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SITE BENCH MAINTENANCE TEST SET

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INTRODUCTION

The flight instrumentation system for Project Mercury spacecraft presented few bench maintenance problems. The small and rather straight-forward PAM-FM-FM flight instrumentation system in Project Mercury contained less than 100 information channels, and bench maintenance of the system at the launch site consisted of fault isolation, calibration, and performance verification at the replaceable module, package, and system levels. These activities were confined to flight information handling equipment oscillators, tape recorders, and PAM-PDM multiplexers and were accomplished with the use of several small manual test sets. Transducer calibration was infrequent and was accomplished in an environmental test laboratory.

Because the bench maintenance equipment was designed to test specific flight hardware configurations, it was often necessary to modify it to support various design versions of the flight hardware. This test equipment inflexibility was not a major problem because of the small channel capacity and simplicity of the test articles. However, launch site bench maintenance of present day manned spacecraft instrumentation does present a problem because of the many kinds of systems to be supported and the size and complexity of these systems. The Gemini operational instrumentation consists of approximately 400 PCM channels. The total Apollo system (command module, service module, and lunar excursion module) consists of approximately 700 PCM channels. In addition to the operational systems, R&D type instrumentation could contribute as much as 100 channels of PAM-FM-FM information to the spacecraft telemetry systems.

Another large system requiring bench maintenance is the ACE-S/C carry-on PCM system. ACE-S/C is the digital stimulation and monitoring equipment used for spacecraft checkout at the spacecraft contractor's facility and at the launch site. The system presently contains 2600 PCM channels of test-point data.

The bench maintenance requirements associated with present day manned spacecraft instrumentation is one of providing reliable equipment to perform rapid and accurate bench tests on the many kinds of high channel capacity flight systems. This paper describes SITE (Spacecraft Instrumentation Test Equipment), the flexible bench test set designed to satisfy bench maintenance requirements at the various NASA-MSC test sites and at spacecraft contractor facilities.

SITE DESIGN CONSIDERATIONS

SITE is a general purpose test set which is flexible enough in its interfaces to accomodate all manned spacecraft instrumentation systems and flexible enough in its programming to accommodate flight hardware design changes. The equipment can test all present instrumentation flight hardware and can easily be made to support future instrumentation systems because of its modular construction using off-the-shelf hardware as building blocks.

SITE is capable of fault isolation and certification at the replaceable module, package, and system levels. The instrumentation system is defined as all spacecraft data handling equipment excluding the transducers and transmitters. An instrumentation package is the smallest item of the system that is connected to spacecraft wiring, and a replaceable module is the smallest serialized unit that is plugged into a package. The certification of an instrumentation system involves the determination of two factors: transfer function and crosstalk. The transfer function is a characteristic of each individual data channel and includes such items as gain, linearity, hysteresis, repeatability, resolution, back current, and frequency response. Crosstalk consists of such outside factors as data channel crosstalk, common mode, and power supply variations.

SITE can be operated manually or automatically. Test time can be compressed by a factor of 1000 to 1 by using the automatic mode instead of the manual mode. The time required to calibrate present day instrumentation systems would be excessive and the results would be subject to operator error if purely manual methods were used. Automatic bench calibration greatly reduces system test time and provides a standardization of test procedure whenever and whereever the tests are performed. Hence, data may be rapidly gathered and interpreted with some assurance that the test procedures were constant. This uniformity of procedure is a fundamental requirement of present day manned spacecraft test operations.

SYSTEM DESCRIPTION

Physically, SITE consists of two basic units: a Control Console Unit and an Equipment Console Unit as shown in Figure 1. The flight hardware to be tested is placed on a table adjacent to the equipment console and is cabled to a set of standard connectors on the console.

Functionally, SITE can be divided into 5 major units: Control and Display Unit, Switching and Distribution Unit, Input Signal Generator Unit, Measurement Unit, and Demultiplexer Unit. Figure 2 is a functional block diagram showing the major units and the basic physical interfaces.

Power is applied directly to the units under test. Stimuli are routed to the units under test and responses to the Measurement Unit by means of the programmable Switching and Distribution Unit. Multiplexed responses are fed directly to the Demultiplexer Unit. The outputs of the Measurement and Demultiplexer Units are sent to the Control and Display Unit for comparison, display, and storage. The Control and Display Unit provides the program control required to accomplish switching and distribution, stimuli value adjustment, measurement unit range control, and demultiplexer control. This control can be generated automatically or manually at the Control Console Unit and is required to accomplish switching and distribution. In addition to remote control by means of command, stimulus and response equipment can be manually adjusted at the Equipment Console Unit.

A more detailed block diagram of SITE is shown in Figure 3. Each major unit can be broken down into basic modular building blocks which consist in most cases of off-the-shelf hardware. It is this feature that provides the flexibility and the capability for the bench testing of yet to be designed instrumentation systems.

CONTROL AND DISPLAY UNIT

The Control and Display Unit is housed in the control console, where three modes of operation are available: tape reader, keyboard, and remote manual. In the tape reader or automatic mode, test control is achieved by means of a programmer-comparator. A punched tape and tape reader constitute the instruction manual for the programmer-comparator and provide detailed instructions for each test configuration in the form of 8-bit command words. A keyboard is provided for manual operation and allows the operator to duplicate punched tape commands. This mode is required to set up the Switching and Distribution Unit during manual tests. The mode also is useful in programming tests and in debugging. Once the Switching and Distribution Unit has been set up, manual operation at the control console is more efficiently accomplished by using the remote manual mode. In this mode, a manual sequencer generates the 8-bit command words associated with each operator function - the operator makes adjustments at the control console instead of punching coded commands on the keyboard.

The command decoder accepts binary inputs from either the tape reader, keyboard, or manual sequencer depending upon the status of the mode select logic. The decoder contains the logic to read the binary inputs and convert them into functional area addresses, subaddresses, and discrete commands. These decoder outputs constitute the program control and are stored, transfered, or steered to the SITE functional areas where they perform device switching and adjustments. The command decoder includes an autocheck capability which is used to assure that the program control information has been routed to the proper functional areas and has been properly interpreted. If an "autocheck no-go" is received, the tape reader will stop. Before each test sequence, a series of commands are read which exercise all the tape reader readout circuits. This performs the same function as parity.

The display portion of the Control and Display Unit consists of a comparator, manual and automatic mode controls and displays, a digital printer, and a tape perforator. The comparator contains a digital portion and an analog portion. The digital comparator reads the analog to digital converter output from the Measurement Unit and compares it to preset limits which are inserted by the tape reader or keyboard. The analog comparator is a Schmitt trigger that detects noise components as small as 1% of full scale in the signal conditioner outputs during crosstalk tests. The comparator outputs are primarily "GO" and "NO-GO" signals which are routed to the control console displays.

In addition to the various controls and displays, the control console contains a digital printer and a tape perforator. The printer provides a permanent record of the tests in any one of several print formats. The formats can be automatically or manually set up. The tape perforator provides a mechanism for automatic data handling and reduction in that test results in the form of punched tapes are generated which can be entered into digital computers for storage and computations.

SWITCHING AND DISTRIBUTION UNIT

The Switching and Distribution Unit routes stimulus and response functions between SITE and the item under test. The unit is controlled by the command decoder during all modes of test and consists of reed relay matrices with solid state drivers, preprogrammable-removable patchboards, and output connectors which provide the interface between SITE and the unit under test. There are a total of 2222 relays contained in six independent matrices.

The precision stimulus matrix selects any one of four precision signals and applies it to a 4-wire bus. The bus can handle single ended or differential signals plus a reference voltage which is used in tests on phase sensitive signal conditioner devices. The bus is routed to the output stimulus matrix which can connect a precision stimulus to any of 1152 output lines to the unit under test. The output lines not connected to precision signals are connected to coarse signals.

Coarse signals are required to maintain ambient conditions on data channels not under test and to perform data channel crosstalk tests. Many of the signal conditioners in present day manned spacecraft would be driven off scale with a short or open circuit input. To prevent overstressing these channels while they are not under test, it is necessary to apply ambient input signals. Data channel crosstalk is measured by observing a particular channel and switching all other channels from nominal zero to nominal full scale. The zero and full scale signals are obtained from present ac and dc voltage supplies. The fixed voltage supply outputs are applied to a scaler unit which consists of a set of preprogrammable voltage dividers. The dividers provide a basic set of 75 nominal zero, ambient, and full scale voltages. The scaler outputs are applied to the coarse stimuli matrix which switches the voltages between zero and full scale. A preprogrammable patchboard is used to expand the basic 75 coarse signals to 1000 and to distribute them to output stimulus matrix.

During a bench systems test it is often necessary to connect instrumentation packages in-series. SITE provides the interface between all series packages so that the individual package transfer functions can be measured. This interface is provided by the Response Matrix, Response Patchboard, and the Response Stimulus Matrix as shown in Figure 3. The response matrix routes data channel outputs to the measurement matrix which can connect any stimulus or response to any number of measurement devices. Those responses that are to be re-applied to the units under test as stimuli (for example, the application of signal conditioner outputs to a PCM unit) are routed back to the SITE interface by means of the response patchboard and the response stimuli matrix.

INPUT SIGNAL GENERATOR UNIT

The Input Signal Generator Unit consists of programmable precision stimuli sources, fixed coarse sources, and power supplies. Device buffers provide the interface between the command decoder and the programmable precision sources. These sources consist of the high and low level voltage and resistance functions required to calibrate spacecraft instrumentation. The precision dc source is programmable in 1-millivolt increments from 0 to 250 volts and is accurate within 0.1 percent of the programmed value. The voltage, frequency, and phase of the ac source are programmable. Voltages from 0 to 250 volts rms can be obtained in 4 ranges each of which is accurate within 0.1 percent of the programmed value. The frequency is programmable from 50 to 4000 cps in 2-cps increments with an accuracy of 0.5 percent of the value. Phase is programmable from 0 to $\pm$ 180 degrees with an accuracy of 0.5 degree. A resistance source is used to test resistance sensitive devices. This source is programmable in 1-ohm steps from 100 ohms to 10,000 ohms and is accurate within 0.1 percent of the setting. The function generator provides the low frequency sine- and square-wave signals required for impulse and frequency response tests on dc signal conditioners.

OUTPUT DATA MEASUREMENT UNIT

Various programmable and non-programmable measurement devices are used as shown in Figure 3. Responses from the units under test are routed to the Measurement Unit by the Switching and Distribution Unit. The measurements made by the analog to digital converter, time interval meter, and the binary to BCD converter are routed to the control console for comparison, display, and storage.

DEMULTIPLEXER UNIT

The Demultiplexer Unit is used to separate time and frequency multiplexed channels. For time multiplexed signals such as PCM, PAM, or PDM, a programmable single channel decommutator is used. This device receives timing and reset pulses as test point data from the unit under test and gates the time slot under test to the measurement unit. A band switching discriminator is used to demultiplex and discriminate FM/FM data. The band pass and low pass filter outputs of this signal are applied to the Measurement Unit. A telemetry indicator is provided to visually observe the composite or individual subcarrier frequency spectrum.

OPERATION

Fault isolation and certification of instrumentation at the system or package level can be readily accomplished with general purpose bench maintenance equipment such as SITE. This is because the packages are usually self contained with respect to function, timing, and programming. This independence of function may or may not exist at the replaceable module level - it tends to characterize the modules of multichannel signal conditioner packages and it does not exist with PCM package modules. To test interdependent replaceable modules without using highly specialized module testers, the method of substitution is used. This method makes use of a non-flight package and set of modules which are electrically equivalent to the flight items. The certification of a module is accomplished by interchanging it with the non-flight equivalent and performing a package test. With respect to present day systems, this substitution method of module testing will be necessary only for the PCM packages.

The certification process in almost all cases involves a 5-point static-calibration that is run from zero to full scale and back to zero. At a given step in this calibration (usually half-scale), the various crosstalk tests are performed. In this fashion, the total transfer function is determined automatically. Fault isolation is largely a manual process whereby the package test points are usually scrutinized with a scope.

In addition to the autocheck feature, which insures that all commands have been properly received and interpreted before execution, SITE contains a self test feature. During this mode, stimuli connectors are jumpered to response connectors and a self test tape is played which exercises the entire SITE system. Self test is the mechanism used to checkout SITE before each test or to perform fault isolation within SITE. The self test time including set up varies from 15 minutes for a gross checkout to 2 hours for complete checkout with fault isolation. With self test, faults within SITE can be isolated to at least 4 replaceable modules.

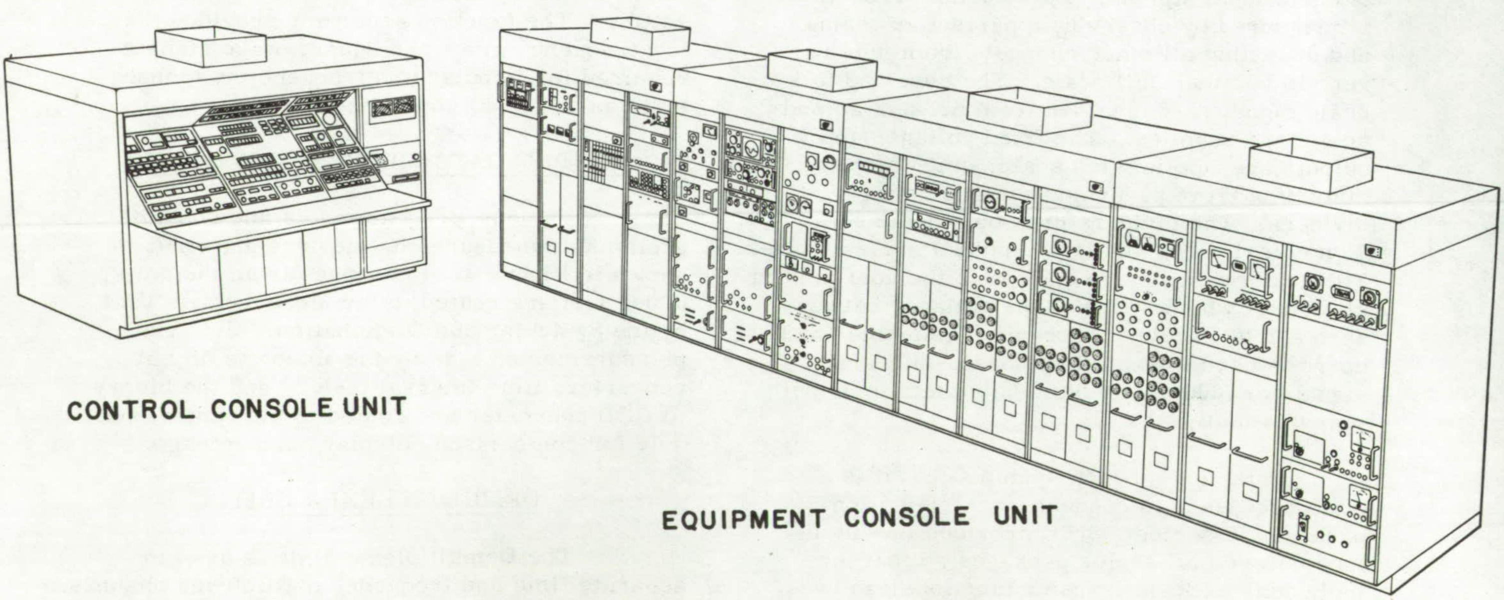

FIGURE I SITE CONFIGURATION

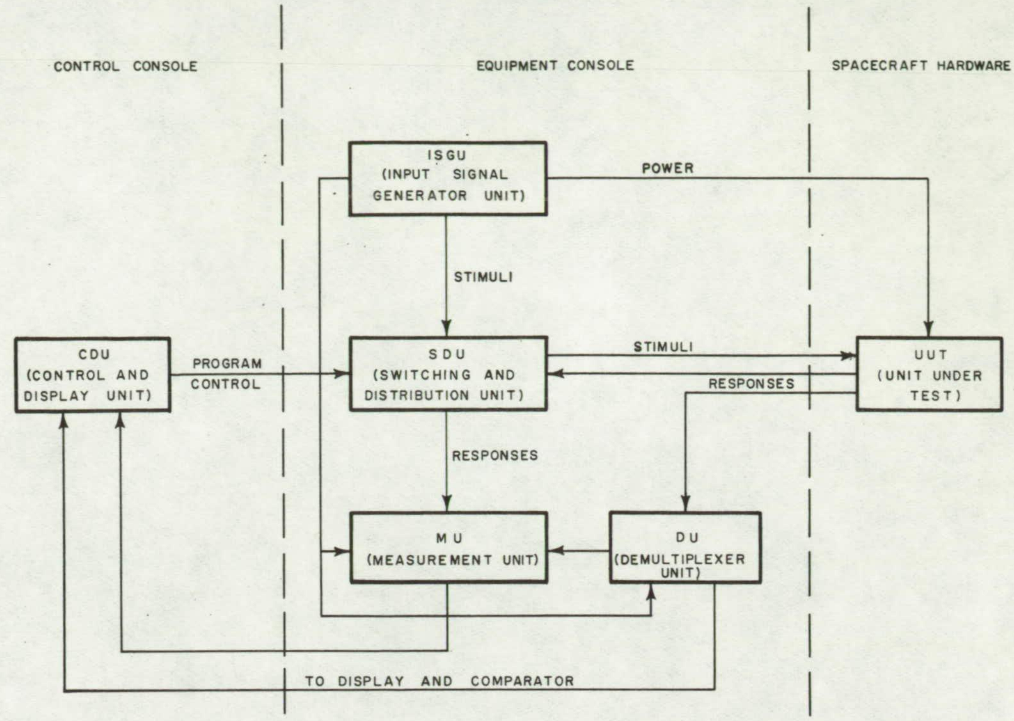

FIGURE 2 BASIC BLOCK DIAGRAM OF SITE

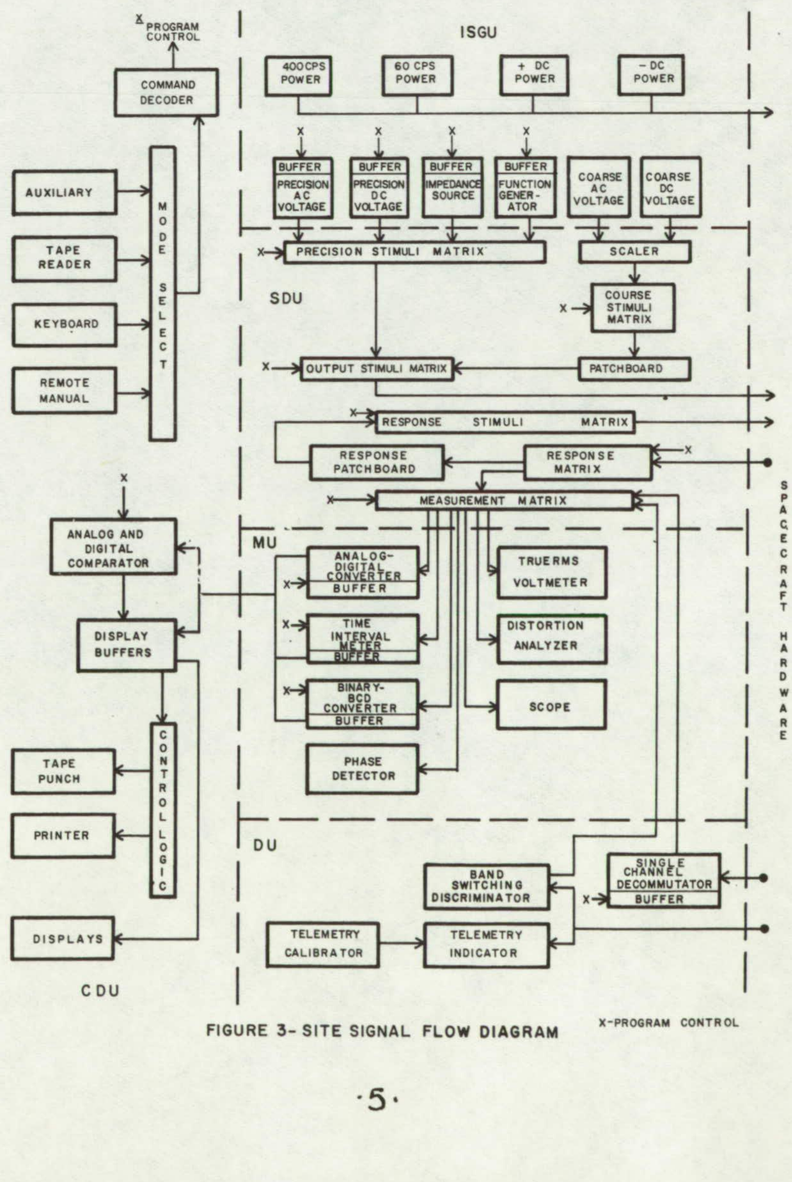

FIGURE 3- SITE SIGNAL FLOW DIAGRAM