

Motivation, Goal, Impact

Motivation: Fire response emergency crews often arrive at a fire scene with **limited information regarding building conditions, fire intensity, structural hazards, and potential victims**. This lack of information can delay effective decision-making and increase risk to both firefighters and civilians

Goal: To design a **Structure Fire Rapid Response Drone System** capable of providing firefighters with immediate situational awareness during the early stages of a structural fire

Impact: Ensures **critical information** is given to firefighters **in advance of arrival**, lowering response time, reducing damage, and **decreasing chance of injury or loss of life**

Requirements

From Customer Requirements:

- Arrive at site of fire as quickly as possible
- Continuous 360° live video feed for 4 minutes
- Cover fire department's ~3 mile radius
- Operational in temps up to 120 °F
- Auto-detection of hazardous flight conditions and system health
- Housing must securely mount to firehouse roof

To Engineering Characteristics:

- Cruising speed - **80mph**
- Hatch Open Time - **3 seconds**
- Total Sortie Time - **10 minutes**
- Maximum Proximity to Fire - **8 meters**
- Housing Yield Strength - **50 kPa**
- Housing Operating Temp - **0° to 120°**

Housing:



Final Design

Drone:



A weather resistant drone housing with motorized rack and pinion sliding hatch system with cable driven lifting platform for VTOL clearance. Integrated sensor and compute suite to determine whether conditions are safe for takeoff.

Housing Subsystems:

- Automated hatch and rising launch platform
- Wireless charging
- Weather detection sensors
- Rooftop mounting mechanism

Autonomous drone launch following a given location via dispatch call, traveling upwards of 80mph using a ABS made fuselage with 360 view hovering capabilities.

Drone Subsystems:

- Standard imaging
- Thermal imaging
- Autonomous navigation compute

Design Calculations

Drone Drag Force Calculations

$$D_{p_o} = (1/2) \rho V^2 C_d A_o \quad \text{Initial chassis drag}$$

$$D_{p_o} = (1/2)(1.225 \text{ kg/m}^3)(30 \text{ m/s})^2(0.00268053 \text{ m}^2) = 1.478 \text{ N}$$

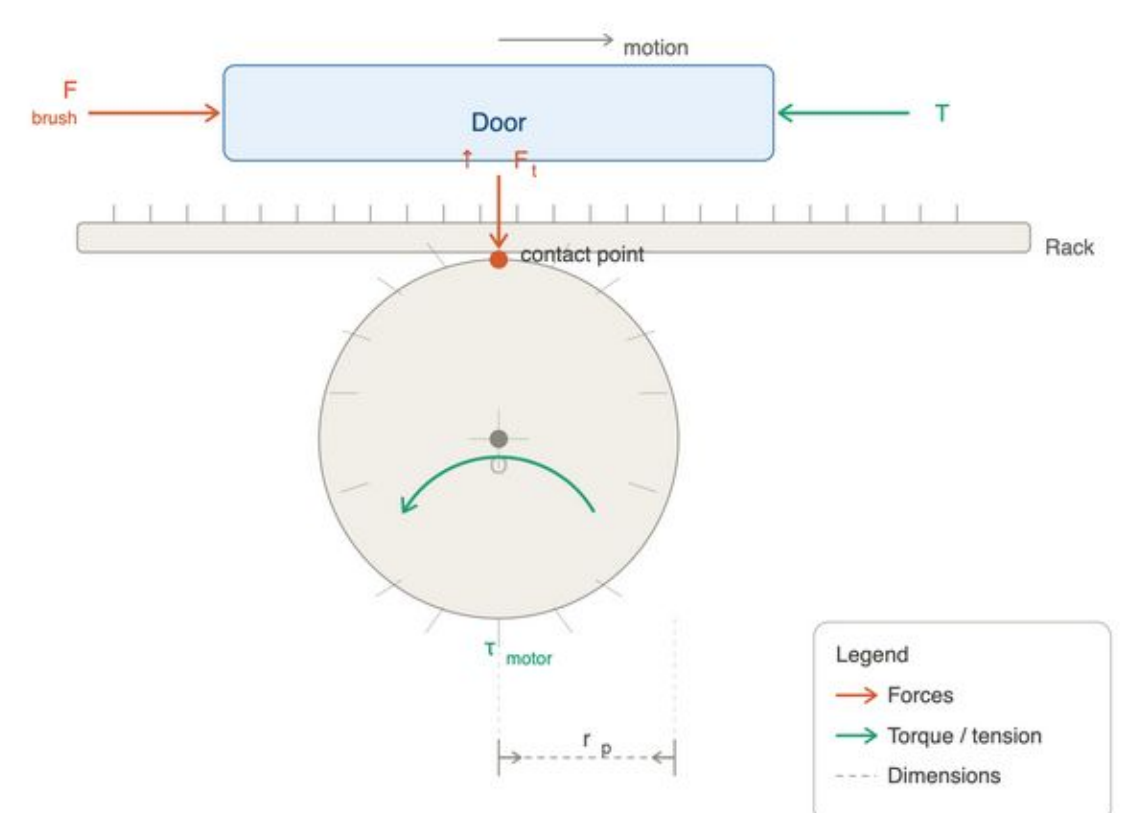
$$D_{p_n} = (1/2)(1.225 \text{ kg/m}^3)(30 \text{ m/s})^2(0.00219295 \text{ m}^2) = 1.209 \text{ N}$$

$$\Delta D_p = D_{p_o} - D_{p_n} \quad \text{Difference in Drag}$$

$$\Delta D_p = 1.478 \text{ N} - 1.209 \text{ N} = 0.269 \text{ N}$$

Using the actual CAD top face areas, the new design has more platform area, but the smoother outer mold line and enclosed battery reduce the estimated center-section parasitic drag by 18.19% in this comparison

Housing Stepper Torque Calculations



To open the doors in the required deployment time as set out in the engineering characteristics:

$$a_{door} = \frac{4 \cdot x_{open, horizontal}}{t_{open}^2} = 0.1016 \text{ m/s}^2$$

Inertial force required to accelerate the door:

$$F_{door, inertia} = m_d \cdot a_d = 0.491 \text{ N}$$

$$m_d = 4.835 \text{ kg (found using CAD model)}$$

Vertical acceleration of the platform:

$$a_{platform} = \frac{4 \cdot x_{open, vertical}}{t_{open}^2} = 0.0791 \text{ m/s}^2$$

Force required to lift platform:

$$F_{platform} = m_p(g + a_p) = 56.95 \text{ N}$$

$$m_p = 5.579 \text{ kg (platform mass)} + 0.18 \text{ kg (drone mass)} = 5.76 \text{ kg}$$

Each door effectively carries half of the platform load:

$$F_{door w/ platform} = F_{platform} / 2 = 28.476 \text{ N}$$

$$F_{brush} = \mu \cdot p \cdot A_{contact} = 9.235 \text{ N}$$

$$A_{contact} = 0.001847 \text{ m}^2$$

Total force required to move the door:

$$F_{door} = F_{door, inertia} + F_{brush} + F_{door w/ platform} = 38.202 \text{ N}$$

Since there are 4 total motors, each motor provides half the force to move one door:

$$F_{motor} = F_{door} / 2 = 19.1 \text{ N}$$

$$\tau_{motor} = F_{motor} \cdot r_{pinion} = 0.243 \text{ N} \cdot \text{m}$$

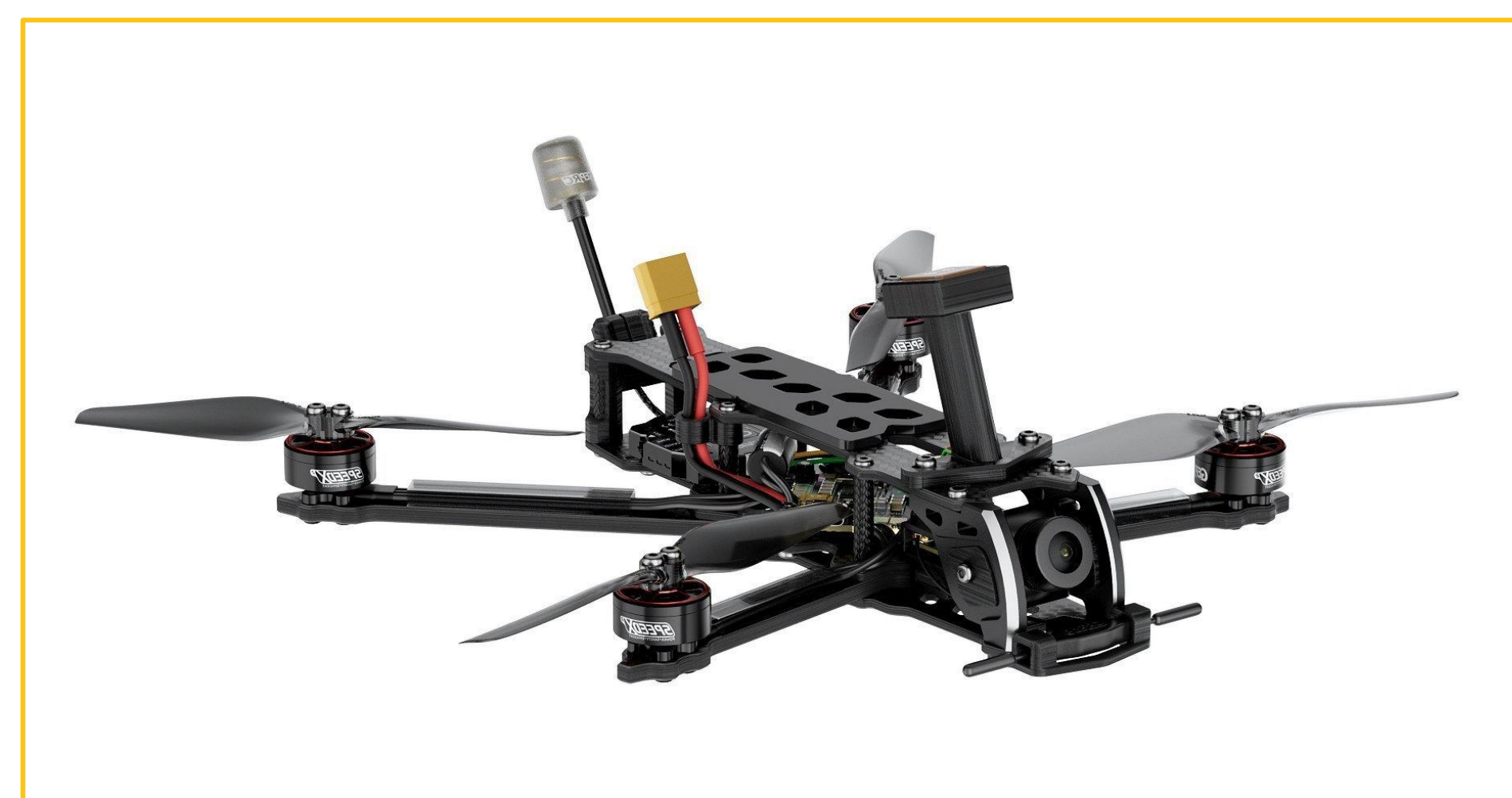
$$r_{pinion} = 0.0127 \text{ m}$$

With our safety factor of 2, we would need motors that fit closer with $0.486 \text{ N} \cdot \text{m}$

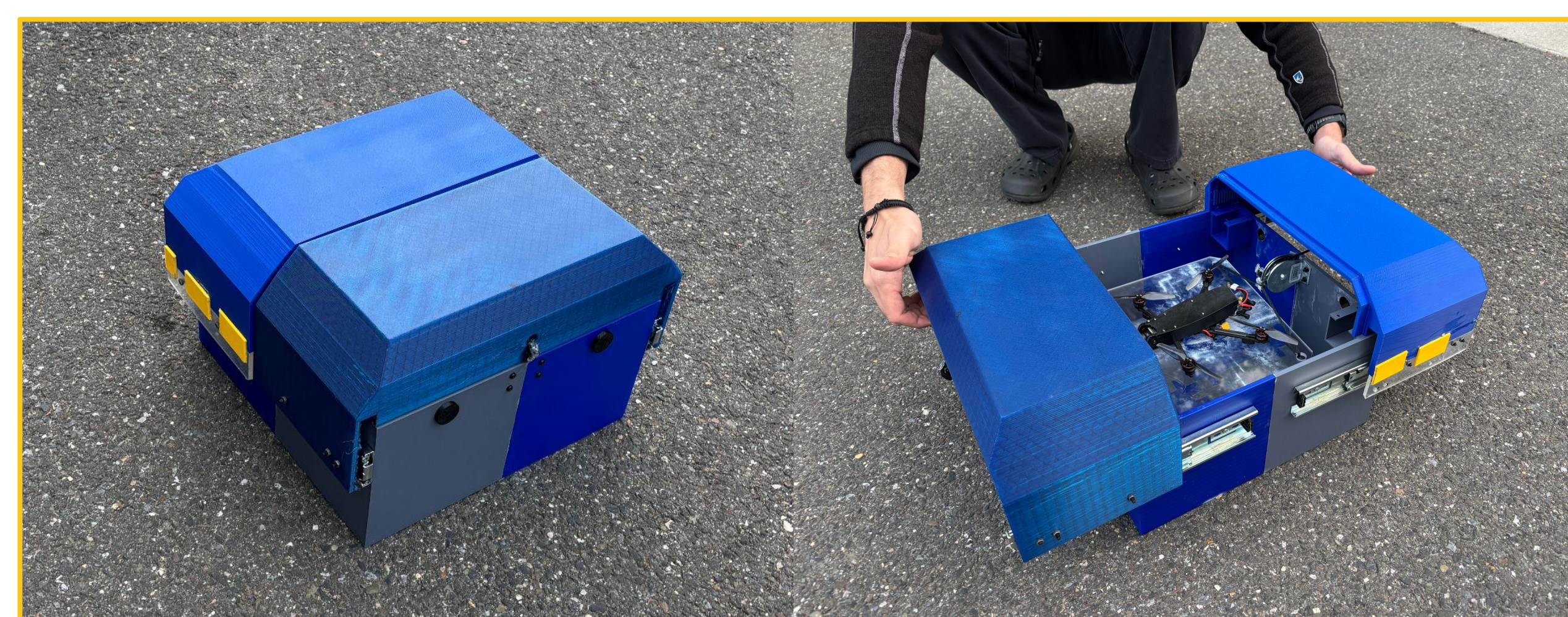


Selected product with wet environment resilience & sufficient torque: **0.56Nm**

Prototype & Test Results



Streamlined chassis to reduce aerodynamic drag, increasing cruising speed and flight time. Testing revealed a +7mph speed increase to 83mph.



Constructed housing prototype with functioning hatch and platform lift system utilizing stepper motors. Prototyping revealed that the system is viable and resilient against external environmental factors. Cable driven platform lift system was found to be effective and efficient, not requiring any additional motors. Final design has greater footprint to allow for greater clearance for drone VTOL.