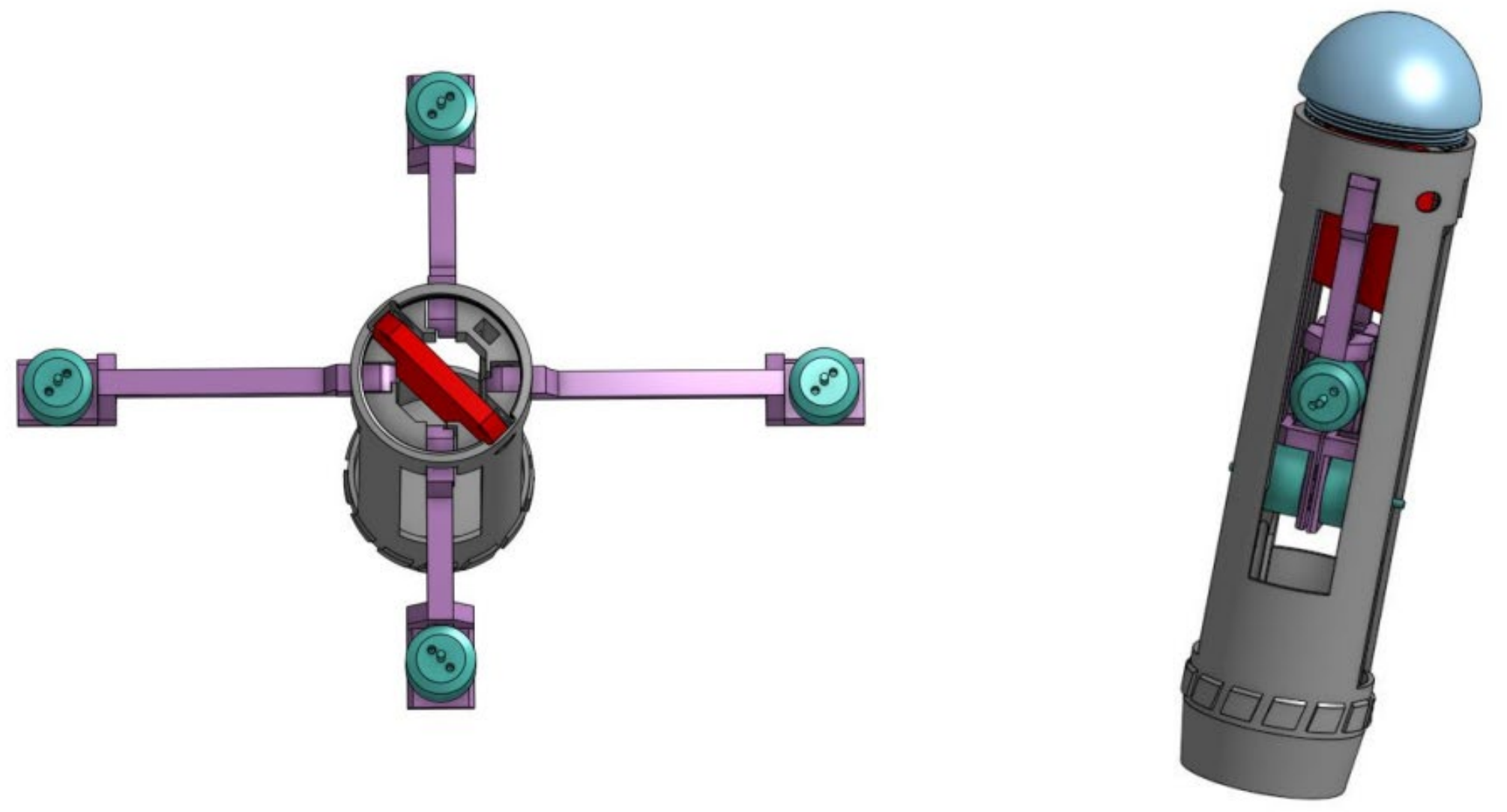
Figure 3: Quadrotor grenade design with staggered motors and folding arms.

Electronics and Software

The electronics on the drone closely follows standard hobbyist quadcopter setups, namely consisting of a STM32 flight controller with an onboard Inertial Measurement Unit (IMU), four electronic speed controllers (ESCs) and motors, a GPS, compass, barometer, and radio receiver. The drone runs either of two closely related open-source flight control software: iNAV or Betaflight. While both software options allow for advanced flight characteristics, iNAV focuses on automation and navigation features and Betaflight focuses on general performance and freestyle flying. As the project nears completion, the capability to edit these software options has become a priority. This capability would allow for the addition of custom sensors and control methods, such as the complete removal of human interaction by emulating a transmitter in software. As of now, telemetry data has been successfully repurposed to output any local variables available on-board to a human observer in real-time.

Vibration Issue

The most notable unresolved issue for the drone-grenade is the prevalence of vibrational noise in the frame. Vibration during flight is picked up by the gyro and propagates through the PID controller to the motors, causing overheating and unstable flight. The primary source of vibration is the arms, one of which is pictured below. 3D printed materials have limited stiffness, so aluminum machining is being explored as an option.

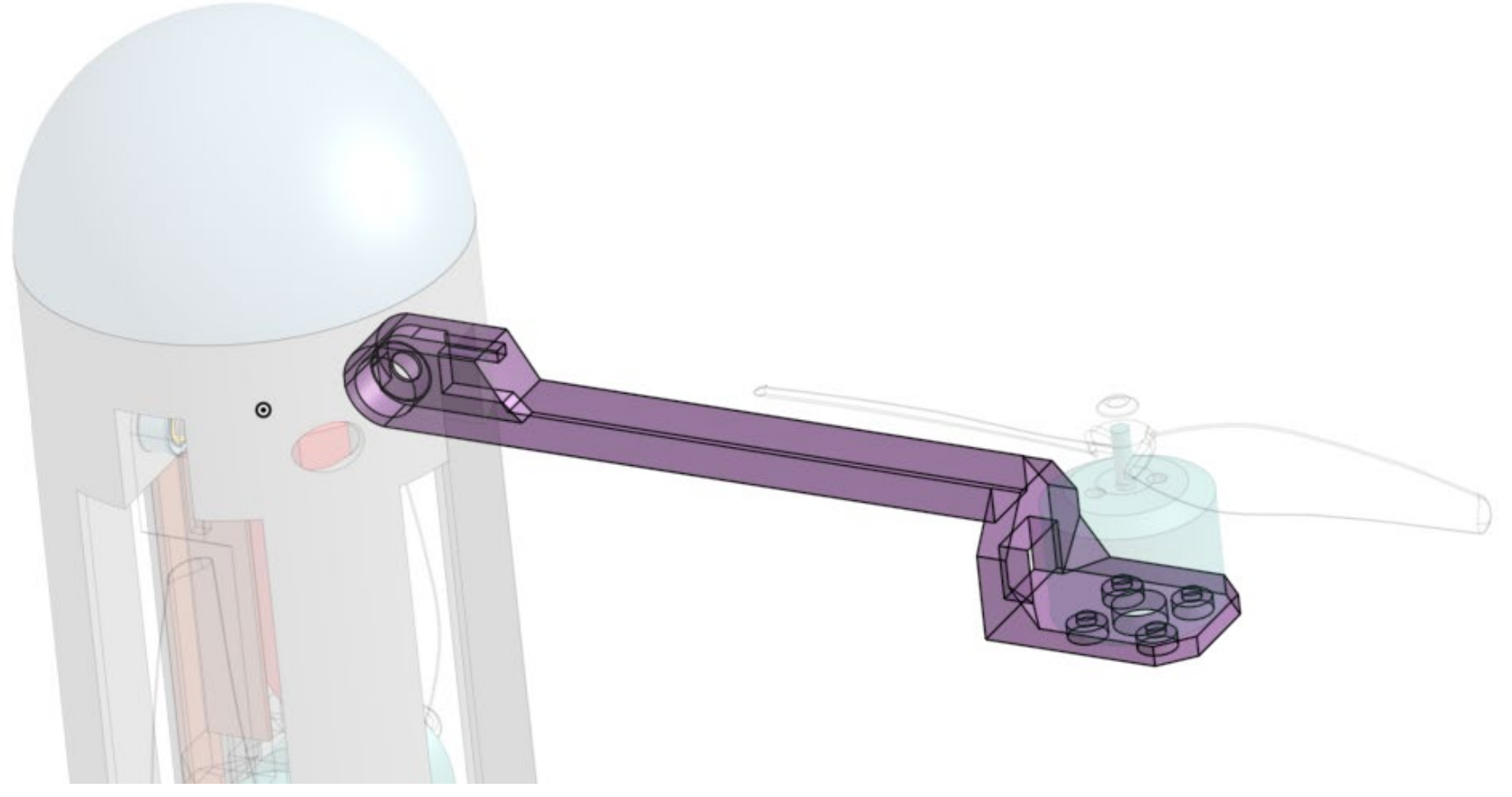
Figure 4: Arm structure isolated.

Testing and Discussion

The drone was tested in an open field wherein it was fired at a 45º degree angle in a rifled round designed for airsoft grenades. Using compressed gas, the droned traveled approximately 100 feet before the arms opened and disrupted stable flight. The drone was then armed and powered, allowing the flight systems to restore control and stability to the drone. The drone was then successfully guided back to the launch location. This test flight yielded valuable information regarding future development options. Notably, the drone's orientation is difficult to distinguish after launch. This will hopefully be rendered inconsequential once automated navigation equipment is correctly configured. The last obstacle to this is compass placement, which is made difficult by crowded nature of a compact drone. It is possible that an additional extending arm will be required to isolate the compass from electrical interference.


Figure 5: Completed drone prototype.

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