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Projectile Motion of a Drone's Payload: **Velocity's Impact on Range Accuracy with Air Resistance**

By: Shaya Ismail & Ada Qian

BACKGROUND & INTRODUCTION

INTRODUCTION

One of the fastest emerging technologies of the 21st century is drone delivery. This is because it offers a more economical, efficient, and more immediate option of delivery than other ground and air methods (Samet, 2024). Drones are powered by electricity, making it is more sustainable than other methods, due to the fact that it produces fewer emissions. Furthermore, it can be used to drop aid such as medicine and food in unreachable countries. One of the key challenges faced by the influx of drone development is its payload drop accuracy. It is essential to achieve range accuracy for the payload to reach its specific target, otherwise the effectiveness of this technology will be compromised. A significant challenge that the drone faces in relation to its range accuracy, is air resistance. Air resistance accounts for major deviations from the drone payloads target drop point. The unpredictable flight path after the influence of this force is because air resistance varies based on the objects velocity and does not stay constant. Therefore, it is essential to investigate its impact in order to account for its influence on the payload.

BACKGROUND INFORMATION

A drone's payload is defined as a projectile, because it is propelled through the air after given an initial force, not undergoing any constant propulsion. As a drone's payload falls through the atmosphere, it is subjected to two external forces, as shown in Figure 1 (NASA, n.d.).

Research Question:

How does the initial release velocity of a drone's payload influence its range accuracy with air resistance?

Aim:

The aim of this investigation is to determine how the initial horizontal release velocity of the drone's payload impacts its range accuracy. By calculating the approximate region, the payload will land with basic projectile motion equations (which do not account for the force of air resistance), the influence of air resistance in the range accuracy of the drone's payload will be additionally analysed. This will be done by comparing the theoretical flight path with the actual data collected from the practical experiment.

QUESTIONING & PREDICTING

BACKGROUND INFORMATION

The first is gravitational force, expressed as the weight of the object (fig.2). Because of this, for most applications in this atmosphere it is safe to assume this to be a constant.

$$F_g = mg$$

Figure 2: Gravitational force is expressed as mass (m) of the object times the gravitational acceleration (g) which is $9.8m^2$

Basic projectile motion calculations account for gravitational acceleration as the primary force that affects the motion of a projectile. This would be true if the object were falling in a vacuum. However, as the payload is dropped in the atmosphere of earth, the secondary force that impacts its range accuracy is air resistance (fig. 3). Air resistance, also known as aerodynamic drag, is a type of friction that causes an opposing force to the motion of the object in the air as it hits air molecules, slowing it down(Nikon, 2022). As the drone's payload encounters both these forces, it adopts a curved parabolic path, though unlike the diagrams influenced from basic projectile motion calculations, the payload's path with air resistance will not be a perfect parabola, instead falling more steeply, therefore reducing its range.

$$F_d = \frac{1}{2} C_d \rho A v^2$$

Figure 3: Drag is defined as half the product of the drag coefficient, the density of the medium, the surface area of the face perpendicular to the direction it is being projected, and the velocity squared.

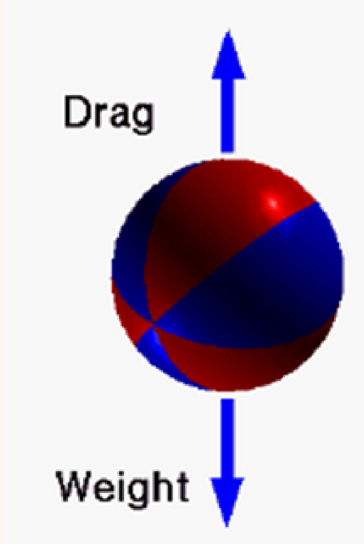


Figure 1: Two forces subjected to a falling object: Drag (Air resistance), and Weight (Gravitational force)

Hypothesis:

It is hypothesised that as the initial horizontal release velocity increases, the horizontal range will increase. However, due to air resistance, the actual increase in range will be less than the predicted range by ideal projectile motion formulas. It is also hypothesised that the deviation from the ideal range will increase as the initial velocity increases. This prediction is derived from the fact that drag (air resistance) is proportional to the square of velocity.

PROJECTILE MOTION FORMULAS USED

Formula Name	Formula	Symbol definitions
Time of Flight (no vertical launch velocity)	$t = \sqrt{\frac{2h}{g}}$	t = time of flight (s) h = drone release height (m) g = 9.8 m/s^2
Ideal Range (without accounting for air resistance)	$R_{\text{ideal}} = v_0 \cdot \sqrt{\frac{2h}{g}}$	R_{ideal} = theoretical horizontal range (m) v_0 = initial horizontal velocity (m/s) h = drone release height (m) g = 9.8 m/s^2
Actual range	$R_{\text{actual}} = \text{Measured horizontal distance}$	R_{actual} = measured distance from drop point to landing point (m)
Deviation from Target	$\text{Deviation} = \lvert R_{\text{actual}} - R_{\text{ideal}} \rvert$	R_{actual} = measured distance from drop point to landing point (m) R_{ideal} = theoretical horizontal range (m) $\lvert \cdot \rvert$ = the absolute value (disregard negative signs)
Percentage Deviation	$\%\text{Deviation} = \frac{\lvert R_{\text{actual}} - R_{\text{ideal}} \rvert}{R_{\text{ideal}}} \times 100$	R_{ideal} = theoretical horizontal range (m) R_{actual} = measured distance from drop point to landing point (m)
Quadratic Drag (Air resistance)	$F_d = \frac{1}{2} C_d \rho A v^2$	F_d = Drag force (N) C_d = Drag coefficient (unitless, ~1.05 for a cube) ρ = Air density (equals 1.225 kg/m^3) A = Cross-sectional area of the object (m^2) v = Speed of the object (m/s)
Gravitational force	$F_g = mg$	m = mass (kg) g = 9.8 m/s^2

PLANNING & CONDUCTING

CHOICE OF METHOD

This method was chosen for this investigation as it is the most realistic scenario, providing us with the necessary forces to calculate. The environment also provided us with air resistance and the correct atmospheric conditions to observe. This experiment is easily repeatable, due to the use of apps to precisely change the speed and distance the drone flies, allowing us to repeat it a sufficient number of times in order to examine the effects. Furthermore, this greatly reduces the time spent operating the drone, due to its limited battery life.

This investigation uses the forces exerted on a falling payload to examine its parabolic trajectory, due to the physical laws of projectile motion. By utilising basic projectile motion calculations, the impact of the independent variable (initial velocity of drone) on the dependent variable (range of payload) is predicted and then the actual effect of air resistance on the payload is observed. The forces on a payload that impact its flight is drag (air resistance) and gravity, resulting in a parabolic path. To calculate the range the payload will achieve, the formula below will be used, a basic projectile motion formula utilised for calculating its ideal range.

$$R_{\text{ideal}} = v_0 \cdot \sqrt{\frac{2h}{g}}$$

Figure 4: Formula for calculating the ideal range of a projectile

In this formula, R_{ideal} is the theoretical horizontal range, v_0 is the initial horizontal velocity, h is the drone release height, and gravitational force is a constant, about 9.8 m/s^2.

Independent Variable:

- Initial release velocity of drone's payload

Dependent Variable:

- Range accuracy (measured by the deviation from target)

Controlled Variables:

- Payload mass
- Payload shape
- Payload surface area
- Drone used
- Atmospheric conditions (e.g. Wind Speed, Temperature)
- Drone flight height
- Release Angle
- Measuring Equipment

PLANNING & CONDUCTING

WHY IS THIS A FAIR TEST?

In order to make sure this experiment is conducted as a ‘fair test’ one variable (independent variable) is deliberately changed and manipulated, and all other variables that could affect the dependent variable are kept constant. This enables us to isolate the effect of the dependent variable in the outcome, and understand the cause-and-effect relationships. Additionally, to fully make sure this investigation is conducted fairly, and to maintain the accuracy of results, each trial with different velocities was repeated five times, with the average calculated. To preserve the integrity of this investigation, during the writing of the discussion, and execution of the experiment, systematic and random biases were discouraged. In order to limit parallax error, the camera was placed on a DIY tripod, and aimed perpendicular to the motion.

POSSIBLE RISKS

Possible Risks	**Likelihood of Risk**	**Risk prevention Measures**
Electrical Risks (Drone)	Low Risk	The battery was safely charged and stored within the drone. The drone was no operated in rain.
Physical Risks such as dropping the payload into someone	Medium Risk	Experiment conducted in empty greenspace. Both students maintained a 2-metre distance gap from the drone at all times
Dropping of payload may cause tripping hazards	Low Risk	It was ensured that the payload was retrieved after each experiment
Operating the drone into a student could cause injuries	High Risk	The operator of the drone was experienced with the controls, and a safe distance and speed was maintained.

EQUIPMENT AND MATERIALS

MATERIALS

- Drone (DJI Mini 4K)
- Payload dropper (to drop payload)
- Drone Payload (Cube, 50mm x 50mm x 50mm, 29g)
- Drone Controller (to control drone's horizontal release velocity)
- Measuring Tape (to measure actual range of drone's payload)
- Phone (to record projectile motion of drone's payload)
- DIY Recording Rig for stability (phone gimbal mounted on music stand for height)
- Marker (eg. Masking tape)

Figure 5: Photos showing materials used during experiment.

PLANNING & CONDUCTING

PRE-EXPERIMENT INFORMATION:
(CONSTANT VARIABLES FOR PROJECTILE MOTION FORMULAS)

- Height dropped (h): 3 m
- Mass of payload (m): 0.029 kg
- Payload frontal area (A): 0.0025 m^2
- Drag coefficient (Cd): 1.05 (cube)
- Air density (ρ): 1.225 kg/m^3
- Gravity (g): 9.8 m/s^2

METHOD

1.Drone's opening position was marked with a strip of tape.

2.DIY Recording Rig was set up perpendicular to flight path and within range of opening position.

3.Drone was flown to a height of 3m and 2m behind opening marker to begin.

4.Recording had commenced.

5.Drone was flown 2m in order to gain correct horizontal release velocity (e.g. 0.30m/s, 0.50m/s, 0.70m/s, 1.00m/s).

6.Once drone reached opening marker, payload was dropped, and parabolic motion was recorded via recording rig.

7.Range was measured from opening marker using a measuring tape.

8.Repeated each velocity group five times for consistency.

9.Determined deviation and percentage deviation for each trial.

10. Estimated drag force using drag force formula.

11. Kept payload mass, shape, release height, and weather conditions consistent.

PROCESSING AND ANALYSING DATA AND INFORMATION

PROCESSING DATA USING PROJECTILE MOTION FORMULAS

Table 1: Horizontal velocity group: 0.30 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	0.3	3	0.029	0.2	0.78	0.23	0.03	13%
T2	0.3	3	0.029	0.21	0.78	0.23	0.02	9%
T3	0.3	3	0.029	0.2	0.78	0.23	0.03	13%
T4	0.3	3	0.029	0.19	0.78	0.23	0.04	17%
T5	0.3	3	0.029	0.2	0.78	0.23	0.03	13%

Table 2: Horizontal velocity group: 0.50 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	0.5	3	0.029	0.34	0.78	0.39	0.05	13%
T2	0.5	3	0.029	0.33	0.78	0.39	0.06	15%
T3	0.5	3	0.029	0.32	0.78	0.39	0.07	18%
T4	0.5	3	0.029	0.34	0.78	0.39	0.05	13%
T5	0.5	3	0.029	0.33	0.78	0.39	0.06	15%

Table 3: Horizontal velocity group: 0.70 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	0.7	3	0.029	0.46	0.78	0.55	0.09	16%
T2	0.7	3	0.029	0.47	0.78	0.55	0.08	15%
T3	0.7	3	0.029	0.45	0.78	0.55	0.1	18%
T4	0.7	3	0.029	0.44	0.78	0.55	0.11	20%
T5	0.7	3	0.029	0.47	0.78	0.55	0.08	15%

Table 4: Horizontal velocity group: 0.90 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	0.9	3	0.029	0.57	0.78	0.7	0.13	19%
T2	0.9	3	0.029	0.56	0.78	0.7	0.14	20%
T3	0.9	3	0.029	0.55	0.78	0.7	0.15	21%

PROCESSING AND ANALYSING DATA AND INFORMATION

PROCESSING DATA USING PROJECTILE MOTION FORMULAS

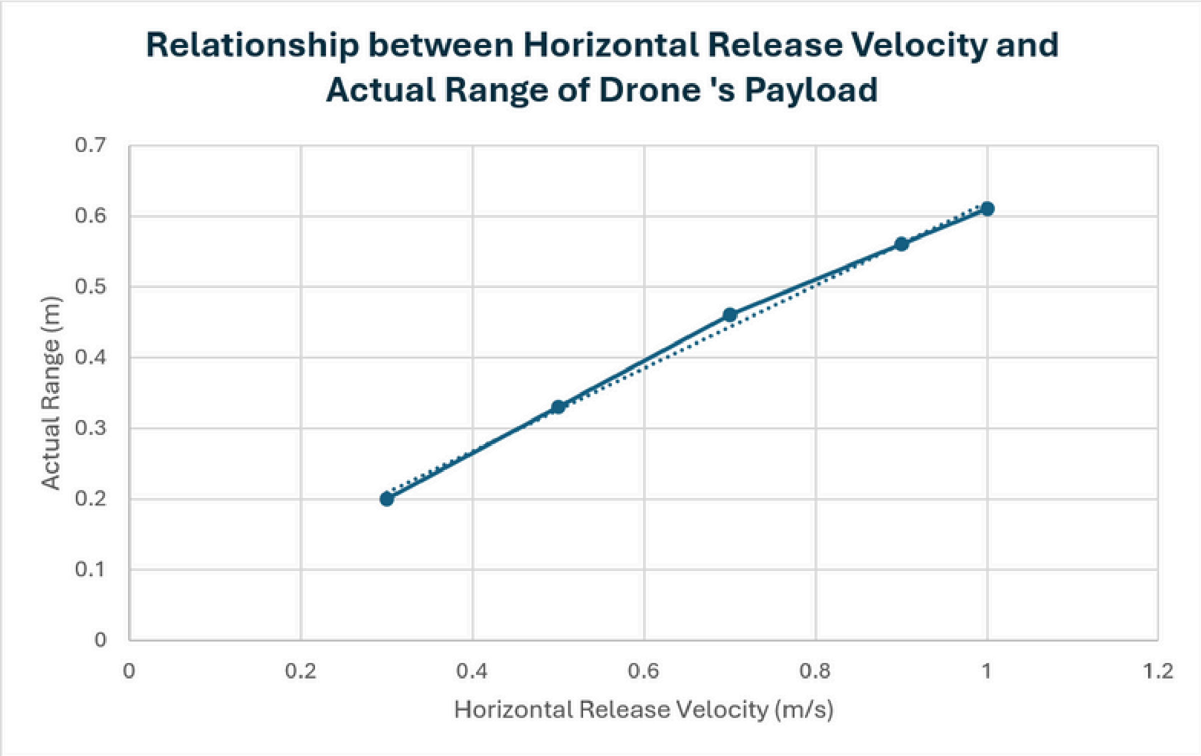
Table 5: Horizontal velocity group: 1.00 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	1	3	0.029	0.61	0.78	0.78	0.17	22%
T2	1	3	0.029	0.6	0.78	0.78	0.18	23%
T3	1	3	0.029	0.62	0.78	0.78	0.16	21%
T4	1	3	0.029	0.6	0.78	0.78	0.18	23%
T5	1	3	0.029	0.61	0.78	0.78	0.17	22%

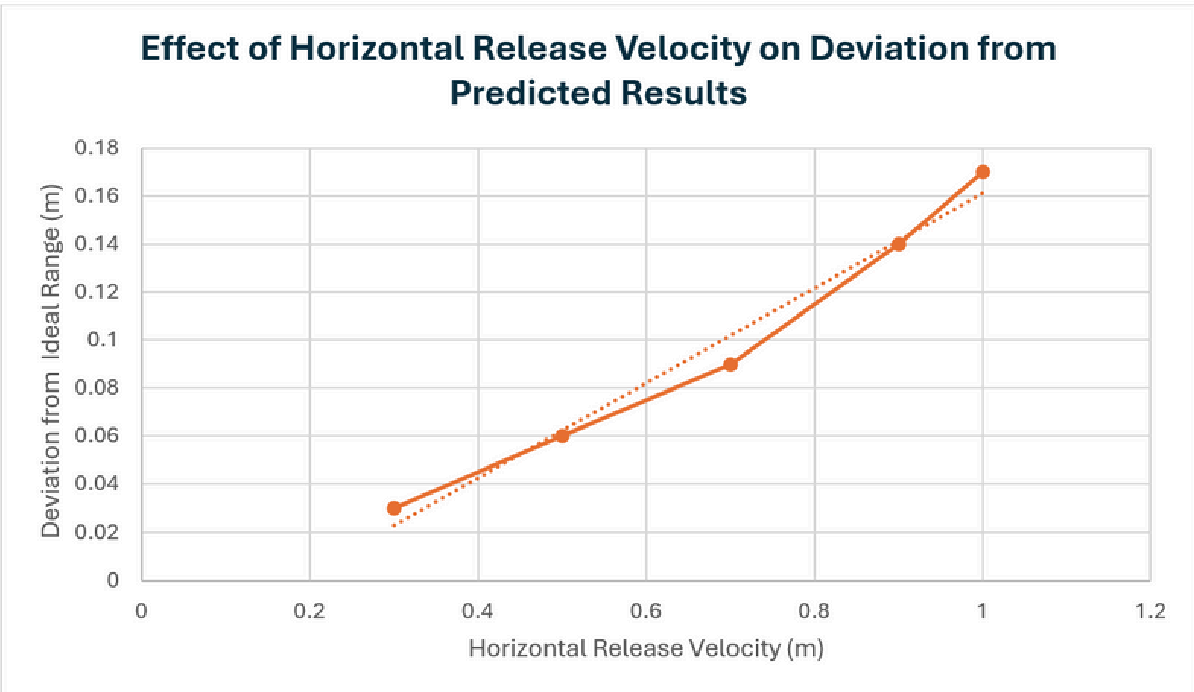
Table 6: Summary table of average calculations for each horizontal velocity group

Horizontal release velocity (m/s)	Avg Actual Range (m)	Avg Ideal Range (m)	Avg Deviation (m)	% Deviation	Drag Force (N)
0.3	0.2	0.23	0.03	13%	0.0006
0.5	0.33	0.39	0.06	15%	0.0016
0.7	0.46	0.55	0.09	17%	0.0031
0.9	0.56	0.7	0.14	20%	0.0058
1	0.61	0.78	0.17	22%	0.0077

GRAPHS MADE FROM SUMMARY TABLE

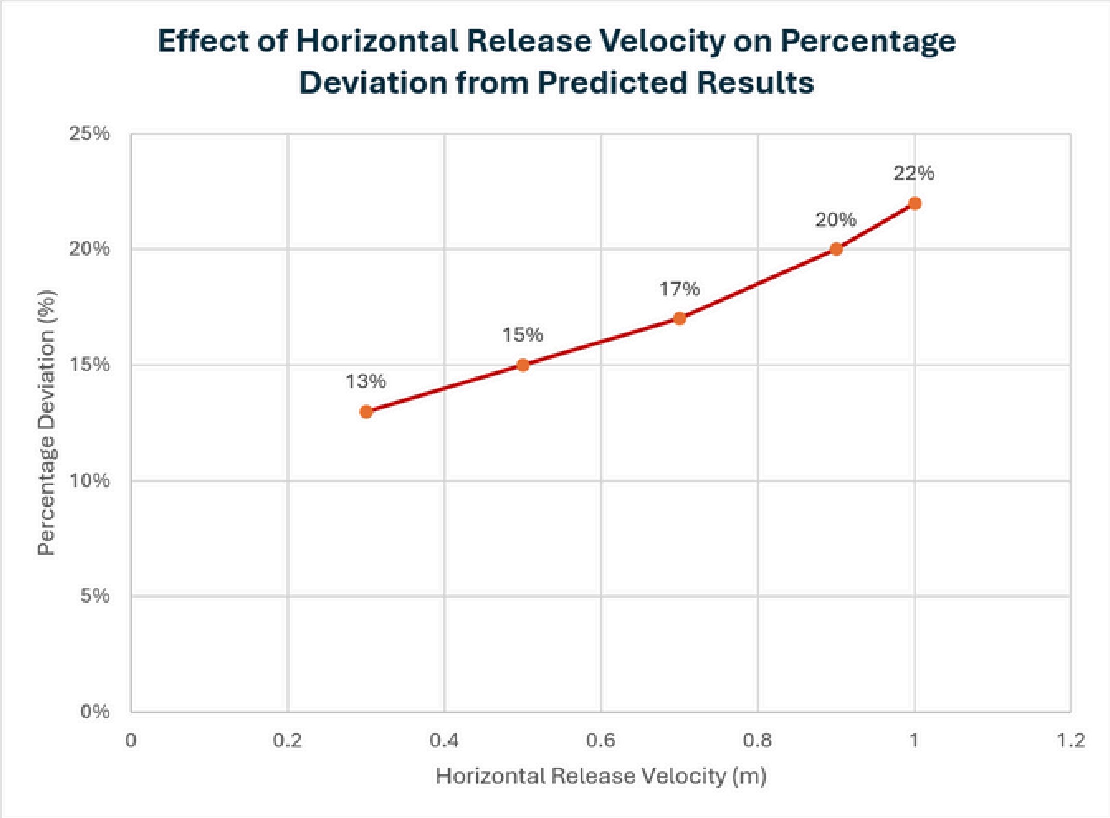


Graph 1: Relationship between Horizontal Release Velocity and Actual Range of Drone’s Payload

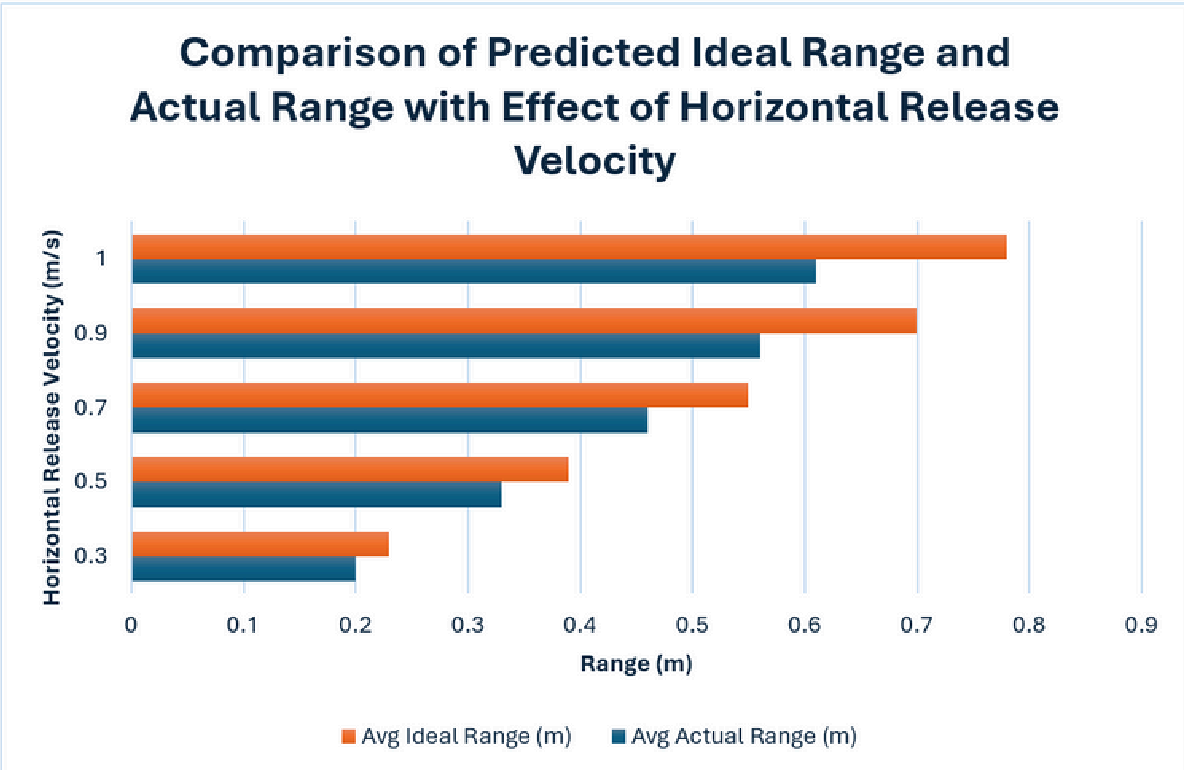


Graph 2: Effect of Horizontal Release Velocity on Deviation from Predicted Results

GRAPHS MADE FROM SUMMARY TABLE



Graph 3: Effect of Horizontal Release Velocity on Percentage Deviation from Predicted Results



Graph 4: Comparison of Predicted Ideal Range and Actual Range with Effect of Horizontal Release Velocity

GRAPHS MADE FROM SUMMARY TABLE

Figure 6: Overlay of screenshots in stages during drone payload recording (velocity: 1m/s) – pink circles highlight stages of drone payload in projectile motion

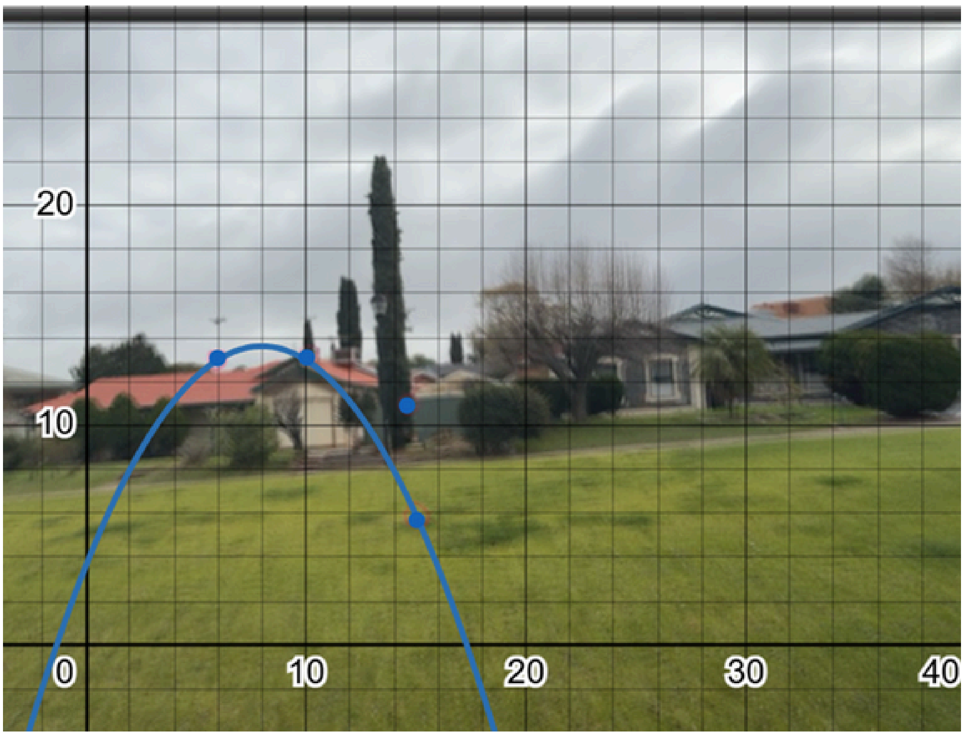


Figure 7: Parabolic projectile motion of drone payload with horizontal release velocity of 1.00 m/s

EVALUATION & COMMUNICATION

DISCUSSION

The experiments emphasised the impact of the initial horizontal release velocity on a drone's payload's range accuracy, with higher velocities leading to more significant proportional losses due to air resistance. Graph 1 exhibited the relationship between horizontal release velocity and the actual range of a drone's payload, showing that it was extremely consistent, due to a nearly linear increase with higher initial horizontal release velocities. For example, an increase in velocity from 0.30 m/s to 1.0 m/s resulted in the average actual range increasing from 0.20m to 0.61m. This trend is a result of fundamental projectile motion, where equations predict that greater horizontal speeds lead to longer time spent travelling horizontally for a given fall height.

An additional observation, central to understanding the influence of air resistance, is the continued deviation between the predicted ideal range and the measured actual range. As depicted in Graph 4, which presents a comparison between the ideal range and actual range with effect of horizontal release velocity, the actual range was consistently shorter than the ideal range across all velocity groups tested. This persistent deviation, even at lower velocities, serves as compelling empirical evidence of the continuous presence of air resistance acting on the payload throughout its flight, which counters its ideal parabolic trajectory.

After further investigation of the data, it was noted that Graph 2, which showcased the effect of horizontal release velocity on deviation from predicted results, revealed that the absolute deviation (difference in metres between ideal and actual range) consistently increased as the horizontal release velocity increased. For example, the average deviation grew from a minor 0.03m at 0.3 m/s to a more substantial 0.17m at 1.0 m/s. The progressive widening of deviation indicates that the effect of air resistance becomes numerically greater as the payload moves faster. Particularly, the percentage deviation allowed for a more informative metric concerning the research question of 'accuracy'. Graph 3, titled 'The Effect of Horizontal Release Velocity on Percentage Deviation', graphically represents the percentage deviation from the ideal range as increasing significantly, once the horizontal release velocity escalated. Rising from 13% at 0.3 m/s to 22% at 1.0 m/s, this trend unequivocally demonstrates that at higher initial velocities, the payload's range accuracy diminished proportionally. This implies that while the absolute range increased, the predictability and precision of the drop were compromised at greater speeds, relative to its frictionless ideal.

DISCUSSION (CONTINUED)

The calculated drag force values presented in Table 6 provide direct quantitative confirmation of the observed deviations. These values show a marked and accelerating increase alongside the rising velocity. For example, drag force increases from 0.0006 N at 0.3 m/s to 0.0077 N at 1.0 m/s, which directly correlates with the increasing deviations from ideal range. The sequential imagery in Figure 6 showcases an overlay of various screenshots depicting the drone payload in stages during flight. Figure 6 visually captures the payload's curved, parabolic flight path. The observed payload trajectory is further modelled by the mathematically fitted parabola shown in Figure 7. While the general parabolic form is a marked characteristic of projectile motion, the significant deviation of a point from the ideal parabola, as highlighted by the quantitative analysis, underscores the real-world influence of air resistance on flight dynamics.

IMPROVEMENTS

One of the main improvements for this experiment is more accuracy in the measuring method. Even though the payload was aimed to be dropped after the drone passed the opening marker, due to human error this period might not have been exact, therefore, accuracy may have been compromised. Next time, using an automation, such as a timed drop using code might improve reliability and reduce human error. Furthermore, atmospheric conditions outside such as wind speed and temperature were labelled as controlled variables, however due to the nature of proceeding with the experiment outside, these variables were not able to be entirely controlled. An improvement could be to proceed with the experiment in an indoor environment, such as a school gym.

POTENTIAL ERRORS

Table 7: Systematic Errors

Systematic Errors	**Effect on Result**	**Improvements**
Drone's internal speed setting may not perfectly correspond to actual velocity, leading to potential inaccurate initial velocity calculations.	Systematically skew ideal range calculations, leading to overpredictions, making the deviation more significant.	Use a more precise method for measuring payloads initial velocity at time of release, such as a high-speed video analysis app.
Consistent inaccuracy in release height, due to inaccuracies in drone altitude sensor.	As 'time of flight' and 'ideal range' formulas directly depend on height, a consistent error will lead to a systematic over or underprediction of theoretical range for all trials.	Either physically measure height with the tape measure, have a physical marker at 3m height, or use a laser distance meter pointed at the drone from the ground.

EVALUATION & COMMUNICATION

POTENTIAL ERRORS

Table 8: Random Errors

Random Errors	**Effect on Result**	**Improvements**
Inconsistent Payload Orientation. Tumbling of payload may change effective cross-sectional area exposed to the air.	Differentiation in payloads orientation during flight would lead to inconsistent drag forces, causing the actual range to vary randomly from trial, increasing the spread of data.	Specialised designing of the payload to be aerodynamically stable, such as 3d printing specific designs may encourage a more consistent orientation.
Inconsistent Payload release, introducing small vertical or horizontal force to the payload as its released in some trials but not others.	Would introduce small random variations in payload's true initial velocity or trajectory. This would lead to inconsistent actual range measurements despite drone's same horizontal velocity.	Rigorously testing and refining payload release system until it is sure that no imperceptible force is introduced. Potential solution could involve using a magnetic release or spring-loaded

FURTHER INVESTIGATION

In order to improve drone range accuracy with air resistance, further investigation could focus on the specific aerodynamics of the payload, with experiments testing payload shape and size to identify designs with lower and more consistent drag coefficients. By minimising the drag coefficients, and ensuring consistency, the adverse impact of air resistance would be decreased. This would make the actual flight path more closely resemble predicted ideal ranges, reducing deviation and allowing for safer and accurate payload drops across varying initial velocities.

CONCLUSION

This investigation successfully determined the impact of the initial horizontal release velocity of a drone's payload on range accuracy, highlighting the influence of air resistance. Conforming to the hypothesis, the horizontal range did indeed consistently increase with higher initial velocities, following fundamental projectile motion principles. However, crucial deviations were observed, where the actual range was persistently shorter than the ideal, and this deviation, particularly in percentage terms, proportionally increased with higher velocities. This rationally demonstrates air resistances negative influence on payload range accuracy, with its effects becoming more pronounced at increased speeds. These findings underscore the importance of accounting for aerodynamic drag in drone payload delivery systems.

EVALUATION & COMMUNICATION

Figure 8: Photos taken during experiment

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Mr. Bartram (science teacher) improved our understanding of projectile motion through discussions and insightfully answered our questions about certain concepts.
Mr. Keller (digital technology teacher) kindly offered school's drones for experiment, but the drones unfortunately had limited capacity for payloads.

WORD COUNT:

2134 words (excluding headings, titles, tables, figure captions, references, and logbook)

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Logbook

Oliphant Scientific Inquiry 2025

Projectile Motion of a Drone's Payload:

Velocity's Impact on Range Accuracy with Air Resistance

Ada & Shaya

Brainstorm

Chemistry

- How do molecular shapes affect drug effectiveness?
- Can we develop plastic that biodegrades within months?
- What makes certain chemical reactions spontaneous?
- Why don't electrons enter the nucleus?
- Can green chemistry eliminate toxic waste in industrial processes?
- How do electrochemical cells mimic biological energy systems like ATP production?
- Why are noble gases unreactive?
- What is the chemistry behind smell and how can it be artificially replicated?

Space and earth science

- How do we detect exoplanets and determine if they could support life?
- What causes the magnetic field reversals on Earth and how do they affect life?
- How do solar flares affect Earth's satellites and communication systems?
- What can ice core samples tell us about past climates and future trends?
- How does space weather impact astronaut health and electronics?
- How do earthquakes and plate tectonics shape the biosphere?
- What are the limits of life in extreme extraterrestrial environments?

Biology

- What genetic mechanisms allow some animals to regenerate limbs, and can we replicate this in humans?
- How do gut microbes influence mental health and behaviour?
- What are the ethical boundaries of gene editing in embryos?
- How does epigenetics shape identical twins into slightly different people?
- Can aging be reversed or significantly slowed biologically?
- How do organisms adapt to extreme environments like deep-sea vents or acidic lakes?

Physics

- Velocity's Impact on Range Accuracy with Air Resistance
- How do quantum tunnelling effects impact modern electronics?
- Why do time and space behave differently at near-light speeds?
- What are the physics behind superconductors and how can we make them more accessible?
- How do gravitational waves work and how are they detected?
- Can sound waves be used to levitate and manipulate objects?
- What happens to light in extreme gravitational fields (e.g. near black holes)

Brainstorm

Practical scenarios to investigate that involves the chosen topic

1. **Projectile Motion of Drones' Payloads:**
   Aerial drones dropping packages (e.g. emergency supplies) from different altitudes and speeds.
   Relevance: Velocity affects how far the payload drifts before hitting the target area, especially in windy condition with air resistance.
   Variables: Driving speed, horizontal release velocity, wind speed, wind direction, shape of payload, mass of payload, drone altitude.

2. **Archery and Competitive Shooting**:
   Archers or precision shooters adjusting for range and accuracy in outdoor conditions.
   Relevance: The in-flight velocity of arrows or bullets is influenced by air resistance, which impacts their landing points and accuracy on target, especially over longer distances.
   Variables: Initial velocity, shooting direction, projectile mass, projectile shape, weather conditions.

3. **Sports:**
   Hitting or throwing balls at varying forces and speeds in sports such as basketball and golf.
   Relevance: The impact of air resistance is considered when players adjust angle and force to aim for scoring.
   Variables: Ball type, spin angle, launch force, launch direction, weather condition.

4. **Military Ballistics:**
   Military weapons such as tank shells and mortars being launched over long distances.
   Relevance: Accurate trajectory calculation must consider the effect of air resistance on velocity.
   Variables: Launch velocity, altitude, projectile design, weather condition, mass and shape of the shells.

5. **Rocketry:**
   Launching rockets or space craft through the atmosphere.
   Relevance: The initial velocity and air resistance received when ascending significantly affect the flight trajectory.
   Variables: Launch velocity, launch distance, rocket mass, rocket shape, fin design, weather condition.

Accuracy Problem
Caused by Inappropriate Velocity and Air Resistance

- Airdropped resources (e.g. food, medical aid, courier parcels) land outside target zones, leading to resource damage or delayed supply.
- Bullets or artillery shells missed the intended target, leading to a failed mission.
- Golf/ Football/ Basketball shots curve off course, leading to failure in scoring.
- Rockets deviate from their planned trajectory or fail to reach a certain altitude, resulting in risk of crash, loss of equipment, and safety hazards.
- Fireworks explode outside designated zones, ruining visual display and increasing the risk of injury and fire.
- Tennis/Badminton players misjudge shots trajectory, affecting competition performance and outcomes
- Weather balloons drift off course, causing inaccurate atmospheric data collection.
- Etc.

Figure 1: Drones delivering medical kit

Projectile Motion Formulas needed for data collection:

Formula Name	Formula	Symbol definitions
Time of Flight (no vertical launch velocity)	$t = \frac{\sqrt{2h}}{g}$	t = time of flight (s) h = drone release height (m) g = 9.8 m/s2
Ideal Range (without accounting for air resistance)	$R_{ideal} = V_0 \cdot \frac{\sqrt{2h}}{g}$	Rideal = theoretical horizontal range (m) V_0 = initial horizontal velocity (m/s) h = drone release height (m) g = 9.8 m/s2
Actual Range	R_{actual} = Measured horizontal distance	Ractual = measured distance from drop point to landing point (m)
Deviation from Target	Deviation = $\|R_{actual} - R_{ideal}\|$	Ractual = measured distance from drop point to landing point (m) Rideal = theoretical horizontal range (m) $\|\cdot\|$ = the absolute value (disregard negative signs)
Percentage Deviation	% Deviation = $\frac{\|Ractual - Rideal\|}{Rideal} \times 100$	Rideal = theoretical horizontal range (m) Ractual = measured distance from drop point to landing point (m) $\|\cdot\|$ = the absolute value (disregard negative signs)
Quadratic Drag (Air resistance)	$Fd = \frac{1}{2} Cd\rho Av^2$	Fd = Drag force (N) Cd = Drag coefficient (unitless, ~1.05 for a cube) ρ = Air density (equals 1.225 kg/m3) A = Cross-sectional area of the object (m²)
Gravitational force	$F_g = mg$	m = mass (kg) g = 9.8 m/s2

Attempt 1 (Failed)

Pre-Experiment Information

Height dropped (h): 3 m
Mass of payload (m): 0.029 kg
Payload frontal area (A): 0.0025 m²
Drag coefficient (Cd): 1.05 (cube)
Air density (ρ): 1.225 kg/m³
Gravity (g): 9.8 m/s²

Equipment:

Drone (DJI Tello)
Marker (eg. Masking tape)
Self-made payload dropper
Drone Payload (Cube, 50mm x 50mm x 50mm, 29g)
Controller (to control drone's horizontal release velocity)
Measuring Tape (to measure actual range of drone's payload)
Phone (to record projectile motion of drone's payload)
Calculator (to calculate deviation, percentage deviation, and drag force using respective formulas included above)

Problems:

- • To save costs, we created a mechanical payload dropper and attached it to the drone (Figure a) instead of purchasing an electronic one. The basic structure of its bottom section is shown in Figure b. We bent a coat hanger into the shape shown in grey using pliers and taped the end part. A nut with the payload hanging beneath it with string is placed in the middle. When the aircraft tilts forward, the nut would slide out from the wider front end, thus dropping the payload. However, during the experiment, we found the drone could only fly level and not tilt, meaning we weren't able to control the payload dropper at all. Additionally, the design was unstable. The nut could slip out unexpectedly during flights, especially at higher speeds or in windy conditions.

Figure a: Drone with the DIY payloads dropper glued on it

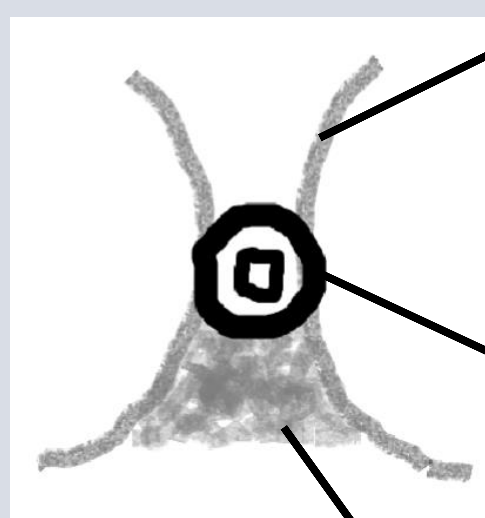

Figure b: Bottom section of the payloads dropper

Attempt 1 (Failed)

Problems:

- The drone's size was too small and lacked sufficient payload capacity. It showed signs of wobbling when carrying the payload during flight, especially with high velocity and windy conditions.

- Recording the drone's flight path and the payload's trajectory by holding a phone manually was unstable. The unavoidable shaking, tilted angles and blurry images can bring inevitable errors into the data, affecting the accuracy of the results.

- We did not allocate enough time for the experiment. We began preparations around 4:00 p.m., but the experiment was still incomplete at 5:30 p.m. By then, the natural light had become too dim to continue outdoors. The poor time management further led to the failure of the experiment.

Possible Improvement:

- Purchase a drone with a larger size and better payload capacity

- Improve/ Redesign the payload dropper system: purchase an electronic airdrop system

- Create or purchase a phone stand to ensure stable video recording and accurate data collection.

Figure a: Electronic Drone Payload Dropper from Amazon

- Check weather forecasts and choose calm and windless conditions for the experiment to reduce external interference

- Plan and manage time more effectively to ensure the experiment can be completed in the set time

Attempt 2 (Succeeded)

Pre-Experiment Information

Height dropped (h): 3 m
Mass of payload (m): 0.029 kg
Payload frontal area (A): 0.0025 m^2
Drag coefficient (Cd): 1.05 (cube)
Air density (ϱ): 1.225 kg/m^3
Gravity (g): 9.8 m/s^2

Equipment

Drone (DJI Mini 4K)

Payload dropper

Drone Payload (Cube, 50mm x 50mm x 50mm, 29g)

Drone Controller (to control drone's horizontal release velocity)

Measuring Tape (to measure actual range of drone's payload)

Phone (to record projectile motion of drone's payload)

DIY Recording Rig for stability (phone gimbal mounted on music stand for height)
Marker (eg. Masking tape)

Calculator (to calculate deviation, percentage deviation, and drag force using respective formulas included above)

Figure a: Equipment for the experiment

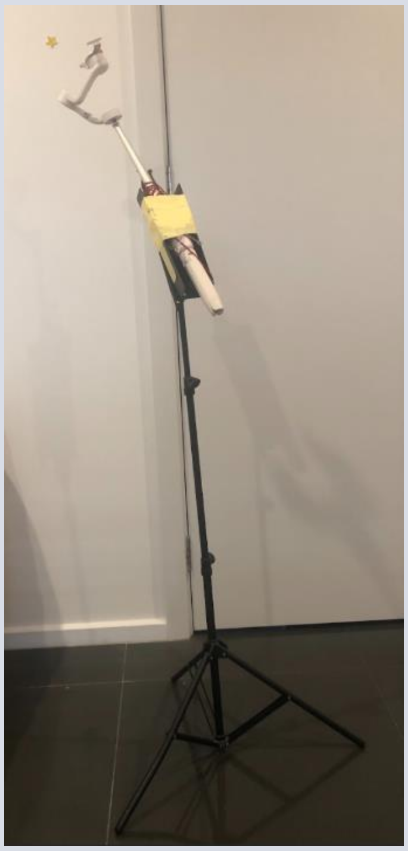

Figure b: DIY recording Rig

07/06/2025

Raw Data & Photos

Table 1: Horizontal velocity group: 0.30 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	0.3	3	0.029	0.2	0.78	0.23	0.03	13%
T2	0.3	3	0.029	0.21	0.78	0.23	0.02	9%
T3	0.3	3	0.029	0.2	0.78	0.23	0.03	13%
T4	0.3	3	0.029	0.19	0.78	0.23	0.04	17%
T5	0.3	3	0.029	0.2	0.78	0.23	0.03	13%

Table 2: Horizontal velocity group: 0.50 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	0.5	3	0.029	0.34	0.78	0.39	0.05	13%
T2	0.5	3	0.029	0.33	0.78	0.39	0.06	15%
T3	0.5	3	0.029	0.32	0.78	0.39	0.07	18%
T4	0.5	3	0.029	0.34	0.78	0.39	0.05	13%
T5	0.5	3	0.029	0.33	0.78	0.39	0.06	15%

Table 3: Horizontal velocity group: 0.70 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	0.7	3	0.029	0.46	0.78	0.55	0.09	16%
T2	0.7	3	0.029	0.47	0.78	0.55	0.08	15%
T3	0.7	3	0.029	0.45	0.78	0.55	0.1	18%
T4	0.7	3	0.029	0.44	0.78	0.55	0.11	20%
T5	0.7	3	0.029	0.47	0.78	0.55	0.08	15%

Table 4: Horizontal velocity group: 0.90 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	0.9	3	0.029	0.57	0.78	0.7	0.13	19%
T2	0.9	3	0.029	0.56	0.78	0.7	0.14	20%
T3	0.9	3	0.029	0.55	0.78	0.7	0.15	21%
T4	0.9	3	0.029	0.56	0.78	0.7	0.14	20%
T5	0.9	3	0.029	0.57	0.78	0.7	0.13	19%

Table 5: Horizontal velocity group: 1.00 m/s

Trial	Horizontal release velocity (m/s)	h (m)	Mass (kg)	Actual Range (m)	Ideal Time (s)	Ideal Range (m)	Deviation (m)	% Deviation
T1	1	3	0.029	0.61	0.78	0.78	0.17	22%
T2	1	3	0.029	0.6	0.78	0.78	0.18	23%
T3	1	3	0.029	0.62	0.78	0.78	0.16	21%
T4	1	3	0.029	0.6	0.78	0.78	0.18	23%
T5	1	3	0.029	0.61	0.78	0.78	0.17	22%

08/06/2025

Conclusion Based on Observation

Payload velocity increases

↓

Actual range increases

↓

Range accuracy decreases

↑

Growing influence of air resistance

Consistent and widening gap between ideal and actual range

↓

Absolute and percentage deviations rising significantly at higher speeds

↓

Air resistance has a progressively greater impact at higher velocities

↓

Reduce the predictability and precision of the payload's landing point despite longer travel distances.

OSA RISK ASSESSMENT FORM

for all entries in (✓) ☐ Models & Inventions and ☐ Scientific Inquiry

This must be included with your report, log book or entry. One form per entry.

STUDENT(S) NAME: Shaya Ismail and Ada Qian ID: ____________

SCHOOL: Wilderness School

Activity: Give a brief outline of what you are planning to do.

Finding the effect of velocity on range accuracy of a drone's payload. This will be done by flying the drone at various speeds, and dropping a bo whilst recording the projectile motion with a camera. In addition, the horizontal displacement of the payload will be measured.

Are there possible risks? Consider the following:

- Chemical risks: Are you using chemicals? If so, check with your teacher that any chemicals to be used are on the approved list for schools. Check the safety requirements for their use, such as eye protection and eyewash facilities, availability of running water, use of gloves, a well-ventilated area or fume cupboard.
- Thermal risks: Are you heating things? Could you be burnt?
- Biological risks: Are you working with micro-organisms such as mould and bacteria?
- Sharps risks: Are you cutting things, and is there a risk of injury from sharp objects?
- Electrical risks: Are you using mains (240 volt) electricity? How will you make sure that this is safe? Could you use a battery instead?
- Radiation risks: Does your entry use potentially harmful radiation such as UV or lasers?
- Other hazards.

Also, if you are using other people as subjects in an investigation you must get them to sign a note consenting to be part of your experiment.

Risks	How I will control/manage the risk
Electrical risks from the drone's battery	→ The drone was not operated during rain.
Physical risks from dropping the payload onto someone	→ The drone was operated in an empty greenspace. Both students maintained a 2m gap ~~st~~ from drone.
Operating the drone into a student could cause injuries	→ The operator of the drone was experienced & had practice with flying it.
Dropping the payload could cause tripping hazards.	→ It was ensured that the payload was retrieved after each trial

(Attach another sheet if needed.)

Risk Assessment indicates that this activity can be safely carried out

RISK ASSESSMENT COMPLETED BY (student name(s)): Shaya Ismail, Ada Qian

SIGNATURE(S): SI, Ada

☑ By ticking this box, I/we state that my/our project adheres to the listed criteria for this Category.

TEACHER'S NAME: Sam Bartram

SIGNATURE: [signature] DATE: 6/26/2025