AN INTELLIGENT ADVISORY SYSTEM FOR
PRE-LAUNCH PROCESSING

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Abstract:

In order to process Space Shuttle vehicles for launch, the various Shuttle systems are subjected to various test and checkout procedures prior to launch. The system of interest in this paper is the Shuttle Data Processing System (DPS) and, in particular, the DPS Multi-Function CRT Display System (MCDS). Due to the complexity of the Shuttle as a whole and DPS in particular, the system may at times behave in an unpredictable yet benign manner in respect to normal operations. Therefore, it is difficult for even experienced systems engineers to determine whether an annunciated error is truly a failure or a benign anomaly. An automated, prototype diagnostic tool is to be described in order to provide a solution to the labor intensive and time consuming diagnostic techniques currently used. The MCDS Diagnostic Tool (MDT) will be capable of monitoring the MCDS system real time, recognizing and analyzing failures giving the user a probable cause of the failure. The MDT is considered to be a pioneering diagnostic system for all DPS subsystems diagnostics.

The primary goal at the Kennedy Space Center is to prepare the space Shuttle system, both the Shuttle and its payload, for launch into low earth orbit. In order for this goal to be accomplished in an efficient yet safe manner, all Shuttle sub-systems are subjected to various test and checkout procedures prior to launch. A majority of these procedures are carried out by systems engineers (via ground software) from firing room resident computer consoles. This network of computer consoles which constitutes a main component of the ground Launch Processing System (LPS), is connected to the Shuttle via a Launch Data Bus (LDB). In this manner, systems engineers are able to monitor and control vehicle subsystems whether the Shuttle is residing in the orbiter processing facility, vehicle assembly building or pads.

The Shuttle system of interest in this paper is the Shuttle's Data Processing System (DPS). The DPS is composed of (1) General Purpose Computers (GPC) (2) Multi-Function CRT Display System (MCDS) (3) Mass Memory Units (MMU), and (4) Multiplexer/Demultiplexer (MDM) and related software. As is currently done, checkout and configuration of DPS subsystems are done by a DPS systems engineer initiating and controlling a set of ground software programs. Additional system configurations are done by manual switch settings inside the cockpit via voice instruction to a space craft operator.

In order to ensure the correct functioning of Shuttle systems, some level of automatic error detection has been incorporated into all Shuttle systems. For the DPS system, error detection equipment has been incorporated into all its subsystems. This error detection equipment is typically manifested as electronic circuitry composed of hardware registers where the bits of a particular register corresponds to particular errors (i.e. power transient detected). Additional errors are annunciated using both visual cues (i.e. mechanical flags and lights) and auditory cues (i.e. alarms and tones). This error detection equipment provides the system engineer with a real time awareness that a failure has occurred and allows him or her to properly safe the system in a timely manner. While this error detecting equipment makes the engineer aware of a subsystem failure, it does not (in most cases) give a cause of the failure. Due to the complexity of the Shuttle, both in terms of hardware and software, errors will fre-

quently arise during normal operations which are of an anomalous but harmless nature, but again due to system complexity, it is up to the systems engineer level of experience to differentiate the harmful from the benign errors. Frequently, an inexperienced (and even an experienced engineer) will encounter a fundamentally benign failure yet diagnose it as a harmful one. In the interim, much paperwork is generated and a possible temporary interruption in launch processing may be experienced.

It is at this point that a brief description of the current diagnostic methods should be discussed. As was stated earlier, the error detection equipment alerts the responsible system engineer that an anomaly has occurred, but not what has caused it. In order to ascertain the cause of an anomaly, the responsible system engineer(s) must apprehend what the overall system environment was when the error occurred, and in order to do this, the engineer must rely on telemetry data. This telemetry data takes on two forms for DPS subsystems. The first is what is called dump data. Two of the DPS subsystems, the GPC's and the MCDS have resident stored memory capacity (GPC of 104K and the MCDS of 8K). When an error occurs in either one of these two subsystems, the malfunctioning component is isolated and the stored memory is then transmitted down the LDB and placed on magnetic tape and paper printout. This memory content of the anomalous subsystem provides the engineer with an image or state of operation of the subsystem during the time at which the error occurred. This information is then combined with the second type of telemetry which is called downlist data. Downlist data is simply the encoded values, states and times of a large number of discrete and analog Shuttle parameters. It is from this raw data which the engineer(s) must review manually, that a diagnosis of the problem is obtained (hopefully). Again, due to the complexity of the Shuttle, the amount of raw data is large (the MCDS alone has 8K of memory locations which must be reviewed manually) and, hence, is labor intensive and time consuming.

As stated in the abstract, we are describing an automated diagnostic system, the Multifunction CRT Display System Diagnostic Tool (MDT), which will aid in a more efficient processing of the DPS. Before going on to describe in more detail the functioning of the MDT, a brief description of the MCDS will be given. The MCDS is composed of three basic systems: (1) Keyboard, (2) Display Electronic Unit (DEU), (3) CRT.

The heart of the MCDS is the DEU which is the information processor for data between the CRT, keyboard and GPC's and allows the astronauts to communicate to the GPC's and vice versa. The DEU is composed of various logical circuitry for CRT data display, keyboard data and processing of GPC commands and data. In addition, the DEU has a memory store of 8K in which to store data and commands for MCDS information processing, as well as, built-in test equipment (BITE) circuitry. This BITE circuitry is composed of three 16 bit status registers and two mechanical flags.

Now that a brief overview of the Shuttle processing and diagnostic environment has been described, a number of shortcomings have been mentioned in regard to the current nature of orbiter related diagnostics. These will now be stated more compactly:

(1) As it stands now, current diagnostic techniques used to arrive at problem resolutions are labor intensive and time consuming.

(2) Due to the complexity of the system (Shuttle, as a whole, and the DPS, in particular) being processed, the behavior of the system can, at times, behave in an unpredictable but benign manner with respect to normal operations. This makes it difficult for the systems engineers to know whether an annunciated error is truly serious or trivial.

Point 2 will have to be expanded upon, in order to make what follows in the rest of this paper consistent. The Shuttle has been in operation for almost 11 years, hence, there is also a commensurate 11 years worth of documented Shuttle behavior. The Shuttle behavior of most interest here is of the anomalous DPS kind, and this type of behavior has been, in most cases, thoroughly documented. This documentation will be described metaphorically as a triadic problem resolving knowledge base. The first part of this triad is known as a Problem Report (PR) database. This PR database is a paper system which is used to track the history and resolution (if one exists) of launch processing related anomalies. The second part of the triad is a "user's note" resource. The user note resource documents and explains DPS subsystem behavior which is anomalous but also benign with respect to the running of normal operations. The last and most important leg of this triad is the cerebral documentation which resides in the minds of our most experienced and astute engineers. It is from the inter-

MDT IN MONITOR/STANDBY — UTILITY NEEDED? → GO TO UTILITY MENU

OFF-NOMINAL BITS DETECTED?

"SNAPSHOT" MCDS ENVIRONMENT — NEED MORE DATA? → QUERY USER → A

A →

ERROR ANALYSIS IN PROGRESS — ANALYSIS COMPLETE? → DISPLAY RESULTS TO CRT & OUTPUT TO PRINTER → RETURN TO STANDBY
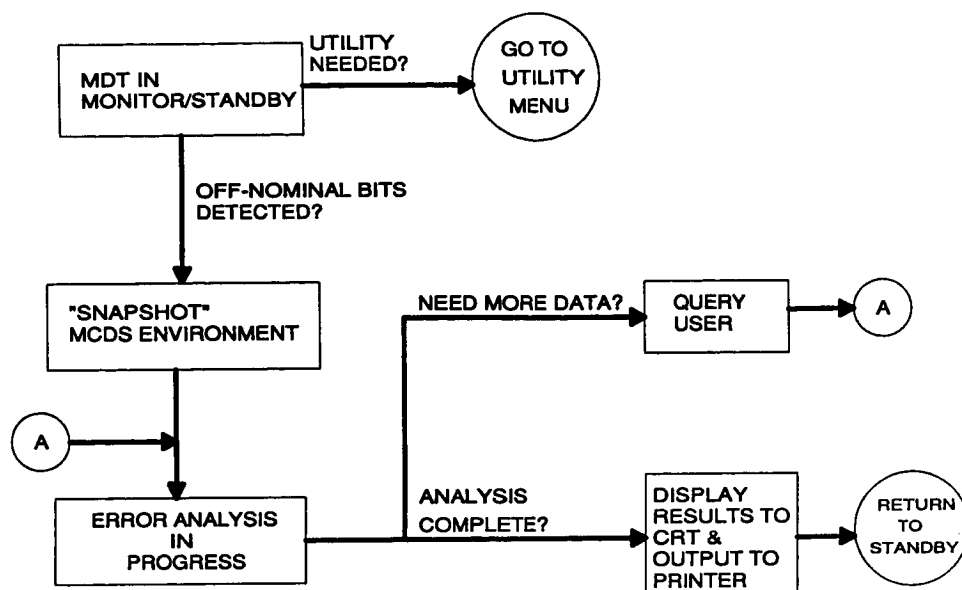
Figure 1.

action of this problem resolving knowledge base that solutions to our problems are derived.

The inherent drawbacks of this system are as stated in (1) above, and also in that our triadic system must rely on a component (i.e. that astute systems engineer) who may not be accessible for some reason or another when a problem arises. These two weaknesses in the system, by their very nature, allow themselves to be alleviated to some extent by automation. By incorporating a high-speed automated system, which has residing within it, both the paper history of problems and the diagnostic wisdom of our engineers (as best as that can be done), an integrative tool can be added to our diagnostic triad to help support the system as a whole. For our particular purposes (DPS), the MDT is a way of realizing an automated diagnostic system which can aid us in doing business with misbehaving avionics boxes. This system is to fulfill the following four goals:

(1) Monitoring of downlist data for MCDS anomalies

(2) Testing the downlist data for the presence of pre-defined error conditions

(3) Presentation to the user of probable cause of the failure

(4) Presentation of problem report and user note information corresponding to the failure detected.

How the MDT proposes to attain these four goals is the topic of our next section.

The MDT is contracted to Rockwell International Corporation, Launch Support Services. The development team consists of Rockwell test personnel from the Avionics Software organization at KSC, Florida, and Artificial Intelligence personnel from the Expert Systems Applications organization at Downey, California. In addition, Abacus Programming Corporation personnel were added to augment the team.

The host computing system will be a SUN SPARCstation 1 Plus. This system was selected for its ability to perform multi-tasking with its UNIX based operating system. In addition, the SUN SPARCstation was selected to maintain compatibility between this advisory system and future firing room applications. The "C" Language Integrated Production System (CLIPS) was selected as the expert system shell to be utilized by the MDT. CLIPS is a forward chaining rule-based language that provides an inference engine and a language syntax that lends itself to interfacing with externally defined functions. As more and more firing room applications are automated, it is believed that a standard shell with increased capabilities will be available with the cost being shared among projects.

The conceptual system (Figure 1) will be powered on in the firing room at all times when the orbiter is powered on.

Figure 2.
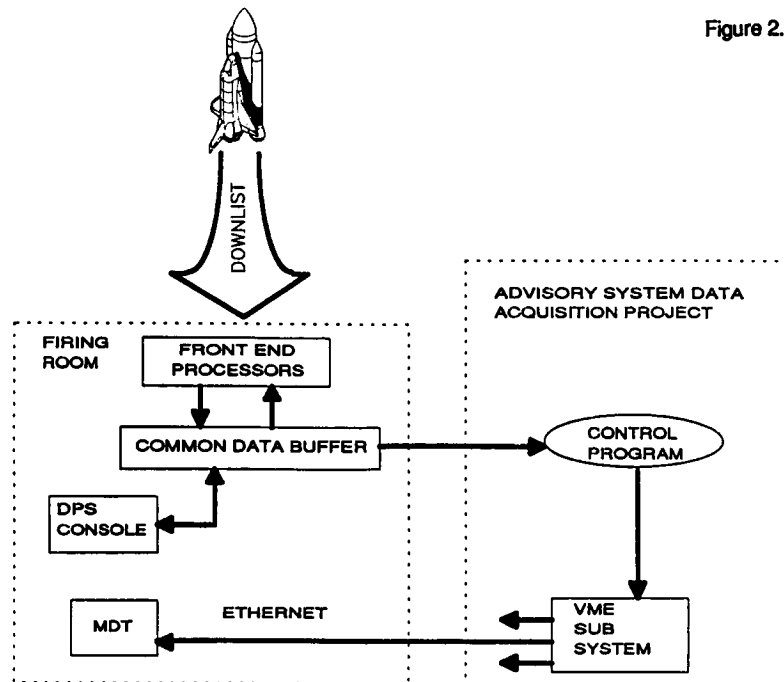
The system will be in a "standby" mode of operation awaiting occurrence of off-nominal conditions. While in "standby" mode, test engineering personnel may pictorially view the current configuration and status of the MCDS system as it is on-board the orbiter. The MDT will dynamically update the System State Model display and monitor for errors with near real time data from a telemetry link to the firing room Common Data Buffer (CDBFR).

The process of acquiring the telemetry data (Figure 2) is a most challenging process, since the present firing room hardware is not compatible with the SUN. A method of acquiring telemetry data has been developed by the Advisory System Data Acquisition Project at KSC [3]. This telemetry data will be read from the Launch Processing System (LPS) common data buffer via a data control program. This program scans the buffer once a second and sends the data to a VME subsystem that blocks the incoming data stream into Ethernet frames and sends it out on an Ethernet line to various system users. The MDT communications process accepts the incoming data and places it in a data buffer residing on the SUN. This buffer is in shared memory and is accessible to the various applications resident on the SUN.

The incoming data will be monitored for off-nominal conditions. More explicitly, the three status registers for each of the four DEU's will be monitored for any abnormal bit pattern change. The monitoring of these 12 parameters can detect up to 90% of all MCDS failures. If an MCDS failure that is not triggered by status register changes occurs, the engineer will be able to utilize a manual mode of operations in which an analysis can be performed without being initiated by changes in telemetry data.

Once an anomalous condition is recognized, a "snapshot" of the MCDS environment is taken and saved for the system to begin the error analysis process. This snapshot process allows the system to complete the analysis process of a single error without possible loss of a secondary error. Once an error is detected, a set of pre-defined error conditions are checked. Each error condition requires the analysis of a unique set of data from the buffer and possibly the user. The user will be queried in situations where telemetry data is either unavailable or insufficient. In general, user requests will be data that may only be obtained by visual inspection of the MCDS (i.e. blank CRT's or tripped mechanical flags). The need for user supplied data will be kept to a minimum to enhance the automated nature of the system.

The system will evaluate and eliminate possible causes of the given failure condition. A hierarchy will exist among the pre-defined error conditions such that if an error condition of high probability is determined to be the cause, other unlikely conditions will not be checked. The possibility does exist for more than one probable cause of a failure to be displayed to the user. This could occur if telemetry data is temporarily unavailable or if the user did not supply the necessary data. As always, the systems engineer makes the ultimate decision concerning the most probable cause of the failure using data obtained from the MDT. The data used in the error analysis process will be saved to a file for later use in the re-creation of failure scenarios for either re-evaluation or training. The data necessary to perform the analysis process is being provided by Rockwell and NASA KSC employees. For each of the possible failure conditions currently recognized, a thorough review of historical data, both documented and un-documented, must be performed. This data is then organized into "rules" that will be encoded into the system by Rockwell, Downey.

All results of the error analysis will be displayed to the CRT and output to a printer. The results are the coordination of the system environment at the time of the error, probable causes of the failure, possible troubleshooting steps to be taken, and references to past problems and user notes pertaining to the failure condition. The coordination of this information is currently done manually by the systems engineers and is a time consuming process. All the information obtained from the results will be utilized to support closure of paperwork generated at KSC due to the MCDS failure.

The mode of operations described thus far constitutes the "Automatic" mode of operation. This mode will have the highest priority and will automatically be run as a foreground task upon receipt of an anomalous condition. This system also includes "Manual" and "Replay" modes that are available on an as-needed basis. The selection of either mode presents the user with sub menu's to access the MDT functions. The user will have the ability to perform "what-if" analysis on the MCDS in a test environment, replay already analyzed failures, review past PR and user note databases, and review the results of past failure analysis.

The MDT is viewed by the systems engineers at KSC as a highly desirable concept. By automating the processes performed manually at this time, MCDS failure recognition and resolution can be performed more rapidly and efficiently. This system will also provide invaluable training experience for systems engineers. The MDT system requirements and specifications, as defined, are such that the previously mentioned diagnostic triad representing an automated problem resolving knowledge base can be utilized.

The MDT is a 3 year project in which the first year prototype will concentrate on the development of a proof-of-concept prototype to demonstrate the four goals defined. The prototype will encompass the utilization of telemetry downlist data to perform diagnostics of the MCDS. The prototype to be delivered by October 1990 will perform automated analysis of between 5 and 10 errors. Its manual mode will provide the capability to search the PR and user note databases and to retrieve information about DEU status register bits. The second year will include the addition of the remaining known error scenarios, as well as, the addition of simulated DEU dump data. The dump data will enhance the diagnostic capabilities of the MDT. The final year will consist of integration with the Expert System for Operations Distributed Users System (EXODUS) [2] and the capture of near real time DEU dump data. This should complete the firing room implementation of the MDT.

The developers of the MDT view this concept as a pioneering diagnostic system for all DPS subsystems (GPC, MDM, MMU). A long term goal of the MDT project is that an eventual integration of all DPS diagnostics will be realized in a distributed diagnostic system. Such a distributed knowledge base concept for launch processing is already being investigated at KSC under the EXODUS program. It is hoped that the knowledge gained with the MDT and other Shuttle advisory systems currently being developed [1] will aid the EXODUS program and, in turn, help in the realization of a distributed DPS diagnostic system.

Acknowledgments

References

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APPENDIX

Acronyms

BITE - Built In Test Equipment
CDBFR - Common Data Buffer
CLIPS - "C" Language Integrated Production System
CRT - Cathode Ray Tube
DEU - Display Electronics Unit
DPS - Data Processing System
EXODUS - Expert System for Operations Distributed Users System
GPC - General Purpose Computer
LDB - Launch Data Bus
LPS - Launch Processing System
MCDS - Multi-Function CRT Display System
MDM - Multiplexer Demultiplexer
MDT - MCDS Diagnostic Tool
MMU - Mass Memory Unit
PR - Problem Report