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THE FIRST IMPLEMENTATION OF A TOTAL FLIGHT TEST SYSTEM IN FORMER YUGOSLAV FLIGHT TEST CENTRE

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Abstract: *This paper describes the overall system design and relevant performance characteristics of total Flight Test Instrumentation Systems (FTI) based on PCM/FM telemetry technique for aircraft testing first implemented in Former Yugoslav Flight Test Centre (FTC). Design and implementation of the FTI System is very important for successful evaluation of the testing prototype of vehicle. The system encompasses subsystems for airborne data acquisition and flight line check-out, a mobile ground telemetry system, and a fixed facility. The fixed facility includes a ground telemetry system for real time data processing and test control, and a data processing system for postflight analysis. The system represents a fully integrated approach to flight test systems which addresses the end-to-end requirements from airborne data acquisition and real time flight monitoring through aircraft performance and stability/control analysis. The architecture of the ground systems illustrates how preprocessing can be utilized to create powerful real time telemetry systems even with modest general purpose computer capability.*

Key words: *Flight Test Instrumentation, PCM/FM telemetry system, Airborne subsystem, Ground Telemetry Station, GTS, FTI Software Manager.*

1. INTRODUCTION

Flight Test Centre (FTC) in Former Yugoslavia was established at Zemun airfield on August 10th, 1945. It continues tradition of Flight Test Group, which was formed on December 1933 by the Yugoslav King Alexander Karadjordjevic decree. The Flight Test Centre is a Research and Development institution of the Air Force and Air Defense Command established for aircraft, airborne equipment and weapons development and verification tests purposes. The FTC is located near Belgrade at Batajnica airport, and serves as the centre of the flight-testing activity. History of Flight testing in the FTC is directly connected with production of aircraft in Former Yugoslavia, present Serbia.

The flight testing is a critical and necessary element in the development of any new aircraft or system. Whether the test object is a new aircraft or a modification of an existing aircraft, flight test should always be performed for any new major system or aircraft

Configuration [4]. Early days of Flight Test Instrumentation (FTI) in the FTC are connected with using analog measurement components including a number of transducers and photo recorders. One configuration of analog FTI is implemented in cockpit of L-17 fighter, as shown in Picture 1.

The modern aircraft is an increasingly complex machine requiring more and more sophisticated flight test techniques and more accurate and complete flight data capture [6]

The pace of development of aircraft and these processes has also precipitated similar progress in the field of measurements and associated technology.

Design and implementation of the FTI System is very important for successful evaluation of the testing prototype of aircraft. The configuration of FTI System is based on the General Plan of Testing of any new aircraft (or significant improvement to an existing aircraft) and missile. Last century, in the early 80s, the Yugoslav aerospace industry was prepared for design and production of its own supersonic aircraft. In order to be prepared for testing so sophisticated aircraft, the FTC was equipped with the FTI System made by American company ***"Loral Data Systems"***, very modern at that time.

Picture 1. An example of integration of photo recorder in the cockpit of L-17 fighter

The main purpose of the FTI System is to acquire data about the operation of the test vehicle and provide the data for processing during post flight analyses. For development, verification and certification phase, aircraft must be equipped with a complete FTI System which consists of three parts: [3], [6].

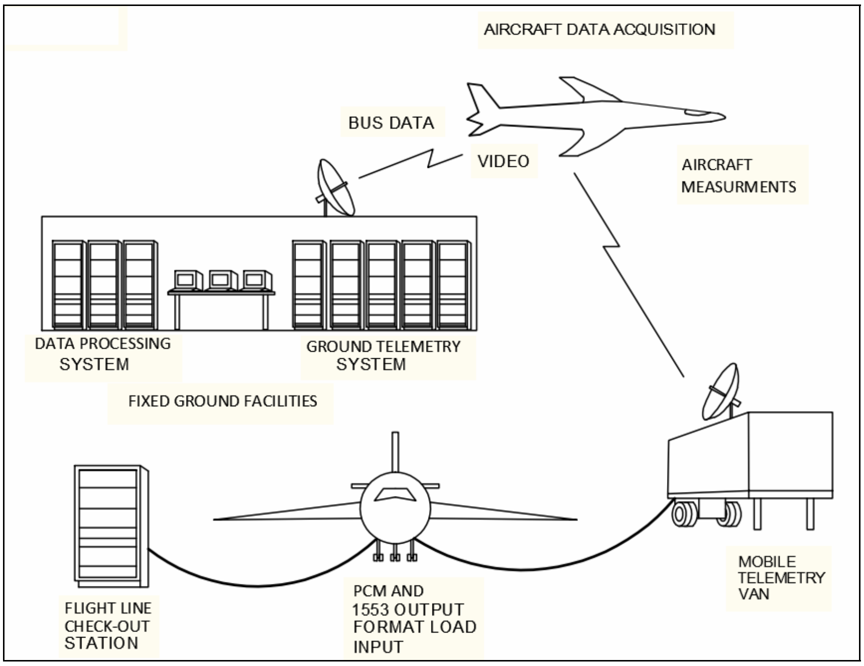
– Airborne Data Acquisition System (DAS),

– Compatible Ground Telemetry Station (GTS),

– Post Test Data Processing System (DPS)

2. THE GENERAL CONFIGURATION OF TOTAL FLIGHT TEST SYSTEM

Figure 2 illustrates the relationship of the various subsystems within the overall flight test center operations. The FTI System based on the PCM/FM (Pulse Code Modulation/Frequency Modulation) has been the primary modulation scheme used for such links for over 40 years. During actual flight tests the aircraft data acquisition systems can transmit telemetry data to either the mobile or fixed ground telemetry stations. The fixed station will normally be used for local flight test operations. In this case, the flight line check-out station is utilized for loading the sample plan data and for preflight checks on the aircraft mounted acquisition hardware. Operations at remote locations will be supported by the Mobile Ground Telemetry Station (MGTS) which will be utilized for telemetry reception and test control. If necessary the airborne system format can be modified and loaded directly from the MGTS. PCM data can also be input to the mobile system directly from the aircraft for test purposes. The normal use of the Data Processing System (DPS) is for processing of data from airborne or ground recorded instrumentation tapes or for post flight processing of data archived to disk from the telemetry stream during flight test operations [3].



Picture 2. Overall System Relationship

2.1. The airborne subsystem

The airborne data acquisition subsystems were required to be general purpose to satisfy the wide range of data acquisition problems normally found in modern aircraft test programs. General requirements included:

– Acquisition and PCM output of normal analog voltage, frequencies and discrete events,

– Programmable sampling plans,

– Recording and telemetry transmission of PCM,

– Acquisition of data from two MIL-STD-1553B busses,

– Output of selected 1553 bus words in the PCM stream,

– Recording of 100% 1553 data from both buses,

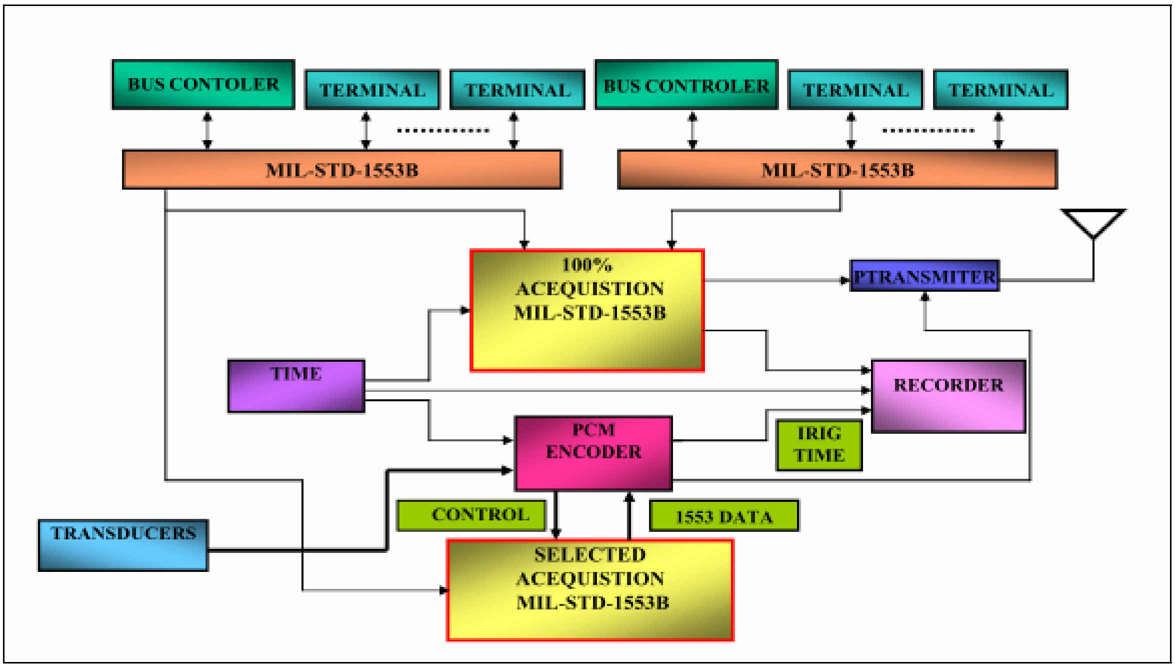
– Color video data recording and telemetry transmission.

Picture 3 illustrates the typical configuration for a system. General aircraft measurement data is acquired using a PCM EMR 5000 Series Ruggedized Data Acquisition System (PCM encoder). This is a remotely multiplexed system which provides a maximum PCM bit rate of 3.2 Megabits per second with a maximum total sample rate of 200,000 samples per second. PCM formats generated may use variable word lengths. This allows analog channels to utilize word lengths of 8, 10, or 12 bits and digital channels to utilize word lengths of up to 16 bits. Each remote signal conditioner chassis may contain up to 16 analog or digital conditioner cards which may contain from 2 to 16 channels each, depending on the conditioner type. Signal conditioning is completely programmable from excitation through PCM output for the acquisition of: High level analog signals , Wideband analog signals, RS-232 buses including TSPI information, Bi-level signals (discrete and relay signals, Temperature data (RTD and Thermo-couple), Strain Gauge, Synchro/Resolver and L/RVDT sensors , Accelerometers (including Motion pack), Frequency and period measurements, GPS and Time , Charge amplifiers [12].

The Standard housing provides 16 card slots and up to 256 signal conditioned channels. Mini-Housings, ideal for small enclosures and rotating platforms, provide 3 card slots with up to 32 signal conditioned channels. A combination of housings can be used in the Master-Slave configuration.

Format and sample plan data are loaded into the system's EEROM memory via an RS232 port. An EMR 5500 All Bus Instrumentation System (ABIS) provides for the acquisition of all 1553B bus data from multiple buses in accordance with the recent Inter-Range Instrumentation Group (IRIG) standard. 1553B bus word selection for insertion (1024 words) in the general PCM output is performed by a data selector card which interfaces to the 5000 data acquisition system like a signal conditioner chassis. The airborne time code generators provide serial time code for recording and parallel time code for input to the 5500 ABIS for 1553B bus data time correlation. "Schlumberger ME4115" airborne instrumentation recorders are provided for direct recording of all data. Video cockpit color cameras and airborne video recorders are supplied for video data acquisition. Dual L-band telemetry transmitters operating on different frequencies are used for the simultaneous transmission of video and PCM telemetry data. The outputs of the transmitters are mixed in a diplexer and the resulting signal is split between two transmitting antennas normally located on the top and the bottom of the aircraft.

All components of the airborne PCM subsystem are designed to provide maximum accuracy of test results in the most severe environments. The airborne part of it is versatile and flexible and can be easily adapted to changing test specifications and future needs [1] [2].



Picture 3. The Airbone PCM/FM subsystem [1]

2.2. The Flight Line Check-Out (FLCO) subsystem

The Flight Line Check-Out (FLCO) subsystem provides equipment for decommutation and engineering units display of the PCM data from the airborne system. It performs flight line loading and updates to the programmable PCM system over an RS232 serial port.

Also, it supports the acquisition and evaluation of on-aircraft end-to-end measurement calibration data. PCM input data is synchronized, decommutated and input to the MicroVAX II. The software hosted in the computer provides for real time display of the decommutated data on a color/graphic terminal. Displays available include fixed alphanumeric, scrolling alphanumeric time histories, barcharts and scrolling graphic time histories.

End-to-end calibrations on the aircraft of measurements, such as control surface positions, can be performed with this system. The operator can store samples of a specified measurement decommutated from the PCM data stream and manually enter the corresponding engineering units value as read from a reference standard. Trial curve fits can then be performed and reviewed by the operator. The polynomial coefficients and/or calibration data table can then be stored to cartridge tape.

Airborne system formats are read from cartridge tapes and downloaded to the airborne package via an RS232 port. These formats can also be edited at the FLCO prior to loading.

2.3. The Ground Telemetry/Data processing System

The main purpose of this system is implementation of the following capabilities:

1. Real time data acquisition,
2. Real time data validation,
3. Test point data extraction and storage,
4. Post-mission data analysis.
5. Report Generation, and
6. Data storage .

The equipment and software installed in the fixed facilities represent two system functions which have been integrated into single system architecture. A simplified block diagram of the system with its combined functions is shown in Picture 4. The integration of the two capabilities has provided several system advantages:

– Some redundancy has been achieved so that the two system functions can back-up each other
– System resources have some flexibility and can be shifted between the two functions
– Independence of operation and the capability for simultaneous operation have been preserved.

The Ground Telemetry System (GTS) supports real time flight test operations and is required to provide the following capabilities:

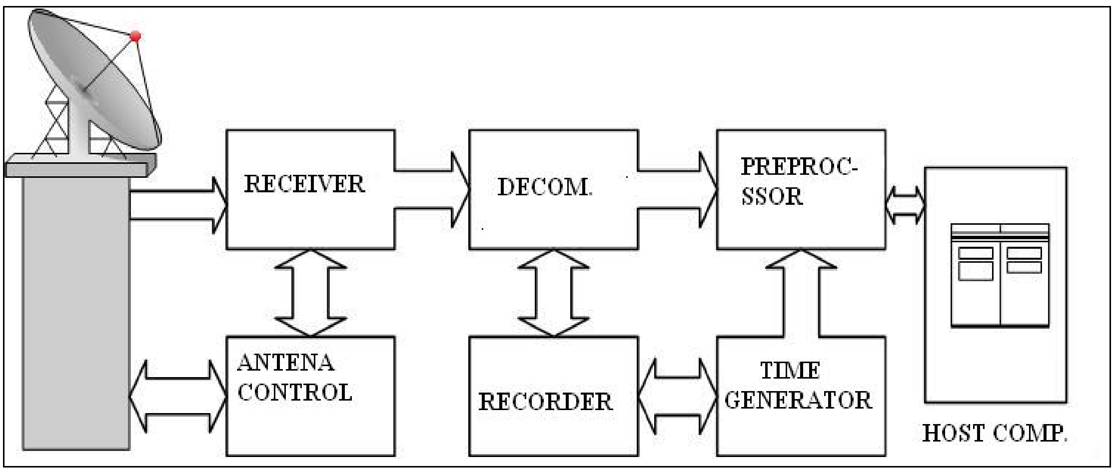
– Dual axis tracking antenna,
– PCM and video telemetry reception and recording PCM telemetry or instrumentation tape playback processing,
– Real time workstation displays for test director,
– Independent real time workstation displays for engineering personnel supporting the test,
– Real time control system transfer function analysis (expandable to real time flutter analysis in the future),
– Disk data formatting with intermaneuver playback analysis.

The Data Processing System (DPS) is utilized for post flight data analysis and report generation. It is required to perform the following functions:

– PCM and 100% 1553 input from instrumentation tape,
– Playback processing from instrumentation tape or disk files,
– Central flight test database management (Calibration files, Airborne sampling plans, Measurement processing definitions, Telemetry processing hardware configuration),
– Aircraft performance, stability/control and other analysis,
– Independent color/graphic workstations for engineering analysis,
– Report data generation.

In the GTS an L-Band dual axis tracking antenna receives the RF telemetry signal containing both the PCM and video data. Dual receivers and a diversity combiner equipped for both pre- and post-detection combining are provided for the PCM data to improve the signal quality. A single receiver is utilized for the video data which may be both recorded and viewed on the monitor. Both the GTS and DPS are equipped with identical instrumentation recorder/reproducers for the recording of telemetry data and playback of tapes.

The GTS is equipped with a single stream of EMR 8000-Series PCM synchronization/decommutation hardware which provides a high performance input link for the telemetry data. The DPS is equipped for the playback processing of three simultaneous streams of PCM data from instrumentation tape - one general-purpose PCM stream, and two PCM streams containing 100% of the data from each of two MIL-STD-1553B buses.



Picture 4. The simplified bloc diagram of the GTS [3]

All input data streams from both systems are input to an EMR 8715 Telemetry Multiplex Processor. This preprocessor performs all preprocessing tasks including 1553 data decommutation, engineering units conversion, limit/events alarm checking, simple derived calculations and other commonly required telemetry functions using parallel word slice, floating point processors. The device uses a dual bus architecture and performs I/O, decommutation, and parallel processing tasks with a family of plug-in modules.

The two systems utilize separate DEC MicroVAX II hosts, but share the single preprocessor. Each system can operate independently and can load, start and stop the processing of different data streams and formats even though the preprocessor is shared.
FTI Software offers the following functionality:

- Flight Test Instrumentation Configuration Management and setup,
- Equipment Calibration and Validation,
- Supported A Flight Test Applications Software Package
- Generation of different reports and description files used by the data reduction and analysis software .

This capability is made possible through configuration support software. This software allows the user to define and logically partition the input, output, and parallel processing modules of the preprocessor among multiple input stream processing tasks. Each set of modules can then be independently loaded with a format processing definition and processing can be started, stopped or reloaded independently on what is occurring within other logical partitions.

An array processor is included with the GTS for real time transfer function computation. A separate output port from the preprocessor outputs arrays to the Analogic AP500 Array Processor through its parallel I/O port. The array processor performs FFT and vector arithmetic operations for calculation of transfer functions. A Q-bus interface between the array processor and the GTS host provides loading and control for program and output of processed transfer functions.

An Ethernet local area network interconnects the two host processors, six DEC MicroVAX 2000 engineering workstations with 19" color monitors, and a server with color hardcopy unit and a laser printer for alphanumeric and monochrome graphic output. Any of the six workstations may independently logon to either host for maximum utilization of facility resources. All hardcopy output is queued to the output devices on the server.

The three primary system computing resources are the preprocessor, the host processors, and the workstations. All system software on the DEC equipment runs under standard DEC VMS as a local VAXcluster. The host processor allocates the functions of database management, data acquisition control, data archiving, derived parameter calculation, data analysis and data distribution. The workstations provide the system user interface, perform data display, do hardcopy formatting of displayed data, and run a powerful graphics display editor.

All system functions can be performed from any workstation using a master menu from which all configuration editing and data acquisition control functions can be accessed. All workstations can be used for real time display and playback processing of data being acquired on the host processor on which the workstation is logged. The graphics editor gives the individual workstation user total flexibility to construct his own displays and connect measurements to drive display symbols.

Data is normally converted to engineering units in the preprocessor and input through the data channels in DEC floating point format.

The workstation display contains a fixed header and footer and a display screen area which may be partitioned into up to four windows with various types of display formats defined for each window. Displays may be dynamically swapped out of individual windows and individual measurements may be added or deleted within individual display windows. An example of a display is shown in Figure 9. Simple derived calculations such as airspeed and Mach number can be calculated at the incoming data rate in the preprocessor and treated as measured data. More complex calculations which are not practical to perform at the real time data rate can be performed in the host processor.

The host is also responsible for archived data retrieval. Data can be recalled from the archival files by any workstation for display. Recall can be performed simultaneously with the real time data acquisition. The host will retrieve the data set and send it over the Ethernet to the requesting workstation. The workstation may then display archived data in one workstation window while displaying real time data in another window. Since the data is archived in engineering units form, no host or workstation processor time is consumed in file references and engineering unit conversions for playback display.

A Flight Test Applications Software Package (FTASP) is also being furnished for aircraft performance and stability/control data analysis. The input to this package is recording engineering units data as well as flight-specific information such as engine start weight, stores loading, fuel density and other test-specific information. Aircraft configuration information such as airspeed calibration data and the orientation of gyros and accelerometers is also required for error correction. The FTASP can execute on a workstation or the host and has provisions for both interactive and batch operation.

The airborne system configuration software also runs on the host processors. Airborne formats can be defined and recorded on cartridge tapes which can then be loaded from either the FLCO or the MGTS. A historical calibration library which can maintain the calibration history of the measurements on a particular test aircraft is also supported. Calibration data can be input to this file manually or transferred from cartridge tapes after being acquired and curve-fit at the aircraft on the FLCO.

The FTI software manager is a highly integrated software capable of interfacing with airborne instrumentation (low bandwidth sensors, high bandwidth sensors and high data rate buses), ground instrumentation configuration software and flight test data center that can provide great benefits by reducing the time from test requirements to system readiness, minimize human errors, reduce cost and increase system flexibility [5].

2.4. The Mobile Ground Telemetry Station (MGTS)

The MGTS is installed in a four-wheel tow trailer and is equipped with a single-axis tracking antenna. MGTS Pictures are shown in Figures 5 and 6. Except for the antenna, the hardware configuration is a subset of the GTS. A telemetry preprocessor, host processor, and workstation comprise the processing elements of the system. The system software is identical to that described for the GTS/DPS. Functional requirements for the MGTS include:

– PCM and video telemetry reception and recording ,
– PCM and 100% 1553 input from tape or umbilical from aircraft,
– PCM input from Damien cassette tape
– Airborne encoder loading/programming via umbilical from aircraft,
– Real time telemetry or tape playback processing,
– Disk data formatting with intermaneuver playback,
– Engineering workstation display for test director,
– Compatibility with fixed ground processing facilities.

Picture 5. Mobile Ground Telemetry Station "LORAL" [3]

Picture 6. Inside of MGTS "LORAL" [3]

3. CONCLUSION

Last century, in the early 80s, the Former Yugoslav aerospace industry was prepared for design and production of its own supersonic aircraft. In order to be prepared for testing so sophisticated aircraft, the FTC was equipped with the FTI System made by American company ***"Loral Data Systems"***, very modern at that time. The system represents a fully integrated approach to flight test systems which addresses the end-to-end requirements from airborne data acquisition and real time flight monitoring through aircraft performance and stability/control analysis. The FTI System is completely based on famous IRIG 106 PCM of acquisition & recording standard which is used primarily for military application. This FTI System was tested in 1989/90 in the FTC during on-site acceptance test procedure using G-4/687 serial aircraft in flight. Airborne part of the FTI System was partly tested in comparison with PCM Data Acquisition System "UAM-V" made by SFIM/France. The airborne 5500 ABIS for 1553B part was not tested in flight because of G-4 avionics imperfections (lack of MIL-1553B avionics). Design of supersonic aircraft has not been realized in Former Yugoslavia so that the system has been used for flight tests support of modernized aircraft G-4M (the school fighter) and plane for initial pilot training "LASTA". Despite the old system, it is still mostly used in its basic configuration in the

Aeronautical part of Technical Test Centre in Batajnica/Serbia.

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