The Wings of Tomorrow: Developing a Kid-Friendly Drone Race Supported by Ruolian Technology

An Interactive Qualifying Project

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Submitted to:

Ruolian Technology, Sponsor

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Abstract

The primary objective of this project was to provide support to our sponsor, Hangzhou Ruolian Technology, in their endeavor to organize an event that integrated themes of education, technology, competition, and entertainment, with a focus on capturing student engagement. Our sponsor's expertise lies in providing high-performance Unmanned Aerial Vehicle (UAV) flight control modules and general UAV solutions tailored for industrial clients. Thus, we, the WPI team, aimed to deliver components of a drone racing outreach event to satisfy this goal, with an emphasis on three core topics: rules and regulations, drone specifications, and event schedule. We accomplished this by conducting a pilot test in conjunction with expert interviews, enabling us to generate research that is both applicable and scalable.

Acknowledgements

We thank Jie Jin, the CEO of Hangzhou Ruolian Technology, for sponsoring this project, as well as the Product Manager Starry for his indispensable support in communications and guidance.

We would also like to express our gratitude to our two project advisors, Professor Hansong Pu and Professor Joseph Sarkis, for their unwavering support throughout the duration of this project. Their direction and leadership have played a crucial role in shaping the outcome of our work.

Finally, we extend our sincere appreciation to the students, professors, and Aviation Club at Hangzhou Dianzi University for all the help they have offered us. Our journey to this point would not have been possible without their support.

Executive Summary

Drone Racing

Drone racing first emerged in the early 2010's as a specialized hobby in which amateur drone enthusiasts came together to create semi-organized racing events. With the advancement of technology, drones have become more capable, resulting in greater popularity of the sport (Frąckiewicz, 2023). This growth has led to the development of massive organizations such as the Drone Racing League (DRL) and MultiGP—two of the largest governing bodies for drone racing (DRL, 2023; MultiGP, 2023). Although great strides have been made, the sport is still in its development stage. Moreover, there are significant opportunities for growth, particularly in the Asia-Pacific region (Maximize Market Research, 2021).

Ruolian Technology

Ruolian Technology, our sponsor, is a start-up company founded in 2015. They are a technical company with a primary focus in providing high-performance Unmanned Aerial Vehicle (UAV) flight control modules and general UAV solutions tailored for industrial clients. Ruolian Technology also features an emphasis on the application of Artificial Intelligence (AI) technology in a multitude of technological domains.

Project Goal

The main objective of this project was to create and develop components for a drone outreach event tailored towards Chinese students with limited prior exposure to drones. Our emphasis was on exploring technical elements of drone racing events. Specifically, this paper capitalizes on the development of three aspects of a drone outreach event: rules and regulations, drone specifications, and event schedule.

Methodology

We focused on inspiring youth interest in STEM fields by employing a comprehensive set of research tactics. These tactics included conducting expert interviews within the drone industry, implementing a pilot test, and evaluating the outcomes of the pilot test. To effectively navigate these objectives, a multitude of resources were used, including the Index of Success Model (Fisher, 2010). Additionally, guidance for the formulation of proper interview questions was drawn from resources, notably utilizing the framework proposed in "Conducting Research Interviews" (Rowley, 2012). This methodological framework and resource integration played a crucial role in shaping the findings aligned with our three research objectives.

Results

Our research unveiled key findings which helped to formulate insightful conclusions regarding each of our three deliverables: rules and regulations, drone specification, and event schedule.

Through the application of academic frameworks, such as Green Tape Theory and Cue Utilization Hypothesis (DeHart-Davis, 2006; Rosegard, 2013), the rules and regulations underwent testing using primary data methodologies, including pilot testing and expert interviews. This process provided evidence of their applicability across various scenarios (see **Appendix I**).

Regarding drone specifications, the pilot test evaluations for the R130 (refer to **Figure 17** and **Appendix J**) concluded that drones similar to this model demonstrate safety, ease of repair, and suitability for beginners.

The event schedule, based on secondary research formats, was refined through trial and error using primary data, effectively captivating the intended audience (see **Appendix K**).

Future Recommendations

By employing a comprehensive approach to address our three research questions, our findings have led to several recommendations for the sponsor. These involve implementing a monetization strategy for long-term sustainability, exploring new demographics and locations, enhancing event quality, and incorporating more comprehensive metrics for effective feedback collection. Monetization is beneficial for sustaining events and benefiting the community, while exploring different demographics and locations can enhance event quality. Additionally, gathering accurate feedback through diverse metrics ensures events adapt to participant desires, promoting overall success.

Authorship

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Abstract	Marc	All
Acknowledgements	Marc	All
Executive Summary	Kayla + Marc	All
1. Introduction	Marc + Kayla	Alisha + Ethan
2. Background	Marc	All
2.1 Roulian Technology	Marc	All
2.2 Involved Parties and Responsibilities	Alisha + Marc + Ethan	Kayla
2.3 Event Planning	Marc	All
2.3.1 Importance of Event Planning	Marc + Kayla + Ethan	Alisha
2.3.2 Schedule and Format	Marc + Kayla	All
2.4 Drones	Marc	All
2.4.1 History of drones	Marc + Kayla	All
2.4.2 Technical Overview	Marc + Ethan	All
2.5 Drone Racing	Marc	All
2.5.1 Rules and Regulations	Marc + Alisha	Ethan
2.5.2 Racecourse design	Marc + Ethan	Ethan
2.5.3 Safety Considerations	Alisha	Ethan + Marc
3. Methodology	Marc + Alisha	All
3.1 Semi-Structured Interviews		
3.1.1 Justification	Ethan	Marc
3.1.2 Interview 1: Starry	Ethan	Alisha + Marc
3.1.3 Interview 2: Aviation Club	Ethan	Marc
3.1.4 Interview 3: Professor Tony Luo	Marc	All
3.2 Experimental Event and Pilot Study	Alisha	Marc
3.2.1 Justification	Alisha + Kayla	Ethan, Marc, Kayla
3.2.2 Event	Ethan + Kayla	Kayla + Marc
3.2.3 Planning	Ethan + Marc	Kayla
3.2.4 Evaluation	Alisha + Kayla	Ethan + Marc
3.2.4.1 Observations	Alisha + Kayla	Ethan + Marc
3.2.4.3 Rubric	Alisha + Kayla	Ethan + Marc
3.3 Limitations	All	Marc
4. Results and Analysis	Marc	All
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5. Conclusions and Recommendations	Kayla + Ethan + Alisha	All

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1. Introduction

Drone racing first emerged in the early 2010's as a specialized hobby in which amateur drone enthusiasts came together to create semi-organized racing events. With the advancement of technology, drones have become more capable, resulting in greater popularity of the sport (Frąckiewicz, 2023). This growth has led to the development of massive organizations such as the Drone Racing League (DRL) and MultiGP—two of the largest governing bodies for drone racing (DRL, 2023; MultiGP, 2023).

Although great strides have been made, the sport is still in its development stage. Moreover, there are significant opportunities for growth, particularly in the Asia-Pacific region (Maximize Market Research, 2021). The sponsor organization of this interactive qualifying project (IQP), Ruolian Technology, is a start-up company founded in 2015. They operate in Hangzhou's "high tech" zone and specialize in the industrial application of drones. With its expertise in drone service and manufacturing, Ruolian Technology has the potential to expand into the recreational and entertainment drone fields.

The sponsor identified high educational and entertainment potential within the drone racing industry. The sponsor's initial vision was clear: they aimed to host an event that integrated themes of education, technology, competition, and entertainment, with a focus on engaging students. Ruolian Technology expressed its commitment to inspiring the younger generation by showcasing that drone racing can be an exciting and captivating prospect.

The main objective of this project was to create and develop components for a drone outreach event tailored towards Chinese youth aged 6-12 with limited prior exposure to drones. Our emphasis was on exploring technical elements of drone racing events. This paper delves into the research conducted on three pivotal elements: drone specifications, rules and regulations, and the event schedule.

The following sections explain key background details and pertinent literature review on drone racing and event planning. The methodology explains the research objectives, research questions, and method employed to address them. The results encapsulate the analysis of the methodology; this section links primary and secondary research together to provide compelling deliverables. Finally, the conclusion summarizes the analysis within the context of the rest of the project, followed by future recommendations for the sponsor to consider.

2. Background

The purpose of this background is to present relevant information along with interpretations of research drawn from primary and secondary data to provide the reader with context that will support later sections related to methodology, findings, and results. Topics discussed include sponsor background, involved parties, event planning, drone background, and drone racing. Many talking points revolve around the consideration of our demographic, their status as beginner drone pilots, the constraint of limited time, the availability of limited resources, and general safety.

2.1 Roulian Technology

Ruolian Technology was established in 2015 as a part of Hangzhou's "5050" plan— a strategy that was implemented to attract STEM talent to the city of Hangzhou (Yueyun, 2020). The company's primary focus is to provide high-performance Unmanned Aerial Vehicle (UAV) flight control modules and general UAV solutions tailored for industrial clients. Additionally, Ruolian Technology specialized in the development of highly reliable and highly integrated robot core components, with an emphasis on the application of Artificial Intelligence (AI) technology in the domains of industrial Internet of Things[1], wireless communications, and embedded computing (The UAV Network, 2019). As a result, Ruolian Technology possessed complete ownership of the intellectual property (IP) for their full stack technology of industrial drones. This encompassed various components, including drone flight control, communication links, cluster control software, and precise positioning technology (Zhuanlan, 2018).

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[1] "The Internet of Things (IoT) refers to a network of physical devices, vehicles, appliances, and other physical objects that are embedded with sensors, software and network connectivity that allows them to collect and share data. These devices — also known as "smart objects" — can range from simple "smart home" devices like smart thermostats, to wearables like smartwatches and RFID-enabled clothing, to complex industrial machinery and transportation systems" (IBM, 2023)

Ruolian Technology, with fewer than 50 employees, was primarily focused on continuous research and development of its products. The majority of the team was dedicated to technological endeavors, but there was a small group focused on technical marketing. Notable clients have included the 2018 World Artificial Intelligence Conference, Honeywell UAV Division, Reliable Flight Control Laboratory of Beihang University, State Grid, and Nokia (The UAV Network, 2019).

2.2 Involved Parties and Responsibilities

Our team consisted of four Worcester Polytechnic Institute (WPI) students specializing in electrical and robotics engineering, computer science, and data science. We employed a mixed-team model working alongside a group of 12 Hangzhou Dianzi University (HDU) students majoring in business. This format allowed us the flexibility to collaborate effectively with the HDU students.

Due to the wide-ranging scope that comes with planning a drone racing event, we identified and delegated tasks between the several groups involved. Our sponsor Jie Jin was an adjunct professor at HDU and suggested reaching out to the school's Aviation Club; he believed they could provide valuable assistance to our project. The Aviation Club was comprised of 10+ HDU students with an interest in drones, mentored by a professor with a focus in electrical engineering. The Aviation Club's involvement was not driven by academic obligation but rather resulted from a request made by the WPI and HDU teams—essentially, it was extracurricular support.

After consulting with the sponsor and the HDU team, we identified suitable roles to distribute amongst ourselves. Our criteria were based on our respective strengths; the HDU team, being Chinese business majors, found a more fitting focus on marketing and outreach aspects, given their native understanding of the area and focus of study. The WPI team consisted of engineering majors, making us better suited for a technical and research-based approach. We delegated the tasks that required communication with other locals to the HDU team as the WPI team had a limited understanding of the Mandarin language.

The sponsor purposefully provided minimal guidance, granting us the discretion to shape our structure. Additionally, the sponsor's initial scope was preliminary, which allowed for various interpretations. Bearing this in mind, we classified each team's responsibilities under three overarching terms, as illustrated in **Figure 1**. We stayed in close contact with the sponsor throughout the project to make sure our plans fit within his guidelines.

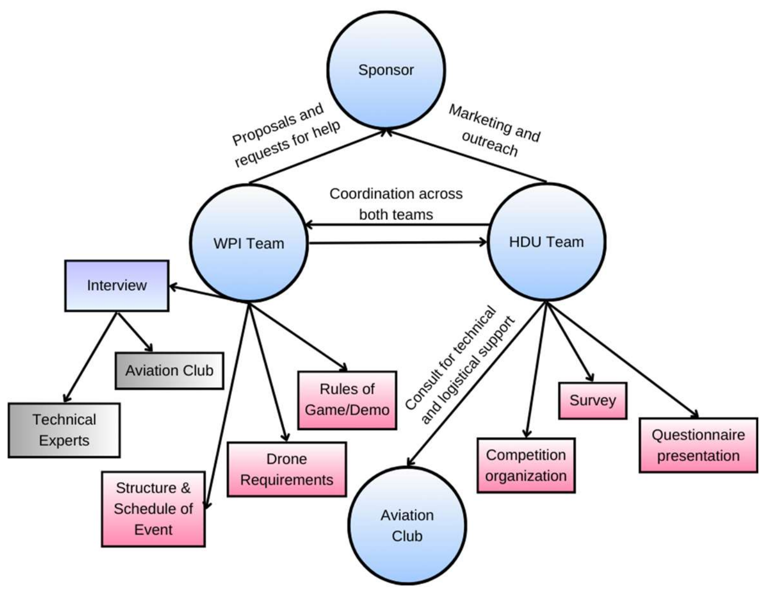

Figure 1: Overall scope.

2.3 Event Planning

In this section, event planning design, key details of what makes for good event planning and relationships to our study are described. The following content played a critical role in our planning, which, as outlined in our methodology, served as the basis for our primary data collection. According to academic research, successful event planning typically begins 6-12 months before the event (Ansuini, 2022). We opted to proceed with a pilot test scheduled for the end of the term, allowing for approximately 2 months of planning time. Nonetheless, the sections that follow should prove useful for events that take place after the completion of this paper.

2.3.1 Importance of Event Planning

Thorough planning plays an integral role in the success of an event which includes budgeting, timelines, selecting and reserving event sites, acquiring permits, food plans, transportation coordination, theme designs, activity scheduling and layout, equipment, facilities, risk management, and contingency plans (IIEM, 2023). Event planning establishes a clear scope and objective, helping organizers mitigate confusion among those involved.

Event planning requires a well-organized structure and schedule, supported by a combination of academic research and practical resources. For example, an illustrative guide can be found in a publication by Mid-Atlantic Robotics titled 'Planning a FIRST® LEGO® League Jr. Expo.' This document provides a detailed, step-by-step guide on how to plan a LEGO Expo, a concept closely aligned with the sponsor's objectives. Key considerations, as summarized in the document, include venue selection, scheduling, and promotional activities (Mid-Atlantic Robotics, 2019). However, the HDU team assumed responsibility for venue selection and promotional activities, which allowed us to concentrate on scheduling. An example schedule is provided by the First Lego League (FLL), shown in **Figure 2**.

SAMPLE TOURNAMENT-DAY SCHEDULE FOR A TEAM		
8:00 – 9:00 am	Team Registration	*Building Lobby*
8:00 – 9:00 am	Team Setup	*Pit Area*
9:00 – 9:15 am	Coaches' Meeting	*Auditorium*
9:30 – 10:00 am	Opening Ceremony	*Gymnasium*
10:15 – 10:30 am	Core Values Judging Session	*Judging Room 1*
10:50 – 10:55 am	Official Robot Round 1	*Gymnasium*
11:20 – 11:25 am	Official Robot Round 2	*Gymnasium*
11:45 am – 12:00 pm	Robot Design Judging Session	*Judging Room 2*
12:00 – 12:30 pm	Lunch	*Cafeteria*
12:45 – 1:00 pm	Project Judging Session	*Judging Room 3*
1:20 – 1:25 pm	Official Robot Round 3	*Gymnasium*
2:00 – 3:45 pm	Possible Judge Callbacks	*Judging Rooms*
3:00 – 3:45 pm	Team Clean-up	*Pit Area*
4:00 – 5:00 pm	Closing Ceremony	*Gymnasium*

Figure 2: Example timeline given by FLL featuring an all-day event spanning from 8:00 am to 5:00 pm (Source: FLL, 2019).

2.3.2 Schedule and Format

Because of the emphasis placed on having an effective schedule, it is good practice to be as thorough as possible. A quality schedule includes a "...meticulously detailed timeline for the event-day..." (pg. 38, Ansuini, 2022) as pictured in **Figure 3**. Other preferred characteristics include flexibility, clarity, and contingency. The National Oceanic and Atmospheric Administration (NOAA) outlines 12 steps to designing and planning an educational project, as shown in **Figure 4**.

FIRST LEGO LEAGUE JR.

Example Expo Schedule

Time	Expo Happenings	Description
9:30 – 10:00	Teams arrive and set up	• Teams set up their models and *Show Me* posters. • Encourage team members to test the motorized part of their model to make sure it works before the start of the Expo.
10:00 – 10:10	Welcome and announcements	• Welcome participants, community members, friends, and families. • Let everyone know where to find activities, snacks, bathrooms, etc.
10:10 – 11:00	Team displays, reviewing, and additional activities	• Teams share their displays and experiences with other team members, community members, friends, and families. • Reviewers meet with teams and ask questions about the models, *Show Me* posters, research, teamwork, etc. (Depending on the schedule and number of teams, plan for Reviewers to spend at least 5 minutes meeting with each team and 2–3 minutes taking notes and transitioning to the next team.) • Team members may participate in other activities when they are not meeting with Reviewers.

Figure 3: LEGO Expo example schedule with clear descriptions and timing (Source: Mid-Atlantic Robotics, 2019).

The Project Planning and Implementation Process

Step 1. (Re)assess need and capability
Step 2. Establish the project planning team
Step 3. Develop project goals and objectives
Step 4. Develop a logic model
Step 5. Select and characterize the audience
Step 6. Establish program format and delivery system
Step 7. Ensure quality instructional staff
Step 8. Ensure quality instructional materials and strategies
Step 9. Assemble materials, resources, and facilities
Step 10. Plan for emergencies
Step 11. Promote, market, and disseminate project
Step 12. Implement project

Figure 4: 12 Steps to planning and implementing an educational project by the National Oceanic and Atmospheric Administration (Source: Day-Miller, 2009).

The format of a drone race varies from league to league (FAI, 2023). Further, a format that is engaging with the audience is ideal. Initial discussions with a WPI professor inspired this topic, emphasizing the need to assess the impact on both dedicated enthusiasts and casual observers. This raises fundamental questions, such as, "How does the format of a drone race affect a bystander?" To achieve Ruolian Technology's goal of education and entertainment, it becomes clear that we must investigate varied formats and prioritize audience engagement in order to shape an immersive experience for the students, their parents, and passersby alike.

2.4 Drones

This section explores the historical evolution and technical aspects of drones. Our aim is to provide readers with insights that serve as a foundation for understanding subsequent topics, particularly those pertaining to drone requirements. The sponsor of this project was not interested in conducting drone research; rather, the sponsor was more focused on the event planning itself. As a result, it was unnecessary to concern ourselves with detailed technical specifications so long as the drones are provided. Nonetheless, the following sections provide general context helpful to the ongoing discussion.

2.4.1 History of Drones

The origins of modern drones can be traced back to World War I, during which the U.S. military-initiated research on practical applications for warfare (Fu et al., 2021). Over time, various militaries globally have employed drones for a myriad of purposes, including training, target practice, air strikes, bomb detection, surveillance, hostage negotiation, and any mission deemed too hazardous for direct human involvement (Beal, 2023).

Primary drone use remained relatively consistent until the early 2000s, with government agencies employing them for disaster relief and border surveillance, while commercial entities utilized them for evaluations and security purposes. However, a significant shift occurred in 2013 when Amazon corporation announced plans to introduce product delivery via drones, capturing the public's attention and expanding the drone industry into mainstream awareness. Approximately a decade ago, there was a notable surge in the recreational use of drones, marking a turning point in their adoption by the general public. Interestingly, the emergence of drones as a source of sport and entertainment, particularly in the form of drone racing, did not originate in research labs but rather with hobbyists during this period (Huiqiang et al., 2023; Young, 2023).

2.4.2 Technical Overview

A drone is defined as an Unmanned Aerial Vehicle (UAV) that is capable of being controlled either remotely or autonomously. Drones used in drone racing, as seen in **Figure 5,** are typically categorized as a type of rotary-winged Micro Air Vehicle (MAV), which is a subset of UAVs. Some key drone components include the propulsion system, the power supply, and the computational power available (Hassanalian et al., 2017). Another important aspect is the chassis on which the components of the drone sit. The material and structure of the chassis affect the weight, balance, durability, and cost of the overall drone making it a crucial factor to consider when analyzing the components used in drone construction.

Propulsion systems for rotary drones are most often driven by brushless DC motors, given their reliability and controllability. Almost all drones of this scale rely on lithium-polymer batteries due their high energy density per kilogram. A significant drawback of this type of battery is that it has a lower overall capacity density when compared to its lithium-ion counterpart; fortunately, this is trivial in this application as drone races only last a few minutes (Triggs, 2023). It should be noted that LiPo batteries have a higher cost, as a result (Hassanalian et al., 2017).

The structure of the drone is governed by the chassis. Materials for the chassis vary widely depending on the use of the drone; however, carbon fiber is often chosen because of its strength to weight ratio (Hexcel, 2023). Because of its cost, it is common to mix additional materials, such as different types of plastic—which is both light and cheap to obtain. **Figure 5** is an example of a drone that uses polycarbonate, a durable type of plastic. DRL opted for "aerodynamic polycarbonate fuselage strengthened to take serious hits," highlighting the need for crash resistant drones. Further, it is highly customizable and easy to machine (Thomas, 2023).

These considerations affect the price and performance of the drone, which scales depending on the level of the event intended by the organizers.

Figure 5: The DRL Racer4 drone. Clean look with bright LED lighting. Classified as a rotary-wing MAV quad-copter; four propellors give balance between practicality and efficiency (Source: Bleier, 2019).

2.5 Drone Racing

There are two forms of drone racing: autonomous and non-autonomous. In autonomous racing, drones operate independently, free from direct pilot control, and navigate the course by relying on their onboard sensors for real-time decision making. Conversely, non-autonomous racing involves human pilots competing against each other. In both cases, the racecourse's physical structure is often comprised of gates that must be crossed in a specific order to denote progress (Standaert, 2020).

Considering various factors like limited time frame, target audience, and budget constraints, it is reasonable to conclude that non-autonomous racing is the preferred method for this specific outreach event.

2.5.1 Rules and Regulations Background

Many drone races adhere to common rules that encompass the following key topics (Doorn, 2023):

- **Course design**
  Often details space, lighting, terrain, indoor/outdoor facilities, and course obstacle elements (Liao, 2021).
- **Race format**
  3 main kinds: circuit racing, time trial, freestyle (Ocampo, 2022).
- **Scoring and Timing systems**
  Method of point scoring and timekeeping.
- **Disqualification rules**
  Typically covers pilot qualifications, safety requirements, illegal moves, and more (Doom, 2023).
- **Drone specifications**
  Many organizations utilize their own technical requirements such as approved drones, equipment restrictions, weight limits, and more (Doom, 2023).
- **Awards, prizes, and recognition**
  May vary from participation trophies to medals for top scorers.

For instance, **Figure 6** displays the Federation Aeronautique Internationale (FAI) 2022 World Games Drone Racing Sporting Rules, detailing some of the key topics mentioned earlier. The FAI, recognized by the International Olympic Committee, serves as a global organization dedicated to promoting air sports and recreational flying (FAI, 2023). Researching governing bodies, such as the FAI, allowed for the identification of standard racing formats in the drone racing community. Additional organizations of interest included the Drone Racing League (DRL) and MultiGP, both boasting millions of viewers and hosting hundreds of competitions globally (DRL, 2023; MultiGP, 2023).

1. **RACING CIRCUIT** ....
2. **GENERAL SPECIFICATIONS FOR MODELS** ....
   - 2.1. Weight and size ....
   - 2.2. Motorization ....
   - 2.3. Propellers ....
   - 2.4. Radio control (RC) equipment ....
   - 2.5. Video system ....
   - 2.6. LED light device ....
   - 2.7. Identification mark ....
3. **NUMBER OF MODELS** ....
4. **MODEL PROCESSING** ....
5. **PRACTICE FLIGHTS** ....
6. **CONTEST ORGANISATION** ....
   - 6.1. Timekeeping ....
   - 6.2. Procedure for the start of the race ....
   - 6.3. Qualification stage ....
   - 6.4. Elimination stage ....
   - 6.5. Final stage ....
   - 6.6. Final classification ....
7. **FLIGHT OCCURRENCES** ....
   - 7.1. Obstacle damaged or destroyed during the race ....
   - 7.2. Faults and penalties ....
   - 7.3. Disqualification from the race ....
   - 7.4. Crash ....
   - 7.5. Safety occurrence ....
8. **REFLIGHTS** ....
   - 8.1. Causes for reflight ....
   - 8.2. Organization of the reflights ....
9. **OFFICIALS** ....
   - 9.1. FAI Jury ....
   - 9.2. Supervisor and pilots' Judges ....
   - 9.3. Other officials ....
10. **INTERRUPTION OF THE CONTEST** ....

Figure 6: FAI 2022 World Games Drone Racing Sporting Rules table of contents (Source: FAI, 2022).

The objective of this background research is to identify best practices established by experts, serving as a comprehensive framework to determine the most effective approach for an event of this nature. Indeed, the primary goals of this event were not driven by financial considerations; instead, they were firmly rooted in educational and entertainment pursuits. Nevertheless, chaotic events are not particularly enjoyable; even recreational activities benefit from a certain degree of structure to enhance their entertainment value.

Thus, modifications of the rules had to reflect this recreation, education, and entertainment intent. The criteria that guided our decision to implement these changes were the demographic, which consisted of grade school students, their status as beginner drone pilots, the constraints of limited time for both preparation and the day of the event, and the availability of limited resources. Above all else, a main priority is safety, for both the participants and spectators."

An appeal to education can be made through engagement, collaboration, and guidance (edutopia, 2005). An increase in engagement may heighten external stimulus, which in turn, "will lead to attention narrowing or a restriction of cues that can be processed," as summarized by the "cue utilization hypothesis" (Rosegard, 2013). This research suggests that students who feel engaged are more likely to pay attention and less likely to get distracted. Collaboration and guidance play the role of "giving special attention to nurturing a student's interests and self-confidence," (edutopia, 2005). Ruolian Technology can facilitate this appeal by offering necessary resources that empower students to succeed. This could involve waiving entry fees, providing comprehensive drone race training, and even recognizing and rewarding outstanding performance with prizes and incentives. By removing financial barriers and providing support, Ruolian Technology can foster a conductive environment for students, making the educational aspect of drone racing accessible and enjoyable for all participants (Chatzis, 2022).

Research suggests in order to create effective rules, or "green tape," several key aspects should be considered. These include having clearly defined written requirements, establishing valid means-ends relationships, ensuring optimal control, and maintaining consistent application. Green tape theory asserts that the combined presence of these components collectively enhances the likelihood of successful rulemaking (DeHart-Davis, 2006).

As depicted in **Figure 7**, having clearly defined written requirements provides a basis for authoritative decision-making. Establishing valid means-ends relationships involves explaining rationale behind decisions to both the authorizer and receiver. Ensuring optimal control allows for flexibility without micromanagement. Consistent application means that rules are applied uniformly and fairly across all relevant scenarios (DeHart-Davis, 2006). It is in our best interest to apply these considerations in our development of the rules and regulations, not only as a reference of framework, but also in the evaluation of our execution.

Green Tape Elements, Mechanisms, and Effects

Element	Mechanism	Effects
Written rules	Legitimize rule requirements	Empower rule implementers
		Facilitate compliance
Valid means-ends relationships	Provide theoretical blueprint Convey rule rationality	Enable effective pursuit of rule objectives
		Elicit stakeholder cooperation
Optimal control	Achieves rule objectives without hampering organizational functions	Enables efficient pursuit of rule objectives
	Conveys priority of rule objectives	Elicits stakeholder cooperation
	Communicates trust in stakeholders	
Consistent application	Conveys procedural fairness	Elicits stakeholder cooperation
Understood purposes	Impart meaningfulness on requirements	Elicit stakeholder cooperation

Figure 7: Green Tape Elements, Mechanisms, and Effects. Five concepts to help ensure effective rules (Source: DeHart-Davis, 2006).

2.5.2 Racecourse Design

As a part of developing the rules, regulations, and other technical concerns with a drone racing event, the WPI team considered racecourse design. There are a number of course design elements that are commonly used in drone racing (Liao, 2020).

- A simple gate
- 180-degree turn (Flag or Gate)
- Hurdle

The selection of these elements was driven by an assessment of both the participant skill levels and the practicality of execution. As illustrated in **Figure 8**, the course elements are straightforward to perform and can be easily set up. **Figure 9** depicts an example drone racing track utilizing several course elements. Other elements, such the slalom shown in **Figure 10**, provide a greater challenge for beginner racers.

The venue was another design consideration; however, this fell under the responsibility of the HDU team. Therefore, we proceeded with the assumption that the selected venue would align with our criteria of being an indoor facility, spacious, and feature flat terrain.

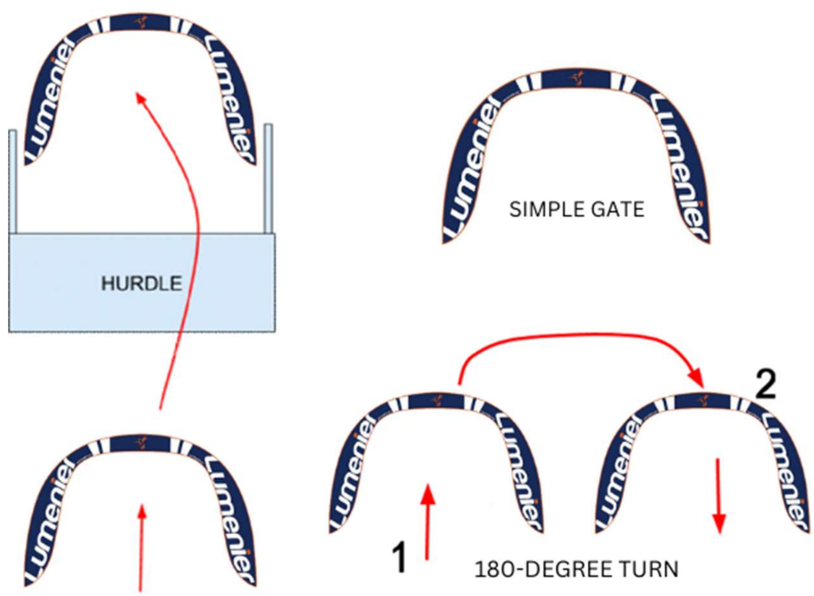

Figure 8: Three course elements depicted. Simple gate (top-right), 180-degree turn (bottom-left), and the hurdle (left). Most elements are comprised of the simple gate; however, it is possible to use flags instead (Source: Liao, 2020).

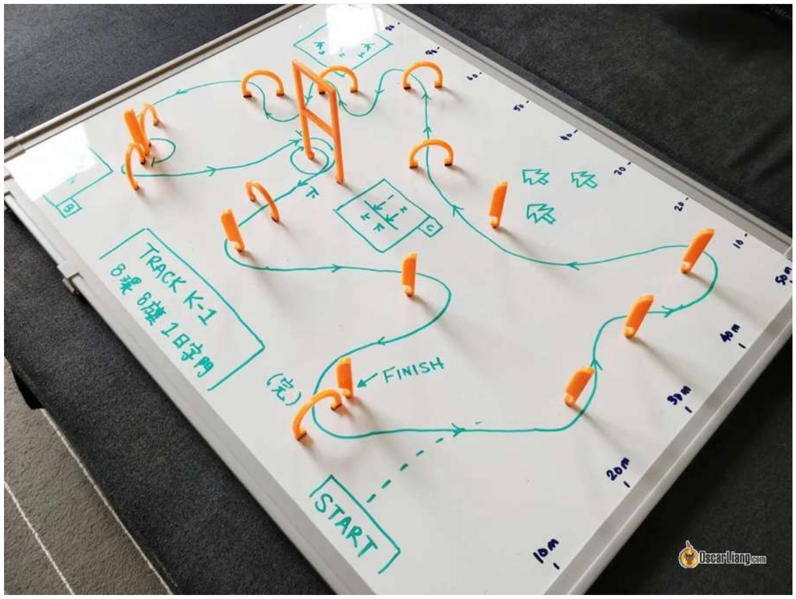

Figure 9: Example drone racing track utilizing course elements such as the simple gate, the flag slalom, the ladder, and more (Source: Ocampo, 2022).

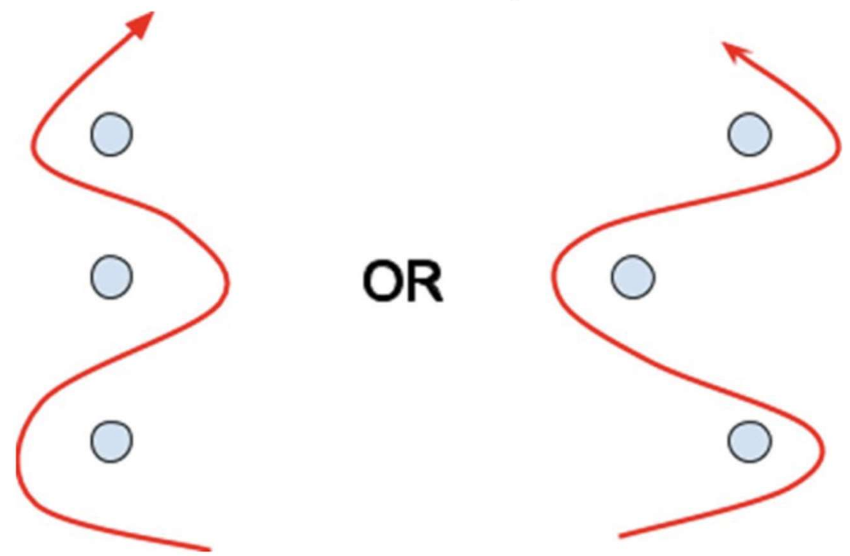

Figure 10: The flag slalom adds complexity in its side-to-side pattern as racers must rotate their drone to maintain speed (Source: Liao, 2020).

2.5.3 Safety Considerations

Safety is a main priority for drone racing events. There are many drone hazards and in order to identify them, safety risk assessments were done for UAV vehicles. Examples of drone-related safety hazards include high loss of altitude, loss of control, loss of transmission, collision with manned, unmanned aircraft or buildings, power lines, partial failure or loss of navigation systems, severe weather or climatic events, existence of corrosion, pilot unfamiliar with area, rotor failures, take-off, and landing incidents such as undershooting or overrunning (Ferrigan, 2022). Certain hazards become trivial or mitigated by design of the racecourse and the nature of the event, so we only address those that are applicable. The UAV risk acceptance level may determine appropriate action; mitigation action can be classified as either corrective or preventative, as seen in **Figure 11** (Ferrigan, 2022).

Acceptance level	Recommended actions
Unacceptable	Immediate mitigation action and escalation is required; An operation stop should be considered
Tolerable	The safety risk shall be mitigated as low as reasonable practicable and should be approved
Acceptable	No actions required

Figure 11: Safety risk mitigation in which action is recommended depending on risk acceptance level (Source: Ferrigan, 2022).

3. Methodology

The goal of our project was to create an event that modified common drone racing structures that aligned with Ruolian Technology's (the sponsor's) objective of educating and inspiring children in the STEM field. As we aimed to provide the sponsor with applicable and scalable research, we focused on three core topics in relation to the event: drone specifications, rules and regulations, and event schedule.

To achieve this goal on research and evidence-based drone racing design, we used two main methodological approaches in addition to secondary background research as described in **Section 2** of this report:

1. **Interview experts to provide insights on our existing content.**
2. **Conduct a pilot test utilizing our proposed materials.**

In the upcoming sections, we detail information we sought, our approach, and the rationale behind our methodology. We also delve into the process of data analysis, the criteria employed, and how we drew upon our final conclusions.

3.1 Semi-Structured Interviews

3.1.1 Justification

Expert opinions and perspectives can effectively help to evaluate our research questions on the design of drone specifications, rules and regulations, and event schedule. Assistance of individuals with prior experience in drones and drone racing provided a sample of experts for information and data acquisition. Among those consulted were Starry, who served as Ruolian Technology's Product Manager, along with members of the HDU Aviation Club.

We directed our attention towards technical factors such as hardware specifications, venue selection, racecourse design, timing and scoring system, safety measures, drone maintenance and repair, and drone regulations. Moreover, our aim was to acquire additional data concerning our demographic and its implications for our objectives. We inquired about how to adapt our secondary research to cater for our target audience. This was achieved by finalizing our compilation of open-ended questions designed to foster discussion, which can be found in **Appendix A.** We ensured the questions maintained clarity, impartiality, and relevance, even after translation.

The initial phase of the interview prioritized the establishment of rapport through the creation of a comfortable and open atmosphere by introducing ourselves, explaining the purpose of the interview, and ensuring interviewee consent. Rather than adhere to a predetermined set of questions, we adopted a flexible approach, using our pre-written questions as guidelines. This made certain that we obtained responses to our initial inquiries while allowing the conversation to naturally evolve.

Typically, we initiated the interview by asking about the interviewee's involvement with the drone racing industry, followed by their opinions and observations made regarding our prepared materials and the application of drone racing for an outreach event. This methodology facilitated exploration of the interviewees' thoughts and experiences, fostering a more organic and insightful discussion. Consequently, it contributed to the development of evidence-based expert information data that identified factors that could lead to success of organizing a drone race. Further, we took care to uphold neutrality and objectivity, steering clear of leading and biased questions that might influence the interviewees' response (Rowley, 2012). We did this by using open-ended questions and balancing positive and negative phrasing. Concluding the interview, we summarized the key points of the discussion and expressed gratitude for their time and participation.

Throughout the interviews, we recorded and took notes, ensuring we had obtained consent for this process; accurate documentation is crucial for our subsequent analysis. We interpreted the data to draw conclusions, which helped in forming our recommendations for the final deliverables (Rowley, 2012). Additionally, we had the opportunity to openly discuss and receive feedback on some of the changes we were considering, which allowed us to make quick and thoughtful revisions to our project.

3.1.2 Interview 1: Starry

Our first interview involved the product manager at Ruolian Technology. His experience consists of having organized, attended, and watched many drone racing events and therefore we believed he was a suitable candidate. We scheduled an interview ahead of time and prepared a slideshow of questions. These questions included topics such as drone specification, event planning, and, to a lesser extent, rules and regulations. We started the interview by asking for consent, as seen in **Appendix A**. We wanted to have an open discussion about event planning and how such an event might be most plausible at HDU. Part of the interview was about drones the company could provide for the event. This interview included discussion of how drone characteristics fit with the target audience and whether they would influence the event rules and regulations. His expertise in drone events helped us adapt our existing methodology to be more suited to our audience and needs. His experience working for a drone making company also allowed us to gain insight on how to adapt drones for their use with a younger audience. His interview transcript can be found in **Appendix B**.

3.1.3 Interview 2: Aviation Club

Members of the Aviation club at HDU were also interviewed. Their experience organizing similar events in the past could provide primary expert knowledge to the three research questions. They have organized and attended many events in competitions; they have familiarity with the rules and schedules that they use. HDU students helped organize a meeting with them. We prepared to ask our research questions in an open discussion format. Some of the information gathered had less to do with the research questions and more about the organization of the event. Thus, we wanted to collect primary data mostly about how the experimental event could take place on the HDU campus and who to ask. Data about event scheduling was gathered from them based on their experiences in multiple drone events.

3.1.4 Interview 3: Professor Tony Luo

Professor Luo possessed substantial experience and familiarity with drones. His background involved judging competitive youth drone races both in Hangzhou and at the national level, coupled with his role as the advisor of the HDU Aviation Club. We approached Professor Tony Luo to gather primary data relating to racecourse design, drone selection, safety considerations, and self-evaluation methods. His formal expertise lay in electrical engineering. Professor Luo was able to provide insight to many aspects of our results and analysis, drawing from the extensive breadth of his experience.

3.2 Experimental Event and Pilot Study

We conducted a pilot study of a drone racing event to inform our research questions and deliverables. The pilot study was meant to be an experiment to test initial design characteristics that are intended to be used on a larger scale (Thabane, 2010). For us, this meant conducting a trial of the event framework, rules, and drone selection.

3.2.1 Justification

In order to understand the efficacy of our research, we designed and executed a pilot test. Having recognized the limitations of relying solely on theoretical frameworks, we acknowledged the invaluable role that primary data and experiments play in practical applications. Through the implementation of this pilot test, we aimed to gain insights beyond the scope of theoretical knowledge. This allowed us to identify successful strategies, uncover considerations that might have been overlooked, and pinpoint areas in need of modification or improvement. This approach provided a real-life perspective, offering a stronger understanding of how various elements interact with each other in a practical setting (Hassan, 2006).

3.2.2 Event

Our pilot study occurred on December 2, on the HDU campus. Participants were recruited through an email list that was sent by the school to professors. The HDU team located a venue to hold the event outside of the HDU gymnasium.

This venue was deemed suitable, as it featured sufficient open space for the provided drones to race in, as well as a nearby charging station to charge the drone batteries. The purpose of organizing this event was to collect primary data that reflects the practical implementation of our three research questions. This reflection allowed us to discern successful aspects and areas that may require refinement or alteration. Throughout the event, we took care to document our observations, with the help of rubrics, which can be found in **Appendix C**, **Appendix D**, and **Appendix E**, to facilitate and organize our notes.

3.2.3 Planning

The plans were loosely based on example schedules such as the FLL Jr. plans found in **Figure 10** supported with the advice our experts supplied. We further adjusted based on the evolving requirements, such as increased capacity of participants. The WPI team was responsible for supplying the rules and regulations, drone specifications, and event schedule, which coincides with our research objectives. The HDU team dealt with logistical planning such as venue booking, volunteer management, and communications.

3.2.4 Evaluation

To benefit from the pilot study, we devised two methods of evaluation: observation and rubric scoring (Chatzis, 2022). These methods were created in order to satisfy the following guidelines in measuring the impact of a pilot study (Sufi, 2018).

1. **Goals or objectives need to be set**
   The outputs, what you want to produce, and what difference you hope it will make, should be defined to help you find what impact you're looking for.
2. **Create metrics purposefully**
   The process of taking an abstract topic and converting it into a metric is known as commensuration. This process makes abstract topics more comparable, simplifying hard to comprehend information and provide a methodology to make decisions easier.
3. **Understand bias**
   Biases will never be fully combatted, but it is important to recognize and act according to what biases would affect the study the most.
4. **Gather data before, during, and after**
   Gathering ongoing data allows us to identify problems as they occur, run a more effective event, and measure impact.
5. **Harness gamification to test participant skills**
   Using games to assess if participant have learned the intended skill eliminates the features of the standardized-testing environments that can cause anxiety.

3.2.4.1 Observations

Documentation, through the form of taking observational notes during the event, serves several purposes. Taking notes in real-time allows for the capturing of details that may be overlooked or forgotten after the event. Taking notes with a focus on our three research topics provides focused attention on the effects of our products. The notes could be categorized as: positive aspects, areas for improvement, and unexpected considerations revealed during the event, which can be found in **Appendix F**, **Appendix G, and Appendix H**. append

3.2.4.2 Rubric

To properly qualify and quantify our observations, we created a rubric to assess each of our three research questions. In these rubrics, there are five subtopics: relevance, efficiency, effectiveness, impact, and sustainability. Each subtopic has a weight of 20% and therefore, a score can be given from a range 0 to 20. Further detail can be found in the "Remarks" column of each rubric in **Appendix C**, **Appendix D**, and **Appendix E**. The parameters are (Fisher, 2010):

1. The relevance index, the extent of applicable contribution towards the program's objectives
2. The efficiency index, the productiveness of the program
3. The effectiveness index, the completion of the program's objectives
4. The impact index, the result on the participants
5. The sustainability index, the long-term viability of the program

3.3 Limitations

This project was not without its limitations. Perhaps most glaringly, the language barrier proved to be a challenge. This issue manifested itself across various dimensions of the project, including interviews, sponsor meetings, working with the HDU team, and interacting with locals, among other aspects.

Another limitation was the limited involvement of the sponsor, who expressed a preference for a more passive role in the project's planning and execution. This passiveness initially hindered the direction and scope of the project; however, it gave us the discretion to leverage the project to our strengths. Further, we had to be mindful of the Institutional Review Board's (IRB) approval following changes in our methodology.

Specific to our pilot test, a budget constraint arose as it took place on a college campus, restricting direct funding from the sponsor. Primary support was expected from either the HDU Aviation Club or individuals' personal contributions. Additionally, the time frame of 2 months posed another challenge, as similar events typically require a planning period of at least 6 months. To overcome these limitations, the WPI team's focus was on topics that could be developed comprehensively within the given timeframe, ensuring that the event planning remains feasible and achievable.

A generic restriction regarding drone racing it that there is generally a high cost of entry, which may deter prospective talent from competing. Additionally, there is a steep learning curve that individuals must navigate before becoming skilled enough to maneuver the drone effectively (Allied Market Research, 2020). Furthermore, current leagues, such as DRL, are highly dependent on sponsors; it remains to be seen if such a system is sustainable.

4. Results and Analysis

The goal of our project was to create an event that modified common drone racing structures that aligned with Ruolian Technology's objective of educating and inspiring students. We emphasized our focus on drone specifications, rules and regulations, and event schedule.

To achieve this goal, we developed drafts of our final deliverables through applied secondary research and refined them with collected primary data, which consisted of expert interviews and pilot testing. By analyzing the information gathered, we developed the following materials:

- Through the application of academic frameworks, such as Green Tape Theory and Cue Utilization Hypothesis (DeHart-Davis, 2006; Rosegard, 2013), the rules and regulations underwent testing using primary data methodologies, including pilot testing and expert interviews. This process provided evidence of their applicability across various scenarios (see **Appendix I**).
- Regarding drone specifications, the pilot test evaluations for the R130 (refer to **Figure 17** and **Appendix J**) concluded that drones similar to this model demonstrate safety, ease of repair, and suitability for beginners.
- The event schedule, based on secondary research formats, was refined through trial and error using primary data, effectively captivating the intended audience (see **Appendix K**).

4.1 Rules and Regulations

As mentioned in **Section 2.5.1**, the three main kinds of drone racing formats are circuit racing, time trial, and freestyle (Ocampo, 2022). Our research indicated that a time trial would be the most appropriate method for students learning to fly drones. This choice was based on considerations relating to interference, collisions, and overall chaos if we chose to compete side by side; uncertainties may be limited by restricting flight to one pilot at a time. This decision was made as a preventative mitigation action for UAV risk acceptance, in reference to **Section 2.5.3.**

Our initial hypotheses were validated following the pilot test, as it reaffirmed that the time trial approach was likely the safest and most practical choice.

As illustrated in our observation notes in **Appendix F**, **Appendix G**, and **Appendix H**, many participants crashed their drones by colliding with the course obstacles. This collision rate would likely have been exacerbated had a racing format been utilized, where competitors are able to bump and collide with one another.

However, following our pilot test, we found that a limitation with time trials was that they took longer than expected. We ran behind schedule by about 30-45 minutes, according to our observations. Despite this set-back, the format is still scalable in the sense that multiple races may occur simultaneously, given identical racecourses. As a result, it is possible to manage the time delays to be more comparable to that of a racing format; however, more research is needed.

Regarding the structure of the competition, we drew substantial inspiration from established drone race competitions. Initially, our intention was to implement a double-elimination bracket, as seen in **Figure 12**; however, it became clear there was not enough time in the schedule. The advantage of this structure is that it allows those who lost in the earlier stages of the event to continue playing for a chance to win. The motivation behind this system is to keep the participants engaged throughout the competition, which is something that we struggled to do with the pilot test. Note, "About a third of kids stayed to the end [of the pilot test]," (**Appendix H**).

Figure 12: Double elimination bracket. A participant gets eliminated upon having lost two matches (Source: Challonge, 2023)

Concerning the rules, we found that in the event of unforeseen occurrences, so long as the decisions made were applied consistently, competitive integrity remained. The importance of this concept is a key component of green tape theory, as summarized in **Section 2.5.1.** Other aspects of the rules and regulations covered in this section include course design, scoring and timing systems, and disqualification rules. These can be found written in detail in **Appendix I**.

1. **Racing Circuit**
2. **Model**
3. **Practice Flights**
4. **Contest organization**
5. **Flight occurrences**
6. **Reflights**
7. **Officials**

Originally, the circuit design in **Figure 13** was intended for the outreach event.

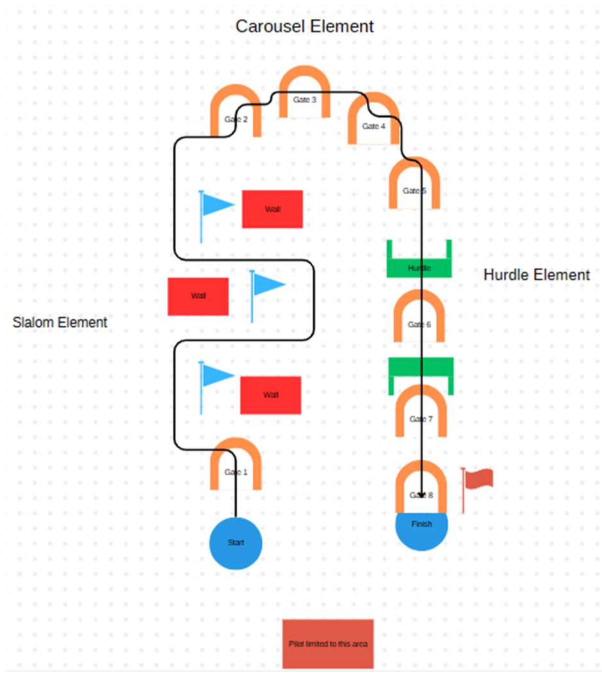

Figure 13: A three-element course consisting of the flag slalom, the carousel, and the hurdle. Dimensions roughly equal 15m x 20m (Source: Canva.com; Prof Tony Luo).

However, this proved much too challenging given our demographic and limited drone capability. Following the advice of Professor Tony Luo to, "keep it simple," we scaled the racing circuit down to just a simple gate, as viewed in **Figure 14**, with the intention of increasing the difficulty as the event went on. **Figure 15** demonstrates a medium level circuit.

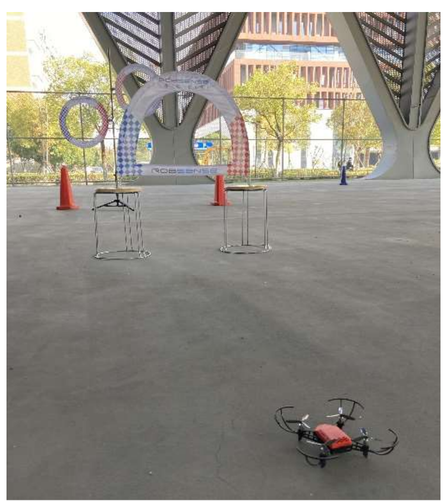

Figure 14: R130 drone sitting in front of a simple gate.

Figure 15: Medium level racecourse featuring a flag slalom (left) and a simple gate (right). The two cones on the right represent the finish line.

As a method of evaluating the pilot test, each member of the WPI team scored the rubric in **Appendix C**. Using this score may give insight on how to improve our final deliverable. As seen in **Figure 16**, the rules and regulations scored a 78/100 with the lowest category being relevance and highest category being impact. Relevance scored low because the prepared documents were initially drafted in preparation for a bracket structure rather than a qualifying and finals round. Impact received the highest score because the index assesses beyond the immediate scope of the race. Aside from the race structure, many of the rules and regulations were still able to apply towards ensuring an impactful event.

RULES	Relevance	Efficiency	Effectiveness	Impact	Sustainability	Average Score
Marc	0.60	0.65	0.70	0.75	0.80	0.70
Ethan	0.90	0.88	0.95	1.00	0.60	0.87
Alisha	0.50	0.50	0.95	1.00	0.85	0.76
Kayla	0.80	0.80	0.80	0.80	0.75	0.79
Average:	0.70	0.71	0.85	0.89	0.75	0.78

Figure 16: Table summarizing observation index of success model scores during the pilot test for rules and regulations.

4.2 Drone Specification

For the pilot test, we chose a readily available drone provided by our sponsor—the R130, as shown in **Figure 17**. To assess drone performance, we compared the qualities of the R130 drone with those we deemed ideal for beginner drone racers. A paper published to the Multidisciplinary Digital Publishing Institute (MDPI) provides a rubric that covers 15 factors to be considered for civilian drone use (**Appendix L**) (Fu, et al., 2021):

- Vehicle flight performance
- Manipulative ability
- Operation duration
- Main application
- Maintenance costs
- Acquisition of parts and operation consumables
- Operation safety/security
- Flight power
- Operation cost
- Maintenance simplicity
- Purchase cost
- Maintenance convenience
- Operation convenience
- Operation supportability
- Operation environmental impact

These factors were brought to 27 expert opinions split between military, research, and academia on what they considered to be most important qualities in civilian drones. The resulting weights can be found in **Figure 18**.

Figure 17: R130 viewed from the top. Battery pack and propeller guards attached. Specification sheet in **Appendix J**.

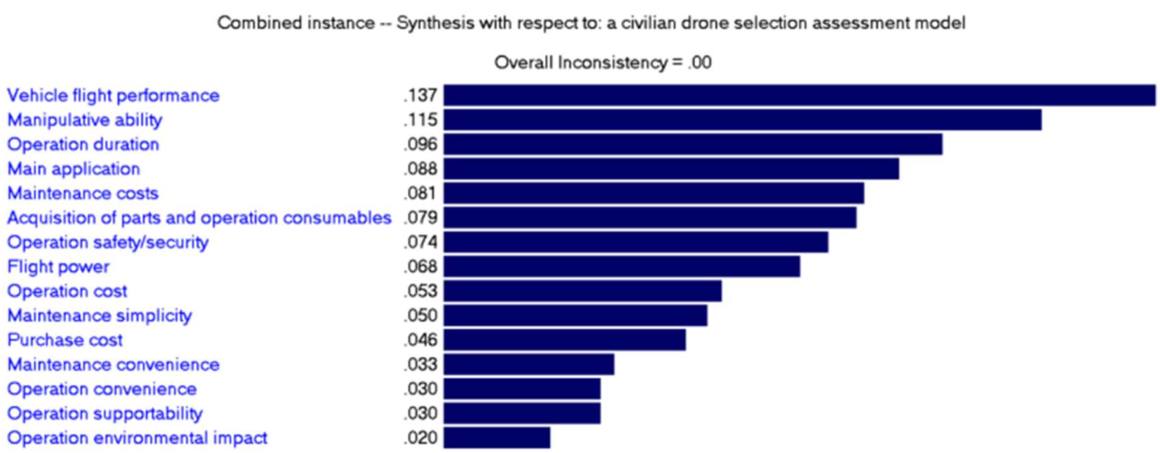

Figure 18: 15 decision criteria aggregated weights (Source: Fu, et al., 2021).

In **Figure 18**, vehicle flight performance is held to the highest priority, followed by manipulative ability. In contrast, both Starry and Professor Tony Luo suggested assigning greater importance to safety by utilizing smaller drones, protective chassis, and propellor covers. Further, because Ruolian Technology supplied the drones and gates for our pilot study, our cost was significantly reduced, lowering its relative priority. Real events will likely prioritize other factors, which limits the applicability of the pilot test, in this regard. Therefore, it is recommended for the organizer of an event to determine what they prioritize in reference to this chart.

In our observations for the pilot study, this drone model proved to be safe, easy to fix, and suitable for beginners. Some safety features included a low maximum speed and height. Throughout the race, despite multiple collisions, the drones remained in use due to their modular construction. Many components were easily replaced, such as the propellors, propellor guards, and battery packs, which allowed the race to continue with little interruption, as demonstrated in **Figure 19**.

The event utilized a phone app as the controller, accessible on both Apple and Android devices. The controls were simple, with a familiar interface and a limited number of buttons. This application even had the capability to stream video from the drone's point of view. The drones were operating in altitude mode, meaning they self-adjusted their own yaw, pitch, and roll for easier piloting.

One limitation highlighted in our observation notes referenced the low battery life which lasted for 3-4 minutes of flight time (**Appendix G**). We addressed the issue with constant battery swaps every other take-off.

Looking at the results of our rubric in **Figure 20**, drone specifications scored a total of 80/100 based on our observations. The lowest category scored was sustainability with a score of 74, and the highest category was effectiveness with a score of 88. The reason for a low sustainability score can be explained by the lack of maneuverability which limits the "skill ceiling" of the children as they improve over time. Despite the lack of maneuverability, the highest score, effectiveness, was a result of the engagement by the participants at the day of the event, making this category a success.

Figure 19: Picture of team member replacing propeller in about one minute.

DRONE	Relevance	Efficiency	Effectiveness	Impact	Sustainability	Average Score
Marc	0.85	0.70	0.75	0.75	0.75	0.76
Ethan	1.00	0.90	0.90	0.65	0.60	0.81
Alisha	0.50	0.75	0.95	0.95	0.75	0.78
Kayla	0.90	0.80	0.90	0.75	0.85	0.84
Average:	0.81	0.79	0.88	0.78	0.74	0.80

Figure 20: Table summarizing observation index of success model scores during the pilot test for drone specifications.

4.3 Event Schedule

Our project was to research drone outreach event aspects designed for youth with minimal drone racing experience. Thus, it was imperative to tailor similar, existing event schedules to suit the needs of the project goal.

We took heavy inspiration from the workshop format discussed in **Section 2.3.2**, placing emphasis on the interactive aspect of the event. As this event is tailored towards young students, keeping children engaged and interested is important to stay mindful of, as explained by the cue utilization hypothesis in **Section 2.5.1.** Our suggested event schedule, found in **Appendix K**, contains the following components:

- Set Up (120 min)
- Opening Ceremony (10 min)
- Drone Showcase (15 min)
- Introduction (15 min)
- Training (30 min)
- Race (90 min)
- Award Ceremony and Concluding Statements (10 min)
- Clean Up

Our first draft of the schedule did not include the drone showcase. After interviewing the Aviation Club president, we received the suggestion to demonstrate drone tricks to capture participant interest. This stimulates the student minds and helps enable them to stay focused (Rosegard, 2013). Additionally, the president highly recommended that we keep the duration as short as possible while being able to achieve our goals for our demographic.

Based on our observations from the pilot test, we determined that the event exhibited thoughtfully chosen activities that engaged and effectively captivated our audience. Nonetheless, the event did extend beyond the initially anticipated timeframe, primarily influenced by unforeseen factors in assessing the duration of activities. One of the values we strove for when creating this event was to create an entertaining, engaging, and memorable experience that would get youth interested in the drone industry. Activities we featured included a drone showcase performed by the HDU Aviation Team, training, and awards, all of which were well received by participants.

Looking at **Figure 21**, the event schedule received the lowest total of all evaluations with a score of 76/100. This is certainly the category that could use the most improvement, as we were behind schedule day-of the event, as indicated by the low Efficiency score of 65. Despite the delays, the effectiveness of the event categories themselves was successful, resulting in a score of 81 in Effectiveness. These observations and insights helped mold the results of our final schedule.

EVENT	Relevance	Efficiency	Effectiveness	Impact	Sustainability	Average Score
Marc	0.70	0.50	0.65	0.70	0.50	0.61
Ethan	0.85	0.80	0.90	0.60	0.70	0.77
Alisha	0.75	0.50	0.88	0.90	0.95	0.80
Kayla	0.85	0.80	0.80	0.90	0.90	0.85
Average:	0.79	0.65	0.81	0.78	0.76	0.76

Figure 21: Table summarizing observation index of success model scores during the pilot test for the event schedule.

5. Conclusions and Recommendations

The purpose of this project was to structure an event that would provide awareness and exposure to the world of drone racing. To this end, we focused on three objectives. First, to identify and delegate the parties involved in our drone event. Second, we focused on three research questions: defining rules and regulations, defining drone specifications, and planning the event schedule. Finally, we were to present recommendations to the sponsor based upon our research.

For three months, we have conducted primary and secondary data collection for the purpose of bolstering our deliverables. Throughout this period, we gathered information on rules and regulations, best suited beginner drones, and scheduling events. Our event was designed for children aged four to twelve years old, with the goal of introducing them to the world of drone racing.

- Through the application of academic frameworks, such as Green Tape and Cue Utilization Hypothesis (DeHart-Davis, 2006; Rosegard, 2013), the rules and regulations underwent testing using primary data methodologies, including pilot testing and expert interviews. This process provided evidence of their applicability across various scenarios (see **Appendix I**).

- Regarding drone specifications, the pilot test evaluations for the R130 (refer to **Figure 17** and **Appendix J**) concluded that drones similar to this model demonstrate safety, ease of repair, and suitability for beginners.

- The event schedule, based on secondary research formats, was refined through trial and error using primary data, effectively captivating the intended audience (see **Appendix K**).

To collect data from our pilot test we created a rubric for each one the categories we were working on. We then each evaluated what we thought our materials scored and therefore could see common areas in which we could improve in.

Rules and regulations scored a **78/100** with the lowest category being relevance and highest category being impact. Relevance scored low because the prepared documents were initially drafted in preparation for a bracket structure rather than a qualifying and finals round. Impact received the highest score because the index assesses beyond the immediate scope of the race. Aside from the race structure, many of the rules and regulations were still able to apply towards ensuring an impactful event.

Drone specification scored a total of **80/100** based on our observations. The lowest category scored was sustainability with a score of 74, and the highest category was effectiveness with a score of 88. The reason for a low sustainability score can be explained by the lack of maneuverability which limits the "skill ceiling" of the children as they improve over time. Despite the lack of maneuverability, the highest score, effectiveness, was a result of the engagement by the participants at the day of the event, making this category a success.

Event schedule received the lowest total of all evaluations with a score of **76/100**. This is certainly the category that could use the most improvement, as we were behind schedule day-of the event, as indicated by the low Efficiency score of 65. Despite the delays, the effectiveness of the event categories themselves was successful, resulting in a score of 81 in Effectiveness.

Some future steps that the company may want to consider include, monetization for sustainability, further exploration of the industry, higher quality events and more metrics to gather feedback. Monetization is important for the long-term sustainability of these races. It allows these events to keep on occurring and provide the most benefit for the community surrounding them as well as create higher quality events for the individuals involved.

Another suggestion would be to explore other areas of interest; our event was specific to the Hangzhou area and involved a small sample of students. Branching out and exploring what works for other demographics and locations is a great way to improve the quality of these events. That comes along with finding more ways to collect data and evaluate the events that you are running. Being able to get accurate feedback on events allows the event to improve and adapt to the desires of those participating, therefore creating a more successful event.

Drones have been an ever-growing industry with a variety of uses from inspection to media. We believe that everyone should be able to access such a fascinating and ever-growing technology. Along those lines, we want to provide a gateway for a younger audience to experience these technologies and potentially find passion in it as many others have. We hope that the work that we have done will inspire our sponsor and hopefully many other people to host events intended for younger individuals. In doing so, we hope to inspire the next generation of pilots and engineers.

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Appendix

Appendix A: Interview Questions with Chinese translation

Informed Consent

Record keeping and confidentiality:

- Only those within the team will have access to the raw data collected, which will be through note taking and/or voice recording if consent is given.
- We will present our filtered information to the cohort and sponsor, as well as the HDU students in our team. This will include the name of the contact, position, and responses to our questions.
- Records of the contact's participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or its designee, and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify the contact by name. Any publication or presentation of the data will not identify the contact.

Goals

- Our project goal is to create a drone racing event for middle schoolers that will teach them how to race. 我们的项目目标是为中学生举办无人机赛车活动，教他们如何比赛
- The goal of this interview is to get insight from experts on how we can adapt drone racing events for children. 这次采访的目的是从专家那里获得关于我们如何为儿童调整无人机赛车活动的见解

Background

- Can you briefly introduce yourself and your experience with drones/event planning? 您能介绍一下自己和您在无人机/活动策划方面的经验吗？

Safety

- What extra precautions should be taken when organizing a drone racing event for kids? 为孩子们组织无人机赛车活动时应采取哪些预防措施？
- How might you restrict drones to the playing field? Net? Auto-lock? 你如何限制无人机进入比赛场地？
- What types of drones are suitable for kids to race with, in terms of size, speed, and complexity? 什么无人机适合孩子们比赛？规模、速度和复杂性？

Drones

- How can you simplify a drone controller for kids? 如何简化儿童无人机控制器？
- Is the easiest setting simple enough for kids to learn quickly? 最简单的设置是否足够简单，让孩子们快速学习？

Product

- Would it be possible for you to perform a drone demonstration at the start of the event? 你们能否在活动开始时进行无人机演示？
- Is it possible to provide brief training sessions to help kids learn how to fly drones before the race? 是否可以提供简短的培训课程来帮助孩子们在比赛前学习如何驾驶无人机？

Reward System

- What types of rewards or incentives work well to motivate and engage kids in drone racing events? 哪些类型的奖励或激励措施可以很好地激励和吸引孩子们参加无人机赛车活动？
- How can you encourage teamwork and a sense of sportsmanship among young racers? 如何鼓励年轻赛车手的团队合作和体育精神？

Appendix B: Interview Transcript with Starry

Note: The following interview was recorded in Mandarin, converted to text, then translated to English using software. Further, ChatGPT 3.5 was used to refine the translated English text, meaning the following may not truly express the original intent of the Interviewee. This is only intended as reference.
Note: "FPV" stands for first person view but can be used interchangeably with drone racing in this context.

Part 1:
Interviewer: Thank you for sharing your thoughts on the project. Let's start by clarifying the purpose of the competition. Could you explain why you initially thought of organizing a competition and what the main goals were?

Interviewee: Certainly. Initially, the idea was to promote FPV and drones in China. We wanted to create a platform where more people could understand and engage with FPV technology. The competition was seen as a means to achieve this goal.

Interviewer: I understand that the focus was on promoting FPV. However, it seems there's a shift in the approach, considering the challenges in finding suitable participants. Can you elaborate on the decision to potentially target elementary school students?

Interviewee: Yes, we encountered difficulties in finding FPV enthusiasts, so we thought about simplifying the process by involving elementary school students. The idea was to make it more accessible and easier for them to experience flying drones. However, we also discussed the possibility of shifting the focus back to an exhibition competition.

Interviewer: So, if I understand correctly, there are two potential directions – one involving elementary school students and another focusing on an exhibition competition. Can you discuss the advantages and challenges associated with each approach?

Interviewee: Absolutely. The advantage of involving elementary school students is that it makes the experience more approachable for a wider audience. However, challenges arise in finding suitable drones for them and ensuring proper coordination. On the other hand, an exhibition competition involving experienced pilots brings its own set of advantages, such as attracting more enthusiasts and potential sponsors, but the challenge lies in securing the right venue.

Interviewer: You mentioned the possibility of collaborating with schools for the exhibition competition. How do you envision this collaboration, and what benefits do you see in engaging with schools?

Interviewee: Collaborating with schools during their technology weeks could be beneficial. We can provide a drone exhibition, attracting students and raising awareness about FPV. This not only introduces them to the technology but also opens opportunities for potential partnerships. It aligns with the school's activities and can be a win-win situation.

Interviewer: In terms of the written article, you mentioned the need to rewrite and reevaluate the content. Could you provide insights into the specific topics and structure you envision for the article?

Interviewee: Certainly. The article should focus on the purpose and goals of the competition, detailing the shift in approach and the potential collaboration with schools. It could discuss the challenges faced in finding participants and drones for elementary students. Additionally, it should highlight the benefits and challenges of an exhibition competition, emphasizing the potential impact on promoting FPV.

Interviewer: Thank you for providing clarity on the project. It's essential to align the goals and strategies to effectively communicate the purpose of the competition. I'll review the details and work on structuring the article accordingly. If you have any additional thoughts or specific points to include, please feel free to share.

Interviewee: Thank you. I believe capturing the essence of our intentions and the potential direction for the competition is crucial in the article. If there's anything more you need from our end or any adjustments, let me know.

Interviewer: Absolutely. I'll keep you updated on the progress, and if further clarification is needed, I'll reach out. Thank you for your time and insights.

Interviewee: Thank you. I appreciate your assistance, and I look forward to the article reflecting our project accurately.

Part 2:
Interviewer: Thank you for sharing your insights and experiences. It seems like you have a good understanding of the competition and its challenges. Let's dive into some specific details. First, can you elaborate on how the collaboration aspect works in your competition?

Interviewee: Certainly. When it comes to collaboration, I've had experience with it a few years ago during our drone project. I also shared the process during our experience class. I can provide you with documentation on that. It involves organizing teams, managing the venue, and creating props. Safety is crucial, especially when involving children. We make sure the venue is secure, and participants wear protective covers. The drones we choose are safe, and I can share more details if needed.

Interviewer: That's great. Safety is a top priority. Now, about the equipment, you mentioned the availability of drones. Can you clarify how you can support in terms of remote-control devices?

Interviewee: Absolutely. Typically, we rent out our equipment, including remote control devices, when approached by others. However, for your competition, we are willing to provide our equipment for free. It's our way of supporting you. If there's an opportunity for mutual benefit, such as publicity for our company, we might consider additional support.

Interviewer: I appreciate your generosity. Regarding the competition itself, what suggestions do you have for rewards or incentives for the young participants?

Interviewee: In our previous experiences, we provided certificates for all participants as proof of their involvement. For winners, we created inexpensive medals or small rewards. It's not about the monetary value but the recognition. You could consider purchasing a plane or two as special rewards for champions. Commemorative items work well for children and help build a sense of accomplishment.

Interviewer: That sounds like a thoughtful approach. Lastly, how do you encourage teamwork and sportsmanship among the young racers?

Interviewee: Teamwork can be encouraged by incorporating programming aspects into the competition. Instead of solely controlling the drone by hand, participants can work on programming tasks and create a relay system. This not only enhances teamwork but also adds a flexible and dynamic element to the competition.

Interviewer: Thank you for sharing these valuable insights. It seems like you have a well-thought-out plan for the competition. If you have any additional details or concerns, feel free to share.

Interviewee: You're welcome. I'll provide more documentation on the collaboration and equipment details. If you have any specific questions, I'm here to help.

Appendix C: Rules and Regulation Evaluation Rubric

Index	Remarks	Percent of success (%)	Weight (%)
Relevance	This index assesses how pertinent and applicable the rules and regulations are to the specific context of the drone race for kids. It involves evaluating whether the regulations address the essential aspects of safety, fairness, and age-appropriate guidelines in the racing environment.		20
Efficiency	Efficiency in the context of drone race rules refers to how well the regulations facilitate smooth operations and compliance without unnecessary complexity or resource wastage. It measures how easily participants, parents, and event organizers can understand, implement, and adhere to the rules without undue complications.		20
Effectiveness	This index evaluates the extent to which the rules and regulations achieve their intended purposes. For a drone race for kids, it would measure how successfully the regulations ensure safety, fairness in competition, and an enjoyable experience for the participants while maintaining the overall integrity of the event.		20
Impact	Impact assesses the broader consequences and effects of the rules and regulations beyond the immediate scope of the race. It includes considering how the rules influence the attitudes, behaviors, and long-term safety practices of young drone racers, as well as their impact on the community and the growth of the sport.		20
Sustainability	This index examines whether the rules and regulations are designed to be sustainable in the long term. It involves evaluating whether the regulations can adapt to technological advancements, changing safety standards, and evolving skill levels of the participants while ensuring the continued growth and development of the drone racing sport for kids.		20
Sum			100

Appendix D: Drone Specifications Evaluation Rubric

Index	Remarks	Percent of success (%)	Weight (%)
Relevance	This index evaluates how suitable and appropriate the chosen drone model is for the age group and skill level of the young participants in the race. It considers whether the drones used are manageable, safe, and foster a positive learning experience for kids in the racing environment.		20
Efficiency	Efficiency, in the context of the drone model, measures how effectively the drones operate and how easy they are to handle for young racers. It assesses factors such as battery life, ease of control, durability, and maintenance requirements to ensure smooth and hassle-free racing experiences.		20
Effectiveness	This index evaluates how well the drone model contributes to the overall success of the race for kids. It assesses whether the drones allow for fair competition, promote skill development, and provide an engaging and enjoyable experience for participants while aligning with the objectives of the event		20
Impact	Impact assesses the broader implications of the chosen drone model. It includes considerations such as how the model influences the interest and enthusiasm of kids in the sport, whether they encourage continued participation, and if they contribute positively to the learning curve and skill development of young racers.		20
Sustainability	This index looks at the long-term sustainability of the chosen drone model for the race. It considers factors like adaptability to technological advancements, availability, affordability, and their ability to grow with the evolving skills of young participants, ensuring the continued interest and growth of drone racing for kids.		20
Sum			100

Appendix E: Event Schedule Evaluation Rubric

Index	Remarks	Percent of success (%)	Weight (%)
Relevance	This index assesses how well the event schedule aligns with the needs, attention spans, and energy levels of kids participating in the drone race. It evaluates whether the timing of races, breaks, and additional activities caters appropriately to the younger participants, considering factors such as school schedules and the duration of attention they can sustain.		20
Efficiency	Efficiency in the context of the event schedule measures how effectively time is utilized during the event. It evaluates whether the schedule allows for seamless transitions between races, sufficient time for practice or warm-up sessions, and minimizes unnecessary downtime to maintain the flow and engagement of participants.		20
Effectiveness	This index examines how well the event schedule accomplishes its intended goals. For a drone race for kids, it assesses whether the schedule allows for fair and competitive racing opportunities, balanced with rest periods to prevent fatigue, and facilitates an enjoyable experience for both participants and spectators.		20
Impact	Impact evaluates the broader implications of the event schedule beyond the immediate races. It includes considerations such as how the schedule influences the enthusiasm and interest of kids in drone racing, their overall experience and satisfaction, and whether it encourages sustained engagement in the sport.		20
Sustainability	This index looks at whether the event schedule is sustainable over time. It considers whether the schedule can adapt to changing circumstances, accommodate varying numbers of participants, and evolve alongside the growth of the drone racing community for kids.		20
Sum			100

Appendix F: Pilot Test Observations 1

- Kids are excited about the drone activity.
- Drones equipped with effective protective covers have a failsafe mechanism to stop blades upon resistance, ensuring safety.
- Intro Ceremony: Starts at 1:35.
  - Demo: Begins at 1:38.
  - Teaching: Starts at 1:44.
- Kids are divided into groups with varying teacher ratios (2 to 6 teachers).
- Kids, including younger ones, grasp drone basics. Initial practice is cautious.
- No major incidents, but concerns about uneven kid-to-teacher ratio.
- Successful navigation; an 8-year-old goes through a gate. Protective cover averts a crash.
- Kids enjoy flying drones.
  - Progress is observed with increasing confidence, ambition, and minor crashes (no major damage).
- Minor safety concerns expressed at 2:17 due to a close call.
  - Object collision at 2:18, but operations continue smoothly.
- A break is taken at 2:23, and note-taking stops.
- Concerns about battery supply and an inconvenient charging station location.
- Overall, the event is engaging, enjoyable, and focuses on safety and skill development in drone flying.

Appendix G: Pilot Test Observations 2

- Started set up at 11 am
- We started with a course with many elements.
  - Tested the course with members from HDU and WPI to see if the course was at the right level of difficulty.
  - If it was unable to be completed the first time, we simplified the course by removing an element or making an element easier.
  - Took us multiple tries to limit it down to one element with possibly making it harder for later in the competition.
  - For fear of being too boring and easy, another element was added.
- Tested that and it was too hard.
- The aviation club team member came to assist with checking the course and making sure they were set for their exhibit.
- While testing the course, we simultaneously tested the drones, found that they needed to be charged and made sure to charge them.
  - Wish we had access to an outlet onsite rather than in a nearby building.
  - Having phones as controllers seems to make the drone harder to control.
- Testing was done till the last minute.
- The kids arriving a bit early did not have much to do and left to entertain themselves.
- 1:31: off schedule
  - Nothing has started.
  - Kids still are missing.
  - Drones are being flown.
- WeChat main method of communication
  - Ex. Competition about to start, please take your seats.
  - Seems to work for the most part.
- Demo could have music.
  - 3 min long
  - Could have more variety.
  - 2 drones driven by two people.
- 1:44 teaching going to begin.
  - Kids split up into groups, parents tag along (5 groups of approx. 4)
  - Shows the controller (phone) and what does what.
  - Teach controls the first time showing each control while explaining as well.
- Have a standardized way of teaching perhaps.
  - Give controller to each kid to try out and give guidance.
  - Made sure the kids stayed a safe distance.
- Would need a waiver for the demo and the event in general.
- One group's drone was not connecting so was delayed in teaching.
- All kids seem very enthused about the drones.
- Battery life is low and can only support 3-4 min.
- Need to have more distance or safety measures when learning how to drone.
- The kids seem to be entertained even when other kids are learning.

    - Content just watching.
- Some teachers took some elements to teach with once they felt the kids were comfortable with the drones.
- Kids are helping each other learn.
- Batteries have to be replaced over and over again.
- 2:02 there was a crash where a 2-circle element was hit and one of the propellers was broken.
    - We had extra parts anticipating this and fixed in one minute (2:03)
- The guards should be more secure.
- There were issues with phone connectivity with a different phone.
- There are drones in close quarters of each other.
    - Need more training elements so they can be practiced by one drone at a time at the same time.
- Batteries are being charged at the nearby security station.
- Need to clear out field, some clutter with left over cones from other event.
- 2:13: kids seem to start to get off track, wandering off.
- 2:18 message was sent about taking a picture soon and a break before the competition.
- There was always someone with a drone flying.
- Better communication system between organizers would be ideal.
- 2:23 the people were corralled.
- 2:35 rules were introduced.
- Pic taken; model airplanes handed out as participation reward.
- Had to make impromptu racecourse.
    - Original too difficult
- No bracket system
    - Top scores got to compete to win.
- 2:45 start racing.
- As the competition went on, parents moved closer and closer to the field.
- Got reflight immediately after crashing.
- First to go left immediately
    - DNF with 2 attempts
- 2nd one took 2 min.
    - DNF
- It is too difficult.
- Wind is affecting drone performance.
- Communication barrier between officials/judges
- Battery is a big disruption.
- An element was removed after the third person tried it.
- 2 tries per person no matter what.
- Most participants struggling with simple gate.
- No one has lost control of the drone yet.
- Crashed through the gate and landed but still didn’t count as a win.
- 3:30: still competing.
- Doing the rounds one at a time got the kids bored and made them play other games.
- SECOND ROUND, harder element, 2 circles

  - Top 3 will win, only top 5 could compete.
- Major simplifications on course deign to accommodate participants and drone, on the whim decision (still in reference to secondary research however was not planned)
- Started without timer.
  - Reflight given.
- There were two judges timing.
- 3:51: kids are more proficient, but we are behind schedule.
- No injuries or mishaps

Appendix H: Pilot Test Observations 3

- Kids split into small groups, some learning to fly, others just playing with each other.
- Some small groups teaching to fly.
- Aviation club practicing, kids like to watch it.
- Maybe we should add music to the drone showcase.
- Keeping kids entertained as the others learn to fly/compete.
- Split into four groups, one drone each.
- Ran out of batteries even though we were charging the rest whenever one died.
- HDU team standing with the batteries.
- Seemed to be enough people to teach.
- One cool thing could be to set up some stalls, maybe the aviation club or the sponsor has some products laid out on a table and kids can look at it, because I noticed some kids walking up to the table of battery-less drone s and looking at it and being interested, so making something that kids can look at and maybe have someone there to talk to the parents about the educational things or product placement might be a good idea. Also fills up the venue's empty space.
- Venue is spread out a lot which makes for many small groups to form and do their own thing, making the event more open-ended and let kids explore.
- Kids having trouble with up and down controls, forward and backwards less so but some kids still struggled.
- Wind affected drone movement.
- Kids all seem to go too high.
- Some kids got bored and started playing.
- Had to change course multiple times in real time, re-explained rules of the competition (when to start and stop the timer, the route the drones go)
- Some kids walked onto the racecourse when we were trying to start (maybe should be stricter with arena borders)
- One drones propeller protection broke.
- We have many extras of the propeller protection and it's easy to reattach.
- But the drone fell many times and propellers and battery never broke, only one propeller fell off once and was easily reattached)
- One timer is good, but two or three would be ideal to get an average.
- Easy to take off and land drone.
- Some kids left because hungry.
- About a third of kids stayed to the end
- Participation awards given early on, before the competition (model planes that you assemble yourself), some kids built and were playing with the planes during the competition.

Appendix I: Rules and Regulations

1. Racing Circuit

The racing circuit is comprised of simple gate elements. The course is intended to be flown in a time trial format.

Course elements:

- Simple gate
- 180-degree turn
- Hurdle

The circuit should take 45 seconds to complete, on average.

Circuit difficulty is to be determined based on the skill of pilots.

2. Model

Each competitor will be given a model R130 before their race begins.

They will be provided to the participant.

Phone to be used as a controller.

3. Practice Flights

There will be a training opportunity available that will allow the participants to practice all 3 course elements (simple gate, 180-degree turn, hurdle). Practice flights coincide with the Qualifying Stage.

4. Contest Organization

The contest will be organized based on two stages:

- Qualifying stage
    - Participants are given time to practice and have 2 attempts to score their initial time, which will determine their placement in the final stage.
    - The top 5 scorers move onto the final stage.
- Final stage
    - Participants will have 2 attempts to compete in a time trial format. The top 3 scorers place first, second, and third, respectively.

4.1 Timekeeping

Time will be kept with a stopwatch. Clock stops when drone flies passed last gate.

4.2 Procedure for the start of the race

- After the models have been placed on the start area, the starter will ask the participant if they are ready to start.
- After confirming the participant is ready, the starter will signal to begin with a count down from 3 (3...2...1...GO).

The starter must immediately stop the race and do a restart when they consider that:

- The start procedure has not been done properly.
- A participant committed an early start (take-off before signaled).

5. Flight Occurrences

I. Obstacle damaged or destroyed during the race.

When an obstacle is accidentally damaged or destroyed during a race, the participants will be informed on how to proceed:

In the case where it concerns whether a damaged/destroyed obstacle is to be crossed, the decision may be to cross the obstacle, to bypass the obstacle, or to stop the race. When bypassing the obstacle is authorized, participants must do their best not to take advantage of the situation.

II. Faults and penalties

In the case an obstacle that needs to be crossed is not effectively crossed, the participant may try to execute a maneuver to cross the obstacle again. If the participant does not cross an obstacle to be crossed, the corresponding circuit lap will not be validated by their assigned judge.

In the case of a circuit cut (for example during a turn), the participant may execute as soon as possible a maneuver to come back into the circuit where the participant left it. If their assigned judge considers that the participant has not made the maneuver with sufficient urgency, the judge can decide that the corresponding circuit lap is not validated.

III. Disqualification from the race

A participant may be disqualified from a race in the following scenarios:

- A start before the start signal if it is considered that this early start gives a clear advantage to the concerned participant;
- A circuit exit (crossing of the safety line);
- Missing a gate;
- Exceeding time limit;
- Crashing;
- The piloting is hazardous or if safety is compromised;

The disqualification is decided at the discretion of the judge assigned to the concerned participant. When a participant is disqualified, they must land as soon as they have been informed. In any case, the result of the participant for the race will not be validated. If the participant is considered not being sufficiently cooperative to land, the concerned participant may be disqualified from the event.

IV. Crash

When a model crashes, the concerned participant can resume if the model is in a situation to do so.

V. Safety occurrence

The participant can be requested to stop the flight if it is considered the model no longer meets acceptable safety standards. It could be for example the case when a model is damaged after a collision or after a crash, or when the battery is dangling.

6. Reflights

Incidents during races such as a collision with an obstacle may justify a reflight. In addition, a reflight may be considered when:

- Either the model cannot start, or the flight cannot be made in normal conditions because of an unexpected cause beyond the participant's control.
- For a reason of safety, either the model cannot be prepared, or the flight cannot be made in the allotted time limit or when either is disrupted by an external interference.
- For a reason independent from the participant's will, the participant has been forced to land by request of an official. Failures of the model, motorization or radio may be considered as reasons independent of the participant's will.

Noise in the environment of the participants (noise in the public, noise from other competitors, …) cannot justify a reflight.

For any participant being granted a reflight, the original flight for which the participant has been granted the reflight is then definitively cancelled.

Reflights should take place immediately after it is determined that one is necessary.

7. Officials

In each race, each participant will be scored by a judge standing behind them. The judge will inform the participant when they are disqualified or must stop the flight considering the model no longer meets acceptable safety standards. The judge may notify the competitor of any infringement or if a lap is not validated but is not required to do so. The judge must be satisfied that any undertaking by the participant to re-attempt a missed gate, obstacle or circuit cut is conducted in compliance with the rules and that any competitive advantage has been forfeited. At the end of the flight, the participant will be informed if the flight is considered to be valid or if a disqualification has been pronounced; in the case of disqualification, the number of circuit laps done at the moment of the disqualification will be communicated to the concerned participant and recorded.

Appendix J: R130 Spec Sheet

Weight: 85g ± 10g
Wheelbase: 130mm
Battery information: 3.7V 1070mAH
Battery life: 8 minutes
Charging method: Micro USB charging interface/battery specific charger 5V1A
Flight altitude: 5m (software height limit protection)
Positioning function: TOF height setting, optical flow positioning
Camera video resolution: 1080P
Protective cover: Yes
Flight function support: one click roll, one click flight function
Flight control methods: virtual joystick remote control, remote control with remote controller, programming automatic control
Control software platform: Windows/Android
Programming language support: Scratch, Python, C++(scalable)
Other functional support: support for image recognition and voice control
Improved positioning accuracy: Support for QR code positioning (provide QR code images)
Cluster control: supported (additional cluster controller required)
Open: Open Network Control Protocol
Expandable hardware module: optional mechanical claw, colorful light, TOF ranging module

Appendix K: Event Schedule

Time	Duration	Event	Description
10:30	120 min	Set Up	Set up the course, including gates, flags, and safety nets. Drones to be tested on course.
13:30	10 min	Opening Ceremony	Quick verbal introduction on what the event is, why it's happening, and how it will be run.
13:40	15 min	Drone Showcase	The HDU Aviation Club will perform a 10-minute showcase.
13:55	15 min	Introduce the race course + Split students into groups	We will introduce the event as well as have the students move into their pre-assigned groups.
14:10	30 min	Training	Participants are given a time block of 30 min to practice flying.
14:40	90 min	Drone Race	Participants will compete in a head-to-head time trial competition
16:10	10 min	Awards + Concluding Statements	Awards will be handed out based on different criteria. Verbal statements congratulating everyone and thanking them for their time.
16:20	------	Clean Up	Clean-up process.

Appendix L: Drone Factors

Factors	Weight	Score
Vehicle flight performance	0.137	
Manipulative ability	0.115	
Operation duration	0.096	
Main application	0.088	
Maintenance costs	0.081	
Acquisition of parts and operation consumables	0.079	
Operation safety/security	0.074	
Flight power	0.068	
Operation cost	0.053	
Maintenance simplicity	0.05	
Purchase cost	0.046	
Maintenance convenience	0.033	
Operation convenience	0.03	
Operation supportability	0.03	
Operation environmental impact	0.02	