BALLOON BOMBERS

Ruptron

DEPARTMENT OF MECHANICAL ENGINEERING

Dahlia Andres, Ben Burnett, David Kenney, Tzvi Meth, Mike Rowe, Kevin Whiten

UNIVERSITY OF MARYLAND 1856

A. JAMES CLARK SCHOOL OF ENGINEERING

Motivation, Goal, Impact

Wildfires are an increasingly devastating global issue, causing destruction to ecosystems, property, and human lives. To help combat this issue, our team has designed a device to help the UMD Crossfire Team in the XPRIZE Wildfire Competition Challenge: To develop autonomous systems capable of detecting and extinguishing wildfires within 10 minutes of ignition over a 1000 km^2 area.

Design Goals:

- Develop a low cost, lightweight, and incredibly precise mechanical timer
- Provide a robust, yet eco-friendly solution that can be mass-deployed during wildfires

The overall impact of our solution aids in early-stage suppression of wildfires to guarantee faster containment to protect both the environment and communities.

Requirements

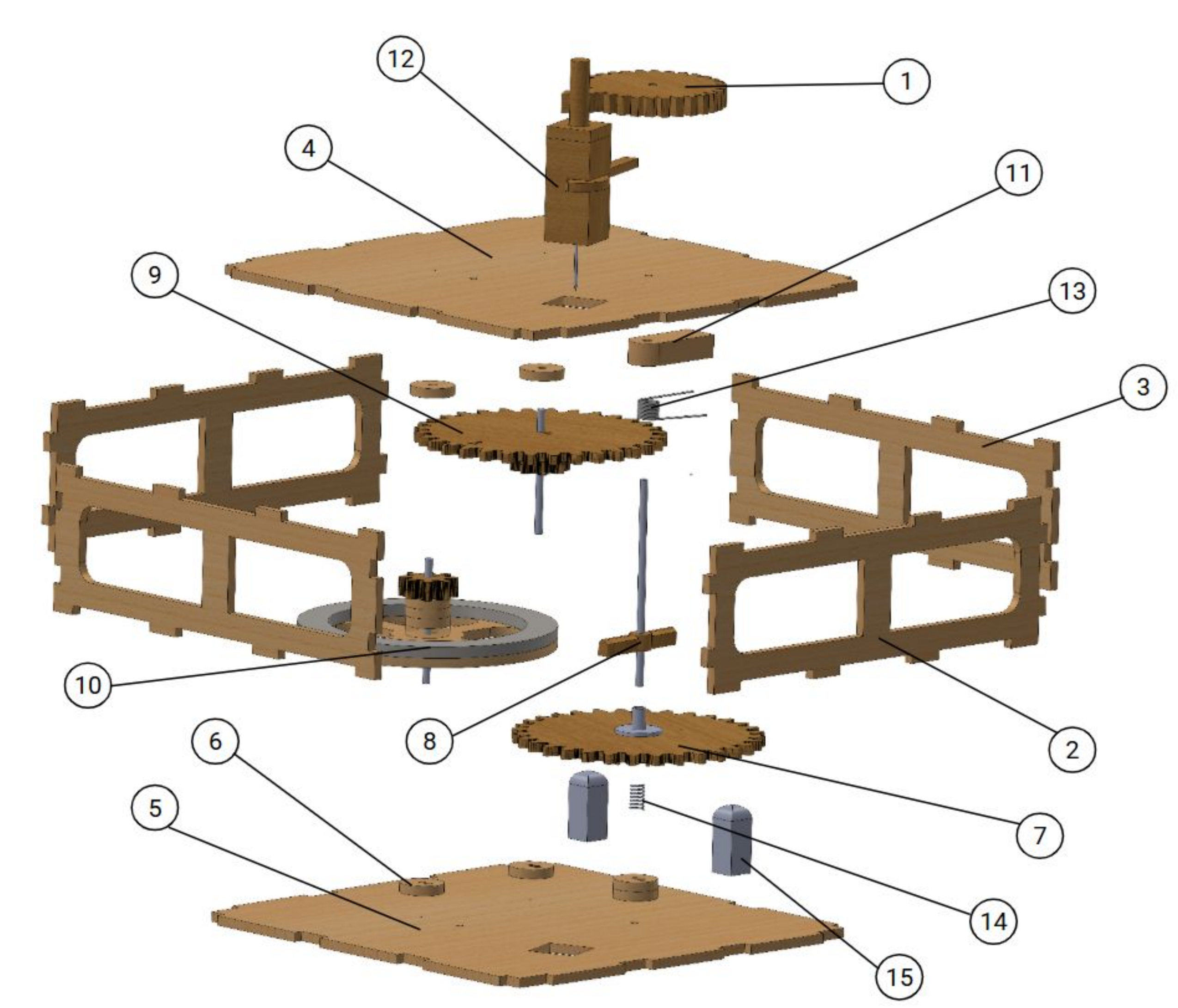
1. Fully mechanical solution capable of popping a 100% latex water balloon
2. Total mass (including water balloon) must not exceed 10.25 kg
3. Must achieve consistent and reliable balloon rupture within a 5m window above the ground from a variety of drop heights (10-100 meters)
4. Timing delay must start only after balloon separates from the drone and must be adjustable for varying deployment conditions
5. System must be durable enough to withstand deployment forces and vibrations without accidental triggering
6. Must prioritize minimal environmental impact
7. Must allow simple adjustment of timing and easy integration with the drone's deployment system

ITEM NO.	PART NUMBER	QTY.
1	DIAL	1
2	LONG SIDE PLATE	2
3	SHORT SIDE PLATE	2
4	TOP PLATE	1
5	BOTTOM PLATE	1
6	BUSHING	6
7	TIMING GEAR SUBASSEMBLY	1
8	FLAG SUBASSEMBLY	1
9	INTERMEDIATE GEAR SUBASSEMBLY	1
10	FLYWHEEL SUBASSEMBLY	1
11	SPACER BLOCK	1
12	RUPTURE MECHANISM	1
13	TORSION SPRING	1
14	COMPRESSION SPRING	1
15	PILLAR	2

Rupture Mechanism:

- Spring loaded plunger activated by a mechanical trigger (scythe)
- Spring stores ~ 4.47 N of force when compressed
- Releases pin when rotated 20º

Final Design



Timing Mechanism:

- Includes Flywheel, Intermediate Gear, and Timing Gear subassemblies
- Torsion spring is used to power timing and provides adjustable delay for balloon to pop at specific elevation
- Dial holds 16 positions for different drop heights

Full Assembly:

- User presets time delay position before loading onto the drone
- Once drone releases the device, a pin attached to the drone is pulled, allowing the system to move

Design Calculations & Decisions

Moment Relation:

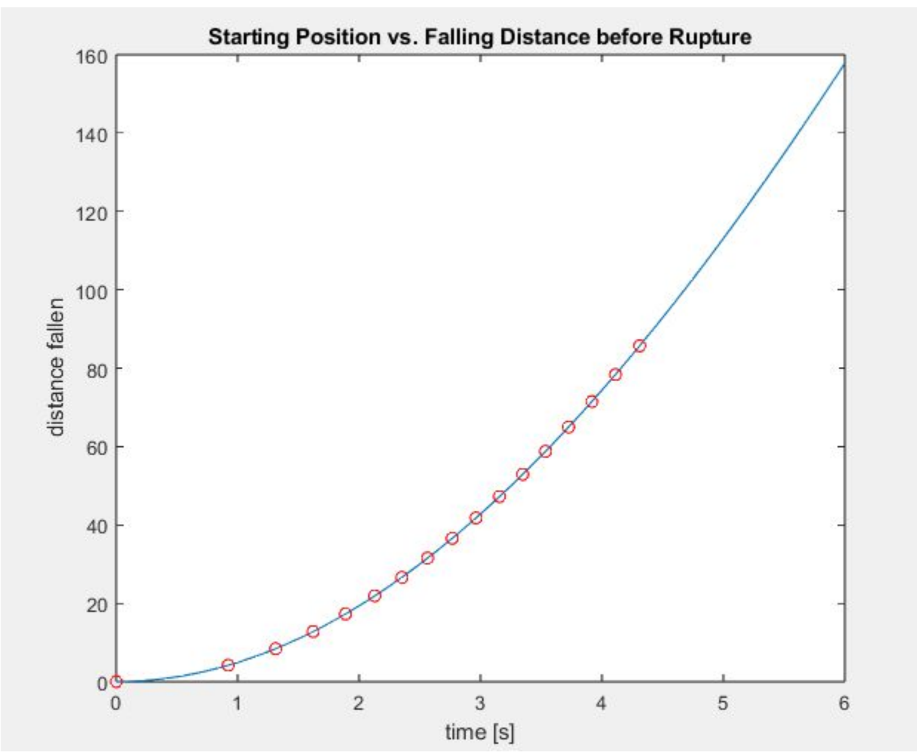
$$\left[J_1 + \left(\frac{C_1}{C_2}\right)\left(\frac{r_1}{r_2}\right)^2 J_2 + \left(\frac{C_1 C_3}{C_2 C_4}\right)\left(\frac{r_1 r_3}{r_2 r_4}\right)^2 J_3\right]\frac{d^2\Theta_1}{dt^2} = M_{spring}$$

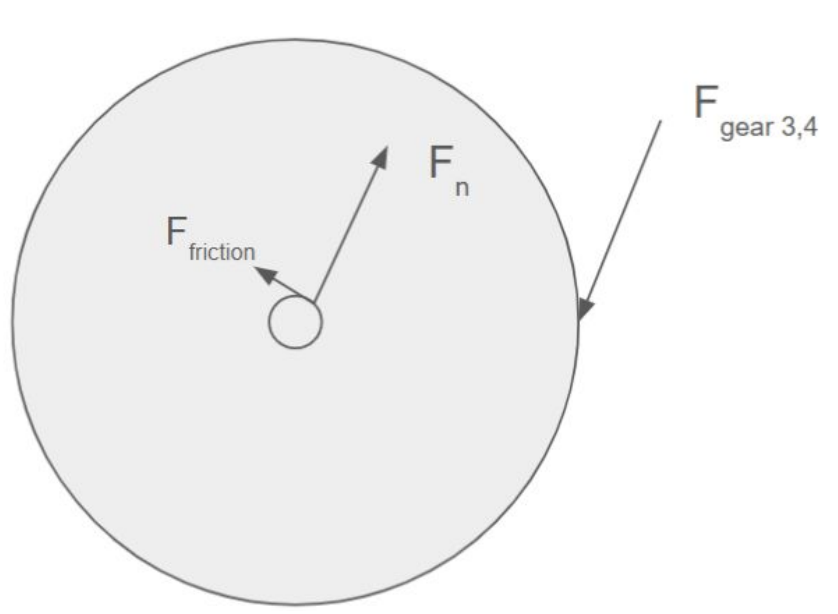
$$C_1 = (cos(\theta_p) - \frac{r_s}{r_1}\frac{F_n}{F_{gear}}\mu_k) \quad C_3 = (cos(\theta_p) + \frac{r_s}{r_3}\frac{F_n}{F_{gear}}\mu_k)$$

$$C_2 = (cos(\theta_p) - \frac{r_s}{r_2}\frac{F_n}{F_{gear}}\mu_k) \quad C_4 = (cos(\theta_p) - \frac{r_s}{r_4}\frac{F_n}{F_{gear}}\mu_k)$$

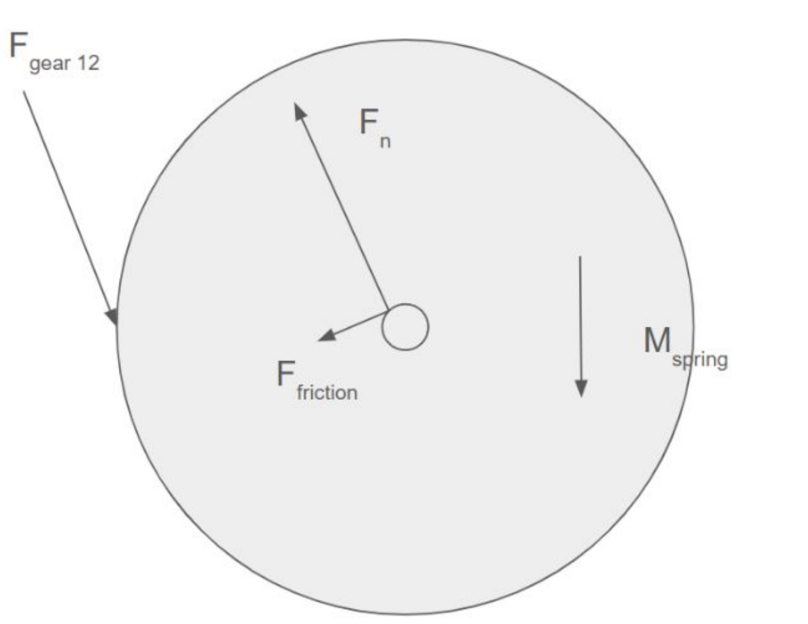
Balloon Drag Force:

$$F_d = \rho * v^2 * C_d * \frac{A}{2}$$

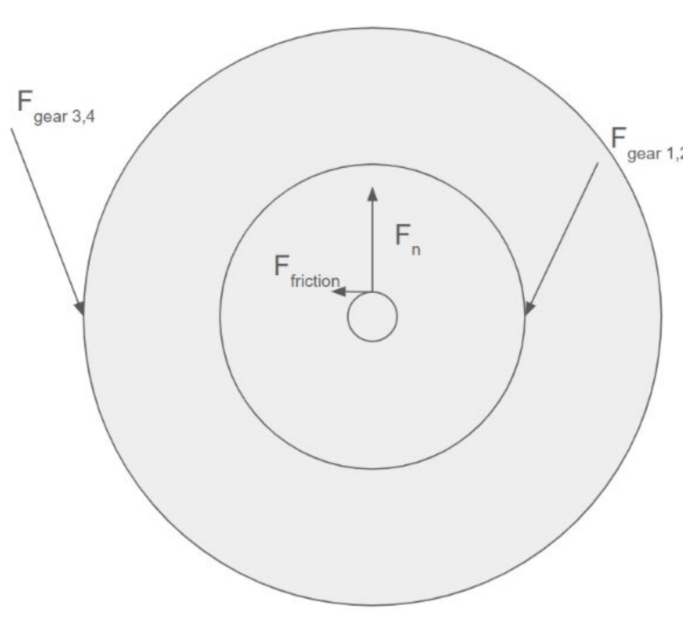




FBD: Timing Gear



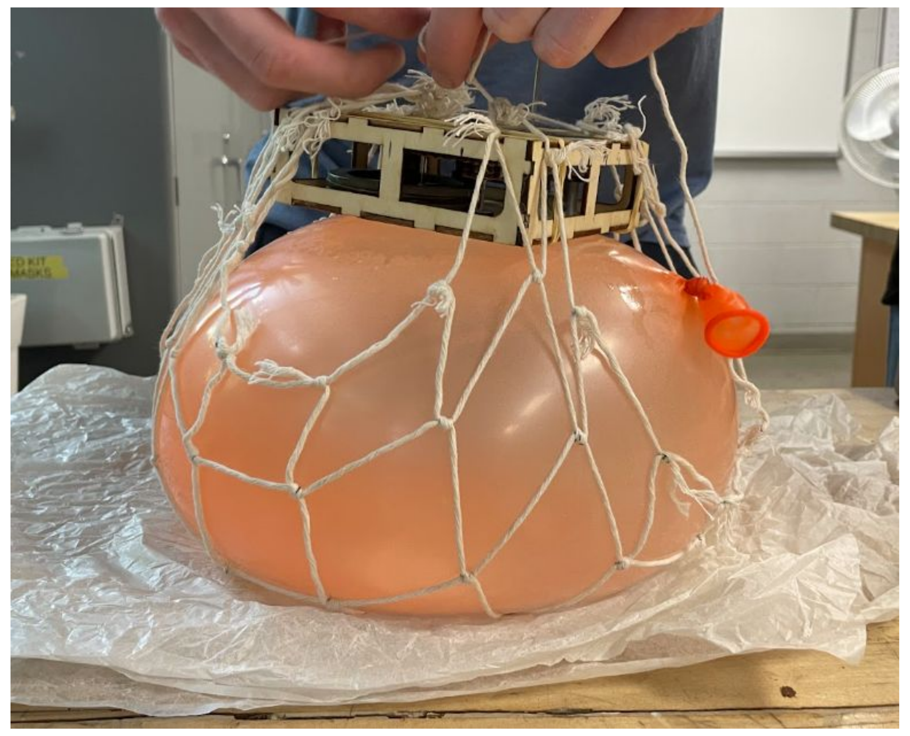
FBD: Intermediate Gear

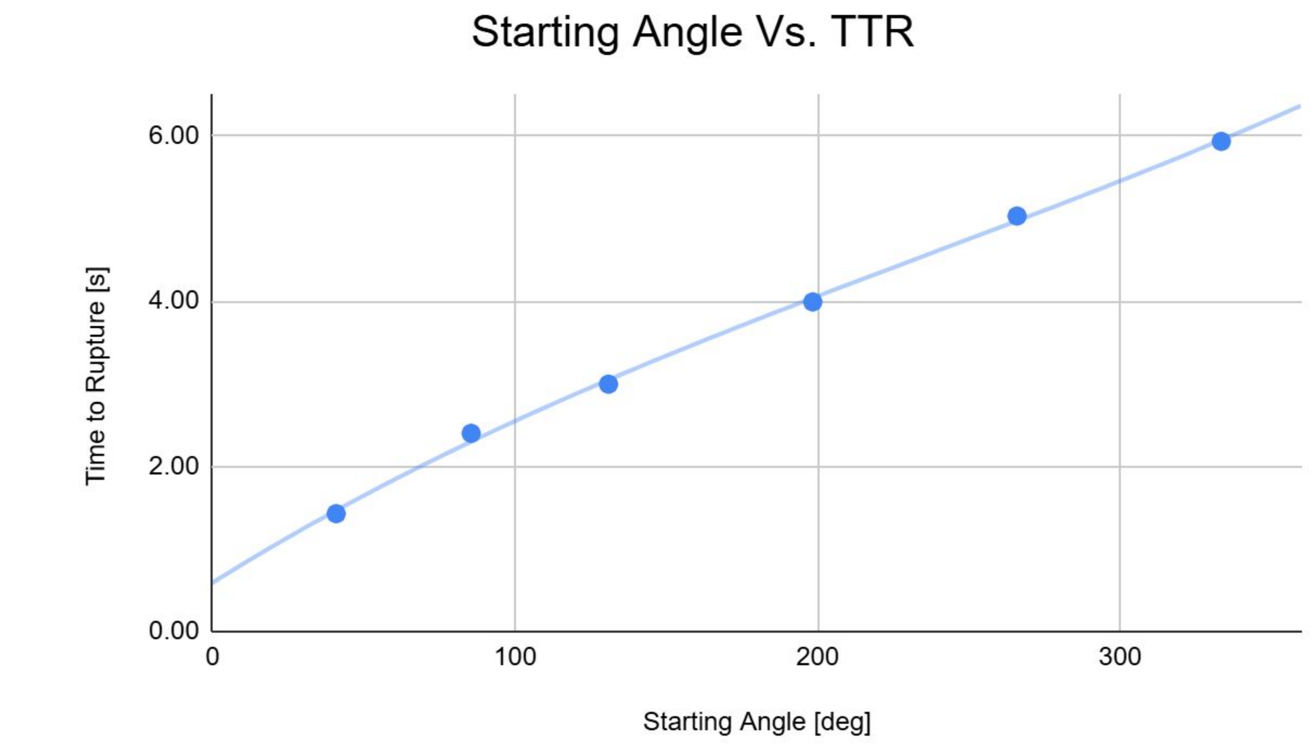


FBD: Flywheel

Prototype & Test Results

High Fidelity Prototype (Ruptron 3000)





Position (Initial Angle)	Average TTR (s)	Expected Average Height (m)	Standard Deviation (s)	Expected Speed at Average TTR (m/s)	Standard Deviation of Rupture Height (m)	95% Rupture Height Range [4σ] (m)
Position 1 (333.4°)	5.94	154.87	0.27	47.07	12.58	50.32
Position 4 (265.9°)	5.03	114.51	0.19	42.10	8.14	32.55
Position 7 (198.4°)	3.99	74.17	0.13	35.28	4.42	17.67
Position 10 (130.9°)	3.00	42.72	0.11	27.66	3.01	12.03
Position 12 (85.9°)	2.40	27.74	0.11	22.64	2.54	10.16
Position 14 (40.9°)	1.43	9.93	0.16	13.80	2.22	8.87