Aerodynamics

International School

2017

Word Count: 3502
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Investigating

Overview and Goal Statement

The goal for my personal project is to expand my knowledge on aviation. Specifically, I will explore the theoretical part of flight. I plan to focus my research on wing-aerodynamics. To show what I learnt, I intend to build a radio controlled airplane, which will definitively reflect my research. During the project exhibition, people will be able to see how planes fly. This project aims to change people's perspective on flight, as people do not understand the wonder of engineering.

Connections to Learning

Connection to Personal Interest & Intellectual Curiosity

Aviation is my passion as it runs in my family. I spent my childhood outside staring at planes flying over my house and since then they fascinate me. I spend most of my free time flying on my home simulator, expanding my practical knowledge day by day. Whenever I have the opportunity of entering a plane’s cockpit, I become speechless. Recently, I have flown a plane for the first time and now I plan to take aviation as my future carrier. I enjoy learning physics, so I am extremely excited for this project, as I believe flight is humanity’s greatest discovery. Even if my plane doesn’t fly, this will still be a great personal achievement which I hope will help me develop my thinking, communicating and research skills.

Connecting to a Global Context

This project connects to the “Scientific and Technical Innovation” Global Context as aviation is a scientific marvel. Through the interactions between people and the natural world, humans have brought communities together. Throughout the project, I will explore the natural world and its laws, then I will defy gravity to achieve “flight”. During the exhibition, I want people to understand that flight is a scientific marvel, as most people think air travel is uncomfortable and painful, but being able to go anywhere in the world in less than 24h is a miracle.
Prior Subject-Specific Knowledge & Skills

This project will help me build upon my knowledge of practical flight. I already have basic practical knowledge on flying, which means I can fly a plane. I have had flying lessons already, where I learnt how to fly a light aircraft. I believe that it is very advantageous to already have a strong understanding on the practical side, as I will be able to connect this to the theoretical knowledge that I will acquire through this project. Also, in previous Grade 9 Science classes, I have very briefly learnt the basic principles of flight. I was fascinated by these lessons and it made me want to learn more about the topic.

Throughout the MYP course, I have done many projects that needed concrete Investigation, Planning, Taking Action and Reflecting stages. This experience will greatly help me during this project. I learnt that time-management is an essential skill that this project will refine.

Evaluation of Preliminary Research

For this personal project, complex understanding on flight is required. I have used a wide range of sources from different organisations, research centres and universities to gain knowledge on the topic. I also learnt new skills using interactive YouTube videos.

In the beginning of the project, I had no idea what my product was going to be, so I discussed this with my physics teacher, Ms. Chuah. She said my topic was too broad so I had to narrow down my research question. She told me to concentrate on wing aerodynamics. This let me create a better research question: How does an airplane wing work?. This discussion greatly helped me refine and gain a better understanding of what kind of research awaits. I showed that with my own initiatives and social skills, I was able to refine my research question.

After this interview, I based most of my research on the NASA database (Glenn Research Centre. "Flight"), this well-known aerospace research centre provided me with an excellent summary of all the information necessary to begin my project. NASA had a wide range of information on aerodynamics, from beginner to advanced. Of course, I used the advanced section from where I was able to greatly expand my knowledge on aerodynamics.
using diagrams, equations etc. After completing research on aerodynamics, I had all the necessary information to start my specifications.

To be able to create an RC plane from scratch, I needed to develop my knowledge. I knew written documents such as pdf, guide etc. would not help me. I discovered a YouTube channel named “FliteTest” which was designed to help people enter the RC Flight Hobby. The channel had a series called “RC for Beginners” which teaches RC electronics from A-Z (RC Planes - Beginner Series. Prod. FliteTest). These sources provided me all the information necessary to create my entire list of product specifications.
(Refer to Appendix B: Extract 4 for full evaluation of sources)

Planning

This second section will provide a detailed account of how my personal project will be planned. I will begin by reviewing the product outcome specifications and then I will explain how I plan to complete the product using a step-by-step timeline. Finally, I will explain how I recorded my process and how it helped me through the project.

Product Outcome Specifications

For a plane to fly, there must be a strong, specific and measurable list of characteristics. I have created a table of specifications that will enable me to create a successful product. The specifications consist of the “Target Description” where I describe which characteristic the product should present. Then I explain why this target must be met in order to create a successful product and finally explain how this goal will be achieved.

(Refer to Appendix B: Extract 1 for full specifications):

1. What the plane must do

2. Control Surfaces
   i. Pitch
   ii. Yaw
   iii. Roll

3. Dimensions
   i. Wingspan
ii. Length
iii. Width

4. Centre of Gravity
5. Weight
   i. Frame
   ii. Electronics
6. Electronics
   i. Battery
   ii. ESC
   iii. Controller
   iv. Motor
7. Wings
   i. Airfoil
8. Material
9. Budget
10. Aesthetics

During the project, I have made multiple changes on the specifications in order to improve my product:

The budget was changed from 600RMB to 800RMB. When ordering the necessary components, I realised I was never going to be able to get all of the electronics under 600RMB. So I increased to 800RMB, which still a reasonable price.

In the beginning, I planned to use one 2200 mAh battery. When conducting research during the process, I saw that having two batteries is always better (RC Planes - Beginner Series. Prod. Flitetest). One battery will be in the plane and the other one fully-charged for backup purposes. The new chosen batteries were also lighter than the original one.
Action Plan

**Plan with Timeline**

To have the best possible outcome, I have created a detailed plan using excel. This plan summarises all the steps necessary to achieve the completion of my product. (Refer to Appendix B Extract 2). This plan consists of multiple steps with exact dates by which a task must be completed. I used the Gantt Chart format as I believe it shows a reasonable amount of detail to complete my product.

A number of changes were made to the timeline during the process as some very unexpected and major issues appeared:

**Nov 1- Nov 8:** After more research done on RC plane building (Biolethal. "RC Electronics."), it was recommended to always build the wing before the main fuselage part because the wing is what makes the plane gain lift, so if the wing has an issue (smaller or bigger than expected), we can adjusting the fuselage’s shape or size if needed.

**Nov 15- Nov 17:** When components were delivered, I realised that most of the electronics were missing connectors. The wires were naked. I quickly did some internet research (Noah. “How to Solder.”) and found out I needed to solder. This delayed me by only a week, which was a great surprise.

**January 5- January 12:** During the process of building the plane, I realised that it would be impossible to do the maiden flight before the 9th of December. I also realised that I needed to spend more time conducting ground tests to familiarise myself with the controls and check the functionality of the control surfaces (Recommended by RC experts: RC Planes - Beginner Series. Prod. FliteTest). I underestimated the time it would take me to get everything arranged for the maiden flight. There are many steps to make sure the product will work at its best (exactly like real life companies such as Airbus, which go through the same process).
Strategies for Managing the Process and Time

As an IB learner, it is very important to plan ahead to be able to create a successful product. To make sure I stayed on time and completed all tasks correctly:

- I met my supervisor every two weeks and recorded feedback points that he gave me. Then I set myself a small goal that I must achieve by the next supervisor meeting.
- I set myself the goal to stay after school every Tuesday and Thursday for 1h30 until the full completion of my product. I will be using the Design centre, where tools are available under supervision. This will give me the perfect workspace to create an RC airplane.
- I will work during lunch breaks when needed, if I sense that I am falling behind.
- By using our school's ManageBac website, I will set myself assignments on the calendar to remind me of tasks I must complete, (for example I can set myself the goal to complete a journal entry etc.) so I would not forget.

Recording the Process

To record the process of my project, I will use a handwritten journal. I have chosen this because I prefer handwriting as it will let me sketch and draw diagrams more easily than on an electronic platform. I will digitalise each entry I add to this journal, to rectify any spelling mistakes and improve the writing. I plan to write an entry as information arises. For example, each time I complete a task on my timeline, I might add an entry describing the process with pictures and an explanation on how it went. When meeting my supervisor, I will also write an entry, recording any feedback and setting myself a goal for the next meeting. I plan to keep each entry quite short, about half a page of handwritten text, which I will later digitalise on a word document.

Taking Action

I knew building a plane was not going to be an easy job, but I was motivated and had the will to build and fly my own aircraft. Before this project, I had never been faced with such a big responsibility to make something work. Here, I had to make decisions on my own, without
any help for decision-making. Here are the four major parts of my project with which I struggled, but refined my skills as an IB learner.

Creating the Plan

Creating the plane’s blueprints was a great challenge that took me a large amount of time. Because of the complexity of this part, I used one of NASA aircraft templates (Glenn Research Center. “Flight”), which I modified using my own airfoil and measurements. This part required me to look back at my research and make sure the different ratios (wingspan, surface area and weight) were matching. This part required me to work with extreme precision, to avoid imbalance.

Soldering

Few days after ordering the electronics online, components started to arrive. However, I quickly realised that some electronics had the wrong connectors or, even worse, no connectors at all. At this moment, I panicked. I had no idea what to do. I knew that I could somehow buy and add new connectors but I did not know how to do it. I quickly conducted internet research (Noah. “How to Solder.”) and found out that I needed to solder. I panicked again, I had no idea how to solder and where to do it. But through research and planning, I was able to relief stress. The next day, I went to talk to the school’s design teacher and asked if I could use the soldering equipment. This task required me to learn a totally new skill, which I enjoyed. This showed developed communication skills, that I did not have before. I was now able to quickly take appropriate actions for issue that arise unexpectedly.

Ground Testing

This was the most exciting part of my project: Experimenting with my own homemade plane. Before the first flight, it was crucial that I made sure the plane was in prefect condition. I experimented with the different control surfaces which gave me a hands-on experience on Newton’s laws (Refer to Appendix B: Extract 8). I made sure every single function was in perfect shape and concluded that I was ready for the maiden flight.
Maiden Flight

I was very excited for this day. After multiple weeks of building my plane, I was ready for the first flight. During this part of the project, I applied my prior knowledge on the topic. I acted as if this had been a real plane. Before the flight, I made sure everything worked exactly like a real-life plane. I checked everything like I would do on a real plane before flying (aircraft inspection etc.), so I could be sure nothing would go wrong. (See Appendix B: Extract 9) Unfortunately, the plane crashed on launch. When the plane was launched, it pitched up and I lost total control over it (my RC transmitter had no effect). I concluded that my plane crashed due to a shift in the Centre of Gravity (Refer to Appendix B: Extract 7 for full report on the incident). During the launch, I believe that the battery shifted back, destabilising my aircraft.

Reflecting

Evaluation of the Quality of Product

My goal was to expand my knowledge on flight, then create and fly a Radio Controlled airplane. By assessing my product against the “Product Outcome Specifications”, I can say that my product was a success. (Refer to Appendix B: Extract 5 for full evaluation)

→ I built a fully functional Radio Controlled Aircraft from scratch (Pitch, Roll, Yaw)
→ All electronics were working fine
→ The Aircraft moved with no problem on the ground using the rudder and thrust.
→ However, the plane crashed during launch caused by a shift of the Centre of Gravity

The product itself was very fragile. It was entirely made of a polystyrene foam, making it exposed to damage. I believed that I should have use a thicker material, which would have made the plane both heavier and stronger (I believe that my plane was too light).

Topic

During this project, I learnt a lot of new forces that act on a plane and specifically on its wings. I conducted a large amount of research on NASA’s complex aerodynamic force research. I learnt mostly on Bernoulli’s principle and Newton’s Third law in relation to the angle of attack. Now, I know exactly how planes fly, which was my goal as a “future pilot
cadet. Next time I fly a plane or a glider myself, I will better understand how my plane reacts to actions I perform.

In physics, learning facts is an important part, but understanding them is even more crucial. During the project, I learnt a lot when playing around with my plane. I better understood why planes had rudders, through experiments where I held the plane in my hands and applied full throttle, I moved the rudder left and right and felt Newton’s Laws in action. This experience really amazed me and gave me a great understanding of Newton’s third law. Through many other experiments, I saw and felt similar laws of physics in action. This was a great experience.

Global Context

During this project, I was able to learn the laws of the natural world surrounding us. I learnt how fluids, such as air, interact with man-made objects and how humans have used these laws to achieve flight. Later on in the project, I applied the theoretical knowledge I gained into practical knowledge through experiments, which really gave me a strong understanding of these laws.

Evaluation of Self-Management Skills

In completing my project, I encountered two major obstacles in managing my time. This first major obstacle was when I discovered that the electronics were missing connectors, some electronics had the wrong connector and some had just naked cables. After, I discovered this, I quickly conducted internet research and realised I needed to solder new connectors. I had never done such thing before. The next day, I talked to the school’s design teacher to ask if I could use the soldering equipment. Using YouTube videos from RC hobby channels and my father’s help, I learnt a new and unexpected skill. This was a great obstacle that delayed my process by a week but I believe that I did a great job at countering this major obstacle.

The second obstacle was that I underestimated the time it would take to build my plane’s wings. The plane’s wings needed to have a perfect symmetrical shape in order to perform a safe and smooth flight. Making a curved airfoil using polyester foam is a very challenging task that I overcame by experimenting with the material.
I believe that my time management skills were effective, this means that I acted as a *Thinker*. During the entire project, I did my work on time, respected every single part of my timeline and took responsibility for my own actions. When I was delayed by an issue, I always found some free time to catch up on some work. For example, I spent my break time working on my plane in the design centre. The timeline was an extremely useful tool that helped me keep track of all the work I had done and had to do.

**Developing as a Learner**

I surprised myself because I kept doing my work on schedule. I was extremely motivated by my love for aviation which gave me the will to build and fly my plane. Every Tuesday and Thursday after school, I spent time working alone on my plane which I first thought was going to be boring, but I was surprised by how much I loved to build things and make them work. Each time there was a problem, I was resilient and never gave up. I always found a way to counter any problems. Overall, I was amazed at how I could manage my emotions such as anger and frustration when I faced issues, and how I responded to them. I discovered how strong my passion and motivation for aviation is and how it helped me overcome such emotions. In the future, when learning to become a pilot, I will need this same passion, resilience and motivation to pass obstacles. I really enjoyed this long process even if my plane crashed.

I believe that I used my process journal correctly. The most important aspect was to be resilient, as obstacles are unpredictable. It was extremely important for me to be a *Thinker*. During the project, I encountered numerous issues that needed troubleshooting. For example, ailerons not moving, aircraft veering to the left etc. I was on my own trying to overcome these problems. I needed to analyse the issue and take appropriate actions to solve these various problems. If I were to do the project again, I would start by building my plane earlier as this would give me more time to troubleshoot problems as they arose.

Another thing that I would do different, is that I would take notes more often. When researching, I overestimated my memory skills, and I told myself “don’t worry I will remember this”, but this was a big lie. Next time, and in the future, I will note every new thing I learn, as this will save me time, which ends up being precious.
Since I was a kid, I always knew that in the future I would fly planes. When choosing this project, I had to set myself a realistic goal. I firmly believed I could build an entire plane from scratch. Because of my passion, I was extremely committed to this project. This taught me that motivation is key to success. I cannot stress how important motivation was for my project and how important it will be for me as an IB student and, hopefully, as a pilot in the future.

The RC Hobby is rewarding, but only after a long period of experiential learning. These kinds of projects are always learnt through experiential learning. After this first attempt at building an RC plane, I now understand the necessary skills and the importance of motivation to complete this project. The RC hobby requires resilience, meaning that I must accept this crash as a path towards success. Like the Wright Brothers, I must never give up. This project was overall a great, fun and rewarding experience.
Works Cited


Appendix

Appendix A: Annotated Bibliography

Dylan Lepicard
Mr. Taylor, Mrs. Surridge
MYP Personal Project
25th November 2016

Annotated Bibliography


This source was an interview made by myself, it is a primary source. The interview was done right after the first meeting with my supervisor. It lasted 30 minutes. From this interview I was able to determine and finalise my Personal Project’s goal. In the interview we discussed the different areas in aerodynamics. In the interview, I interviewed Ms. Chuah, the school’s physics teacher. The purpose of this interview is to get started with my research on the personal project. After the interview I understood that I need to concentrate in one area of aerodynamics as suggested by Ms. Chuah. So I chose to only research on wings. This interview was very valuable, it led me in the right direction to learn more about aerodynamics.


These documents are a secondary source. It summarizes all the aerodynamics regarding the wings. NASA’s Glenn Research Center has done all the experiments on aerodynamics and has documented this in-depth. The Glenn Research Center is one of the ten NASA branches, specialised in research related to astronautics and aeronautics. These documents are meant to be read by high school students who already have a basic knowledge on this topic (physics). There are many simple and very detailed diagrams representing wings and airflow. From this document, we can learn and understand most of the physics involving the wings. This source is very important to be able to achieve my goal. What I learn in these documents, I must teach it to other people during the final personal project presentation.

This article gives all the necessary basic knowledge to start building any radio controlled device. This article talks about all the necessary components needed to build an RC device such as a plane. It explains all the safety precautions we must follow and includes many different diagram to help understand. This document was written by a well-know user on Instructables RC community. He has written many articles on RC electronics and he is an expert in RC Electronics. Instructables is a very famous publisher for DIY (Do It Yourself) guides. This article was written in 2012 but since then, RC electronics have not changed much. This article is intended for beginners that have no or very little prior knowledge. After reading this article anyone should be able to start and install any electronics on a RC device. This source was vital for me to build my product. After reading this article, I knew everything I needed in order to start ordering and installing all the electronics. Of course this guide is limited for my topic. Airplane RC electronics are different to car and boat electronics, so this article was limited to the general RC world. We will still need to research more on airplane RC electronic guides to full understand how to use these electronics.


These videos explain how to fly an RC plane from A to B. It explains many things such as how to fly the plane, how to land and explains many safety precautions when flying. The video was created by Josh Bixler. Josh Bixler has been flying and building RC planes for more than 25 years. The videos were published by FliteTest on YouTube. These videos were created in 2014, this means the video includes the latest RC technology. These videos are intended for beginners that know nothing about RC Electronics. After watching these videos, we should be able to fly our newly built RC plane without crashing. This source will greatly help fly the plane to prove the principals of physics.


This source is very important to understand the principals of physics. This source summarises all the principles of flight such as: pressure drag, friction drag, vortex drag and lift. This website uses many diagram making it easier to understand the principles. This source was created and published by
the Smithsonian National Air and Space Museum. This source is intended for aviation enthusiast that want to learn more about basic aerodynamics. From this article we should know all the essential aerodynamics that my RC plane should prove. However, this source is very basic, there is very simple information about each subject to learn more we must research in more advanced sources such as NASA's database.

Appendix B: Process Journal Extracts

Extract 1

<table>
<thead>
<tr>
<th>Category</th>
<th>Target Description</th>
<th>Why must it be respected?</th>
<th>How it will be achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>What will it do?</td>
<td>The airplane will take-off and fly at a constant altitude for at least 2 minutes and land without damaging the fuselage</td>
<td>The flight will be used to demonstrate the physics behind flight.</td>
<td>Test the plane during the maiden flight. Get help from someone to complete this task on time.</td>
</tr>
<tr>
<td>Control Surfaces</td>
<td>Must have 3 axes (Pitch, yaw and roll)</td>
<td>The ailerons let the plane turn left and right. The elevators let the plane go up and down.</td>
<td>The plane will have ailerons (wing) and elevators (tail)</td>
</tr>
<tr>
<td>Dimensions</td>
<td>Wingspan: 100-115 cm Length: 60-70 cm Width: 20 cm</td>
<td>If wingspan is not met, the plane will have too much lift or not enough lift.</td>
<td>During the Build Planning phase, the parts will be designed at the exact dimensions</td>
</tr>
<tr>
<td>Center of Gravity</td>
<td>The center of gravity must be below the wings or the plane will crash/not take-off</td>
<td>This is the most important specification. If the plane is nose or tail heavy, the plane won’t fly.</td>
<td>During the process of the entire build, I must keep all components in a way that the CG is below the wings.</td>
</tr>
<tr>
<td>Weight</td>
<td>The plane will be 800g maximum Frame: 50-75g Electronics: 500g max</td>
<td>If the plane is too heavy, it will be too hard to control and will have difficulties taking-off.</td>
<td>Weigh all components and reduce amount polystyrene foam and check the weight of electronics before buying</td>
</tr>
<tr>
<td>Electronics</td>
<td>2x LiPo 3S 1500mAh min (approx. 20 min of flight) 4 9g Servos min 50A ESC FS-i6 Controller 1000kV Motor</td>
<td>I must respect the electronics or it will cause malfunctions or even fires. If the motor is too powerful or weak, the plane will crash.</td>
<td>When ordering online check the exact specifications to avoid any incompatibility with different electronics.</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Wings</td>
<td>It will use an optimized airfoil</td>
<td>When using this airfoil, the plane’s aerodynamics will be much more optimized. Gliding will be more efficient.</td>
<td>Polystyrene Foam will be cut and shaped with the CLARK-Y airfoil.</td>
</tr>
<tr>
<td>Materials</td>
<td>6 sheets of 6mm 70x100cm Depron Polystyrene Foam and 5mm 10x10cm Plywood and 3 rolls of Duct Tape</td>
<td>Using these materials, the plane will be lighter. If the plane is lighter, it will be more efficient especially when gliding.</td>
<td>All materials will be bought in a local construction shop with exact dimension to avoid any possible problem</td>
</tr>
<tr>
<td>Budget</td>
<td>Maximum of 800RMB or 100EUR</td>
<td>I must not spend too much on this project.</td>
<td>When buying search for best quality to price.</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Plane will have an IST logo to represent IST. Polystyrene will be plain white. Try to keep all electronics invisible.</td>
<td>This will make the plane &quot;attractive&quot;</td>
<td>Print out colored IST logos. Wires and servos will be placed inside the fuselage</td>
</tr>
</tbody>
</table>
### Extract 2

<table>
<thead>
<tr>
<th>Task</th>
<th>19 Oct</th>
<th>26 Oct</th>
<th>27 Oct</th>
<th>01 Nov</th>
<th>03 Nov</th>
<th>09 Nov</th>
<th>15 Nov</th>
<th>17 Nov</th>
<th>22 Nov</th>
<th>24 Nov</th>
<th>29 Nov</th>
<th>05 Dec</th>
<th>06 Dec</th>
<th>12 Dec</th>
<th>09 Jan</th>
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<th>12 Jan</th>
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<tbody>
<tr>
<td>Research on airfoils and make a final decision</td>
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<td>Develop the plane production plan</td>
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<td>Construct the main fuselage and tail</td>
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<tr>
<td>Construct the wing</td>
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<tr>
<td>Solder the necessary connectors to the wires</td>
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<tr>
<td>Install motor, ESC and propeller</td>
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<tr>
<td>Install the servos on the ailerons, rudder and elevators</td>
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<tr>
<td>Install and adjust the receiver</td>
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Discussion with Ms. Chuah

Today I met with Ms. Chuah, the school's Physics teacher. I went to see her to expand on my research question so I can finalize my product idea and start researching. This is a summary of what we talked about:

Areas to look at:

- The research question "How do machines fly?" is too broad. There are too many principles to learn. Ms. Chuah told me to concentrate my research on:
  - Wings:

![Diagram of Angle of Attack](image1)

![Diagram of Lift and Drag](image2)
- These are the most important principles of flight that are easily comprehensible by anyone.

**Research Question:**

After my interview with Ms. Chuah, I finalized my research question. It will be: "How does an aircraft’s wing work?"

This research question will let me explore all the principles of flight behind an aircraft’s wing. I will mostly explore:

- Lift
- Drag
- Angle of Attack

I will certainly use NASA’s databases. They provide diagrams, great explanations and videos.

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**Extract 5**

<table>
<thead>
<tr>
<th>Category</th>
<th>Target Description</th>
<th>Criterion Assessment</th>
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<tbody>
<tr>
<td>What will it do?</td>
<td>The airplane will take-off and fly at a constant altitude for at least 2 minutes and land without damaging the fuselage</td>
<td>Unfortunately, the product did not meet this criterion. As we saw in the maiden flight video, the plane lost control right after the launch. When the plane was thrown, the plane climbed drastically and suddenly stalled. This was caused by a CG imbalance. The CG shifted during the launch, this cause the plane to lose control. I wasn’t able to control the plane at all, so this criterion was not met.</td>
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<tr>
<td>Control Surfaces</td>
<td>Must have 3 axes (Pitch, yaw and roll)</td>
<td>The plane did have the 3 control axes, using the ailerons, elevator and rudder. All were fully functional, the rudder however, was vibrating a lot. This was not a major issue but this might have effected the amount of turbulence during flight.</td>
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<td>Dimensions</td>
<td>Wingspan: 100-115 cm Length: 60-70 cm Width: 20 cm</td>
<td>The plane had all the correct measurement, these measurements had to be of a extreme accuracy to be able to have a controlled flight. The plane’s plan had all the correct dimensions, with e</td>
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<tr>
<td>Center of Gravity</td>
<td>The center of gravity must be below the wings or the plane will crash/not take-off</td>
<td>The center gravity was effectively placed below the wings. This was checked multiple times before the flight. Unfortunately, during the launch the battery shifted causing the plane’s center of gravity to move. I lost total control and the plane hit the ground.</td>
</tr>
<tr>
<td>Weight</td>
<td>The plane will be 800g maximum Frame: 50-75g Electronics: 500g max</td>
<td>The total weight of the entire plane was 490g safely under the 800g. The plane’s fuselage was weighed before I added the electronics and it weighed 90g. Although the fuselage was heavier than expected, the plane was safely under the maximum weight. However, the plane was too light. The engine was too strong for this small weight.</td>
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<tr>
<td>Electronics</td>
<td>2x LiPo 3S 1500mAh min (approx. 20 min of flight) 4 9g Servos min 50A ESC FS-i6 Controller 1000kV Motor</td>
<td>All these electronics were used, all the electronics functioned correctly. Using these electronics, all the control surfaces were fully functional. The batteries were large enough to function a long period of time. To improve on this, I would need to use a larger battery, for example a 2200mAh. This would increase the plane’s weight as it was a bit too light.</td>
</tr>
<tr>
<td>Wings</td>
<td>It will use an optimized airfoil</td>
<td>This criterion was met, the plane’s airfoil used the Clark-Y airfoil researched by the NASA. This airfoil is very similar to the one used in most light-aircraft.</td>
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<tr>
<td>Materials</td>
<td>6 sheets of 6mm 70x100cm Depron Polystyrene Foam and 5mm 10x10cm Plywood and 3 rolls of Duct Tape</td>
<td>The plane used the correct materials. However, this material was too weak. In future airplanes I will build, I will certainly use a thicker foam as this was too thin. With a stronger material there would have been less structural damage during the crash. During landings, the plane’s landing gears would cause less damage at impact to the fuselage.</td>
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<tr>
<td>Budget</td>
<td>Maximum of 800RMB or 100EUR</td>
<td>The budget was respected, I spent a total of 787RMB during this project, including the extra connectors I bought in emergency.</td>
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<td>Aesthetics</td>
<td>Plane will have an IST logo to represent IST. Polystyrene will be plain white. Try to keep all electronics invisible.</td>
<td>This goal was not met, I was planning to put the decorations after the first flight, however the plane crashed and I was unable to stick any decorations to have nice aesthetics. However, all the cables were effectively hidden, which also helped the plane’s aerodynamics.</td>
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*Extract 6*

**Soldering**

This step of the production was not expected. I needed to learn a new skill, soldering. I had personally never done any soldering. I was very nervous when I was doing it.

It took me about 1h30 to finish all the soldering. My father helped me solder. He has done it about 10 years ago but he still remembers how to do it. It was challenging
to learn this new skill. I really enjoyed learning how to solder. I successfully soldered all the required electronics.

Here is a picture of one of the XT60 connectors, I used a heat sleeve to cover the exposed soldering iron. The result looks great. I completed this task with unexpected success.

Extract 7

Air Crash Investigation

After my plane crashed, I immediately started to investigate the reason of the crash. In the video, we see the plane going in a rapid climb and then it stalled. There are multiple reasons for this sudden increase in altitude. I was pushing the stick down trying to get the plane to stop climbing but it did not respond. The most probable reason is that the plane was tail heavy. However, this is impossible because I checked the CG twice before taking-off. Now the only reason for this crash is that during the launch, the the CG moved from its original position. This means that something within the plane moved backwards causing the plane to lose control. This happened to a Boeing 747, 10 years ago in Afghanistan. The cargo shifted backwards causing the plane to lose control. Now, my plane cannot be repaired, only the wing is intact.