

## Hardware

### Airframe

#### Turnigy Talon Quadcopter frame

- This is a carbon quadcopter frame that provided the foundation of what would become the firefighting drone. This simple kit is equipped with four 10 inch hollow carbon rods, and two small carbon plates to act as the core structural components of the drone.
- The quadcopter kit also has a motor mount for each of the four carbon arms, and connection brackets for the center plates and carbon arms.

#### Additional Carbon Rods

- Additional 1 cm thick carbon rods were implemented as a means of adding rigidity to the airframe as well as providing mounting space for the 10 ultrasonic sensors.
- These carbon rods connect each of the four drone arms to one another meeting each at a 45 degree angle.

#### Aluminum Corner Brackets

- Four aluminum corner bracket were milled from solid pieces of metal. The holes were then drilled through each bracket; one hole large enough to fit the main arms of the drone and two smaller holes drilled at 45 degree angles until they intersect the larger hole in order to place the additional smaller carbon rods from one corner to another.

#### Additional Carbon Fiber Plates

- Additional 2 mm thick carbon fiber plates were used to make longer legs for the drone when the middle section is extended for fitting of all the extra components.
- The new legs were simply cut in a triangular shape for simplicity then attached in the same fashion as the original legs.

#### Brass Connection Rods

- Various length brass rods each with a female threaded end and a male threaded end were used extensively in the construction of the center column. The rods connect carbon plates and attach various electrical components to the main body of the airframe.

## Electronic Components

\*\*Component specs and manuals are included under the Downloads section of the website.

#### BeagleBone Black Microcontroller (BBBK)

- The BBBK was chosen for its versatility in embedded Linux applications. It was used for the purposes of having efficient execution and control with software for near real-time performance.

### KK2 Flight Controller and KK2 Programming Board

- The KK2 is the chosen flight controller for the copter due to its versatility, ease of use, and general familiarity. The programming board was used to change the flying mode of the KK2 board, as it has multicopter support options.

### Turnigy 9X 9Ch Transmitter (Receiver included)

- This is the interface between pilot and drone. The receiver can receive up to 9 channels, however our drone only uses 5.

### Ultrasonic Sensors

- The chosen sensors for obstacle avoidance and collision detection implementation for safe and easy flight mechanics. HC-SR04 was the model.

### IMU - Razor 9DOF

- The IMU provides an accelerometer, gyroscope, and magnetometer for precise orientation measurements. This is useful for smoother control.

### Logic Level Converter

- This is required to shift 5V signals to 3.3V signals and vice-versa, as the BBBK is only 3.3V tolerant.

### Cameras

- A Logitech C920 webcam was used for high fidelity streaming purposes for FPV (first person view) remote piloting.
- A Seek Thermal camera was used for a video feed that would be unperturbed by smoke and locate victims and potential danger spots before firefighters enter the building.

### Wifi Adapter

- Using an AP (access point) configurable Wi-Fi card, a connection was established between a client (most often a laptop) and the drone for display of video feeds.
- The AP was also used for programming the BBBK.

### Motors and ESCs

- Brushless motors are used to drive the propellers. ESCs (electronic speed controllers) are fed PWM (pulse-width modulation) signals, which are translated into a DC source for the motors. Longer pulse within period = higher voltage = higher rpm.

### Custom PCB

- Designed to simplify wiring to/from the BBBK. This is not a necessary component, it just made many lives easier.

## Power Setup / Batteries

- One 4000mAh 4S LiPo battery became the final power source. The distribution method is described below in the electrical wiring section.
- We used a Turnigy HV SBEC 5A Switch Regulator to drop the voltage coming off the battery to 5 volts, which can be used to power the BBBK, ultrasonics, KK2 and receiver.

## Initial Design Plan

Initially, we planned on building a pentacopter as seen in Image 2. We progressed all the way to flight testing phase when we realized that the wasted thrust from the center prop overlapping with the smaller props as well as the central tower was so much that we were unable to achieve anymore flight than ground effect. We were forced to switch to the final version of the copter as seen above.

## Final Airframe Design

The airframe is very simple. From the base of the Turnigy quadcopter, the landing gear legs are extended to 6 inches in order to compensate for the addition of parts in the center tower. The final design does not add any more plates for mounting any components in the tower, instead the use of brass connection rods to extend the bottom plate was employed. This gives ample space for wiring and a lightweight design. The hollow carbon fiber arms were also cut in half in order to fit through a doorway. Without cutting the arms, the craft would have never been able to fit through a typical door. The addition of carbon fiber rods for the mounting of ultrasonic sensors were also used. Aluminum holders were used to hold the rods in place; this also served to stiffen the airframe from twisting under full payload.



*Image 1: Initial Pentacopter Design*

## Lessons Learned

After constructing the pentacopter we found that the current configuration created way too much drag for the craft to lift off the ground more than an inch or two. The center column of electronics and wires essentially blocked all of the thrust provided by the main lifting center propeller. In an effort to actually get the drone airborne the decision was made to convert it into a quadcopter configuration. Without extending the arms the four outer motors were replaced with larger (type of motor) motors with 12 inch propellers. Since the drone arms were too small for the larger propellers; we had to stagger the height of the motors by an inch which made it particularly hard to calibrate the drone for flight. In the future it would be best to set up the firefighting drone in a quadcopter configuration with every motor level with one another and without any propeller overlap. This could be achieved with higher power motors, notably the same ones used by Team Hindenburg. The motors and propeller setup would be able to fit in the same footprint as our modified drone without propeller overlap. The need for the shorter main arms is to fit within a door-frame.