

Virtual Instrumentation Techniques in Test and Evaluation of Launch Vehicle Avionics

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ABSTRACT

This paper presents the concept of virtual instrumentation and its importance in test and evaluation of launch vehicle avionics. The experiences at the Vikram Sarabhai Space Centre (VSSC) with virtual instrumentation systems, highlighting the virtual instrumentation-based checkout systems of pyro current monitoring package and video image processing unit are presented. The virtual instrumentation system-based checkouts present cost-effective, compact, and user-friendly human-machine interfaces for the test and evaluation of these packages. The issues of a common hardware-software platform for testing different telemetry packages and the capability of real-time virtual instruments for testing navigation, guidance, and control packages have been investigated.

Keywords: Virtual instrumentation, test and evaluation, launch vehicle, avionics, computer-based instrumentation

1. INTRODUCTION

Computer-based instrumentation has been the choice of the day due to the increasing power of microprocessor chips and software techniques. Virtual instrumentation is the natural evolution of computer-based measurement systems and makes use of the enhancements in the computer hardware as well as the new programming techniques. Virtual instrumentation represents a new generation of instrumentation and has been widely adopted by the test and measurement community.

A virtual instrument, in principle, is a computer-based software-driven instrument for test, measurement, or process-control applications. Virtual instrument, thus, are composed of layers of software and hardware having a virtual control panel that only appears on a computer display. The use of the computer allows

confining the hardware components (dedicated to the measurement application) to the data input/output subsystems responsible for data acquisition and generation. All operations of the test and measurement procedure, like control of information, display and analysis of acquired data, data management (such as archiving, printing, internet publishing, etc.) are performed by the software. Thus, a virtual instrument defines its specific functions through software programming and is software-intensive.

The major advantage of virtual instruments, as compared to traditional hardware-based instruments, is its flexibility, which is of particular value to test and evaluation of launch vehicle avionics during the developmental stages. The functionality and the user-machine interface of conventional test instruments are manufacture-defined and the end-users have no control to expand or modify the

existing functions. In comparison, the functionality of a virtual instrument can be explicitly defined, modified, and expanded by its users through software programming. Once the platform of a virtual instrument is established, users can define specific test functions they need, adopt a user interface they like, and modify the instrument functionality, whenever necessary.

The computer-based measurement systems, even if effective and efficient from the measurement point of view, may appear very different from the conventional instruments as far as the user interface is concerned. In the virtual instrumentation systems, the appearance of real instruments and measurement workbenches are mimicked so that these resemble the interfaces of their real counterparts. The advanced graphic features of most of the modern PCs allow for implementing a realistic user interface of the computer-based instruments and workbenches, very similar to the real ones. The front panel presented on the computer screen comprises the graphic representation of the conventional controls, like knobs, switches, selectors, potentiometers, and indicators, like graphs, lights, etc. and provides the interface for interactive operations. Graphic flexibility also allows for an easy merging of the front panels of several instruments to create a comprehensive workbench of virtual instruments with all the components of the envisioned application. This simplifies the user interaction with the monitoring and control system since it concentrates all the relevant instruments in a single interrelated display, discarding the information and the functions not of direct and immediate interest.

The effectiveness and efficiency of virtual instrument design is largely due to the user-friendliness associated with the programming process itself. Control flow is not the proper paradigm for an instrumentation environment; the asynchronous nature of instrumentation problem is far more naturally accommodated in a data flow-based graphical environment. Thus, instead of conventional, text-based procedural programming languages, where syntax and punctuation are the sensitive aspects of a programme, visual or graphic-based programming is ideal for virtual instrumentation. Graphical icons replacing

text commands are simply wire-connected to each other by means of a drag-and-drop operation. It simplifies the definition of the measurement procedure by means of object-oriented data-driven techniques. The measurement procedure is obtained by drawing a procedural diagram or a graph that defines data dependencies and operations to be performed. The graphical user interface (GUI) presents a clear, logical, and visually appealing overview of the inner working of the entire program. Also, it simplifies program development, documentation, and maintenance and effectively reduces programming errors.

Visual programming for virtual instruments can be essentially viewed as writing the block diagram of the measurement procedure by means of a computer program. This block diagram is then translated into the computer-executable code by some graphical programming compiler. The interpreter performs translation and immediate execution of the functional blocks without storing these in a file. This feature is very useful during system development to interactively test the procedure behaviour without the need of completing the system definition, generating the executable code, and leaving the development environment to run the executable code itself. National Instrument's LabVIEW and Hewlett Packard's HP VEE are the two popular graphical programming languages for the virtual instrumentation applications.

The use of virtual instrument integrates various measurement functions into a PC-based control environment that otherwise would have been accomplished by several stand-alone measurement instruments, which are generally expensive or may not be available in a realistic application environment. Also, replacing multiple instruments with an integrated virtual instrument increases the portability of the entire system while reducing the space requirement, which is of particular importance for the test and evaluation of launch vehicle avionics as it needs shifting and setting-up of test systems at different locations for various environmental tests.

The interchangeable virtual instrument concept, introduced recently, further reduces the development time and also improves the quality of virtual

instruments by incorporating some standards. With this, measurement subsystems from different sources would be having standard connections and user interfaces so that these can be connected easily and directly to build complex measurement systems¹⁻².

2. EXPERIENCES AT VIKRAM SARABHAI SPACE CENTRE

At Vikram Sarabhai Space Centre (VSSC), test and evaluation of launch vehicle avionics is carried out using automated checkouts. These checkouts use either GPIB or serial interfaces to control different programmable instruments. Some PC-based instruments with either ISA or PCI interfaces are also being used in some checkouts. Virtual instrumentation-based checkouts have been successfully developed for telemetry packages, like pyro current monitoring (PYCM) unit and video imaging system (VIS) using general-purpose data acquisition cards. However, a general-purpose hardware (PC plug-in input/output card) is yet to be finalised for use in various checkouts to achieve optimised performance. This ensures high flexibility in the system without requiring hardware changes as long as it guarantees that the signals are acquired or generated with the required accuracy and sampling rate, and also within the required cycle time. This leads to the simplification and standardisation of the input/output interface boards for acquisition and actuation, and consequently, to reduce the overall cost of the system ownership.

2.1 Virtual Instrument-based Checkout for Pyro Current Monitoring Unit

The PYCM measures current pulses going through various squibs in different stages of the vehicle. The testing of PYCM requires a multichannel current signal generator to supply input current pulses to the package and a data acquisition device with decentralised and programmable onboard PCM system (DROPS) bus interface to acquire the output data from the package.

Here, a DAQ card was used as the general-purpose hardware for making the virtual instrument^{3,4}. The software was developed using the graphical

programming environment of LabVIEW, which is highly modular and gives room for easy expansion. The total checkout software was configured in three virtual instruments, viz., PCSG controller, data acquisition and data analysis and presentation. These three virtual instruments were integrated into the final main virtual instruments. The GUI of the main virtual instruments (Fig. 1) allows the user to select different tests like channel accuracy test, cross-talk test, pulse width test, command inhibition test, etc with different test conditions and parameters. Also, it displays the output waveform graph, test data, and percentage deviations along with OK/not OK judgment for each of the 40 sensors. Also, the checkout has an option for automatic test report generation in HTML format using active X controls.

2.1.1 System Performance

The virtual instrument developed for the automated checkout meets all the expected requirements and is way ahead of the traditional test system in speed, cost, compactness, and portability, while meeting the accuracy requirements of different functionality tests. A comparison between the old test system and the virtual instrumentation-based new system is given in Table 1.

The main objective of saving on time was achieved by sequentially carrying out the functions of input current signal configuration, data acquisition and presentation, and test report generation.

Table 1. Comparison between the old and the new pyro current monitoring test system

Parameters	Old test system	Virtual instrumentation-based system
Test time (initial SRC tests and test setup) per DUT (h)	04	01
System cost (Rs)	21,50,000.00	16,00,000.00
Compactness and portability	Low	High
Automatic test report generation and publishing	No	Yes

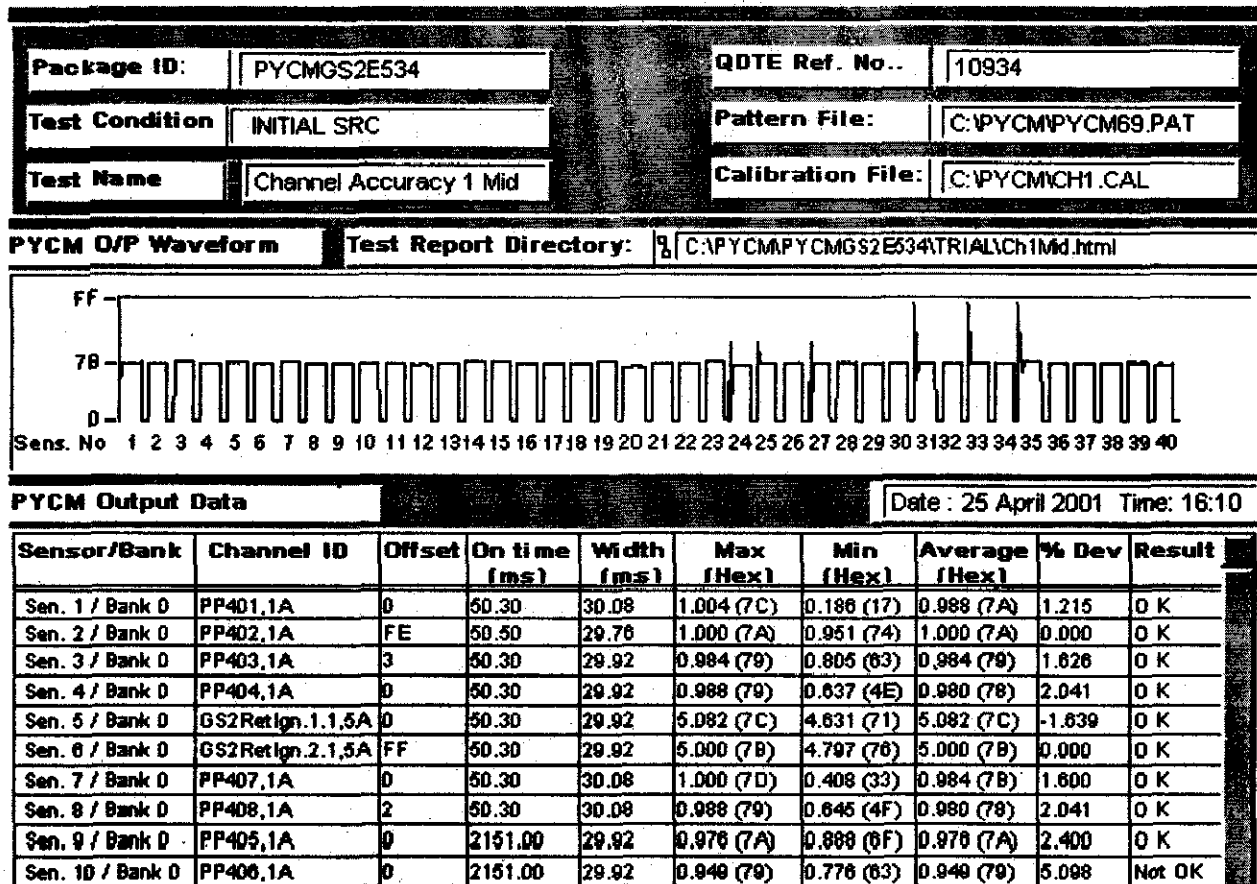


Figure 1. Graphical user interface of pyro current monitoring checkout data acquisition and analysis

Earlier, these were carried independently, in different software environment, in a semi-automated mode.

2.2 Virtual Instrumentation-based Checkout for Video Imaging System

Here, a virtual instrument was developed using a general-purpose digital input/output card for simulating the actions of DALSA digital camera. The virtual instrument software was developed using the graphical programming environment of the LabVIEW 6i. The virtual instrument generates digital patterns from the picture file, which can be selected by the user through the GUI (Fig. 2). This pattern would be sent out through the digital input/output card to the package after getting an external trigger pulse from the package. This would be the same as the camera output for the same picture with a constant resolution. The frame rate and the data rate can be selected by

the user through the GUI of the checkout system. This virtual instrument has helped to reduce the complexity of the video imaging system checkout. Also, since it gives out a standard pattern as input to the package, the error caused to the image by the package, due to processing, can be quantified. This was not possible with the actual camera.

The checkout gives room for easy expansion as a full-fledged automated setup for evaluating the performance of the package by acquiring the output and computing the mean square error between the input and the output patterns.

3. COMMON HARDWARE-SOFTWARE PLATFORM

The telemetry packages of launch vehicles^{5,6} are having a common interface, eg., DROPS bus interface to the PCM control unit. Thus, a digital

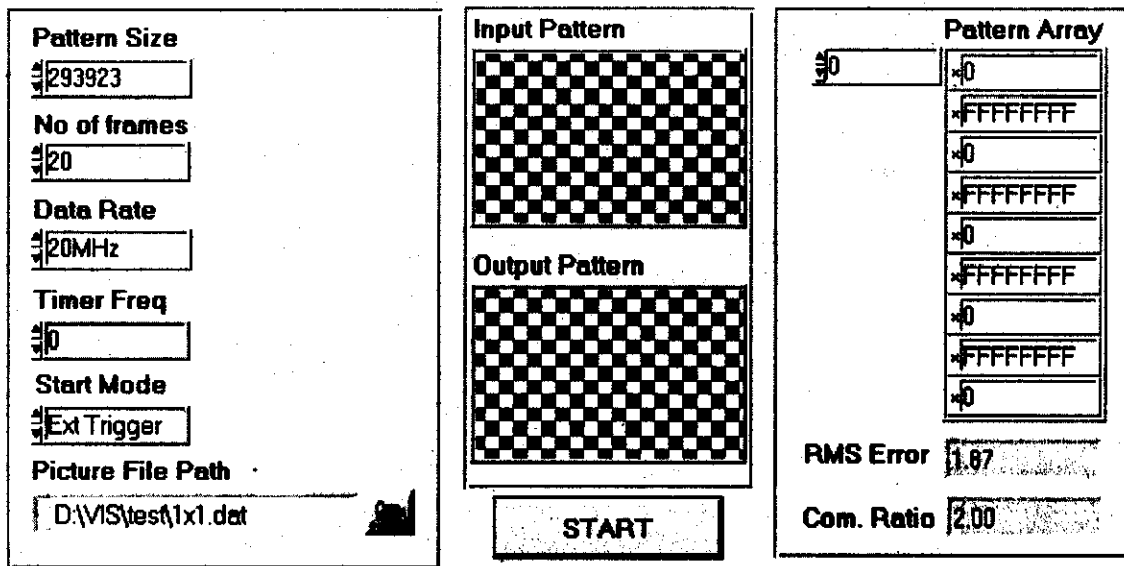


Figure 2. Graphical user interface of video imaging system checkout

input/output card with this interface, developed in-house was used to develop a virtual instrument for acquiring and analysing the output data from these packages. This hardware-software platform is very useful in developing virtual instrumentation-based checkouts for launch vehicle telemetry packages. This would eliminate the need to have a PCM data acquisition card and a PCM control unit in these checkouts. This virtual instrument has been successfully used in PYCM checkout system.

4. DSP-BASED REAL-TIME VIRTUAL INSTRUMENTS

The checkouts of navigation, guidance, and control packages in launch vehicles need virtual instruments with real-time capability to analyse the output signals from these packages in real-time. Thus, DSP-based instruments are ideal in such cases. Here, a DSP-based PC plug-in card with an input/output module can be considered as the general-purpose hardware. Virtual instrument software modules can be developed using some real-time graphical programming environment like LabVIEW-RT, depending upon the measurement applications. This would eliminate the need for costly measurement instruments like spectrum analysers, oscilloscopes, thermal data recorders,

random signal generators, etc. in these checkouts. Instead, these instruments would be characterised by the general-purpose DSP card and the associated software modules.

In DSP-based measurement systems, a measurement process is associated with a dedicated algorithm that is implemented on the general-purpose DSP card. By changing the algorithm, the same system performs new measuring processes. The core metrological characteristics of the DSP-based measurement systems are determined by the characteristics of both the input/output module (as far as accuracy, resolution, and sampling rate are concerned) and the DSP unit (as far as the overall bandwidth and accuracy are concerned).

5. CONCLUSION

Virtual instruments are computer-based measurement systems having a GUI and a general-purpose data input/output card that makes these more programmable, portable, re-usable, and cost-effective in test systems and checkouts. The experiences at the Vikram Sarabhai Space Centre with virtual instruments by highlighting the virtual instrumentation-based PYCM and video imaging system packages have been presented. Also, issues of common hardware-software platform for test

and evaluation of telemetry packages and real-time virtual instruments for naval guidance and control packages have been discussed.

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REFERENCES

1. Spoelder, H.; Ullings, A. & Groen, F. Virtual instrumentation: A survey of standards and their interrelation. *In 1997 IEEE Instrumentation and Measurement Technology Conference (IMTC/97), Proceedings Vol. 1, May 1997. pp. 676-81.*
2. Hans, J.W. Spoelder. Virtual instrumentation and virtual environment. *IEEE Instru. Measure. Mag.*, September 1999, 14-19.
3. Mc Connel, E. Future of virtual instrumentation. *Sensors*, 1997, 14(7), 22-24.
4. Wright, J. Virtual instrumentation cuts test setup time. *Noise Vibration Worldwide*, 1996, 27(11), 13-15.
5. Sethunadh, R.; Athuladevi, S. & Sankara Iyer, S. Virtual instrumentation system results in faster testing of launch vehicle telemetry avionics. 2001 Measurement and Automation Technology Conference Proceedings (NI Week 2001 at Austin, Texas, USA, 2001).
6. Sethunadh, R. & Abdul Samad, A.K. Virtual instrument simulates digital camera output for test and evaluation of video imaging system used in launch vehicles. 2002 Virtual Instrumentation Conference Proceedings (NI Week 2002 at Austin, Texas, USA, August 2002)

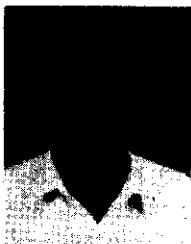
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