

# A Solution to Reduce Data Transfer Duration for Onboard Recorded Raw Data

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## Abstract

During flight test activities, Flight Test Instrumentation (FTI) data are recorded onboard aircraft using dedicated recorders. Following flight completion, these data sets must be transferred to ground systems for analysis. When performed through physical means, the data transfer requires multiple manual steps such as removing the onboard storage media, copying the data to intermediary computers, and transferring it to internal storage systems. This process is time-consuming and results in and operational delays, particularly as data sizes continue to increase.

This study proposes a wireless data transfer solution that enables the transfer of recorded data from the onboard recorder to a data transfer computer which is connected to Turkish Aerospace internal network on ground immediately after landing. To support this process, dedicated software applications have been developed for both the onboard FTI system and for the data transfer computer, enabling controlled data transmission, monitoring, and management of the transfer process. The objective of this approach is to significantly reduce turnaround time between flight completion and data availability, while minimizing human intervention and operational effort. Key considerations include reliable data transfer under dynamic ground movement conditions, seamless handover between ground clients, and robustness against link interruptions. The developed software components play a critical role in ensuring synchronization, transfer reliability, and operational robustness throughout the process.

**Key words:** Flight Test Instrumentation, Data Transmission, TCP, PCAP, Network

## Introduction

Turkish Aerospace (TA) is one of the Türkiye's leading companies in the defence and aerospace sector. The company operates in a wide range area including aircraft, helicopter, UAV satellite and space systems design and production. TA has led major projects such as ANKA UAV, ANKA-3 UAV, Aksungur UAV, ATAK Helicopter, T-625 Gökbey Helicopter, Göktürk-3 Satellite, Hürkuş Trainer Aircraft, Hürjet Advanced Jet Trainer and Fifth Generation Fighter Jet Turkish Fighter-X (TF-X, KAAAN). Flight tests are carried out during the aircraft development process. In these flight tests, various data are collected from the aircraft by the Flight Test Instrumentation teams in order to evaluate the aircraft design activities. A Bombardier Global6000 aircraft is being used as Experimental Test Bed. This aircraft is used for especially "Modern Avionic System Development and Test" missions for TF-X fighter jet. The wireless data transmission project described in this paper will primarily be

implemented in the Experimental Test Bed project. You can see the Bombardier Global6000 Aircraft on Fig. 1., and Fig. 2., also you can see the TF-X on Fig. 3.



Fig.1. Bombardier Global6000 Aircraft



Fig. 1. Experimental Test Bed



Fig. 2. TF-X

Flight test campaigns require precise acquisition, storage, and transfer of data obtained from multiple onboard sensors, avionics buses, and communication systems. These data are crucial for validating aircraft performance and safety.

Flight Test Instrumentation (FTI) systems collect data at high sampling rates, often storing raw data in PCAP format for detailed post-processing and analysis.

Traditional communication protocols used in FTI environments, such as UDP-based telemetry, prioritize low latency but do not guarantee reliability. In contrast, TCP provides a connection-oriented approach with built-in mechanisms for ensuring data delivery.

This study proposes a TCP-based wireless data transfer framework specifically tailored for FTI applications. The system ensures:

- Lossless transfer of PCAP-based flight data
- Synchronization between airborne and ground systems

The proposed approach is particularly suitable for transferring the FTI data to the internal network. Flight test instrumentation data recorded after the completion of a flight activity of an instrumented aircraft is uploaded to the internal network. Following the completion of the mission, the onboard data recording device is physically accessed. The recording unit within the device is removed and then physically transported. Subsequently, the flight test instrumentation data stored in this unit is transferred to the TA internal network for further examination. You can see the data recording system architecture on Fig. 4. The data recorded in the storage unit of the onboard data recording device used in the aircraft is stored in the “.pcap” file format. The recorded pcap files are shown in Fig. 5.

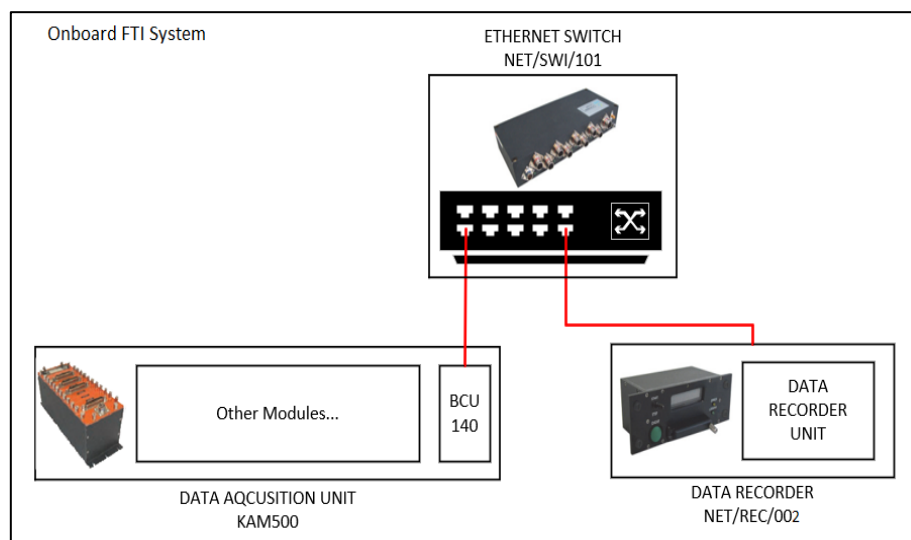


Fig. 3. Onboard Data Recording System Architecture

|              |                   |                      |           |
|--------------|-------------------|----------------------|-----------|
| out_254.pcap | 3/26/2026 9:56 AM | Wireshark capture... | 32,241 KB |
| out_255.pcap | 3/26/2026 9:56 AM | Wireshark capture... | 32,241 KB |
| out_256.pcap | 3/26/2026 9:56 AM | Wireshark capture... | 32,242 KB |
| out_257.pcap | 3/26/2026 9:56 AM | Wireshark capture... | 32,241 KB |
| out_258.pcap | 3/26/2026 9:56 AM | Wireshark capture... | 32,240 KB |
| out_259.pcap | 3/26/2026 9:56 AM | Wireshark capture... | 32,241 KB |
| out_260.pcap | 3/26/2026 9:56 AM | Wireshark capture... | 32,242 KB |
| out_261.pcap | 3/26/2026 9:56 AM | Wireshark capture... | 32,241 KB |
| out_262.pcap | 3/26/2026 9:56 AM | Wireshark capture... | 32,242 KB |

Fig. 5. Recorded .pcap Files

With the currently employed methods, transferring this data to the TA internal network involves manual access to the aircraft, manual transfer of data between computers, and the physical removal and reinstallation of the recording unit. These processes can lead to significant time and cost losses, as well as potential damage to the equipment installed on

the aircraft. For these reasons, a wireless network-based and automated data transfer system has been developed as an alternative to conventional wired and labor-intensive manual transfer methods, in order to enable efficient and reliable transmission of flight activity data to the internal network. The wireless data transfer system architecture is shown in Fig. 6.

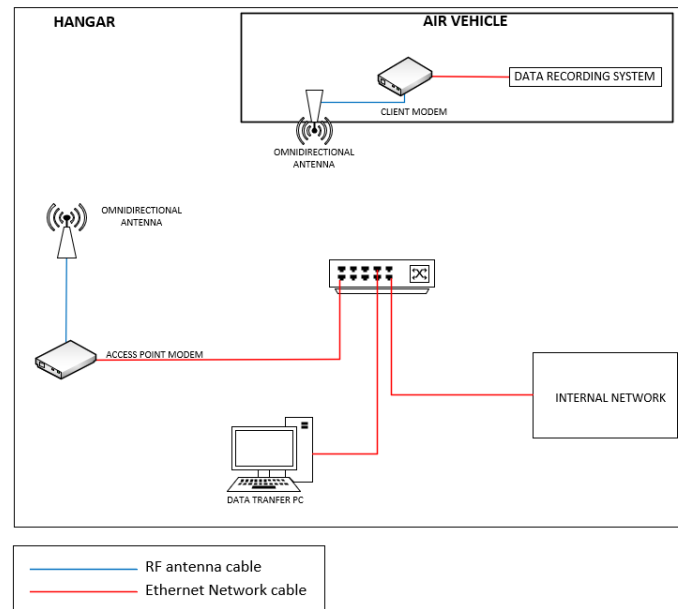


Fig. 6. Wireless Data Transfer System Architecture

### Related Works

Flight test data transfer has become an important research topic in recent years due to increasing data volume and analysis requirements. In traditional systems, data is typically recorded onboard the aircraft and transferred after the flight using physical methods. However, these methods are time-consuming and lead to operational delays.

Studies on the integration of wireless communication technologies into aviation systems propose significant improvements to this process. In particular, research on both onboard and air-to-ground communication shows that wireless systems reduce cable dependency, lower maintenance costs, and increase system flexibility [1]. However, the reliability and continuity of these systems remain a critical research challenge.

Studies on air-to-ground communication continuity demonstrate that mobility, altitude, and environmental conditions have a direct impact on link quality [2]. This highlights the importance of maintaining uninterrupted communication, especially for high-volume post-flight data transfer scenarios.

In addition, data security in aircraft systems is another important research area. Studies on the security and integrity of aviation communication systems emphasize that current communication infrastructures have several vulnerabilities and that reliable data transfer mechanisms are required [3].

With the development of wireless transmission technologies, research on high-speed data transfer systems have also increased. In particular, studies on unmanned aerial vehicles and similar platforms show that existing data transmission methods are insufficient to handle increasing data rates and that more advanced wireless solutions are needed [4]. However, existing literature indicates that integrated solutions combining wireless communication, reliable data transfer, and automated post-flight data offloading are still limited. This study addresses this gap by proposing an approach that enables fast, reliable, and automated transfer of flight test data to ground systems immediately after landing.

### Materials and Methods

In order to enable wireless transmission of the data recorded during the flight activity, the aircraft must be equipped with the sender

system which consists of a modem, an antenna, and a computer. Similarly, on the receiver side, a fixed modem and antenna are required to facilitate data transfer to the data transfer computer. The system is designed to provide data transmission based on the TCP Ethernet protocol between two devices that are wirelessly connected. The TCP protocol operates using a “handshake” mechanism, ensuring mutual acknowledgment between devices and thereby preventing any data loss during transmission. (See Fig. 7)

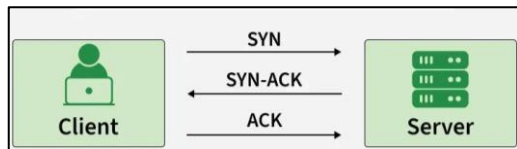


Fig. 7. TCP Handshake Process

Following the completion of the flight activity, data transmission begins automatically as the aircraft approaches the hangar and the sender and receiver modem connect with each other's coverage range. The “.pcap” files containing the recorded data of the completed mission are transmitted sequentially via sender system. For transmission, the sender system identifies the relevant “.pcap” files based on the date of the completed activity. Meanwhile, on the receiver side, the receiving application is launched and remains in a “ready” state to accept incoming data.

Once communication between the devices is established, the sender system first accesses the data corresponding to the current date and completed mission. If there is a mismatch in date or mission information between the sender and receiver systems, the data transfer is not initiated. After successful validation, the sender application first transmits the total number of files associated with the mission to the receiver application. This approach helps prevent packet or data loss during transmission. The application screen during data transferring is shown in Fig. 8.

```

Receiver ready
Status : Receiving out_257.pcap
File 175 / 281 | out_257.pcap

Current File : [#####] 100%
Total Files : [#####-----] 62%
Reconnect Count : 0
  
```

Fig. 8. Application Screen During Data Transferring

The receiver system determines which aircraft the flight activity belongs to by examining the Ethernet port information of the sender system (such as IP and MAC addresses), and selects the storage location accordingly. To provide real-time user feedback, a “status” variable is used to

indicate whether the data transfer is ongoing or has been interrupted. In addition, the same interface displays the number of data files related to the activity that have been successfully transmitted.

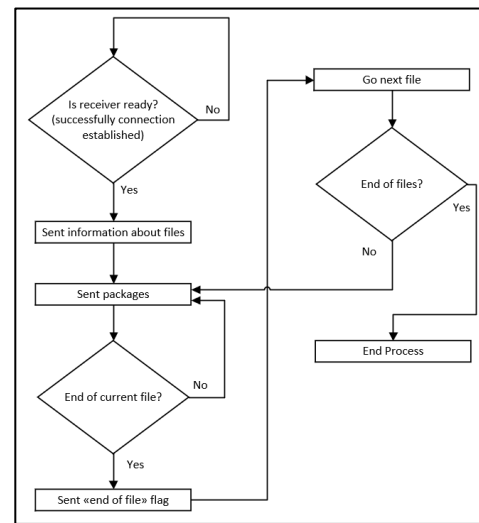


Fig. 9. Sender System Flowchart

During a flight activity, hundreds of “.pcap” files are recorded. The generated data packets are identified by the sender system as belonging to “.pcap” files and must be reconstructed on the receiver side with identical names and sizes. To ensure that the “.pcap” files are recreated with the correct names and sizes on the receiver side, the sender system transmits specific “flag” variables indicating the start and end of each file. These flags eliminate issues such as incorrect file sizes or mismatched file names. As a result, all data recorded during the flight is transferred completely and accurately to the receiver system with identical file names. Due to the nature of wireless network structures, connection interruptions may occur if any condition disrupts the “line of sight” during transmission. The proposed system must be resilient to such connection losses. In the event of reconnection, data transfer should resume from where it was interrupted. To ensure robustness against connection interruptions, the packet-level characteristics of the “.pcap” file format have been utilized. The receiver application continuously maintains information about the last successfully and completely received “frame,” including which file it belongs to and its sequence index within that file. In the event of a connection interruption, once the connection is re-established, this information is first transmitted back to the sender. Based on this feedback, the sender identifies the next packet to be transmitted and resumes the data transfer from the exact point where it was interrupted. (See Fig. 9)

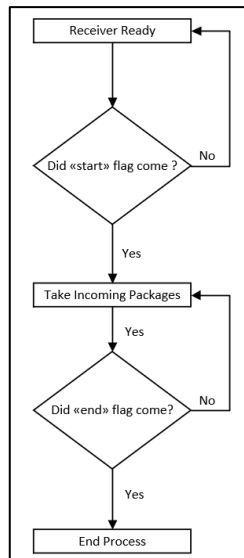


Fig. 10. Receiver System Flowchart

On the receiver application side, a connection loss and the completion of file transfer may be interpreted as the same condition, since both result in the cessation of data flow. In cases where the data stream has not actually finished but the connection has been interrupted, the receiver application may incorrectly determine that the data transfer is complete and therefore terminate the application.

To resolve this issue, the receiver application uses a “resume” feature for scenarios in which the data transfer is not completed but a connection loss has occurred. In such cases, the application stores the last successfully received packet in its memory. When the connection is re-established, the receiver responds to the sender’s query by providing the information of the last packet it processed, and the data flow resumes from that point.

Upon completion of the data transfer, the sender application transmits a “flag” value indicating that all packets related to the completed activity have been sent. (See Fig. 10)

After completion of developing data transfer process, the overall system must be tested with real cases. To prove applicability of the system several scenarios were created.

Firstly, to simulate real FTI data, several data sources (analog, gigabit ethernet, discrete) were prepared and taken acquired via KAM500 data acquisition system. The recorded data was converted to the recording format of the data recorder devices. After this process, the system is ready for data transfer application. The test was performed with approximately 10 gigabytes of data. The table about this test’s results are shown in Table 1. The overall FTI data uploading process to the TA internal network takes

approximately five hours. The overall process time is reduced approximately 13 minutes via using developed wireless data transfer system.

Tab. 1: Data Transfer Duration

| Data Size | Average Data Download Speed (Distance :100m) (Mbps) | Wireless Data Transfer to Data Transfer PC (min) | Data Transfer to TA Internal Network(min) | Total Data Transfer Duration (min) |
|-----------|-----------------------------------------------------|--------------------------------------------------|-------------------------------------------|------------------------------------|
| 10 GB     | 300                                                 | 4                                                | 9                                         | 13                                 |

Cisco 9165 and 9167 modems were used to perform wireless data transfer process. These modems operated with omnidirectional antennas. Modems are shown in Figure 11.



Fig. 11. Cisco 9165 & 9167 Modems

A new test was performed using a moving land vehicle representing the aircraft in order to examine the distance-dependent transmission rate of the system under field conditions. Approximately 300 Mbps data transfer speed was measured at 100 meters. The graph of this test is shown in Fig. 12. With the developed data transfer application, connection loss problem and reconnection process were tested. The connection loss occurred at arbitrary times and lasted for uncertain durations. The fluctuations observed in the graph are caused by various obstacles, such as vehicles and buildings, that intermittently obstruct the line of sight between the in-vehicle modem and the fixed modem during data transmission. The reconnection graph is shown in Fig. 13. After completion successfully data transfer process, transferred data were observed without any loss in receiver side.

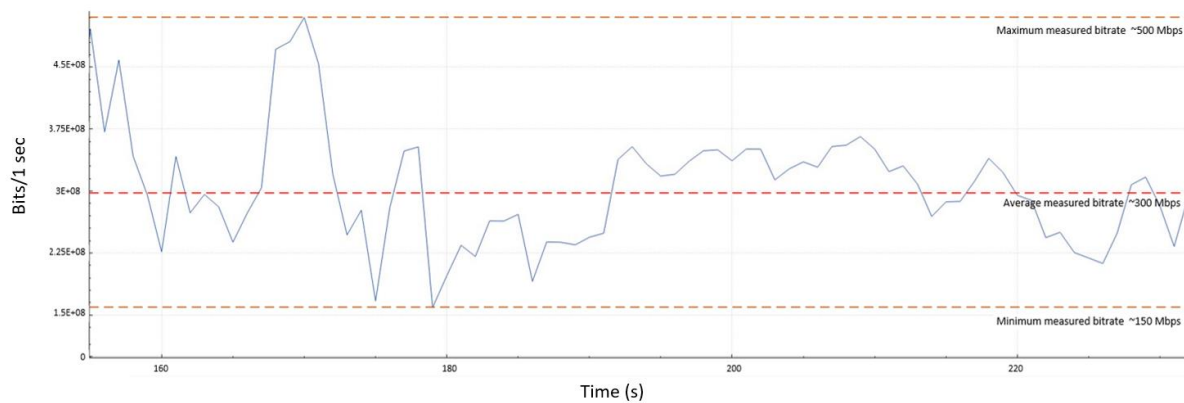


Fig. 12. Transmission Rate at 100m Distance

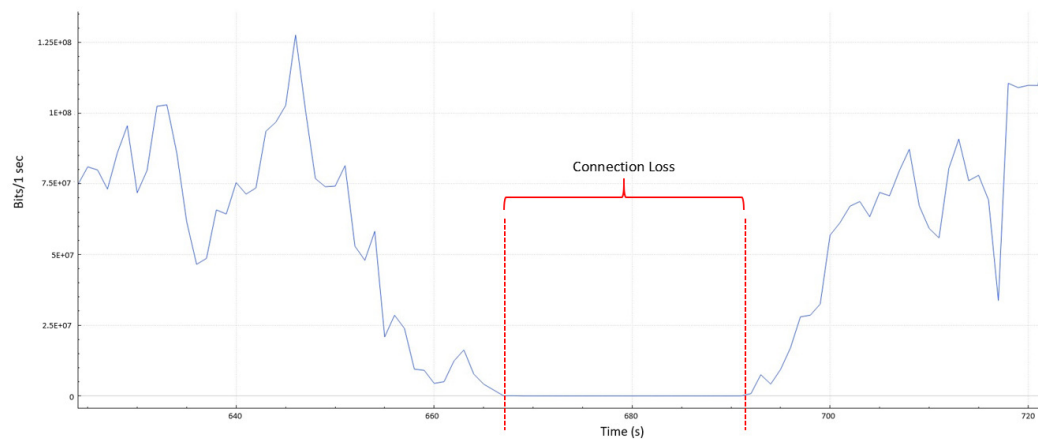


Fig. 13. Reconnection Graph

### Future Works

Future studies may focus on improving the performance, scalability, and reliability of the proposed wireless data transmission architecture under different operational conditions. One potential enhancement is the integration of higher bandwidth wireless communication technologies, such as Wi-Fi 6/6E, 5G, or future aerospace communication standards, in order to further reduce transfer duration for large-scale flight test data.

Another important area for future work is the development of adaptive transmission algorithms capable of dynamically adjusting transfer parameters according to signal quality, aircraft position, and network congestion conditions. In addition, advanced interruption recovery and automatic retransmission mechanisms may be incorporated to ensure

uninterrupted and secure data transfer even under unstable wireless link conditions.

Future developments may also include the implementation of end-to-end encryption, authentication, and cybersecurity monitoring mechanisms to enhance data security during transmission to the internal network. Furthermore, support for simultaneous transfer operations from multiple aircraft could be investigated to improve operational efficiency in intensive flight test environments. Finally, comprehensive field tests under varying environmental and operational scenarios may be conducted to evaluate the robustness and long-term reliability of the proposed system in real-world aerospace operations.

### Results

During flight test activities conducted within TA, the data recording device installed on the aircraft captures FTI data throughout the flight mission.

After the completion of the flight test activity, the recorded mission data is uploaded to the TA internal network and made available for analysis through a series of defined steps. Once the mission is completed, the data recorded by the onboard data recording device is transferred to the TA internal network through various transfer and security procedures. In this way, the data is made available within the TA internal network for further examination. The overall system

With the currently used methods, the process of transferring this data to the TA internal network involves manual access to the aircraft and manual transfer of data between computers. These procedures result in significant time losses and, in some cases, financial damages due to potential equipment damage inside the aircraft.

Thanks to the developed wireless data transmission architecture, substantial advantages have been achieved compared to the existing system. The data transfer system has been transformed into an autonomous structure, eliminating all manually performed and contact-based operations. During data transfer, no human intervention is required to access the aircraft. Thus, the amount of operational effort required to transfer recorded data to the TA internal network is significantly reduced.

Currently, transferring recorded flight data to the internal network involves processes such as physically bringing the data recording unit to a computer, performing disassembly and reassembly operations, and manually transferring data within the network, all of which lead to considerable time losses. With the newly developed wireless data transmission system, these time losses have been eliminated. By minimizing human involvement in the data transfer process, the system also aims to reduce human error and ensure that the recorded data is securely transferred into the system. Data transfer duration into TA internal network is shown in Tab. 2.

*Tab. 2: Data Transfer Duration into TA Internal Network*

| Data Size                                | Current Total Data Transfer Duration to TA Internal Network (min) | Proposed Data Transfer to TA Internal Network (min) |
|------------------------------------------|-------------------------------------------------------------------|-----------------------------------------------------|
| 10 GB                                    | 25                                                                | 13                                                  |
| 100 GB<br>(Approximate Flight Data Size) | 250                                                               | 130                                                 |

As soon as the modem on the aircraft and the fixed modem on the ground come within each other's coverage area, data transmission begins and is automatically directed to the designated file location. Without requiring any human intervention, the recorded data from the completed mission is transferred to the internal network in an automated manner, with data rates of approximately 300–350 Mbps.

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