

# **A NEW MINIATURE DATA ACQUISITION SYSTEM FOR F-16 FLUTTER AND LOADS TEST AIRCRAFT**

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## **ABSTRACT**

The USAF SEEK EAGLE office, which has responsibility for all Air Force aircraft – store compatibility/certification activity is located at Eglin AFB FL. Two Eglin F-16 aircraft, primarily used by the SEEK EAGLE office for flutter and loads testing, recently underwent major instrumentation upgrades. This paper presents a comparison between the previous, pre-mission labor intensive analog FM-FM/low speed data acquisition system and the new miniature data collection system, referred to as Mini Common Airborne Instrumentation System (MCAIS), including PC work station compatible digital recorders. Issues concerning existing flight test aircraft instrumentation compatibility, commonality, installation design considerations, data supportability, reduced manning automated preflight data validation, low cost PC work station and data reduction are discussed.

## **NOTATION AND UNITS**

AATIS. Advanced Airborne Test Instrumentation Systems  
mCAIS. Miniature Common Airborne Instrumentation System  
pDAS. Programmable Data Acquisition System  
FM. Frequency Modulation  
PCM. Pulse Code Modulation  
PC. Personal Computer  
LRU. Line Replaceable Unit  
EPROM. Erasable Programmable Read Only Memory  
LVDT. Linear Voltage Differential Transmitter  
MARS II. Modular Airborne Recording System

## **INTRODUCTION**

The Instrumentation Division specified minimum performance limits, procured, and integrated a new miniature data collection system into two F-16 aircraft in support of the Air Force Seek Eagle Office (AFSEO), located at Eglin AFB. It is AFSEO's mission to provide the USAF with increased combat capability through aircraft store certification,

compatibility, ballistic accuracy and flight clearance recommendations. This paper presents a comparison between the previously installed, labor intensive pDAS and the new miniature data collection system referred to as Mini Common Airborne Instrumentation System (MCAIS). Insight is provided into the initial use of the new all digital flutter/loads instrumentation architecture. Issues concerning obsolete technology, flight test aircraft CAIS compliance, commonality, installation design considerations, data interchange, reduced manning, automated preflight data validation and low cost PC workstation data reduction are discussed.

## **BACKGROUND**

Lockheed-Ft Worth, previously instrumented two Eglin F-16 aircraft for flutter and loads testing. The initial instrumentation system (see Figure 1) for each aircraft consisted of two Base Ten Systems Inc. programmable Data Acquisition Systems (pDAS) and FM/FM systems. The Pulse Code Modulation (PCM) outputs from the two pDAS systems were telemetered via individual S-Band transmitters and recorded on an analog recorder onboard the aircraft.

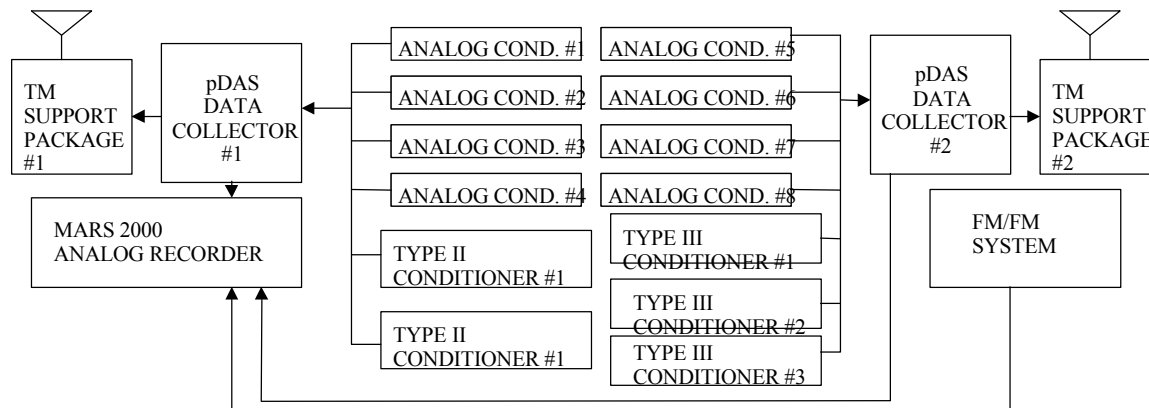
pDAS is a modular family of instrumentation LRU's for the acquisition and processing of analog and digital signals into a PCM bit stream. The primary building block of pDAS is the Data Collector which provides, under user programmable EPROM memory control, timing and control signals to the other system units. System capabilities are as follows:

- Programmable Bit rates 5K – 800K bps limited to 10 or 12 bits/word
- 4K EPROM memory for up to four externally selectable programs
- Hardware programmable gain and offset capability
- One 1553 mux bus per Type III Digital Signal Conditioner
- Four Type III conditioners per pDAS collection system
- 32 analog input channels per Analog Signal Conditioner
- 10 bit A/D conversion

Two pDAS systems were required due to the number of parameters required and the resulting bandwidth versus record time limitations. In addition, a frequency modulation (FM) subsystem was installed to collect data that required a higher frequency response than pDAS.

Each aircraft pDAS installation consisted of two pDAS Data Collectors, two pDAS Type IIA digital conditioners (synchros, LVDTs), three pDAS Type III digital conditioners (1553 mux) and eight analog conditioners (strain gages, accelerometers). The two pDAS systems were installed in the Ammo Bay in each of the two F-16 aircraft. pDAS system #1 was used primarily for load parameters. pDAS system #2 was used primarily for flutter parameters.

## pDAS & FM/FM SYSTEM BLOCK DIAGRAM



**Figure 1**

**pDAS Limitations.** PDAS provided limited capability when compared to data collection systems that are available today. Its parallel architecture required multiple sets of wires for box-to-box communication. Also, multiple boxes were required due to system architecture. Additionally the pDAS manufacturer stopped producing and/or maintaining components in 1988, thus making the system obsolete. In short, mid 1970's technology and substantial manpower were being used to meet next century performance requirements.

**pDAS Disadvantages.** PDAS instrumentation was very labor intensive and time consuming. The preflight required on average 3 to 5 men and 4 to 8 hours per aircraft. The aircraft ammo bay cover panel had to be removed on every preflight to gain access to the analog conditioners for offset and gain adjustment and to verify (using an oscilloscope) the analog signal from each transducer located in/on the wings of the aircraft. When a new format was required, EPROM's had to be physically removed from each pDAS box, erased and then reprogrammed. Due to the number and size of pDAS LRU's, their installation was limited to the ammo bay compartment. As a result, large wiring harnesses had to be added to the wings and aircraft fuselage. Where wire could not be added, and due to insufficient space at the weapon stations, signals had to be FM multiplexed and then demultiplexed and interfaced to the pDAS system. Overall system bandwidth limited the number of parameters which could be sampled by the system causing aircraft reconfiguration on daily mission requirements.

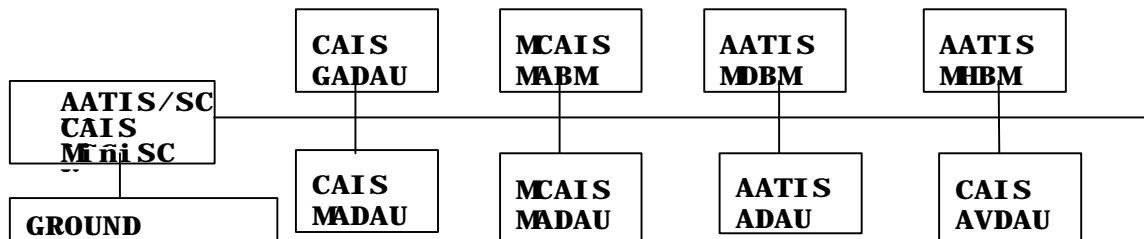
## SOLUTION

It was the goal of the Instrumentation Division to purchase a new system that would simultaneously monitor all parameters for both flutter and loads testing and incorporate an all new digital calibration, recording, and preflight verification method. The new system was required to be interoperable with the existing inventory of Advanced Airborne Test Instrumentation System (AATIS) and the Common Airborne

Instrumentation System (CAIS) hardware. The new system was to provide a low cost solution, at least 35% cheaper than the existing AATIS or CAIS equivalent system, combine multiple functions per channel, be 80% smaller than existing pDAS, AATIS, CAIS units and be operational within a year from procurement. A further goal was to have the system integrated with the Test Information Management System (TIMS) thus eliminating the requirement of retraining personnel on new support equipment/software. Preflights would have to be reduced to one hour with no hardware reconfiguration required for change of offsets and/or gains, and be limited to a minimum of two preflight personnel. All goals were met or exceeded with the Miniature Common Airborne Instrumentation System (MCAIS) integrated with the TIMS automated programming and data limit checks, and the total digital recording with the MARSII digital recorder. MCAIS is a time-division multiplexed digital data acquisition system. The system is a family of modular components which are interconnected via a four wire serial communications bus (CAIS / AATIS bus). The inherent modular architecture is equivalent to that of AATIS or CAIS allowing individual units to be centrally or remotely located throughout the test aircraft. Figure 2 depicts a system level block diagram.

## MCAIS SYSTEM OVERVIEW

FIGURE 2



**Miniature Analog-Discrete Data Acquisition Unit (MiniADAU).** The miniADAU operates as a remote unit on the CAIS / AATIS bus. The MiniADAU contains its own internal power supply and operates from a nominal 28 VDC source, and is programmed over the CAIS / AATIS bus. The MiniADAU supports high speed and digital sampling rates up to 417 KSPS as well as simultaneous sampling that allows multiple channels to be captured at the same time. The functionality of the MiniADAU is customized by the addition of up to 8 user selected Signal Conditioning Cards (SCC). In the MiniADAU, signal conditioning functional blocks (i.e. filtering, gains, simultaneous sample) are combined on a per channel basis, thus eliminating the need for interconnects between cards. The MiniADAU provides 12 bit A/D resolution, programmable gain of up to 2000 per channel, programmable offset, and provides for .1% to .5% accuracy (depending on gain and temperature).

**Bridge Signal Conditioning Card (BSCC).** The BSCC provides six channels of bridge conditioning and two excitation sources per card. The functionality of the card was derived by combining functions and technology from several ADAU signal conditioning

cards (SCC) onto a single card on a per channel basis, thereby eliminating the need for interconnects between multiple cards to produce a signal conditioner channel. The BSCC combines filtering, gain, multiplexing, simultaneous sampling, autozero, and 1/3 attenuation on a per channel basis. With the combined functions and 1/3 attenuation, the BSCC is also suitable for general purpose analog signal conditioning.

**Discrete Signal Conditioning (DSCC).** The DSCC provides 32 channels of single ended discrete inputs and one 32 bit asynchronous serial input. The functionality of the card was derived by combining functions and technology from several ADAU SCC's onto a single card. One group of 16 bits can also be configured as 8 differential discrettes. Discrettes can be either 28 VDC/Open or Open/GND type.

**Piezo Electric Signal Conditioner Card (PSCC).** The PSCC provides six channels of signal conditioning/excitation per card. The PSCC combines filtering, gain, multiplexing, simultaneous sampling, and autozero on a per channel basis.

**LVDT Signal Conditioner Card (LSCC).** The LSCC provides four channels of signal conditioning per card. The LSCC combines full wave rectification, filtering, gain, multiplexing, simultaneous sampling, and autozero on a per channel basis. The output of the LSCC is a time varying DC voltage that is proportional to the input AC amplitude and phase.

**The Calibrator Signal Conditioner Card (CSCC).** The CSCC provides six channels of analog stimulus and six calibrator enable outputs per card. The analog outputs are selectable as either AC, DC, or AC with DC offset on a per channel basis. The CSCC allows users to provide a known stimulus (either AC or DC) to Analog Signal Conditioning Cards to use as a P-BIT or health status of the SCC.

**The Miniature System Control Unit (miniSCU).** The miniSCU operates as a Bus Controller Unit on either the Common Airborne Instrumentation System (CAIS) or the Advanced Airborne Test Instrumentation System (AATIS) bus. The miniSCU contains its own internal power supply and operates from a nominal 28 VDC source. The miniSCU is used in small system applications with PCM output rates from 125 KBPS to 5 MBPS. Up to 16 different formats can be programmed into its 32K word format memory. Each format is user selectable through an external interface. The controller simultaneously provides primary PCM as NRZ-L, RNRZ-L, and BIØ-L outputs. The miniSCU controls the miniSeries and CAIS/AATIS Bus compatible data acquisition units (DAU) contained in the instrumentation system, collects data from these DAUs and formats the data into an output PCM stream for both telemetry transmission and recording.

**MARS II Recorder.** The MARS II is a hostile-environment, modular, digital recorder/reproducer system, with the capability to record (up to 40 Mbps aggregate) and reproduce eight (8) completely asynchronous channels of PCM data or dual redundant MIL-STD-1553 data and two auxiliary channels (IRIG Code and Voice). Data is recorded on a computer peripheral storage device (DLT 7000). Data stored in the DLT 7000 tape can be digitally processed by any PC.

**Test Information Management System (TIMS).** The 46 TW/TSI specified and integrated requirements of MCAIS units into the TIMS architecture (see figure 3). The original intent for the creation of TIMS was to provide flight test engineers with utilities for creating programs that instruct the control unit and any programmable remote units what data to collect and how to format it for recording or telemetry purposes. TIMS provides the capability to define the instrumentation network consisting of control and remote units, design PCM formats using a spreadsheet-like application, and automatically generates program load modules which it then loads into the aircraft instrumentation system. Using the same PCM format layout, TIMS generates the program which allows the user to decommutate and display the test results. Outputs can be displayed as raw test data or in engineering units as line graphs, bar graphs, or values. TIMS offers a wide range of capabilities, ranging from defining how test data is processed, how the test data is displayed, and on into digital recording and playback. The capabilities include standard analysis reports and an interface to a PC based statistical analysis tool. Once test data has been recorded, the flight test engineer can initiate a request that specifies time slices and parameters of interest, and frequency of output in samples per second. The output of this job can be in the form of a printed report, a file that can be imported into Microsoft Excel, or a binary format that can be processed by other analysis programs. TIMS comprehensive support capabilities simplify complex tasks and saves substantial development time while reducing keyboard entry errors.

**New F-16 Flutter and Loads System Architecture.** The new instrumentation system (see figure 4) provides for simultaneous monitoring of flutter and loads parameters, greater than 480 analog channels, greater than 96 discrete signals, as well as over 32 channels of LVDT and synchro parameters. Digital MIL-STD-1553 data monitoring is accomplished on 7 busses and is collected in both selective and total bus mode. Data is simultaneously recorded and transmitted at a 3.33 MBS rate. The CAIS / AATIS compatible architecture has reduced the number of wires required from 48 to four per wing. The small MiniADAU's are installed in the launcher racks and pylons, thus further reducing the amount of wiring and aircraft downtime required. In addition, multiple function SCC's eliminated the requirement for separate unique signal conditioning. GAIN and offsets are software programmable thus eliminating the need to open aircraft panels to gain access to the units. Flexibility within the MiniSCU's 32K of memory allows eight times the amount of memory as compared to the previous system and affords bit rates of greater than 6 times that of pDAS. System resolution also benefited from the

new system 12 bit A/D versus 10 bit A/D, and sampling of 16 bits per word. Data recording has improved from a maximum record time of two hours to six hours and an increased bit error rate from 1 E-6 to 1 E-12. Digital calibration allows for simultaneous activation of all channels for an automated preflight go/no-go determination.

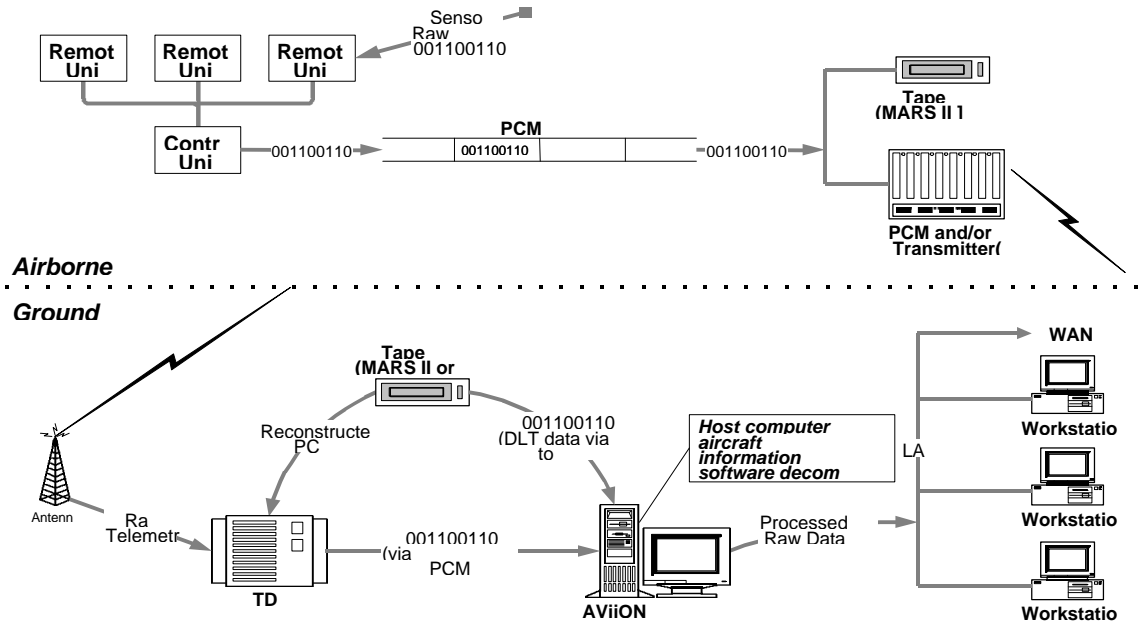
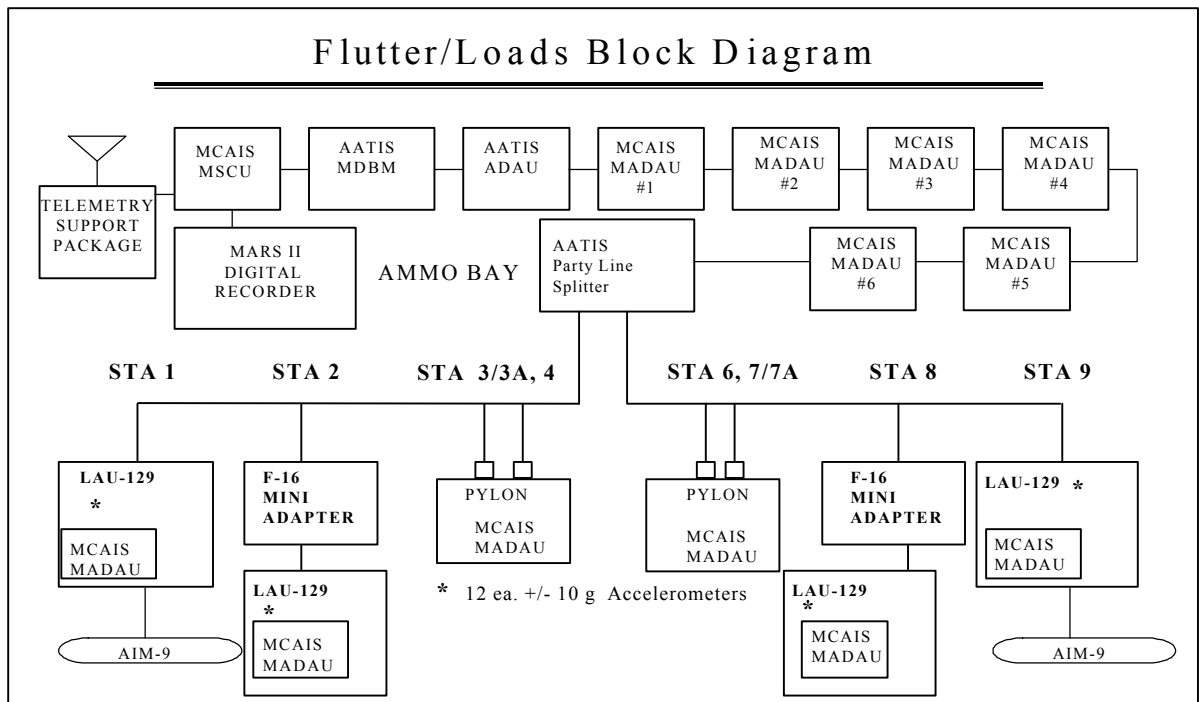


Figure 3. Example TIMS Data Flow

**TIMS Quick Software Decommuration.** Integration of MiniCAIS components in the TIMS architecture has allowed for existing software to be utilized for real time preflight verification utilizing the Graphical User Interface (GUI) to display data in engineering units and to perform automatic data limit checks on critical mission parameters. Software decommuration capability has additionally allowed for data quick look on a PC without the requirement of a telemetry front end. Data interchange between ground reduction facilities allows for transfer of parameter information to the data analyst in a digital format. Utilization of TIMS has allowed for simultaneous monitoring of multiple parameters thereby reducing preflight and calibration time.

## CONCLUSIONS

The successful F-16 Flutter/Loads flight test program has demonstrated the clear benefits of the MiniCAIS system. It is a first step towards extending the usefulness of existing instrumentation data system equipment by introducing new technology while retaining compatibility. Without a doubt, the key elements that made this project successful were a clear set of goals, a stable set of requirements, and a clear understanding of existing limitations. MiniCAIS, when used in conjunction with TIMS, is a powerful and effective solution especially in today's reduced manpower, cost conscious flight test environment.



**FIGURE 4**

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