VERIFICATION AND VALIDATION OF CONTROL CENTER OPERATIONS USING A TELEMETRY SIMULATION

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ABSTRACT

In space applications, telemetry systems are traditionally used to provide a front end for processing Control Center data. Control Center operations dictate the content and processing requirements of the telemetry data to enable the control center personnel to make proper decisions concerning the operation of their space vehicle. Unfortunately many anomalous operational scenarios do not arise during control center checkout procedures which are designed to test the functionality of the Control Center equipment. However, an interactive telemetry simulation, which involves producing telemetry data using real-world formats and data rates, can create many of the situations control center personnel may encounter. A host computer is used to drive a telemetry system which in turn produces simulated vehicle data. As a result, a telemetry simulation can not only verify the functionality of the Control Center hardware and software, but also validate Control Center procedures and train Control Center personnel in the process.

KEY WORDS

Telemetry Simulation, Control Center

INTRODUCTION

At the Johnson Space Center (JSC) in Houston, Texas, telemetry simulation has been used for over 15 years to train ground controllers and support personnel in the proper use of NASA's Space Network (SN). The SN is used by various NASA control centers to communicate with a vehicle or payload. The SN is composed of the following (see Figure 1):

1. Tracking and Data Relay Satellites (TDRS) in geosynchronous orbit around the earth's equator

2. Ground terminal equipment at the White Sands Complex (WSC), New Mexico

3. The Network Control Center (NCC) at the Goddard Space Flight Center (GSFC), Maryland

4. A Domestic Communications Satellite (DOMSAT) system which connects the facilities.

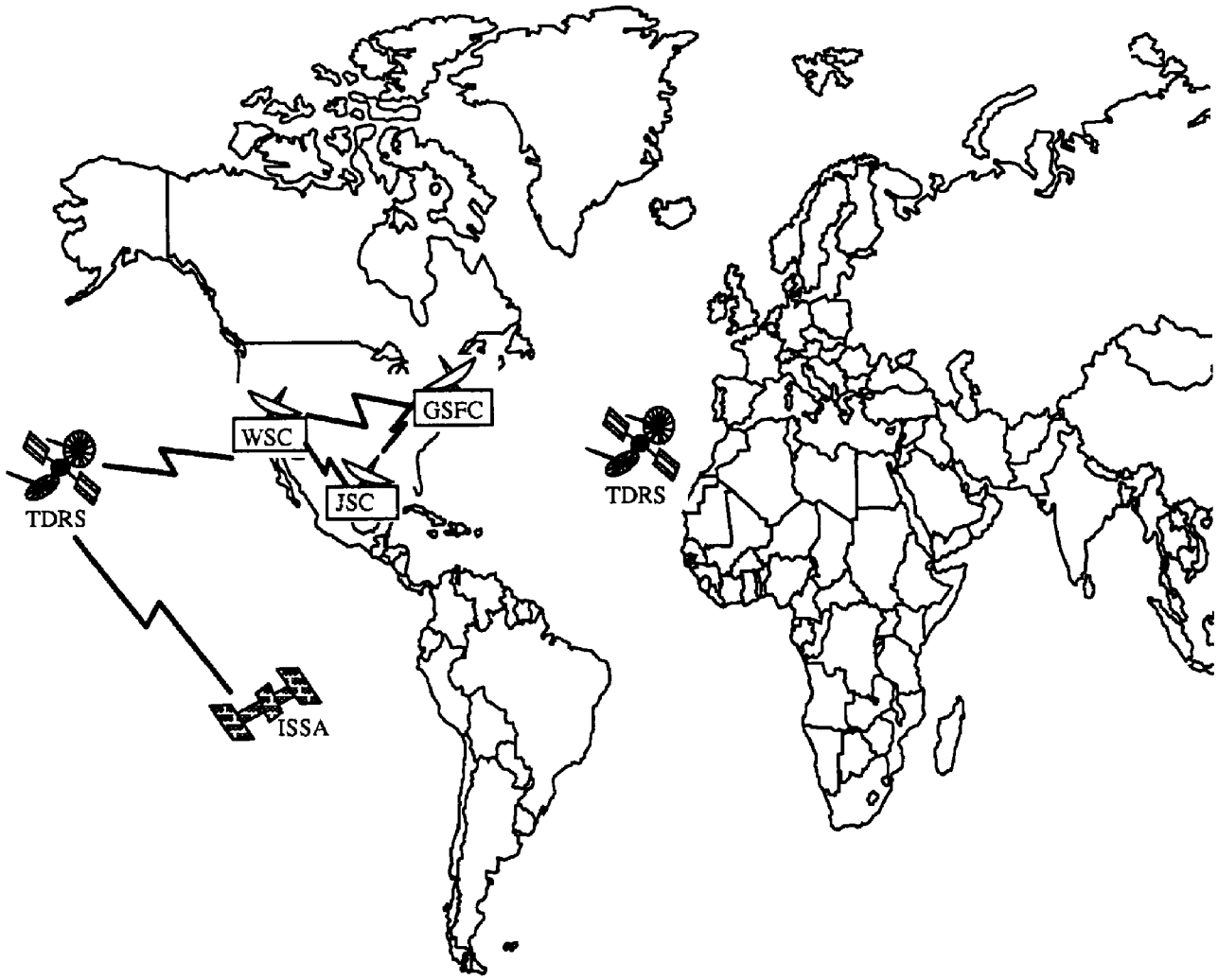

Figure 1: Overview of Space Network

To use the SN for the International Space Station Alpha Program at JSC, the Mission Control Center (MCC) provides a facility which can generate messages used for requesting SN resources and, once a link is established, transmit uplink vehicle commands to the Space Station through the SN. Also the MCC can receive vehicle

telemetry from the Space Station and messages from the SN which indicate; data quality monitoring of the link, responses to resource requests, and the configuration of the SN. To use this large and complicated system, strict protocols and message formats are required. Improper use of the SN and MCC will cause a loss of communications with the Space Station. If the reason for a communications loss is not known, a substantial amount of time may pass before the link is reestablished, resulting in a loss of user vehicle telemetry and an inability to command the vehicle. On the Space Station program, the Space Network Simulator (SNS) is used to validate the MCC consoles and train the MCC ground controllers. The SNS, which is part of the Space Station Verification and Training Facility (SSVTF), is a real-time telemetry simulator capable of providing Space Station telemetry and SN status data in real-world rates and formats.

The simulator trains the students at the control center consoles by executing a real-time software model of the SN components and using the outputs of these models to mode a telemetry system which in turn drives the control center displays. Also the students can interact with the simulation by entering control messages as they would in a real-world situation. The simulation processes these message requests just as the real-world SN components do and provides the same feedback as the real-world components do which involves data outages, error messages, acknowledgements and/or simulated vehicle telemetry. Due to the thorough nature of the simulation's modelling, all aspects of the control center's operations and functionality are tested, thus providing a verification and validation function in addition to a training function.

REQUIREMENTS

The requirements for an effective real-time telemetry simulation are based on the functional requirements of the control center being driven by the simulation. To make the control center believe it is connected to the real-world SN, all interfaces to the control center are duplicated by connecting at the real-world communications interfaces. The main requirements of the SNS are as follows:

1. Accept network requests in the form of 4800-bit NASA Communications Network (NASCOM) blocks at a rate of 1.544 Mbps to configure the simulated SN components

2. Produce network status in the form of 4800-bit NASCOM blocks at a rate of 1.544 Mbps based on the simulated configuration of the S N

3. Accept S-Band vehicle command streams from the control center at a rate of 72kbps and 6 kbps and forward them to the spacecraft simulation based on the

SN configuration and the response of the Radio Frequency (RF) and environment models in the host computer

4. Produce S-Band vehicle telemetry streams using the real-world packet protocol (CCSDS packets) at a rate of 192 kbps and 12 kbps and forward them to the control center based on control and moding from the host computer to reflect the state of the SN

5. Simulate the SN components by reacting to control center and external events, and producing real-world reactions to these events

6. Provide a capability to malfunction simulated components to produce real-world anomalies which may occur during operations and have all data reflect these conditions (e.g. RF outages and noise, simulated equipment failures, erroneous telemetry and command processing).

THE SPACE NETWORK SIMULATOR

The SNS provides an accurate simulation of the SN by simulating the components of the SN which receive and process the real-world telemetry and command data. To accomplish this, the SNS is composed of the following (see Figure 2):

1. A telemetry processing system which performs the physical data manipulation.

2. A control center interface which provides the necessary connections to route the data between the various locations of the simulator and control center at JSC

3. A host computer system which contains the SN Software Models and external interfaces to the SSVTF

4. The SN Software Models which drive the SN modeled components based on external events.

These elements alone provide a standalone environment for control center interfacing. An integrated environment which includes the remainder of the SSVTF and combinations of International Partners and other control centers, is also provided to train ground controllers with flight crews. This scenario allows the various groups to be trained as a team.

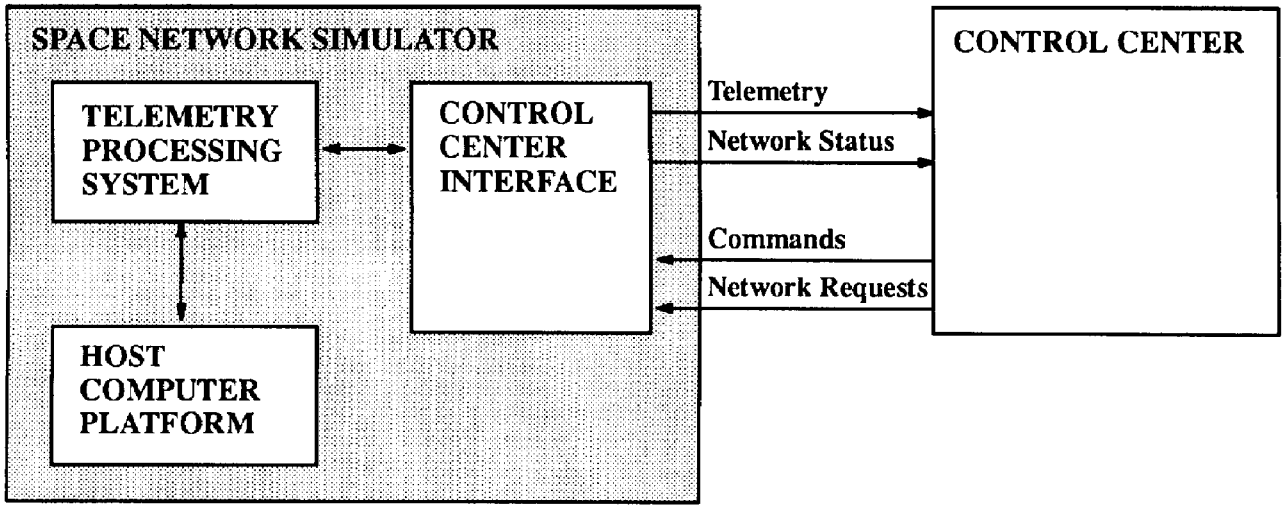

Figure 2: Overview of Space Network Simulator

The Telemetry Processing System:

The main functions of the Telemetry Processing System are to perform front end processing for the SNS and to provide hardware specific data processing functions to ensure the outgoing data is in real-world rates and formats. The telemetry processing system is controlled and moded by the applications models on the Host Computer Platform. Network management commands and requests are received by the Telemetry Processing System from the Control Center Interface and passed on to the Host Computer Platform after signal processing functions perform error detection and correction (EDAC) and non-essential header information is stripped. Network Status data is generated by the applications models on the Host Computer Platform and converted into the 4800-bit NASCOM format by the Telemetry Processing System. The NASCOM blocks are constructed by filtering the data into the real-world format, appending a Cycle Redundancy Check (CRC), and by placing the appropriate routing data into the block header.

The components of the Telemetry Processing System are as follows (see Figure 3):

1. Recorders: A bank of recorders is used to log and delog the data streams for playback and analysis. During real-time simulation, it can become difficult to pinpoint problems as the data is processed at the rapid real-world speeds. The recorders allow validation of control center telemetry processing by providing repeatability testing.

2. Programmable Switch Matrix: A programmable switch matrix is used to dynamically switch the data sources and destinations. This allows data destined for the Control Center Interface to be selected from the recorders or the telemetry system.

3. Telemetry System: A telemetry system is used to perform the main signal processing functions. These include bit synchronization, frame synchronization, time tagging with both a Greenwich Mean Time (GMT) and Simulated GMT (SGMT), and NASCOM block encoding and decoding The real-time moding of the telemetry system by the software models allows data modification to occur instantly as it would during real-world operations.

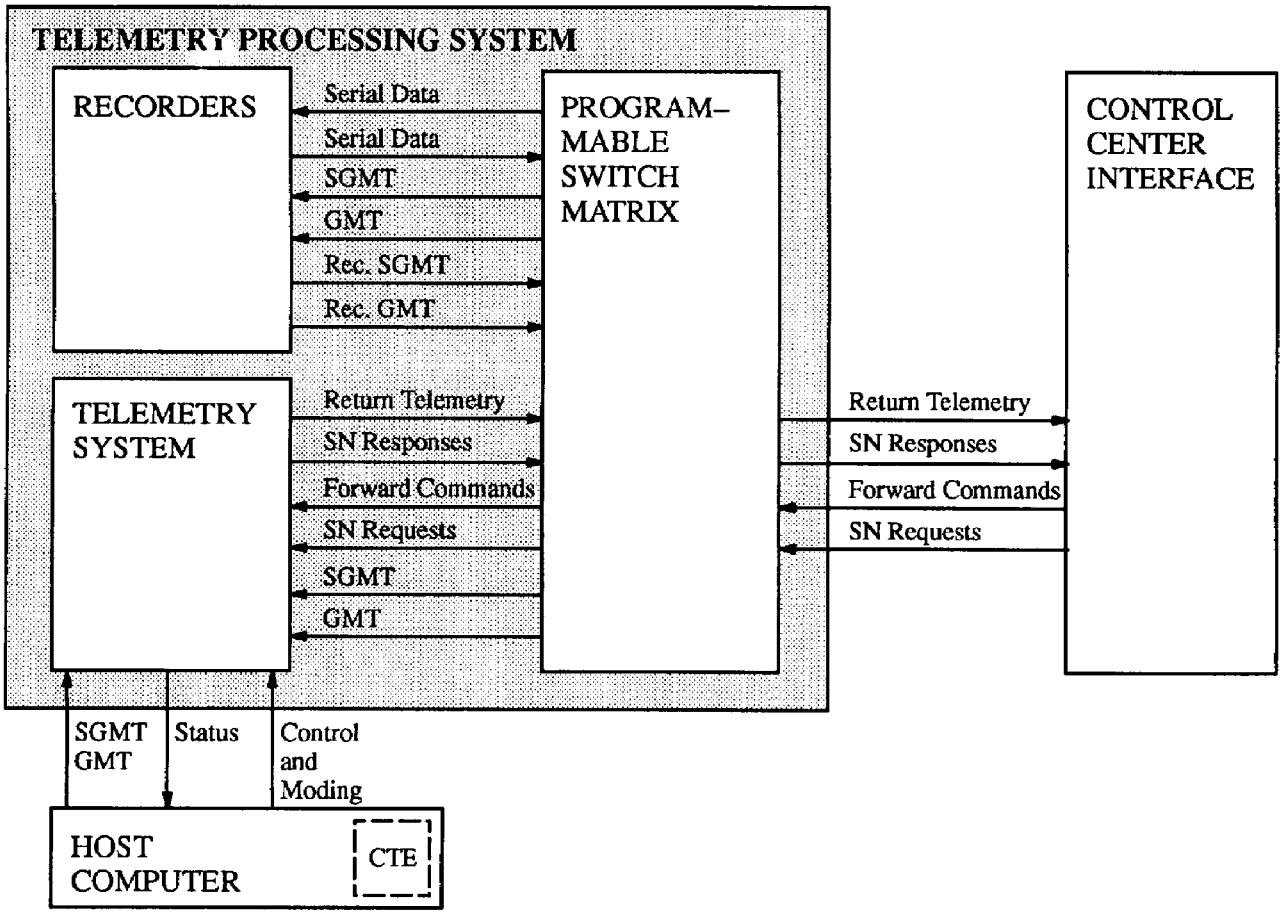

Figure 3: Overview of Telemetry Processing System

The Control Center Interface:

The main functions of the Control Center interface are to route the data between the different buildings at JSC and provide a compatible electrical interface with the control center. This is accomplished with sets of fiber-optic multiplexors connected by fiber-optic cable which runs between the buildings.

The Host Computer Platform:

The main functions of the host computer platform are to provide an execution environment for software applications models which represent the resources of the SN. The models run as tasks and are controlled by a real-time executive which coordinates message passing between the tasks. An object-oriented composition hierarchy is used to model all aspects of the SN from the TDRS constellation to the RF environment which simulates the propagation of the RF signals through space. Also, the host applications models use telemetry system processing status (e. g. percent frames in lock, data transition density percentages) to formulate the data fields for the 4800-bit NASCOM blocks which are then sent back to the system for encoding and transfer to the control center. These simulated data fields are observed by the ground controllers at the control center and are used to make decisions on how to make the proper requests of the SN.

The SN Software Models:

The SN Software Models provide the simulations of all the physical systems and natural phenomena that affect communications with the Space Station. These models include a capability to accept control inputs from the SSCC and provide status outputs to the SSCC in such a way that the appearance to the hardware, software, and operations personnel within the SSCC is that they are interfacing with the actual Space Station through the SN. These simulation models have fidelity to the extent that orbital positions and attitudes in space of the Space Station, Relay Satellites, and significant celestial bodies are identical to those during the timeline of the actual mission scenario. This provides an opportunity to check out operations procedures to perform on-orbit operations against real-world constraints, including those that affect telemetry and command communications during the mission scenario. Simulations with these models provide the most faithful end-to-end verification of the control center flight software. Implementation of these models in software provides a flexible way to rapidly run through contingency scenarios and verify them as well. All such verification is performed against simulated real-world "physical" or "system" constraints.

This type of simulation provides operations signature exposure to SSCC electronic systems, software and software procedures, and human operations personnel in a team environment under actual mission conditions, including; team interaction to resolve problems, and select and observe contingency scenarios based on simulated conditions.

CONCLUSIONS

Simulation of spacecraft telemetry and command interfaces provides both training and spacecraft mission control center software and hardware validation benefits. This is possible when the simulation has high fidelity, real-world models and interfaces to the spacecraft control center at the real-world interface points, thus exercising the same systems, software, and personnel used in an actual space mission. Therefore simulation of spacecraft and interfacing systems, as well as physical phenomena including orbital positioning and timelines, is possible and beneficial in the real-time training of control center personnel and validation of control center operations.

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LIST OF ACRONYMS

CCSDS	Consultative Committee for Space Data Systems
CRC	Cyclic Redundancy Check
CTE	Central Timing Equipment
DOMSAT	Domestic Communications Satellite
EDAC	Error Detection and Correction
GMT	Greenwich Mean Time
GSFC	Goddard Space Flight Center
JSC	Johnson Space Center
MCC	Mission Control Center
NASCOM	NASA Communications Network
NCC	Network Control Center

RF	Radio Frequency
SGMT	Simulated Greenwich Mean Time
SN	Space Network
SNS	Station Network Simulator
SSVTF	Space Station Verification and Training Facility
TDRS	Tracking and Data Relay Satellite
WSC	White Sands Complex

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