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A data acquisition system for the RNLAF MLU F-16; Requirements and proposal

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ABSTRACT
In 1983 the Royal Netherlands Air Force (RNLAF) requested the National Aerospace Laboratory NLR to design, procure and install a flight test data acquisition system to be used with the F-16 fighter aircraft. The design was heavily based on the systems, which were at that time nearing their completion for flight tests with Fokker aircraft. The system was delivered to the RNLAF in 1984 and has been continuously in use since that time.
With the coming introduction of the Mid-Life Update programme of the F-16, it was foreseen that the current system would not be able to fulfil its tasks anymore. The RNLAF together with NLR draw up the requirements for a new data acquisition system. A proposal for the new system was made by NLR, again based on recent developments of flight test instrumentation for Fokker aircraft, but also with future developments in the field of airborne flight test instrumentation in mind.
In this paper the requirements for the new system will be given. The proposed system will be described by means of a general concept. Although the final implementation of this general concept is not decided upon yet, the benefits and drawbacks of a possible implementation, based on the Common Airborne Instrumentation system standards, are discussed. It is concluded that there is a preference for this implementation, provided the tight time schedule can be met and the costs for familiarisation and equipment ar not prohibitive.

Summary

In 1983 the Royal Netherlands Air Force (RNLAF) requested the National Aerospace Laboratory NLR to design, procure and install a flight test data acquisition system to be used with the F-16 fighter aircraft. The design was heavily based on the systems, which were at that time nearing their completion for flight tests with Fokker aircraft. The system was delivered to the RNLAF in 1984 and has been continuously in use since that time.

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Contents

(13 pages in total)

Abbreviations

1553RT	1553 Remote Terminal
AP	Airborne Processor
ASC	Airborne System Controller
AVDAU	Avionics Data Acquisition Unit
BIM	Bus Interface Module
CAIS	Common Airborne Instrumentation System
CC	Central Controller
CDU	Cockpit Display Unit
ECS	Electronics Cooling System
EPROM	Electrical Programmable Read Only Memory
FLR	Flight Loads Recorder
GPS	Global Positioning System
GSU	Ground Support Unit
MDAU	Miniature Data Acquisition Unit
MFD	Multi Function Display
MLU	Mid-Life Update
MMSC	Micro Miniature Signal Conditioner Unit
NLR	National Aerospace Laboratory (Dutch acronym)
PC	Personal Computer
PCM	Pulse Code Modulation
PCU	Programmable Conditioner Unit
PFU	Portable Flight-line Unit
RDAU	Remote Data Acquisition Unit
RNLAF	Royal Netherlands Air Force
US DoD	United States Department of Defence

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A Data Acquisition System for the RNLAF MLU F-16 Requirements and Proposal

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1. SUMMARY

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2. INTRODUCTION

In 1983 the Royal Netherlands Air Force (RNLAF) awarded a contract to the Netherlands National Aerospace Laboratory (NLR) to design, build and install a data acquisition system in one of their F-16 aircraft. The system had to be used for two types of flights, namely operational flights and flights with a technical objective. The first type consists mainly of flights for mission training where recording of data may improve tactics and trials to determine or improve the quality of a system. The second type consists of flights mainly related to a special programme, e.g. certification of new stores or technical evaluation of new or modified aircraft systems.

In October 1984 the instrumentation was installed in a single seater F-16A aircraft. Shortly hereafter a two seater F-16B aircraft was modified to allow the installation of the instrumentation package in this aircraft as well. Because in the course of the flight tests the RNLAF preferred to have an additional two seater over a single seater, it was decided in 1987 to bring the F-16A aircraft back to standard and modify a second F-16B instead. Up till now the instrumentation package has performed to its specification. Moreover NLR has successfully used similar systems to support flight test programmes of their other customers.

In the time span from the beginning of 1998 until 2000 all the aircraft of the RNLAF will be modified on behalf of the Mid-Life Update (MLU) programme. After the modification programme the aircraft are expected to be operational until 2020. Since the avionics of the MLU F-16 is extended significantly, for instance resulting in four instead of one Mil-Std-1553 buses, it became clear that a new instrumentation package will be necessary. For that reason the RNLAF asked NLR to propose for such a new instrumentation package. Besides specifying new functional requirements also attention was paid to improve the operational performance of the system.

In the next sections both functional and operational requirements are discussed. Additionally the proposed system meeting these requirements is described in some detail. Because the new system is based on long term experiences with the present system, a short description of the present system will be given as a start.

3. PRESENT SYSTEM

The starting points for the development of the present system were:

- The system should have the potential to be used for the various flight test programmes with minor modifications.
- It was required that reconfiguration of the aircraft from test status to operational status could be done in a very short time (less than 24 hours).
- The permanent structural modifications to the aircraft should be as limited as possible.

The resulting system is depicted in figure 1. The data acquisition system, mainly consisting of a signal conditioning unit, a multiplexing and digitising unit and an airborne digital data recorder, is located in a dedicated instrumentation rack, mounted in the ammodrum compartment. The various analog and digital input signals are connected to the data acquisition unit via a patch panel, mounted in the gun barrel compartment. From there a standard wiring harness is routed to nine wing and centreline stations. At these stations the transducers required for a specific flight test programme can be installed. This concept allows for a relatively easy reconfiguration of the instrumentation system to the needs of a flight test programme. The camera system, mainly used to record the separation trajectory of a store, consists of up to five independently operable high speed film cameras. This system makes use of the same wiring harness as the data acquisition system.

The data acquisition and camera system can be controlled from both the forward and aft cockpit by means of additional control units.

For installation of the instrumentation the ammodrum and gun have to be removed from the aircraft. The permanent modifications to the aircraft are mainly:

- installation of the instrumentation wiring harness to the remote stations;
- installation of wiring to the cockpit;
- mounting points for the instrumentation package;
- modifications to the Electronics Cooling System, providing adequate cooling of the instrumentation.

A more detailed description of the present instrumentation can be found in Ref. 1.

4. REQUIREMENTS

4.1 Functional requirements

For the new system at least the same functional requirements as for the present system apply, which will not be repeated in this paper. However, since the avionics of the MLU F-16 are extended significantly, the instrumentation has to be extended too. The main items are:

- The system has to provide input capacity for four dual redundant Mil-Std-1553 multiplexer buses and the F-16 weapon data bus. Selections of data to record from these buses have to be made, however for possible future avionics flight testing, it must be possible to upgrade the system for recording of complete data buses.
- The throughput rate of the present system is 1.5 Mbit/s, which occasionally has been used. The increase of required parameters from the multiplexer buses will demand for systems with a significant higher throughput rate. It is estimated that for the new system a maximum throughput rate of at least 5 Mbit/s is required.
- Since the number of video sources is increased, i.e. by use of Multi Function Displays (MFD's), targeting and navigation pods and TV guided missiles, provisions have to be made to record the various video signals.

An important addition compared to the present system is the requirement to have a display in the cockpit on which in-flight selectable sets of at least four parameters in engineering units and in numeric format can be displayed.

4.2 Operational requirements

Most of the operational requirements are based on the twelve years operational experience with the present F-16 instrumentation. In general there is a strong requirement to limit the degradation of the aircraft from its operational status as much as possible. Preferably the aircraft has to be fully operational with all the instrumentation installed. This means:

- No removal of gun and/or ammodrum required for installation of instrumentation. Moreover it even must be possible to use the gun while instrumentation is installed.
- No additional cooling requirements for the instrumentation which would make adaptation of the aircraft ECS necessary.
- The additional flight test wiring has to be limited as much as possible.
- No adaptations to the cockpit lay-out for instrumentation control and display of selected parameters. For this purpose it is preferred to make use of the Multi Function Display (MFD), already present at both the forward and aft cockpit.

In addition the following requirements apply:

- In the present data acquisition system the sampling sequence is stored in Erasable Programmable Read Only Memory (EPROM). If changes in the sampling sequence are required, the data acquisition unit has to be accessed to replace the EPROM. For the new system the sampling sequence shall be externally programmable by means of a data link.
- Because of reduction of time required for processing of film and maintenance of equipment, it is preferred to replace the present film cameras by high speed video cameras.

4.3 Other requirements

Although an optimised system from a technical point of view is preferred, also requirements related to the time schedule can influence choices in the realisation of the instrumentation system. The first flight tests with the MLU F-16 are foreseen in the middle of 1998. One of the first dual seaters which are modified will be allocated to be instrumentated. This aircraft is expected to become available for installation of the instrumentation in January 1998. The instrumentation has to be operational before June 1998.

5. PROPOSED SYSTEM

5.1 General concept

Free from equipment limitations the requirements can be translated into a general concept. Figure 2 shows the general concept of the proposed data acquisition system.

A Central Controller (CC), which will be mounted in the aft avionics compartment, acquires all data and distributes these data to a recorder, a telemetry system

and a cockpit display unit. The signals locally available at the aft avionics compartment, such as the Mil-Std-1553 buses, weapon bus and a part of the analog and digital signals, tapped from the Flight Loads Recorder (FLR) inputs, are connected directly to the CC. The CC takes care of conditioning, multiplexing and digitising these signals.
Analog and digital signals at remote locations, i.e. the wing and centreline stations, are acquired by miniature Remote Data Acquisition Units (RDAU). These units are able to condition, multiplex and digitise the signals to be measured. They also provide transducer excitation voltages if necessary. The RDAU's are connected via an instrumentation bus to the CC. Via this bus the CC is able to set up the RDAU measurement channels, e.g. amplifier gain and presample filter cut-off frequency, and acquire the digitised values.

In this concept the film cameras or future high speed video cameras can also be considered as a RDAU, receiving control commands and sending status information via the instrumentation bus.

The CC accepts an external time code signal, e.g. from a Global Positioning System (GPS) receiver, to synchronise its internal time code generator. This synchronised time code data will be available at the data outputs to recorder, telemetry system and cockpit display unit.

The formats of the CC output data streams to recorder, telemetry system and cockpit display are downloaded to the CC from a Ground Support Unit (GSU). With this GSU also data can be displayed for check-out and maintenance purposes. The data formats can be configured independently, for example all required data to the recorder and a subset of these data to the telemetry system.

The Cockpit Display Unit (CDU) will be able to display in-flight selectable sets of at least four parameters in engineering units at both the forward and aft cockpit. To meet the requirement not to change the cockpit lay-out, use can be made of one of the aircraft's MFD's. The switches of the MFD can be used to control the instrumentation.

5.2 Implementation

Experiences, gained with designing, building and operating large data acquisition systems for flight tests with Fokker prototype aircraft, learned that the described general concept can very well be realised with the Programmable Conditioner Unit (PCU) or the Programmable Master Unit (PMU) as the central controller. Both units are manufactured by Aydin Vector Division and make use of the Aydin Vector proprietary instrumentation bus, the so called 10-Wire Interface (10-WIF), to communicate with the RDAU's. Because of its small size the Micro Miniature Signal Conditioner (MMSC) will be a suitable solution for these RDAU's.

However new developments in electronics tend towards creating systems based on an open bus architecture, which are expandable by several suppliers. In the field of airborne flight test instrumentation, equipment meeting the standards of the Common Airborne Instrumentation System (CAIS) is under development since March 1991 (Ref. 2). The CAIS standard is being developed by the United States Department of Defence (US DoD) to promote standardisation, commonality and interoperability among aircraft test instrumentation. By US public law of November 1991 all developments regarding airborne instrumentation system for US Army, Air Force and Navy have to be based on the CAIS standards. The F-22 and F-18 flight test programmes are the first users of CAIS (Ref. 3).

There are strong arguments to base the instrumentation of the MLU F-16 on the CAIS standard too:

- Commonality: because it is expected that many manufacturers of flight test equipment will develop equipment meeting the CAIS standard, the procurement is not restricted to one supplier.
- Modular, expandable open architecture: this provides the capability to expand the system to meet flight test programme requirements, upgrade system components with new technologies, and meet emerging technical requirements. More data acquisition capacity can be added to an existing instrumentation installation without redesigning, removing and reinstalling a completely new system.

Figure 3 shows the CAIS implementation version of the data acquisition system. The Airborne System Controller (ASC) has a central place in the system. It takes care of controlling the CAIS instrumentation buses (up to three) and of formatting and distributing the acquired data. The maximum data output rate is 24 Mbit/s, which allows for future system expansion, for example with monitoring of the complete Mil-Std-1553 bus data.

The ASC is extended with two 'slices': the Airborne Processor (AP) slice and the 1553 Remote Terminal (1553RT) slice. The AP processes the data to engineering units. The 1553RT is intended to communicate with the MFD for instrumentation control and display purposes.

The acquisition of data from the aircraft avionics buses is performed by the Avionics Data Acquisition Unit (AVDAU), extended with two Bus Interface Modules (BIM). The acquisition of other digital and analog data is performed by the Miniature Data Acquisition Unit (MDAU).

The Portable Flight-line Unit (PFU) is based on a Personal Computer (PC) and providing capability to generate and load data formats; load, modify and verify the memory contents of the airborne units; execute initiated built-in test; verify airborne system configuration; and display/record the results of all significant operations.

In the present F-16 instrumentation good results are obtained using the Merlin PCM to Video Encoder ME-981 and a TEAC Hi-8 airborne video recorder. Maximum input rate of this system is 2.2 Mbit/s but upgrades to 5 Mbit/s are available now. Because ground station facilities are based on this equipment too, it is preferred to leave this part of the system unchanged.

6. CONCLUSIONS

At this stage final decisions about the implementation of the instrumentation are not made. In the described CAIS implementation several problems still have to be solved in more detail. The main problem areas are:

- How can the camera's be controlled as a remote unit connected to the CAIS-bus?
- How can the AP and 1553RT be programmed to communicate with the existing MFD's for parameter display and instrumentation control?

Besides technical problems, the requirement to have the instrumentated MLU F-16 ready for flight tests before June 1998 can be an important reason to fall back on well known and proven techniques and equipment. On short terms the availability of equipment meeting the CAIS standards have to be investigated and an assessment has to be made how much time for familiarisation will be necessary.

The present F-16 flight test instrumentation system has supported the flight test programmes of the RNLAF for more than twelve years. Similar systems were used in flight test programmes for other customers of NLR. In 1998 there will be a system installed in the MLU F-16 aircraft, very well capable of supporting flight test programmes for at least another decade.

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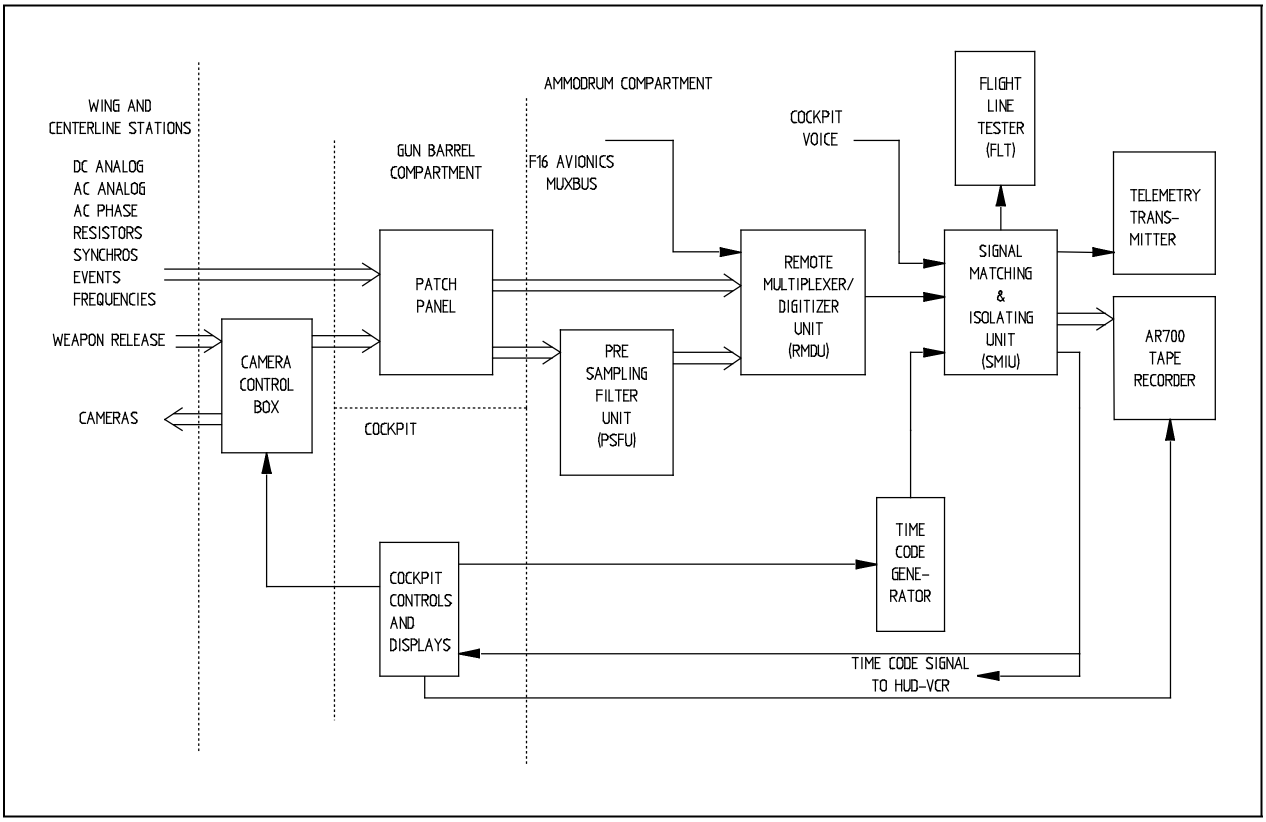

Fig. 1 Block diagram of the present F-16 instrumentation

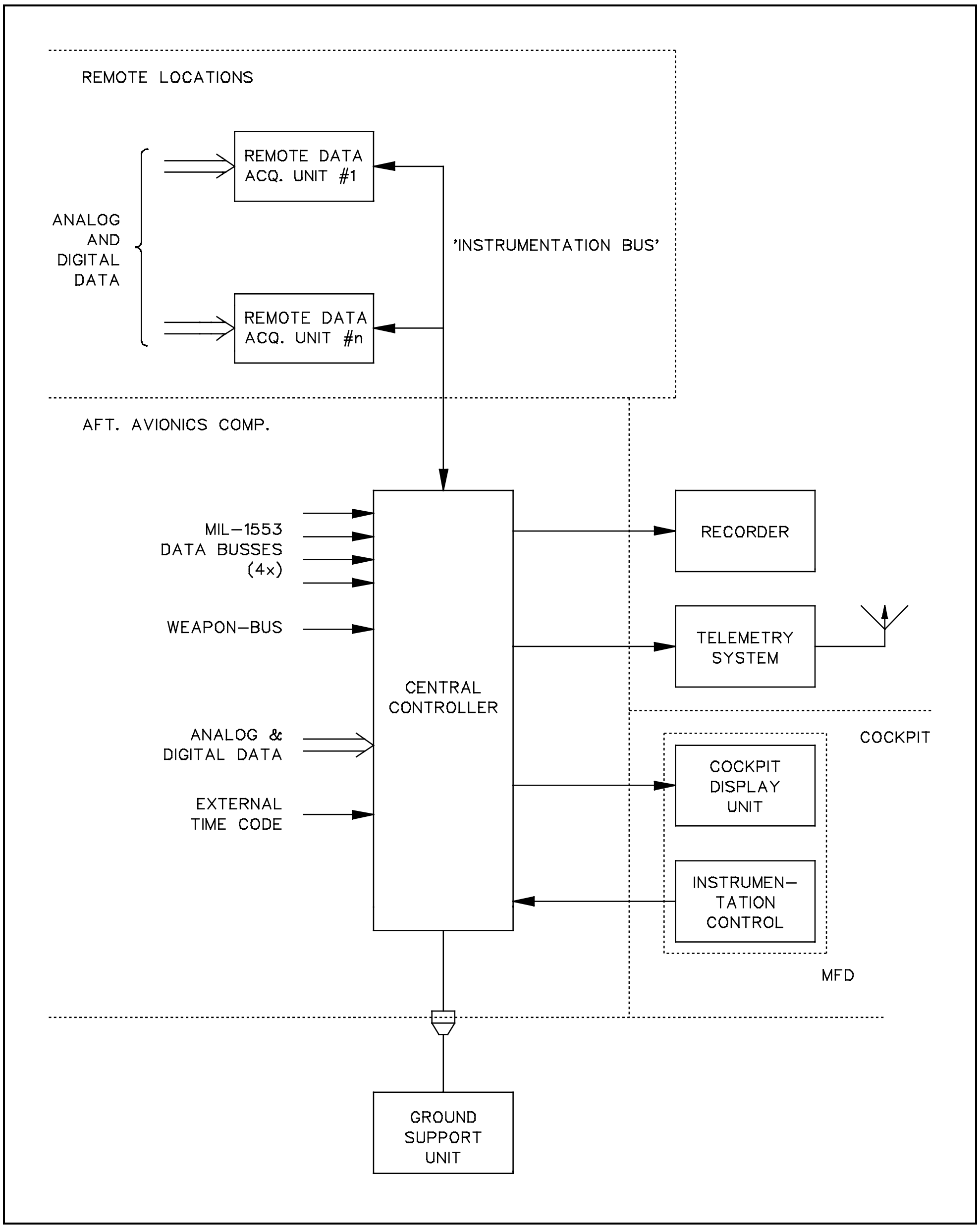

Fig. 2 The general concept of the proposed data acquisition system

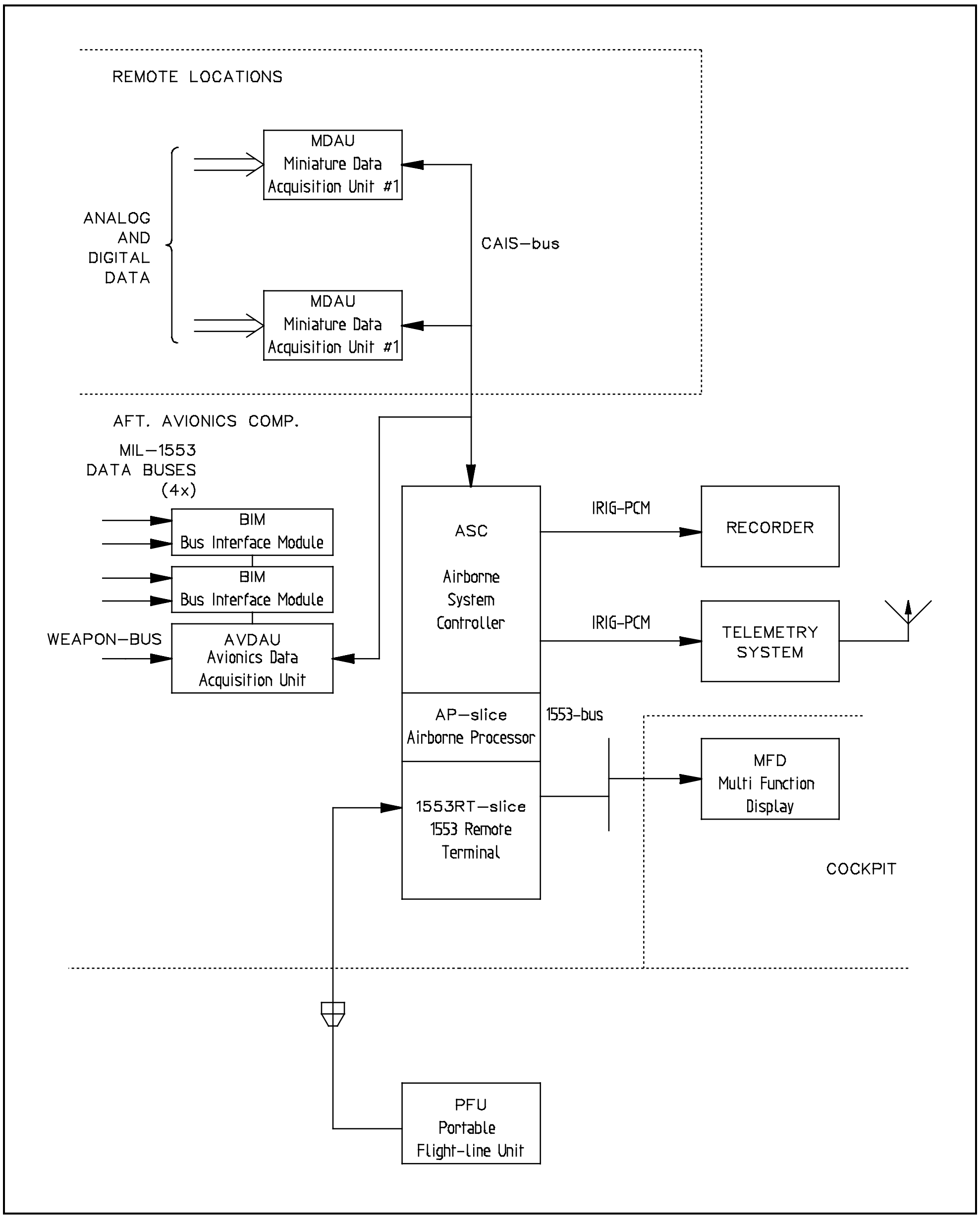

Fig. 3 CAIS implementation of the proposed system