CAIS: FTI SYSTEMS FOR ADVANCED APPLICATIONS

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Abstract

Today's Flight Test Instrumentation (FTI) engineers are faced with a variety of "traditional" challenges including equipment installation in composite aircraft, fitting and wiring the equipment in tight locations, developing standardized low-cost ground support processes, and increasing the utilization of low-cost, computerized tools and technology. FTI engineers are also responsible to select solutions that will satisfy "non traditional" programmatic requirements such as supportability, interoperability, expandability, flexibility, and long-term support, especially when the equipment is used on long-term, multi-year programs. Finally, in order to respond to the inevitable need for change, the FTI engineer must also plan for ways to effectively incorporate new technology such as high-speed serial data networks including Fibre channel, IEEE-1394b Fire-wire, Ethernet and others. And all of this must be done in such a way as to be compatible with the existing baseline FTI system.

This paper demonstrates that CAIS-based FTI Systems satisfy all of these requirements for today's advanced FTI system requirements. The paper will describe the features and capabilities of these systems considered most important to the modern FTI engineer. The paper also discusses those enabling CAIS features that guarantee CAIS' role as the key standardization concept for flight test programs of the future.

The paper also summarizes experience gained during the selection and application of the Joint Strike Fighter (F-35) FTI system. JSF uses a CAIS-based FTI, and is prototypical of today's modern aircraft development program, serving well to illustrate the concepts covered throughout this paper.

Key Words

Common Airborne Instrumentation System (CAIS), Flight Test Instrumentation (FTI), Data Acquisition, Fibre Channel, Firewire, Smart Sensors

Introduction

CAIS stands for "Common Airborne Instrumentation System", and has been used for many years throughout the flight test industry. Most CAIS products are available as pre-qualified, COTS solutions with extensive flight test history on major programs such as the F-22 program. CAIS can be described as a robust, open-architecture command/response communication bus protocol with system-wide synchronization capability. The system is

scalable to operate at data rates of up to 1 Gigabit per second with the capability to expand to 2 Gigabits per second.

The CAIS concept was developed and first deployed over 15 years ago, which is a "long time" in this age of rapid technological development. Flight Test Instrumentation has seen significant growth and development since then, but CAIS remains the "tool of choice" for many instrumentation system designers, even as performance and throughput demands continually escalate. The longevity of the CAIS system is especially important when considering the long-term, multi-year nature of modern aircraft development programs.

CAIS is a paper standard describing a command/response communication protocol. It was developed to promote interoperability among equipment used throughout the flight test instrumentation industry. After the release of the paper standard, several companies pioneered a new breed of advanced instrumentation products and components that capitalized on the benefits of the standardized CAIS system. These products now form an arsenal of fully compatible, flight-qualified tools available for use by the entire Flight Test Instrumentation community.

Although each CAIS bus command/response communication port is limited to a 5 Mbps data throughput rate, the concept has been utilized on systems requiring data throughput several orders of magnitude greater. System topologies have been developed to handle data in the gigabit-per-second range.

Benefits of CAIS Standardization

CAIS compatible products and software are available for use on a variety of systems, ranging from low bandwidth "simple systems" up through extremely advanced and complex systems such as those used on the F-22 and more recently on the F-35 (JSF).

Since major programs can run for dozens of years and the proposition of retooling the entire FTI system is neither desirable nor economically affordable, the flexibility, growth potential and longevity of CAIS systems are extremely attractive and cost effective. CAIS has enabled F-22 and several other major flight test programs to not only achieve baseline goals, but to evolve through the years along with technology in order to meet an ever growing demand in the overall vehicle development.

The CAIS community is continually developing new products to further enhance operation and better utilize the latest technology. CAIS compatible equipment is modeled after the "Plug-and-play" capability initially pioneered for use in the Personal Computer (PC) industry that are now taken for granted by modern computer users. Instrumentation products are now expected to offer growth expansion in terms of both hardware and software compatibility; CAIS compatible products satisfy this need.

CAIS on F-22

The F-22 program was started in 1987 and is still running today. F-22 EMD (Engineering and Manufacturing Development) relies on the CAIS system for the flight test instrumentation, and software products. CAIS was able to fully support the initial development portion of the F-22 program, and is still able to fully support the current phases of this ongoing program. F-22 has seen a revolution in the available technology, and CAIS

has enabled this technology to be used within the same baseline FTI system architecture. F-22 is an excellent example of long-term FTI evolution, based on the CAIS concept.

System Requirements

Vehicle complexity is one of the key drivers for the selection and application of FTI equipment. As the amount of vehicle data increases, the demands on the FTI system increase as well. The ability to efficiently handle large amounts of data results in a direct reduction in the required number of flight test hours. As the flight test program matures, the FTI system must respond to changes in the kinds of data that must be acquired, as well as the amount of data needed to support post-mission analysis and real-time safety-of-flight checks. The system must often be reconfigured to tailor the system on a flight-by-flight, aircraft-by-aircraft basis.

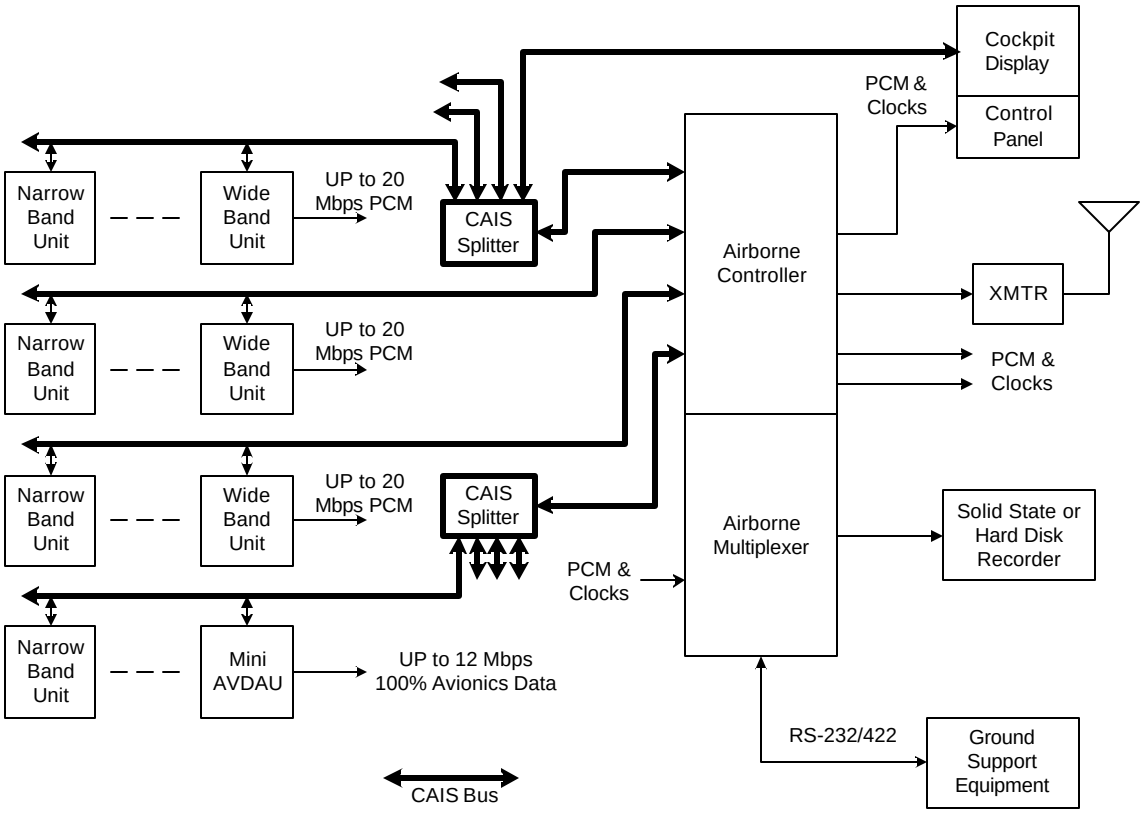
The primary goal for the FTI system is to monitor data in the areas of performance and flight safety. But it has become very favorable for the FTI to also communicate with other vehicle systems such as avionics, stores, pilot communications, telemetry, etc. The CAIS FTI has evolved to accommodate these sources and interleave these various kinds of data in such a way that it improves system performance and safety, and reduces the overall cost of vehicle development.

New high-speed technologies are delivering data to the FTI system at faster than ever rates. The introduction of Fibre Channel and Firewire technologies into aircraft instrumentation has now driven CAIS-based FTI systems to breach the 1 Gigabit data transfer threshold. CAIS-based FTI systems now provide program and communication links with cockpit displays, recorders, transmitters, and a variety of other complex equipment. It seems inevitable that the number of measurements will always be increasing, the amount of data will always grow, and the diversity of various systems and components outside CAIS will be growing and becoming more complex. A typical CAIS System example is shown in Figure 1.

Performance is not the only issue. Flight Test Engineers are always looking for ways to speed up the integration and checkout process. CAIS has pioneered the use of "single-point-access" to all system components so that installation, setup, operation and maintenance activities can be consolidated into a single set of standardized tools and software. CAIS systems utlilize their communication cables to achieve these additional links, thereby reducing system wiring complexity and cost.

PC-based products are now quite common in the support of advanced aircraft systems as the old days of complex, customized systems are diminishing. Turn-key CAIS-based software systems now provide the user with fully integrated tools to support all airborne acquisition and ground based data recovery/analysis activity. Operators no longer need to be experts in multiple, non-synchronized computer languages in order to support a single, CAIS FTI system. The result is that training requirements are reduced, preflight checkout time is minimized, support equipment and software costs have been reduced, and vehicle availability has significantly increased.

Figure 1 Typical CAIS System Example.



Technology Insertion

The CAIS "open architecture" allows adaptability to a variety of new bus interfaces. These include smart sensors, Fibre channel, IEEE-1394b Fire-wire, Ethernet, along with existing MIL-STD-1553, RS232 and others. Greater reliance on computerized software tools has resulted in solutions that can be quickly configured to accommodate new communication schemes without the need to retool the instrumentation hardware. Plug-in modularity allows new interfaces to be quickly developed and integrated into the existing FTI equipment base. This integrated development/product environment also promotes participation by new vendors, manufacturers and customers within the CAIS community.

Application on the JSF Program

The Joint Strike Fighter contract was awarded in late 2001. The program involves the production of an initial 22 aircraft in the program's $25 billion System Development and Demonstration (SDD) phase formerly known as Engineering and Manufacturing Development (EMD). The F-35 Joint Strike Fighter is a stealthy, supersonic multirole fighter designed to replace a wide range of aging fighter and strike aircraft. Three variants derived from a common design will ensure F-35 meets the performance needs of the U.S. Air Force, Marine Corps, Navy and allied defense forces worldwide, while staying within strict affordability targets.

The flight test program centers on three different variants of the F-35 aircraft. Multiple instrumented aircraft will be operated from multiple test sites and will be supported by instrumentation personnel from multiple organizations. CAIS-based instrumentation data acquisition systems were selected to meet the system requirements, to facilitate commonality of flight test instrumentation between aircraft types, and to guarantee interoperability between DoD and contractor test facilities.

The most important feature of the CAIS bus is that it functions synchronously in a command/response fashion and transmission occurs in a full-duplex manner by means of a command bus and a reply bus. CAIS is a deterministic bus that provides data coherency based on the sample timing from the placement in the PCM format. Single Point System Programming allows operations and setup of the instrumentation system via a single RS-232/422 interface using COTS turn-key Ground Support Units. This equipment consists of affordable, lightweight, versatile, fully functional laptop tools, each configured with integrated receivers, bit synchronizers and decommutators. The reliance on industry-standard PCMCIA form-factors greatly enhances the equipment portability, supportability and expandability, and also dramatically reduces cost.

The simplicity of serial communication cables between CAIS remote DAU's allows a distributed data acquisition to be installed on test aircraft as it is being built on the production line. Typical measurements such as acceleration, current, discretes, flow, mechanical positions, pressures, RPM, strain gage, temperatures, and vibrations would be wired to remote DAU's strategically installed in various sections of aircraft to "contain" signal wiring within a bay or section of aircraft. This reduces the number of disconnects and minimizes the amount of "orange wires" that have be routed across bulkheads. System checkout will take place on production line using turn-key Ground support solutions that are small, lightweight, portable and versatile. Future measurement requirements throughout the flight test program can be accommodated via growth provisions that were carefully planned during system design, thereby reducing aircraft down times. The result is that the instrumentation system will be ready to support flight test activities when the aircraft rolls out of the production line. Ultimately, significant savings in cost and schedule will be achieved.

Conclusion

CAIS is a proven, qualified solution to meet all goals of major FTI programs. The concept satisfies all needs at both the performance and programmatic level, and has been shown to be a reliable baseline on which to plan the support for long-term flight test instrumentation programs such as the F-22, M346 and the F-35 (JSF). The CAIS concept is wide open to the flight test community at both the user and developer level, and the benefits of reliance on such a long-term, well accepted, internationally recognized standard are many.

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