# **Project Summary**

**Abstract:**

During Aerobatic flight, pilots would like to correlate their control inputs to the airplane’s behavior and to be able to visualize what the maneuver looked like from the ground. As a result, we are going to design an Aerobatic black box system which contains two parts. First, a hardware data collecting system can collect attitude, position(by AHRS/INS), control input, and flight gauges(by camera ). Second, simulation software can process the data and generate the aircraft maneuver from the judge's position. The system can help the pilot to learn flight, and also provide a better method for practice.

# **Need for this Project**

Aerobatic performances are very different from ordinary flying tasks. General pilots use scientific methods to avoid risks during training, while aerobatic pilots take the initiative to face risks and use their lives to challenge the limits of aircraft performance and flying skills. In the field of aerobatics, there is no limit to the exploration of pilots' flying skills. In different aerobatics, the aircraft's flight status, altitude, speed, direction, and overload parameters change drastically. The pilot must be aware of the flight status at any time, understand the changes in motion parameters, and control the aircraft to move on a predetermined trajectory in a timely and accurate manner. During competition training, ordinary avionics cannot record and replay 3D demonstrations of flight training, and pilots cannot make precise movement adjustments based on their supervisor's experience.

In order to help pilots to understand the status of the aircraft, the AHRS came into being, which can help pilots understand the real-time aircraft attitude. However, this system lacks 3D playback of aerobatics, cannot help the pilot to watch the aircraft attitude from the referee's point of view, and cannot record real-time pilot input, which does not meet the needs of an aerobatic pilot during training.

Our Aerobatic Black Box will address these issues by providing a hardware part which contains AHRS, INS, and a camera to collect pilot input, and a software part which allows pilot replay 3D demonstration of flight training, and also provides pilot input corresponding to every maneuver. Aerobatic Black Box is specially designed for introductory aerobatics pilots and aerobatics training. This system will allow pilots to observe different angles of flight attitude for the next flight adjustment, and also solves the lack of digital AHRS in some aircraft, and greatly reduces the difficulty of aerobatics training.

# **2 Problem Statement and Deliverables**

**2.1 Problem statement:**

Our system not only displays and records the visualization of the plane’s status over the map during the flight but also records the pilots’ input data which can be viewed after the flight. In reality, multiple devices can display and record the flight data, but no one can display the direct view of the plane’s status, and it is impossible to record pilots’ input. In our system, we incorporate AHRS and INS systems with the visualization of the flight from the judge’s position, so the pilots can easily see the real-time plane behaviors, and they can compare their input with the plane behaviors after flying. Also, our system can record the data from the flight gauges such as the airspeed and engine speed. This can help some beginners to see the difference between their inputs and the actual plane’s status. Our system also can record the video from the cockpit to share online. Furthermore, our system has to be easy to install and remove, and the pilots don’t need to interact with it during the flight. For some experienced pilots who are engaging in the flight competition, our system has the ability to monitor the plane’s behaviors if it violates the rules of competition.

**2.2 Deliverables:**

1, A Central Processing Unit(CPU):

1. Storing pilot's input.
2. Extracting data from AHRS and INS.
3. Building the 3-D model of plane’s behaviors from AHRS and INS.
4. Recording the plane’s behaviors which can be incorporated into pilots’s inputs

after flying.

2, AHRS sensors:

1. Getting the information of the plane's altitude, acceleration, angular rotation, and magnetic force.

3, INS sensors:

1. Getting the orientation, position, and velocity of the plane without external references.

4, Cockpit Camera:

1. Capturing the pilot’s input from the cockpit of the plane.
2. Sending the pilot’s input to the CPU.
3. Recording the data from the plane’s dashboard.

5, User Interface(UI):

1. Displaying the real-time 3-D model of the plane’s status.
2. Displaying pilot’s input with the recorded plane’s behaviors after the flight.
3. Sharing the flight data online.

# **3 Visualization**

This short section should help the reader see the relationships among project functions and possibly the physical or interface requirements defining the project. The visualization could take many forms. Choose the one or two that best convey the problem’s structure. Focus here on conveying the required form of the project, rather than presenting a preliminary design.

1-2 pages

# **4 Competing Technologies**

Describe the more significant competing technologies that you have studied. Don’t bother to argue what is better about your ideas. The point here is to extract insight about your requirements. What did these competing projects have as requirements? Are you incorporating these in your requirements?

Competing technologies might be products that solve the same problem as your project. Or they might be similar technologies to your project, or similar to a significant part of your project.

Patents, IEEE/ISO/ASME standards might also be listed as “competing” technologies, in that they state formal requirements relevant to your work.

These documents, web sites, patents, etc. should be listed in the References.

The competing technology we studied is called Data Comets, which is designed for Unmanned aerial vehicles (UAVs). Generally, the project is to design a visualization tool for analyzing autonomous aerial vehicle logs with grounded evaluations. Its main fundamental function is to visualize the Autonomous Aerial Vehicle flight path and communicate the flight logs with ground. This technology has a high similarity to our project. Since both projects are all aiming at the plane and the log of the plane.

The first thing which interests us is its requirement for monitoring pilot input, since we are told that it is not allowed for us to import anydata from the plane. We adjust our means of monitoring aerobatics to using multiple optical sensors which record both the data shown in the dial and the movement of mechanical structure to interpret the aerobatic status.

After that, We notice there are also some advantages in its user interface, it will display three main views: the map, attribute tree, and timeline. In the maps, the flight path, setpoints and predicted flight path can be optionally shown. The timeline shows the velocity of the whole flight and could adjust what section of time the user would want to watch. In our project, we are trying to improve and incorporate these three functions into our project. In the map view, our project is trying to not only visualize the flight path but also what the maneuver looked like from the ground. Moreover, we also want to develop the function of setting setpoints and desired flight path in further development. In the attribute tree view, our requirements are adjusted to show the most pilot inputs like roll angle and pitch angle, air speed, altitude, and velocity. Since most of the clients are interested in competence, with these functions, users can easily review the flight and find what they could improve to better drive the flight.

# **5 Engineering Requirements**

This is the low level work.

Each requirement should meet the criteria for good requirements (abstract, verifiable, unambiguous, and traceable). You can present these in any format. See the examples Dym, Little, and Orwin “Engineering Design – A Project-Based Introduction”.

**Data Collection System**

Measurement Requirements

* The data collection system must measure and record the position (latitude, longitude, and altitude) and attitude (pitch, roll, and yaw) of the aircraft over time
* The data collection system must measure and record the positions of the flight stick, rudder pedals, and throttle (collectively the pilot’s control inputs) over time
* The data collection system must measure and record the value of the airspeed indicator dial located in the cockpit of the aircraft over time
* The data collection system must continuously record each of the above data points at a frequency of at least 20Hz
* The data collection system must record a timestamp alongside each of these data points

Operating Environment Requirements

* The data collection system must survive temperatures of -40C to 50C in storage and 0C to 40C in operation
* The data collection system must continue to collect data according to the Measurement Requirements and remain securely attached to the interior of the plane while under a g-force of at least 15G
* The data collection system must survive the vibrations of an aerobatic plane in flight – to be tested in a Citabria 7ECA
* The data collection system must operate for at least 30 minutes during flight without any interaction from the pilot
* The data collection system must be powered either by a 12V bus or by battery
* The data collection system must not modify any part of the aircraft to comply with FAA regulations

**Visualization System**

Requirements

* The visualization system must provide a 3D representation of an aerobatic flight reconstructed from the flight data recorded by the data collection system
* The visualization system must allow the user to view the flight from any camera angle
* The visualization must play at 20Hz or more

# **6 Appendix A References.**

List, in appropriate bibliographic form, those standards, patents, articles, etc. used in this document.

Saffo, David & Leventidis, Aristotelis & Jain, Twinkle & Borkin, Michelle & Dunne, Cody. (2020). Data Comets: Designing a Visualization Tool for Analyzing Autonomous Aerial Vehicle Logs with Grounded Evaluation. 10.31219/osf.io/a4hfd.