ThroughBox: better Blackboxes using 4G technology

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***Abstract*—Small aerial vehicles do not come with traditional black boxes, making it difficult to retrieve critical flight data and diagnostics in the event of an air crash. This paper introduces "ThroughBox" a novel approach that leverages 4G technology to replace conventional black boxes by continuously transmitting flight data at regular time-periods. The proposed solution integrates a 4G module into a specially designed, metal-encased compartment within the aircraft. This compartment not only ensures the continuous transmission of real-time data to ground-based systems but also enhances the chances of locating the compartment after an incident. By transmitting essential flight information, "ThroughBox" aims to improve post-accident investigations, provide quicker access to data, and enhance safety protocols for small aerial vehicles.**

***Index Terms*—FDR, 4G, Black boxes, Data transmission**

I. Introduction

Small flying vehicles, like manned drones and light planes, usually do not have regular black boxes. This makes it hard to get important flight data and checks during a flight or after an accident. Without this data, finding out what happened in incidents can take longer or may not be clear, which can be a danger to both the aviation industry and public safety. This paper introduces a new method called "ThroughBox," replacing traditional black boxes by sending flight data continuously at set times via 4G technology.

The "ThroughBox" includes a 4G module in an aircraft mounted within a specially designed metal box. This device assists the forwarding of live flight data into the ground systems. This process also aids in restoring the box room after an accident and offers quicker access to critical flight information. In this process of transmitting data in real-time, "ThroughBox" aims to contribute toward better investigations after accidents and enhance safety regulations for small aircraft by presenting a useful and affordable alternative to regular black boxes.

II. History of Black boxes in Aviation

Black boxes, or flight data recorders (FDRs) and cockpit voice recorders (CVRs), represent an important tool that records how an airplane performs and what pilots say to help in making flying safer. The idea began in the middle of the 20th century when fast commercial flying growth escalated risks so much that it became important to find out why accidents occurred. Most of history can be broken down into three parts.

It is said that the idea of a black box was the idea thought of for the reliable recording of data after so many aerial mishaps. Often, this masterpiece was credited to the Australian scientist, Dr. David Warren. In 1953, he first conceived the idea of the flight recorder that would record flight data and what pilots were communicating. His first apparatus was termed the Flight Memory Unit. The flight memory unit was to endure crashes and be tamper-proof.

However, by the middle stages and improvements, black boxes became required in many countries due to rules from aviation authorities. This was also the time of new technology, including magnetic tape-based recorders, which improved recording ability and strength.

Today's black boxes are digital and have solid-state memory. This helps them store more data, last longer, and record for a longer time. The creation of underwater locator beacons also made it easier to find them after ocean crashes.

III. Regulations

Organizations such as the International Civil Aviation Organization as well as the Federal Aviation Administration in the United States have stated that it is necessary for black boxes to be fitted on aircraft carrying more than 20 passengers. By using these black boxes, comprising of the FDR and CVR, it becomes possible to capture flight data as well as sounds from the cockpit. This will help the researches know what happens wrong in case of accident and make air travels safe the next time.

It does not matter in case of the smaller airplanes which include a lot of private jets and helicopters. These carry less than 20 passengers, thus do not require the black boxes.

Then this becomes a safety concern since most of the crashes do not give the investigators all the information they would need to understand what had happened. It becomes difficult to be able to learn the lesson that would have possibly made safety even better and changes that may be important may not actually occur to prevent accidents.

This is an important gap in the regulations because most of these crashes involve smaller, private airplanes. In fact, statistics show that general aviation or personal and non-commercial flights make up a large percentage of all air accidents. Investigations into such occurrences tend to be incomplete without black boxes, with questions remaining unanswered and opportunities for safety improvements unexploited. This project proposal will bridge the gap between commercial aviation and personal aircraft safety. It provides data transmission as opposed to the conventional read-and-hold method.

IV. Prototype

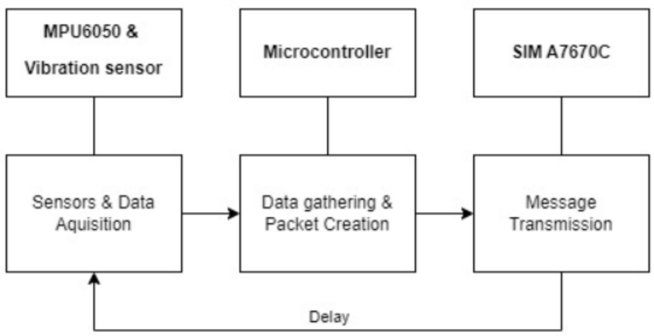

Fig. 1. Dataflow for the protoype including devices.

The new black box system has incorporated an innovative prototype which is carefully built to gather and transmit basic and critical data with the aim of improving safety measures and ensuring adequate accident analysis. The new system's workflow begins by gathering data from MPU6050, including a gyroscope and an accelerometer, further which uses a dedicated vibration sensor used in monitoring vibrations. From there, the microcontroller takes over to process the information and organize it into structured packets ready for transmission. At the final end of this operation, the SIM A7670C 4G module finds use in efficiently transmitting the packages in structured form to a remote server or database, ensuring that the data is communicated safely and efficiently. This cycle works as a continuous one where the delay mechanism is discovered to ensure a periodic time interval between each occurrence of data transmission events.

The MPU6050 is a sensor of high regard and very extensively used in different applications because it perfectly integrates a 3-axis gyroscope along with a 3-axis accelerometer into one device. This makes it very suitable for properly detecting orientation, motion, and acceleration that are all important for the accurate reporting of the dynamics of a vehicle when it is in flight. It has the ability of providing sensitive and real-time data that could be instrumental in reconstructing patterns of movement or sudden changes that could occur and precede an accident.

The vibration sensor is meant to detect the mechanical vibrations. So, in case it can sense any abrupt jolt or change happening in motion, it will capture that too. It would complement the MPU6050 perfectly by offering an additional sensitivity layer intended particularly for impacts or mechanical disruptions - something that might generally indicate some underlying issue worth paying attention to.

The microcontroller plays a vital role as the core processor in the prototype system, serving the essential function of gathering data from the various sensors and subsequently organizing this information into packets that are appropriate for transmission to other devices or systems. While it is true that there are numerous microcontrollers capable of fulfilling this important role—examples of which include the ESP32, STM32, and various Arduino-compatible chips—I ultimately decided to select the ATmega 328. This choice was influenced primarily by its widespread availability in the market as well as its user-friendly characteristics that make it easy to work with for both beginners and experienced developers alike. One of the most used microcontrollers of the Arduino Uno boards is the ATmega 328; it equips an appropriate amount of processing power along with a reasonable capacity of memory. Therefore, it would be possible to cover various tasks such as sensor data collection, preliminary stages of data processing, communication processes that are required for relating to external modules, and much more. Besides that, it is endowed with an extremely powerful support system - very rich in various very useful tools and libraries - which greatly simplifies the developers' task of programming and prototyping. Even if simple enough in design, the ATmega 328 proves to be reliable and efficient when performing tasks involving sensor interfacing and serial communication. Therefore, it is highly practical in terms of the needs of this prototype project.

The SIM A7670C represents a very sophisticated form of the 4G communication module in which the concept of data transmission to remote locations was specifically designed. This module supports high-speed data transmission, and thus sensor data transmitted rapidly is ensured to be reliably transferred to the assigned server or in cloud-based storage solutions. Additionally, due to its affinity for using a wide variety of network protocols and its very impressive capability to work successfully in real-time, this module stands as an ideal choice that meets the very varying and dynamically changing needs of modern data transmission. This module exploits some of the advanced capabilities provided by the 4G network to establish highly efficient connections between the microcontroller and various remote data handling systems. Ensuring that critical information in the black box is available for retrieval after the occurrence of an incident so it can be analyzed and reviewed exhaustively.

Literature Review

Now there is very limited data available in the domain of transmitting raw information over distances utilizing 4g technologies. Following articles match my project work and have been useful and educative with respect to my efforts for this paper.

[1]This section introduces the various terminologies and data types that constitute the Flight Data Recorders (FDRs) in modern aircraft and explores the significance of this data across multiple domains, including the commercial market, flight school education, and judicial processes. FDR data can be collected from a variety of sources, such as avionics, cockpit controls, and monitoring systems. Traditionally, this

data is stored on a Solid State Drive (SSD) within the black box of the aircraft. However, my proposed approach suggests a significant departure from this conventional method by writing critical FDR data to the nearest Air Traffic Control (ATC) or home base, thereby enhancing accessibility and reliability.

[2]This section discusses the evolution of black boxes, particularly focusing on improvements in data management, storage capabilities, and physical durability over time. Historically, black boxes have been primarily designed with commercial aircraft in mind, neglecting the unique requirements of smaller, private aircraft. My proposed design aims to address this disparity by bridging the gap between the security concerns of commercial and private aircraft. This innovation would provide enhanced data transmission capabilities that are equally suited to both types of aircraft.

[3]This section outlines the crucial parameters that should be considered when developing an information package for transmitting data from an aircraft to a home base or ATC. The paper argues that understanding and optimizing these parameters is vital for ensuring the successful transmission of flight data, which is critical for a range of applications, from post-incident investigations to real-time monitoring.

[4]This published paper talks about Black boxes, composed of the Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR), are crucial for post-incident investigations. These devices capture vast data sets including altitude, airspeed, engine performance, and cockpit audio. Despite their resilience—able to withstand extreme forces and temperatures—there are limitations. Issues such as damaged units or unrecovered black boxes have hindered some investigations, as seen in the 2014 Malaysia Airlines Flight MH370 incident. Current models consists of drawbacks such as Data Limitations, Battery Constraints. This paper also talks coincidentally with focus on integrating real-time data transmission via ”glass box” systems that utilize cloud computing. This concept proposes streaming flight data to ground servers, enhancing immediate post-crash information retrieval. Satellite communication, while costly, is the primary channel for over-sea data transfer.

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