Overview of F-22 Upgraded Instrumentation System

Louis Natale
F-22 Instrumentation Sr. Staff Engineer
Lockheed Martin Aeronautics Co.
Marietta, GA USA

Albert Berdugo
VP and Chief Technology Officer
Teletronics Technology Corporation
Newtown, PA USA

ABSTRACT

The F-22 flight test program used a traditional distributed data acquisition system and a non IRIG-106 Chapter 10 recording system for its flight test program. In addition, it required a separate and very large Harris DAU system to monitor and record avionic data buses carrying secure data. Due to the size, cost, and the obsolescence of the Harris DAU system and components, Lockheed evaluated replacement systems. TTC proposed to develop F-22 specific Fiber Optic avionics bus monitors and an avionics PCM Data Selector / Encoder as part of its distributed IRIG-106 Chapter 10 Multiplexer / Recorder system to replace the Harris DAU. This replacement system challenges the traditional system approach used in many flight test programs.

This paper describes the evolutionary process to design two independent distributed data acquisition and recording systems handling data with different classification levels. The data separation is maintained by way of system wiring, proper hardware that holds no residual data once power is removed, different transmission channels, hardware-based message blocking, and a separate IRIG-106 Chapter 10 multiplexing / recording system.

KEY WORDS

Data Acquisition, Recorder, IRIG-106 Chapter 10, Data Acquisition

INTRODUCTION

The current F-22 flight test program uses two systems to acquire, record, and transmit flight test sensor and avionics data. The first system uses traditional PCM data acquisition equipment to condition and acquire wideband and narrowband sensor data with data from up to eight MIL-STD-1553 buses. This system allows the transmission of selected MIL-STD-1553 parameters and some sensor data, while recording 100% of acquired data. The second system uses a very large Harris DAU to acquire avionics data from up to six Fiber Optics buses and several MIL-STD-1553 buses. This DAU outputs 100% of its data to its own dedicated recorder, and outputs selected data via a MIL-STD-1553 for data transmission. The Fiber Optic avionic bus called FOTR is designed specifically to the F-22 platform and operates at a 400 MHz rate. These two systems were separated by way of different hardware, wiring, TM and recorders. This separation prevented the possibility of mixing data from both systems for various reasons. The first system uses SCI PCM controller called ASC and an eight-bus monitor unit called AVDAU, also from SCI. These two units have been obsolete for the past few years. The second system uses an obsolete Harris DAU that is too large to be used in future flight test programs. Due to the size, cost and obsolescence of these key components, Lockheed embarked in the evaluation of a replacement system. They evaluated the systems developed by TTC for use on the F-35 (JSF) program as a potential replacement. Although some of the components used for the F-35 can directly be used to replace the SCI obsolete components, some additional development was needed to replace the Harris DAU.

The remainder of the paper will describe the evolutionary process that was used to design a system that replaced all of the obsolete components, maintained system separations and met all of the original system requirements. The replacement system also used smaller units, provided newer technology, utilized new recording standards and provided lower cost.

BACKGROUND

The original instrumentation system used on the F-22 program included two separate systems called “System 1” and “System 2.” Several units used in both systems are no longer available due to obsolescence (identified as “obsolete” in the following list). Additionally, the space used for the Harris DAU is no longer available for future flight test programs. Refer to figure 1 for the original system diagram. The various units used in this system include:

- Several narrowband MCDAU-2000 acquisition units
  - Acquire data from low bandwidth sensor data
  - All acquired data is provided to the ASC via the CAIS (Common Airborne Instrumentation System) bus
- Several wideband MWDAU-2000 acquisition units
  - Acquire data from high bandwidth acoustic sensors
  - All acquired data is directed to the MiniARMOR multiplexer for recording
  - Selected RMS channel data is provided to the ASC via the CAIS bus
- An SCI AVDAU (Avionics Data Acquisition Unit) (obsolete)
  - Acquires data from up to eight 1553 busses. The data is formatted per IRIG-106 chapter 8 PCM, and directed to the MiniARMOR multiplexer for recording
  - Selected MIL-STD-1553 data is provided to the ASC via the CAIS bus
- An SCI ASC (Airborne System Controller) with three CAIS Buses (obsolete)
  - “System 1” acquisition controller unit
  - Has three CAIS busses for data acquisition from remote units, and operates at up to 15 Mbps
  - Provides 15 Mbps PCM to the multiplexer for recording and several Programmable Secondary Outputs (PSOs) for TM and Cockpit unit.
- A MiniARMOR as a PCM multiplexer unit with interface to a data recorder (obsolete)
  - A high speed multiplexer and recorder interface unit. Operates at up to 30 MBps
  - Multiplexes data using propriety data format (Non IRIG-106 chapter 10)
- A Cockpit Control and Display unit (obsolete)
- “System 1” Transmitter
- “System 1” Recorder
  - A DCRSi interface recorder. Receives all its data via the MiniARMOR unit
- A Harris DAU for avionics data acquisition (obsolete)

- o Acquires up to six F-22 FOTR buses
  - o Capable of generating FOTR data for test purposes
  - o Acquires several MIL-STD-1553 buses
  - o Provides DCRSi interface to system 2 recorder
- MCDAU-2000 for encoding Harris data for transmission
- “System 2” Transmitter
- “System 2” Recorder

The recording units used in both subsystems utilized a DCRSi interface, which predated the new recording standard known as IRIG-106 Chapter 10.

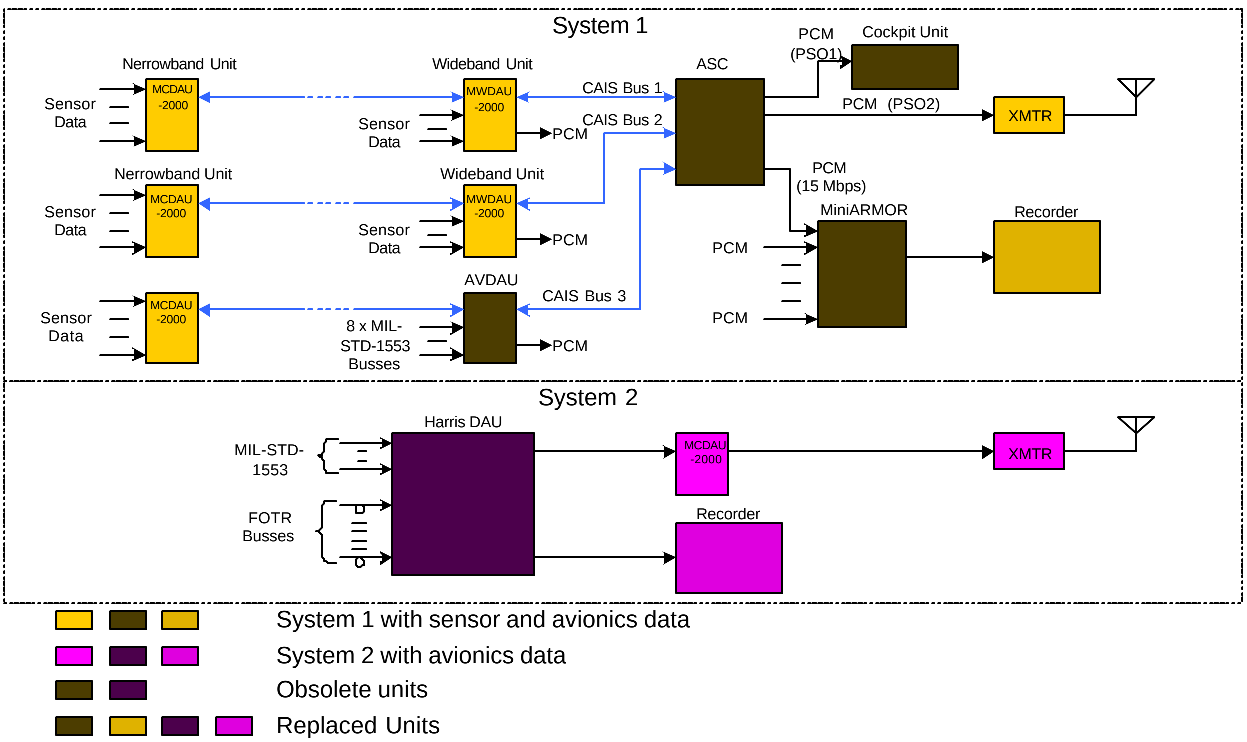

Figure 1. F-22 Original Instrumentation System

INITIAL SYSTEM APPROACH

TTC’s initial system approach was to combine both systems with a single distributed Chapter 10 multiplexer that interfaces with a dual-media recorder unit via a single fibre channel. Two enabling factors allowed this approach:

- The distributed Chapter 10 multiplexers allow the user to steer data sources to any target recording media. In this case, the user can program the system to steer “System 1” data to one recording media, and “System 2” data to the second recording media.

- The distributed Chapter 10 multiplexers will be connected to the PCM controller via the CAIS bus, and the controller will output the equivalent of “System 1” TM and “System 2” TM.

This approach was not adopted as a result of two basic weaknesses: 1) the use of a single distributed Chapter 10 multiplexer system did not provide separation between the two systems, and 2) the approach relied heavily on proper programming of the system to steer “System 1” data to one recorder, and “System 2” data to the second recorder.

The second approach was to maintain clear separation of the two systems by using a Chapter 10 multiplexer / recorder within each system. This approach simplified the “System 1” replacement, but provided some challenges for the replacement to “System 2.”

SYSTEM 1 REPLACEMENT UNITS

The replacement system must meet the requirements of the original system of preserving data separation and throughput, while providing smaller size units and providing lower cost using COTS units wherever possible. To meet these requirements it was decided early on to leverage the experience and investment done by Lockheed and TTC in the development of the F-35 instrumentation system [1].
“System 1” replacement presented no challenge since the F-22 program is already using TTC’s data acquisition units for narrowband / wideband data and the F-35 program is already using TTC’s Cockpit unit, PCM controller and IRIG-106 Chapter 10 multiplexer / recorder system. Refer to figure 2 for the New “System 1” Diagram. The units used for this system are:

- **ASC Replacement**: AIC-4000 unit as the airborne instrumentation controller with up to eight CAIS busses, and four programmable secondary outputs operating at up to 20 Mbps.
- **Cockpit Replacement**: CCDU-2000 cockpit control and display unit with built-in frame correlator for processing and viewing selected instrumentation data and for controlling TM, recorders and other subsystems. The unit operates as a remote DAU unit on the CAIS bus.
- **AVDAU Replacement**: An IRIG-106 Chapter 10 multiplexer acquires the MIL-STD-1553 buses for 100% data recording and operates as a data acquisition unit for retrieving selected bus data by the CAIS controller
- **MiniARMOR Replacement**: The IRIG-106 Chapter 10 multiplexer acquires PCM and avionic bus data for recording. The multiplexer interfaces with the recording media using SCSI over Fibre channel. This interface resulted in replacing the F-22 recorder with a fibre channel media similar to the one used on the F-35 program.

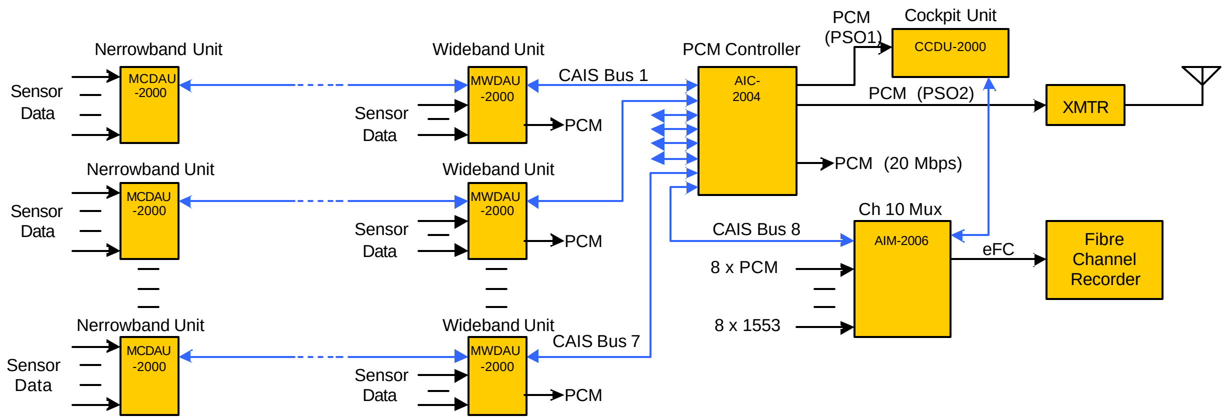

Figure 2. F-22 New "System 1" Diagram

SYSTEM 2 REPLACEMENT UNITS

The main component used in "System 2" was the Harris DAU; used for monitoring up to six F-22 FOTR and several MIL-STD-1553 busses. The same DAU is used for ground test to generate test bus traffic on both buses. Avionics data acquired by this DAU was recorded using a dedicated DCRSi recorder. Selected FOTR data was rerouted by the Harris DAU over a MIL-STD-1553 bus for training and TM purposes. Lockheed's goal was to replace the Harris DAU with as many COTS items as possible, provided that size is reduced drastically and system capability is maintained. The proposed replacement system is a distributed Chapter 10 multiplexer / recorder system described in [2] with several new development cards and a small, "off the shelf" data acquisition unit as shown in figure 3.

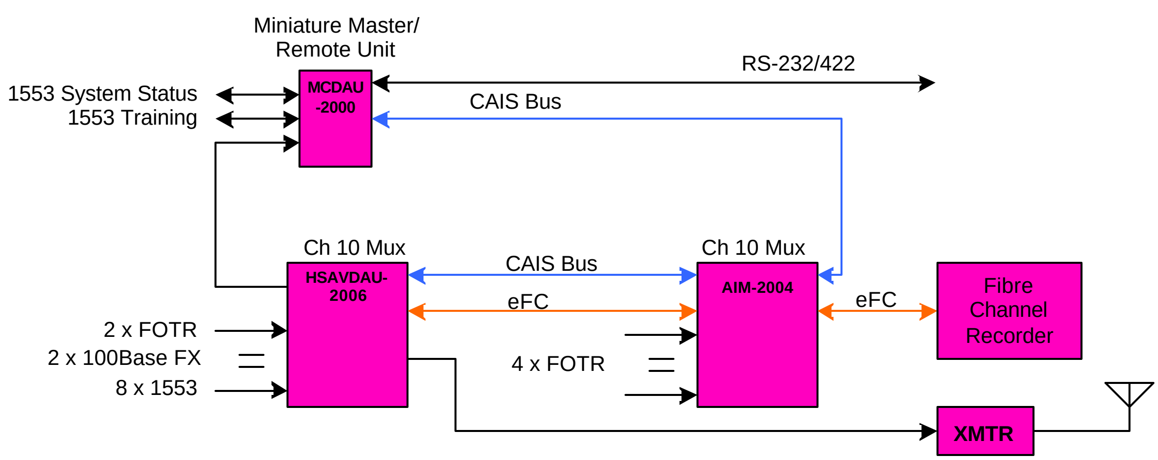

Figure 3. F-22 New "System 2" Diagram

The CAIS controller interfaces with the distributed Chapter 10 multiplexer via a CAIS bus for setup and for acquisition of status/data from the multiplexer / recorder units. The CAIS controller hosts two MIL-STD-1553 bus controller modules. One 1553 bus controller is used for mapping the CAIS controller's PCM into several 1553 messages for transmission by the Chapter 10 multiplexer. The second 1553 bus controller maps data acquired by the Chapter 10 multiplexer from one or more FOTR buses. Three new cards were developed to meet the required replacement of the Harris DAU:

- FOTR Acquisition Card
- Chapter 10 Multiplexer / Recorder Telemetry Card
- FOTR Bus Simulation Card

The FOTR acquisition card is a two channel 400 MHz fiber optics bus interface card operating in the monitor mode only. It is capable of identifying FOTR bus messages for data recording and data blocking (programmable filtering), and providing programmable message tagging for TM purposes. The card can be hosted in the AIM or HSAVDAU unit. Three cards are used in the distributed multiplexers for monitoring up to six busses.

The Chapter 10 multiplexer telemetry card receives preprogrammed data from the host chassis's processor for TM. The PCM output is based on IRIG-106 chapter 4, Class I output. It includes a 64K x 32-bit format memory for sampling 1553 data, FOTR data, IRIG time, and an on-board CVSD voice channel. It operates at various programmable bits per word and bit rates. TM data may utilize a built-in, digitally adjustable 6 pole Bessel filter for operating at PCM rates of up to 20 Mbps.

The FOTR Bus simulation card was not required for airborne use. Therefore it was best to implement this function for PC-based use in a ground server system. The design included a single channel FOTR receiver section and a single channel transmitter section. The card can operate in a 64-bit, 66 MHz host PC to allow for maximum throughput for data simulation. The API driver for this card was written using Linux 2.6 distribution. Application software for the card was left for the user.

Conclusions

This paper shows that it is possible to upgrade legacy obsolete system with newer technology. The upgrade system provided cost, size, and many advantages that were not possible in the legacy system. Finally, the new system allowed the user to migrate from propriety storage format to an industry standard format per IRIG-106 Chapter 10

REFERENCES

[1] Dug Vu, and Albert Berdugo, "Overview of an Integrated Instrumentation Data System used by The JSF (F-35) Test Flight Program", Proceedings of the 43rd Annual International Telemetry Conference (ITC/USA 2007), USA, October 23-25, 2007.

[2] Albert Berdugo, " Design of a Gigabit Data Acquisition and Multiplexer System", Proceedings of the 39th Annual International Telemetry Conference (ITC/USA 2003), USA, October 21-23, 2003.