Open Access and Peer Reviewed Journal ISSN 2395-1303 https://www.ijetjournal.org/

RESEARCH ARTICLE OPEN ACCESS

Design and Simulation of an ARINC-429 Interfacing and Ingestion Module for Real-Time Aircraft Data Acquisition: System Overview and Functional Validation

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Abstract — *Flight Data Recorders (FDRs) and Cockpit Voice Recorders (CVRs) are the standard systems for capturing aircraft data, designed primarily for post-flight and accident analysis. They do not provide a continuous real-time monitoring channel to the ground. This paper presents the system design and functional simulation of an Interfacing and Ingestion Module (IIM) for the BLUE BOX real-time aircraft telemetry system. The IIM acts as a non-intrusive, parallel monitoring lane alongside the existing FDR/CVR systems. The proposed module accepts flight data, cockpit audio, and cockpit video as inputs and processes them through a chain that includes engineering-unit conversion, CRC-16 error detection, timestamp generation, priority handling, FIFO buffering, and packetization. The system is modelled and simulated in MATLAB/Simulink. Functional validation results covering controlled error injection, CRC-16 error detection, ground-station data recovery, and throughput measurement confirm that the proposed IIM processing chain operates correctly and provides a viable architecture for real-time aircraft data monitoring.*

Keywords — BLUE BOX, Interfacing and Ingestion Module (IIM), aircraft data acquisition, real-time monitoring, CRC-16, error detection, MATLAB/Simulink, FDR, CVR, flight data recorder

I. INTRODUCTION

Modern aircraft generate continuous streams of flight parameters, navigation data, engine health indicators, and cockpit activity information throughout every flight. The conventional Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) store this information for post-flight or post-incident investigation, but they do not transmit it to the ground in real time. This means that during the flight, ground engineers have no visibility into the aircraft's condition — an anomaly can develop and escalate without any ground-side awareness until after the flight has ended or, in the worst case, after an accident has occurred.

The BLUE BOX system is proposed to address this gap by providing a continuous, real-time telemetry path from the aircraft to the ground station. The Interfacing and Ingestion Module (IIM) is the first and most safety-critical component of this system. It acquires data from the aircraft's avionics buses and sensor systems without interfering with the existing certified recording equipment.

The present paper focuses on the system-level design, architecture, and functional simulation of the IIM. The primary contribution is a demonstration of the complete IIM processing chain — from data acquisition through to ground-station packet recovery — using MATLAB/Simulink. The paper is organised as follows: Section II reviews related work, Section III describes the proposed methodology and architecture, Section IV presents the simulation environment, Section V discusses results, and Section VI concludes with directions for future work.

II. RELATED WORK AND RESEARCH GAP

Several works have addressed aspects of aircraft data monitoring. Santos et al. [1] examined reliability enhancement for avionics data communication using additional error-detection information. Jayathissa [2] identified the need for continuous real-time access to aircraft data beyond on-board recording. Zhang et al. [3] developed an architecture for real-time civil aviation data analysis, while Wang [4] studied flight-data monitoring in aviation safety management. Özdemir and Savas [5] proposed a simulator-based flight data recording and analysis framework.

A common limitation of these works is that they address individual aspects of aircraft data processing — reliability, monitoring, recording, or analysis — without integrating them into a single, continuous, non-intrusive processing path. The proposed BLUE BOX IIM addresses this gap by combining data acquisition, engineering-unit conversion, CRC-based validation, error injection testing, timestamping, priority handling, buffering, packetization, and ground-station recovery into a unified MATLAB/Simulink processing chain.

III. PROPOSED SYSTEM ARCHITECTURE AND METHODOLOGY

A. Overall Architecture

The proposed BLUE BOX IIM is designed as a parallel, non-intrusive monitoring path. It does not modify, interrupt, or replace the existing FDR/CVR systems. The IIM passively acquires aircraft data from the avionics buses using transformer-coupled or opto-isolated taps, processes it through the chain described below, and transmits it via the BLUE BOX wireless link to the ground station.

The processing chain consists of the following sequential stages:

- Passive data acquisition from avionics buses (ARINC-429/717 and MIL-STD-1553B)
- Engineering-unit conversion of raw acquired values
- Data validation using CRC-16 error detection
- Timestamp generation for temporal ordering of all data streams
- Priority handling: flight data assigned higher priority than audio and video
- FIFO buffering for orderly queue management before transmission
- Packetization: data, timestamp, and CRC combined into a transmission packet
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- Simulated transmission channel to ground station
- Ground-station reception, depacketization, and data recovery

B. Data Acquisition and Engineering-Unit Conversion

The IIM acquires representative aircraft data values corresponding to the types of parameters recorded by a standard FDR — altitude, airspeed, heading, engine parameters, and control surface positions. In the MATLAB/Simulink implementation, these are represented as scaled numerical values. Engineering-unit conversion is applied as:

$$D\_eng = S \cdot D\_raw + O$$

where D_raw is the acquired raw data value, S is the scaling factor, O is the offset, and D_eng is the resulting engineering value. The Simulink model applies a unity-gain, zero-offset conversion to produce numerically scaled representations of the flight parameters.

C. CRC-16 Error Detection

Following engineering-unit conversion, each data frame is validated using CRC-16 (Cyclic Redundancy Check, 16-bit). A CRC is computed over the data polynomial and appended to the transmitted message. At the receiver, the CRC is recomputed and compared:

$$V = 1 \text{ if } R\_rx = R\_calc \quad \text{(no error)},$$
$$V = 0 \text{ if } R\_rx \neq R\_calc \quad \text{(error detected)}$$

In the simulation, controlled error injection modifies the flight data value after CRC generation. Since the CRC was computed over the unmodified data, the verification at the receiver detects the mismatch and outputs V = 0, confirming error detection. This validates the integrity-checking capability of the IIM.

D. Timestamp Generation, Priority Handling, and FIFO Buffering

Each processed data value is assigned a timestamp derived from the simulation time, ensuring temporal ordering for all transmitted frames. When multiple information sources (flight data, audio, video) are active simultaneously, priority handling assigns the highest priority to flight data parameters. Lower-priority sources (audio, then video) are admitted to the transmission queue only after flight data requirements have been met. All prioritised data is placed into a FIFO buffer with capacity of 10 samples before packetization.

E. Packetization and Ground-Station Recovery

Each processed data frame is assembled into a transmission packet containing three fields:

$$P = \{ D\_eng, \quad T\_s, \quad CRC \}$$

where D_eng is the engineering value, T_s is the timestamp, and CRC is the error-detection code. The packet is passed through a simulated transmission channel and received at the simulated ground station, where depacketization separates the three fields for inspection and logging.

IV. SIMULATION ENVIRONMENT

The complete IIM processing chain was implemented in MATLAB/Simulink. Representative flight data, cockpit audio placeholder signals, and a cockpit video placeholder constitute the input sources. The simulation does not use actual aircraft avionics data or certified ARINC-429 protocol decoding — it demonstrates the functional processing chain at the system level. Key simulation parameters are listed in Table 1.

Parameter	Value
Simulation Tool	MATLAB/Simulink
Primary Input	Representative flight data
Engineering-Unit Conversion	Applied (unity scaling, zero offset)
CRC Method	CRC-16
Error Injection	Flight data modified by +1 after CRC
Timestamp Generation	Simulation-time based
Priority Handling	Flight data → Audio → Video
FIFO Buffer Capacity	10 samples
Packet Structure	D_eng, Timestamp, CRC
Transmission	Simulated channel
Ground Station	Depacketization and field recovery

V. RESULTS AND DISCUSSION

The BLUE BOX IIM was evaluated across four functional tests: controlled error injection, CRC-16 detection, ground-station data recovery, and throughput measurement.

A. Controlled Error Injection

A +1 modification was applied to the flight data value after CRC generation to simulate a data integrity violation. The Simulink scope confirmed that the modified signal was observable as an intentional error prior to CRC verification. This test establishes that the simulation can generate a known error condition for subsequent detection testing.

B. CRC-16 Error Detection

The verification block recomputed the CRC over the received (modified) data and compared it with the transmitted CRC. Because the data was modified after CRC generation, the values did not match. The simulation verification output was V = 0, confirming correct error detection. This result validates the data-integrity checking function of the IIM.

C. Ground-Station Data Recovery

The transmitted packet was received and depacketized at the simulated ground station. The recovered values were: flight data ≈ 34,910; timestamp = 10.14; CRC ≈ 21,700. These values match the transmitted packet contents, confirming correct transmission and recovery of all three packet fields.

D. Throughput Measurement

The throughput measurement block produced an output of 96 in the simulation scale, indicating that the implemented data-handling path can sustain the required processing rate. Table 2 summarises all simulation results.

Test	Parameter	Value
CRC-16 Error Detection	Flight data	34905.17
	CRC value	21699.11
	Verification output	0 (error detected)
Controlled Error Injection	Modified flight data	34905.11
	Timestamp	10.00
	CRC value	21699
Ground-Station Recovery	Recovered flight data	≈ 34,910
	Recovered timestamp	10.14
	Recovered CRC	≈ 21,700
Throughput Measurement	Output value	96

VI. CONCLUSION

This paper presented the system-level design and MATLAB/Simulink simulation of the Interfacing and Ingestion Module (IIM) for the BLUE BOX real-time aircraft telemetry system. The IIM provides a non-intrusive, parallel monitoring path alongside existing FDR/CVR recording systems. The implemented processing chain — covering acquisition, engineering-unit conversion, CRC-16 validation, timestamping, priority handling, FIFO buffering, packetization, and ground-station recovery — was validated through four functional simulation tests. CRC-16 error detection was confirmed, ground-station data recovery was demonstrated, and throughput measurement produced a measurable output. These results confirm the functional feasibility of the proposed BLUE BOX IIM architecture and establish a simulation baseline for subsequent hardware development and ARINC-429 protocol-level integration.

VII. FUTURE SCOPE

Future work will extend the IIM to include actual ARINC-429 and MIL-STD-1553B protocol-level word decoding, synchronous integration of cockpit audio and video streams, and realistic wireless channel modelling. Hardware-in-the-loop testing using representative avionics data will be pursued in the next phase of the BLUE BOX project.

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