AN INSTRUMENTATION CONTROL SYSTEM THAT UTILIZES AN AVIONICS PILOT DISPLAY INTERFACE

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ABSTRACT

Flight Test instrumentation control units have traditionally been low-technology units with mechanical switches, readouts, and perhaps an RS232 interface. As the complexity of Flight Test Instrumentation systems and operational requirements increase, and as cockpit space becomes scarce, these control units are no longer sufficient. These control units need to provide capabilities commensurate with the complexity of the instrumentation systems they control.

This paper describes an instrumentation control system that uses a Boeing Integrated Defense Systems (IDS) Flight Test Instrumentation designed Instrumentation Control Unit (ICU). The ICU communicates with the avionics system to allow pilot control via existing aircraft displays. By taking advantage of a relatively simple protocol to interface with the avionics system, the substantial cost of reprogramming the avionics software is avoided, and software control is shifted to the Flight Test group, thus allowing a tremendous increase in system flexibility at reasonable cost. Functions of the unit can be changed relatively quickly and inexpensively. This promises a wide range of future applications, such as in-flight monitoring of flight-critical instrumentation parameters by the pilot, control of the instrumentation system via uplink (with pilot override), and real-time in-flight selection of telemetered data streams and parameters.

This paper describes the baseline instrumentation control system and requirements to be used on the EA-18G Flight Test Program, plus additional future capabilities.

KEYWORDS

Keywords: Instrumentation system control, flutter, uplink, iNET

INTRODUCTION

The EA-18G System Development and Demonstration (SDD) Program for Boeing IDS Flight Test Instrumentation represents a significant step forward into a 21^{st} century instrumentation system. This program represents the first opportunity to monitor a significant number of Ethernet-based and Fibre Channel-based data streams, in addition to traditional analog parameters. Because of the number and bandwidth of the data streams, the flight test telemetry system is also significantly more complex than for previous aircraft flight test programs, transmitting two combined data streams with multi-mode (PCM-FM and SOQPSK) transmitters through multiple antennas. In addition, the instrumentation system includes a Fibre Channel Interface Unit[1], solid-state video and data recorders, and a video encoder.

If this increase in complexity and data bandwidth were not enough, several critical Flight Test support features have been removed from the aircraft's Advanced Mission Computer (AMC) Operational Flight Program: 1) the Head-Up Display is no longer able to display Flight Test parameters (such as Flight Test AOA and AOSS), 2) support for previous flight test control panels is not available, and 3) support for the Boeing Flight Test Instrumentation built Flutter Exciter Control Unit (FECU) has been removed.

In an effort to address these control issues, and to reinstate critical flight test functions, the Flight Test Instrumentation department at Boeing IDS Saint Louis has developed a Flight Test instrumentation control system using an avionics pilot display interface. This system supports the current requirements of the EA-18G SDD program, and provides an extensible platform on which future advancements can be made.

SYSTEM CONFIGURATION

The aircraft configuration for the instrumentation control system is shown in Figure 1. There are three primary components of the control system: 1) The Instrumentation Control Unit (ICU), 2) the Instrumentation Multiplexer Unit (IMU), and 3) the Auxiliary Control Panel (ACP). The ICU is the "smart" box of the system, which communicates with the pilot via the AMC, pilot display, and Auxiliary Control Panel. It controls the instrumentation system through the IMU, which provides an interface to discrete and serial control signals required by the instrumentation equipment.

The ICU communicates with the avionics system via a dedicated avionics format. This allows the ICU to control the display of information and receive pushbutton information directly without intervention from the AMC.

The ICU communicates with the IMU via two RS232 interfaces. The first RS232 interface conveys control commands from the ICU through the IMU to the target equipment, and likewise receives status back from the target and controls operation of the ACP. A control line from the ICU tells the IMU to ignore RS232 information and pass it through to additional IMU's or to the ACP. The second RS232 interface allows the Ground Support Unit (GSU) to program any target device through the IMU's RS232 multiplexers. A control line originates in the GSU and is used to initiate pass through mode. This mode eliminates the need for the control system to handle a large number of complex protocols at varying speeds, while allowing a single-point connection for pre-flight loading of the instrumentation equipment.

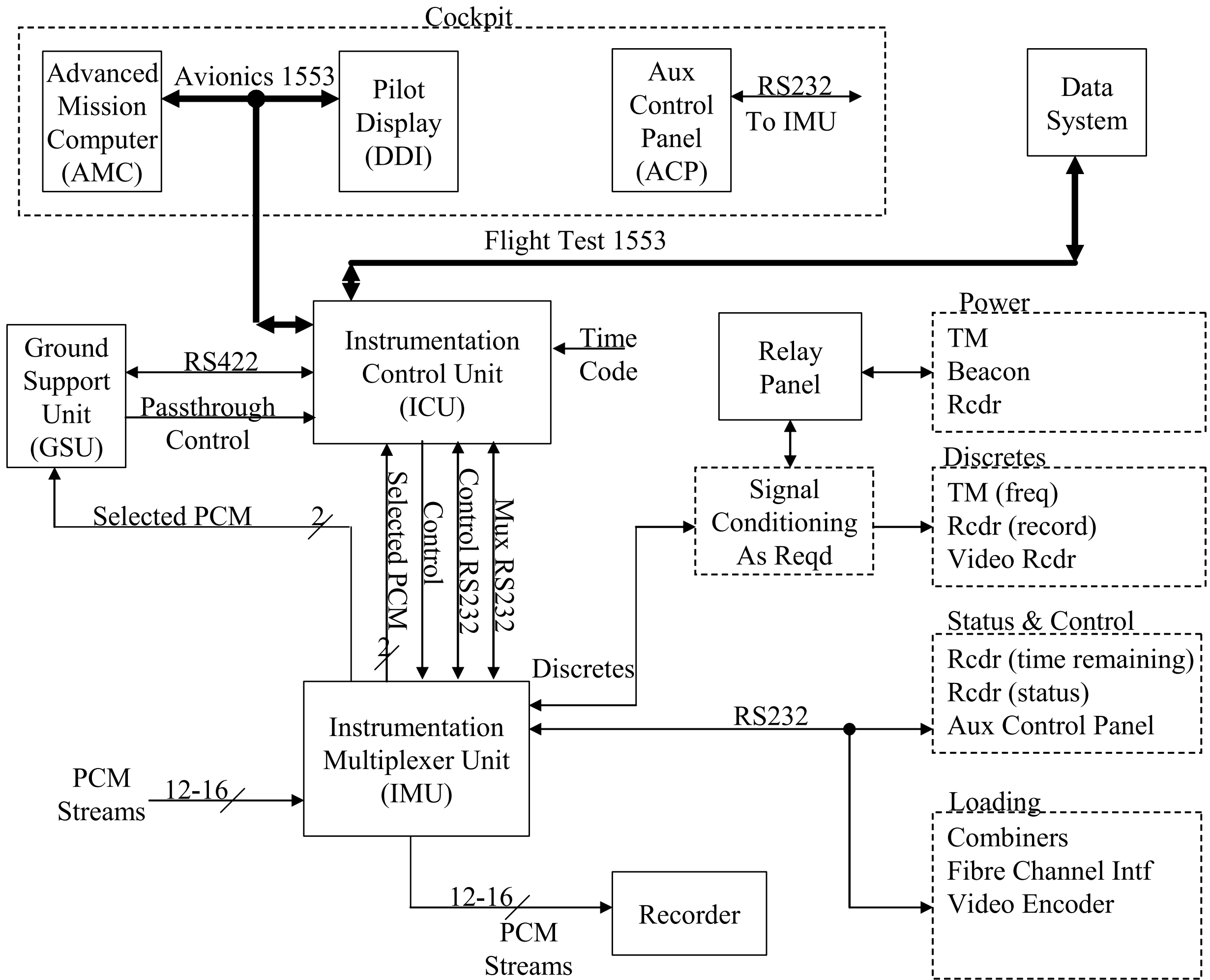

Figure 1. Instrumentation Control System EA-18G Aircraft Configuration

In addition, the IMU buffers the serial data streams sent to the onboard recorder, and selects up to two streams to send to the GSU and up to two streams to send to the ICU for in-flight monitoring of Flight Test parameters. The GSU connection is used in pre-flight checkout of the instrumentation system, and this configuration simplifies selection of the desired stream while eliminating the problems caused by connecting a "Y" bundle to high-speed serial lines.

The ICU also supports a dedicated Flight Test 1553 bus, in which it is the Bus Controller (BC). This is currently used to retrieve specified Flight Test parameters from the onboard data system. This 1553 port may also be used for a variety of future applications, as described later in this paper.

This system architecture allows the instrumentation control system to perform the following tasks:

- Control and status monitoring for all instrumentation equipment, through discrete lines or RS232, with pilot inputs from either the pilot display or Auxiliary Control Panel.
- Display of status information such as Run Number and Media Time Remaining on the pilot display, and conveying this information to the Data System for telemetry to the ground.
- Display of Flight Test parameters on the pilot display, computed with appropriate calibration information.

There are a number of significant advantages to this control system architecture:

- The dedicated avionics format requires no ongoing avionics support after its initial integration checks with the Flight Test equipment. This allows Flight Test to change pilot displays and overall system function without incurring costly and time-consuming avionics support.
- The dedicated avionics format is implemented in production avionics software, allowing Flight Test to use this mode on any future production aircraft. It is not a special "patch" for Flight Test.
- Large wiring bundles for the PCM data and system control signals are isolated to the IMU.
- The IMU is a modular design, which accommodates future changes in instrumentation requirements by adding additional modules.
- The system provides a single connection point for pre-flight loading and checkout of instrumentation equipment.

SYSTEM SOFTWARE DESIGN PHILOSOPHY

The system design philosophy of the instrumentation control system is to allow an Instrumentation Engineer to program pilot menus, displays, and control functions using a PC-based software tool. The tool creates load information that is then loaded from the GSU to the ICU during pre-flight.

To this end, the firmware of the ICU has been designed to provide a stable platform of system functions driven by the ICU load information. These functions include displaying menu items and readouts (such as media time remaining), responding to pilot button pushes, transmitting and monitoring discrete control lines, and transmitting RS232 commands and requesting RS232 status. The basic functionality is strictly provided by the load information; the ICU simply responds as programmed by the software load.

To accommodate future growth, the ICU firmware has been designed to be event-driven, and to respond to a number of events in addition to pilot button pushes. For example, commands can be received from the pilot display or Auxiliary Control Panel, and future applications may receive commands from 1553 messages or from an uplink receiver. In addition, status updates are required periodically from equipment such as the onboard recorder. In the ICU firmware, all of these events are treated equally to trigger specific actions, resulting in a very flexible, extensible architecture that is driven by the software load. Not only can menus be changed readily, but the overall function may be reprogrammed with an appropriate load.

An example is shown in Figure 2. Here, the menu shows "Run Inc" to increment the run number on pushbutton 1. When pushbutton 1 is depressed, it triggers the "DDI:Run Inc" item in the Event list, which points to a table of functions in the Task List, causing the internal run number counter to be updated, as well as the counter on the pilot display and the console display. The event list also shows (with dashed arrows) that other events may update the run number: either the glare shield panel or uplink receiver command may also update the run number.

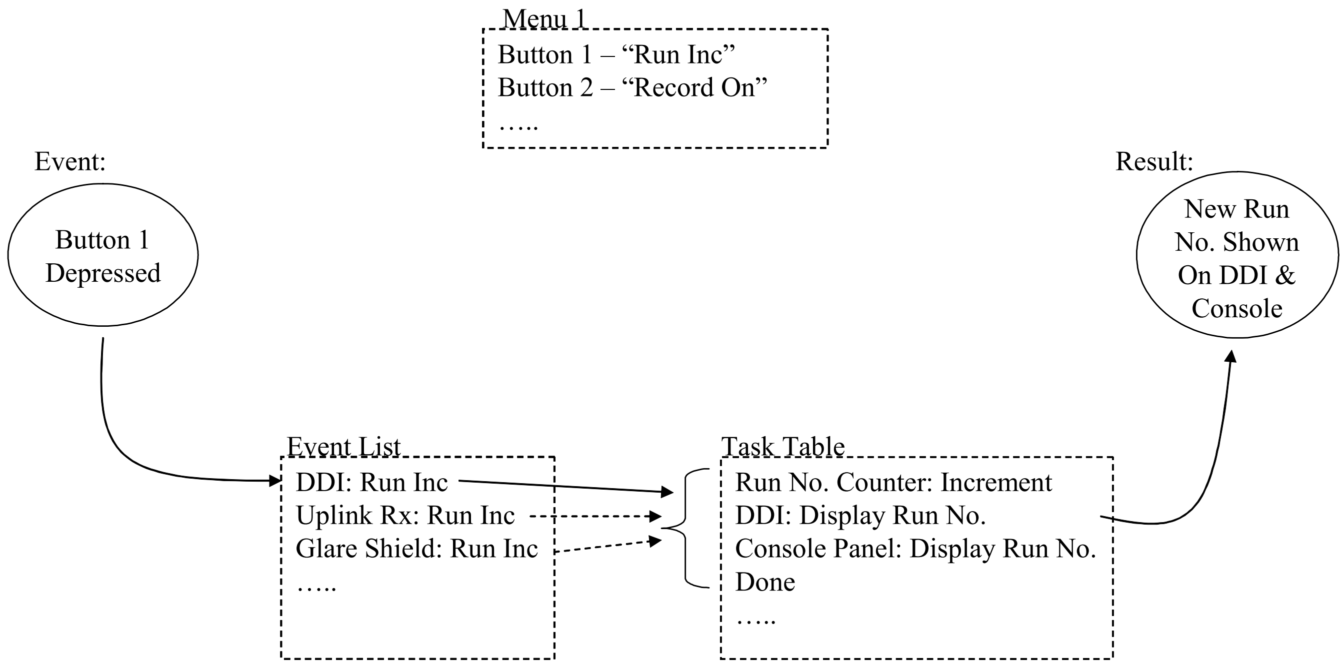

Figure 2. ICU Menu Example

Another aspect of the system design philosophy relates to the presentation of Flight Test parameters on the pilot display in-flight. Boeing IDS Flight Test has developed an integrated system known as the Flight Test Client-Server System (FTCSS) that generates load information for the data system, created from a database that includes calibration information for each Flight Test parameter. When Flight Test parameters are required on the pilot display, the system retrieves this calibration information for the specified parameters and includes it in the ICU load files.

DETAILED DESCRIPTION OF INSTRUMENTATION CONTROL SYSTEM UNITS

The ICU consists of a General Purpose Processor (GPP) and a 1553 I/O Board, built into a chassis with a backplane, with I/O coming from "microD" connectors on each board. This concept is an outgrowth of the Second Generation Onboard Processor[2] (OBP), and the ICU uses a short version of the OBP chassis and the OBP's GPP processor. The ICU measures approximately 6.9 inches wide by 6.13 inches long by 4.5 inches high (not including mounting feet) and weighs approximately 8.5 pounds.

Figure 3 shows the ICU internal operation. It consists of a PowerPC™ with significant operating speed and storage capacity. In its OBP implementation, the GPP will contain a real-time operating system that will not be available in time for use in the ICU; thus the operating system has been created from new and existing code written in C. The GPP provides one RS422 interface which is connected externally to the 1553 I/O Board, and one RS232 interface that communicates to the IMU Control RS232 interface. It also provides two 10BaseT Ethernet ports that are not used in the current ICU implementation; these ports will be implemented for future ICU applications once the real-time operating system is in place to provide Ground Support communication.

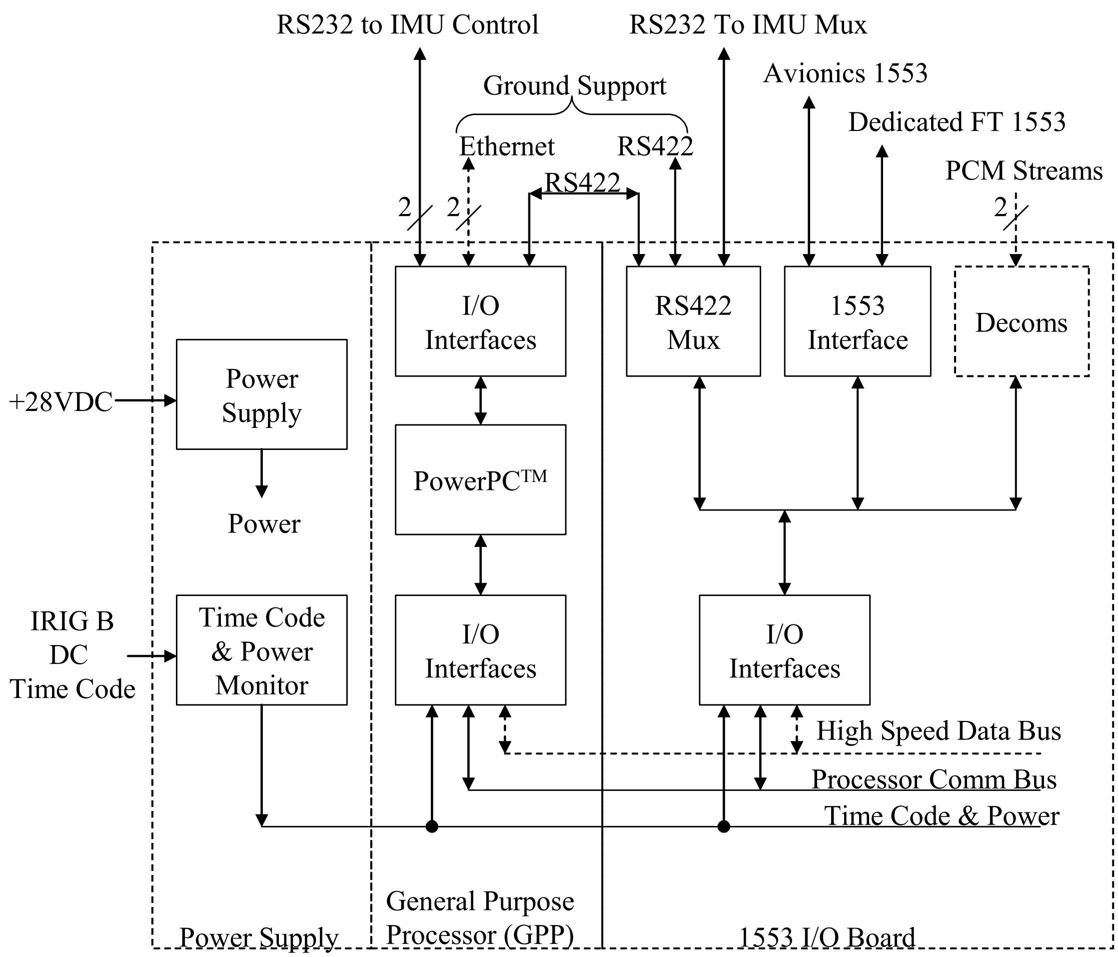

Figure 3. ICU Block Diagram

The 1553 I/O board communicates with the GPP via a processor communication bus. One 1553 interface acts as a Remote Terminal (RT) on the Avionics 1553 bus, and provides communication with the AMC to display information on the pilot display and to receive pushbutton commands from the pilot from that display. A second dedicated Flight Test 1553 bus provides communication with the data system, providing run number information to the data system and receiving selected parameters for display from the data system. This dedicated bus also provides for a wide range of future expansion capabilities.

The 1553 I/O board also contains a multiplexer which allows serial communication from the GSU to be passed through to an IMU RS232 multiplexer (and then on to the target equipment), or allows the GPP serial interface to communicate directly with the GSU to send and receive ICU and IMU setup and control information.

The 1553 I/O Board also receives two serial PCM streams for receiving Flight Test parameters for pilot display. The current VHDL implementation does not currently support decommutation of these streams, but this feature is planned for future applications. Logic on the 1553 I/O Board is implemented in programmable logic using VHDL. This allows upgrading functionality of the ICU without circuit board changes.

The IMU block diagram is shown in Figure 4. The IMU uses plug-together modules that allow for additional modules as instrumentation system requirements increase. The basic IMU for the EA-18G consists of a 16 Channel In/32 Channel Out Discrete Board, 28 Channel RS232/4 Channel RS422 Board, and two 8 Channel PCM boards with an endplate. It routes power, TTL RS232, and a slow-speed I/O bus down an interconnect bus for each module. The basic IMU is approximately 5.5 inches wide by 5.08 inches long by 3.50 inches high (not including connectors) and weighs approximately 5.0 pounds.

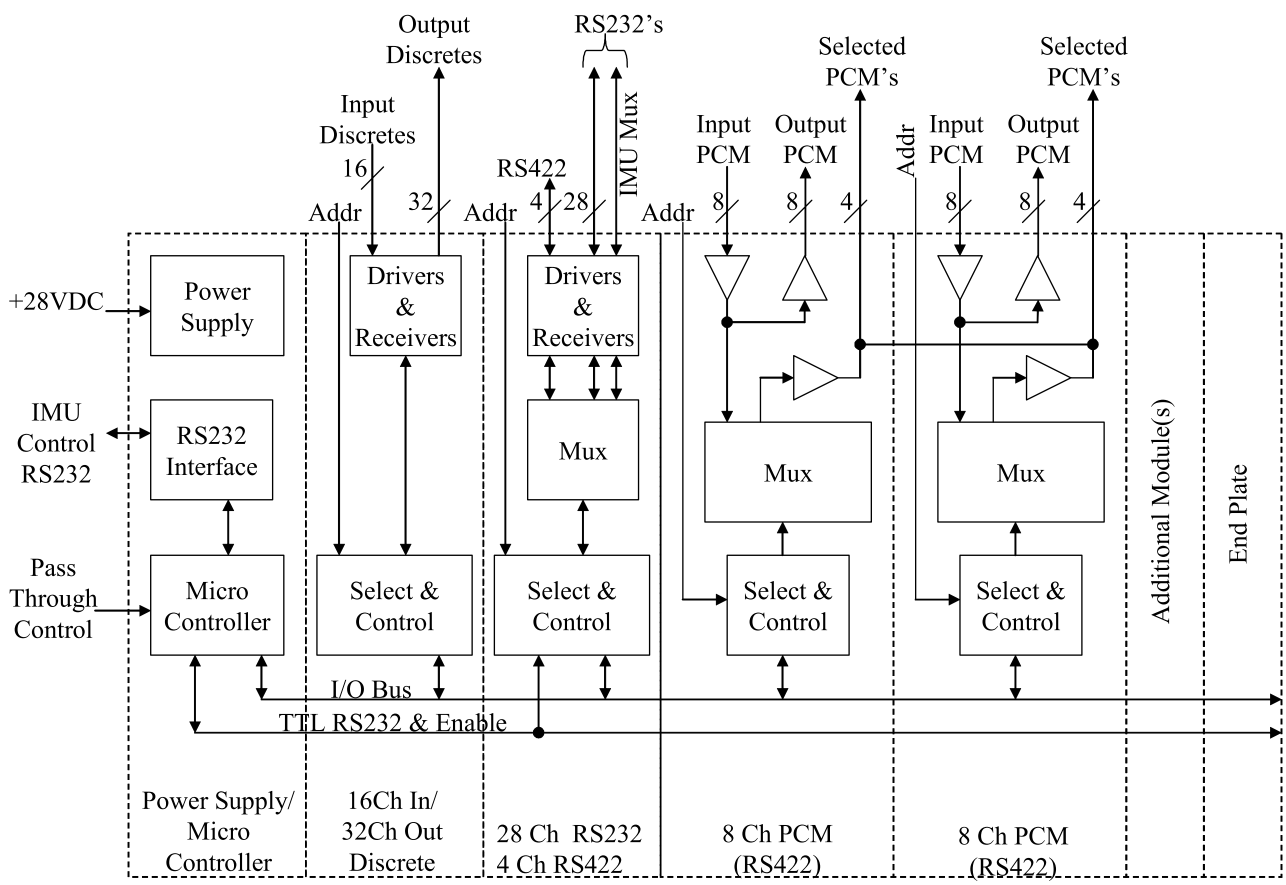

Figure 4. IMU Block Diagram

The microcontroller receives RS232 commands from the ICU, and either passes them through or decodes them to select the appropriate bilevel, RS232 or PCM output. The serial protocol from the

ICU is relatively simple, resulting in a fairly simple firmware and hardware implementation in the IMU. The 16Channel In/32 Channel Out Board provides optically isolated groups of discrete levels. The RS232/RS422 board multiplexes signals to and from multiple RS232 and RS422 channels; the serial connections default to Transmit/Receive sets, but can be set in groups to the full Transmit/Receive/RTS/CTS configuration for a reduced number of channels. The 8 Channel PCM Boards buffer serial PCM data and clock as differential RS422 pairs, and select 4 streams for output (two for the ICU and two for the GSU); the Mux outputs are tri-state devices attached together, minimizing stub wire lengths, and allowing a number of 8 Channel boards to be ganged together.

The Auxiliary Control Panel consists of two physical panels, one located on the Glare Shield and one located in the console. The Glare Shield Panel provides functions like Run Number Increment and Record On/Of (with lighted feedback from the recorder end-of-tape indication) which are needed even when the Flight Test page from the ICU is not shown on the pilot display. The Console Panel provides a sunlight-readable Run Number display, along with a hard wired switch to control Flight Test Master Power, and houses the microcontroller electronics. The microcontroller monitors button pushes and conveys these to the ICU through the IMU. Run number and switch lamp control are also commanded through the RS232 from the ICU.

ADVANCED CAPABILITIES

The modular architecture of the IMU and flexible hardware and software design of the ICU lend themselves to a number of advanced capabilities. Most notably, the event-driven software design philosophy allows the software load to make minor menu changes, or to create entirely new "personalities" for the ICU. Past history with the Onboard Processor[3] further indicates that users will identify new and creative uses for a flexible tool that were not envisioned by the original designers once the tool is available.

One advanced capability is reinstatement of a Flutter Exciter Control Unit capability lost in revisions to the avionics software. The FECU is a Boeing Flight Test designed box that communicates with the avionics system to control the pilot display and to receive programming and operating commands from the pilot, using a protocol similar to the dedicated avionics format used by the ICU. With the ICU implementation, the ICU acts as a conduit through which the existing FECU (without design changes) can communicate with the pilot and AMC, regaining the previous functionality. Some additional avionics support is still required, however, to implement shutdown capabilities.

Another potential application that has significant implications in the future operation of instrumentation systems is the incorporation of an uplink receiver to control instrumentation system components. The operating system of the ICU is designed from the ground-up to support control of the instrumentation system from multiple sources in a seamless fashion, and the flexibility of the IMU provides a hardware connection to a future uplink receiver through several possible mechanisms. This would allow an instrumentation engineer on the ground to control instrumentation system functions such as run number and telemetry antenna selection, and to retrieve status information such as media time remaining. Another potential function that has significant implications with the iNET[4] system to be implemented later in this decade is that the ICU could command selection of specific flight test parameters for telemetry from an iNET-capable data system through the uplink.

Further hardware architecture enhancements are also possible. The system has been designed, for example, to allow multiple IMU's that may be located near groups of instrumentation equipment to minimize wiring. An additional architecture enhancement is the incorporation of a Boeing IntelliBus™ interface, which provides a daisy-chained serial bus architecture to which are connected conditioning devices to deliver RS232 and/or discrete control throughout the aircraft with minimal wiring intrusion.

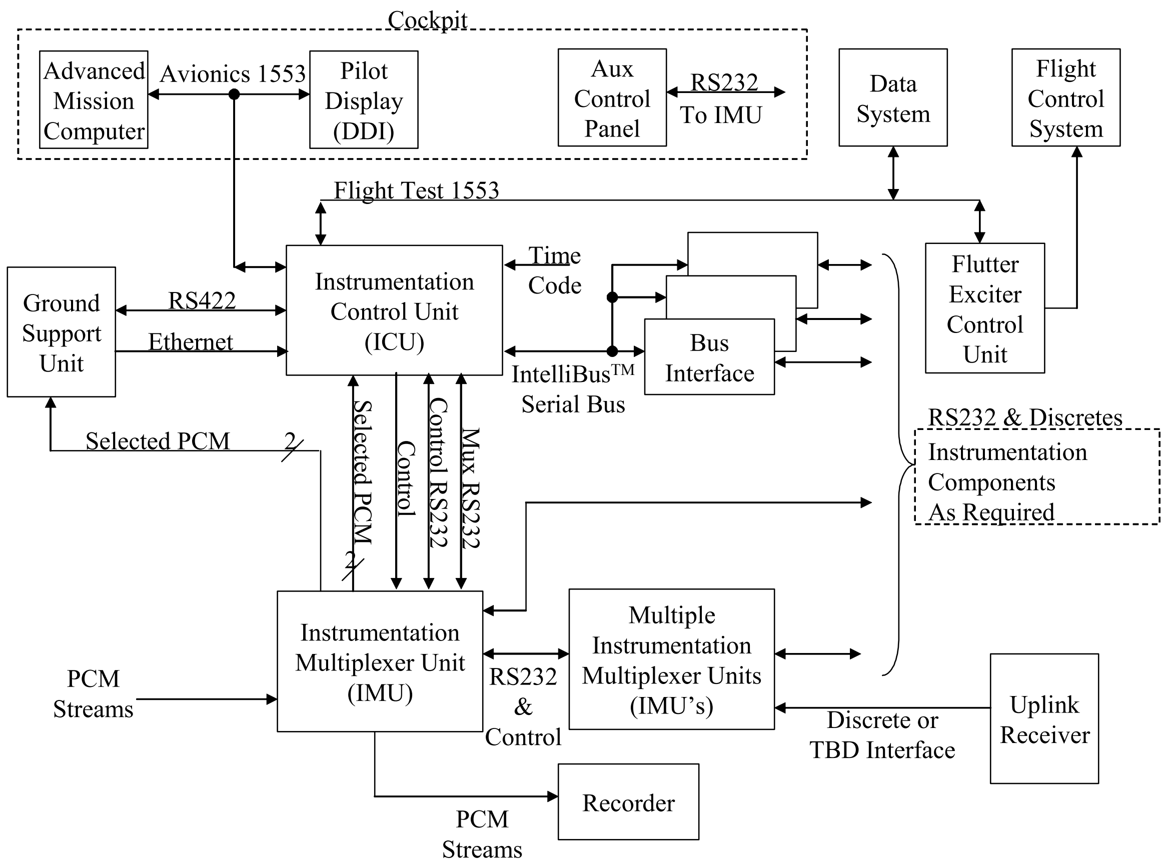

Figure 5. Advanced System Capabilities

Other advanced capabilities include more elaborate tab displays of Flight Test parameters on the pilot display, by implementing the ICU's IRIG 106 Chapter 4 decommutation capabilities. The storage capabilities in the ICU allow for a large number of possible parameters to be displayed and the OBP capable processing horsepower of the ICU can also be used to provide displays derived from multiple Flight Test parameters. Further, the implementation of a second-generation Onboard Processor on the aircraft could also allow for significant, flexible, computational horsepower in the display of Flight Test parameters.

CONCLUSION

The instrumentation control system is flexible and modular, allowing for changes in the instrumentation system requirements. The system design allows maximum flexibility in redefining menu operations and functions and system functions with minimal impact on hardware and firmware.

Since it is implemented using a dedicated avionics format for communication with the avionics system, day-to-day changes in what is controlled and how information is displayed is under control of Flight Test engineering, and does not require time-consuming and expensive avionics software and integration activities. The architecture supports software tools for creating ICU menus that are powerful and flexible, and allows functionality to be changed by loading a new software load.

The current implementation in the EA-18G reinstates and provides significant in-flight monitoring of instrumentation system performance and Flight Test parameters by the pilot, and provides a convenient one-stop Ground Support hookup to program and verify all instrumentation components.

Advanced application of the instrumentation control system includes reinstatement of the lost Flutter Exciter Control Unit capabilities, and seamless uplink capabilities.

REFERENCES

1. Zettwoch, Robert N., "Flight Test Monitoring of Avionic Fibre Channel Networks for Recording and Telemetry", Proceedings of the International Telemetering Conference, Las Vegas, October 21-23, 2003.

2. Wegener, John A. and Blase, Gordon A., "An Onboard Processor for Flight Test Data Acquisition Systems", Proceedings of the International Telemetering Conference, Las Vegas, October 21-23, 2003.

3. Ibid.

4. Skelley, Dan S., "Integrated Network-Enhanced Telemetry", Proceedings of the International Telemetering Conference, Las Vegas, October 21-23, 2003.

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