THE GENERIC DATA CAPTURE FACILITY

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ABSTRACT

The growing complexity of space science missions is causing a dramatic increase in the data rates and volumes from spaced-based experiments, and the ground operations functions associated with handling data from these missions are growing in complexity consistent with this increase. A key requirement on the systems that provide data handling support is to control operations costs carefully while providing high-quality data capture functions. One approach to meeting this particular objective that has been taken at the Goddard Space Flight Center has been to initiate the development of a Generic Data Capture Facility (GDCF) that can provide data capture support for a variety of different types of spacecraft. The GDCF is emerging through a blend of new system development and evolution of existing systems, and when complete, it will have the capability to support the two major data formatting schemes (packet and Time-Division Multiplexed (TDM)). The specific implementations are designed to support the Gamma Ray Observatory and the Upper Atmosphere Research Satellite, but the GDCF will provide the baseline system to support various new missions as they emerge.

INTRODUCTION

“Data capture” is a general description that encompasses a variety of functions routinely applied in the initial acquisition of satellite data, including protection against data loss, recreation of the original data form, and generation of data quality and accounting information. Since these functions are applied to all of the data acquired from the National Aeronautics and Space Administration’s (NASA) Earth-orbiting satellites, the concept of a multimission data capture facility has been viewed as a key to controlling operational costs. Developments are underway at the Goddard Space Flight Center (GSFC) for data capture systems for the two major data format types: TDM and packet formats. The systems are being designed to support the Upper Atmosphere Research Satellite (UARS) and the Gamma Ray Observatory (GRO) but they also will be capable of supporting other satellites and together will form the nucleus of a generic data capture facility.

DATA CAPTURE FUNCTIONS

There are numerous data capture functions. As previously stated, data capture is a general description that includes a broad range of activities including some initial data processing. To avoid confusion with data recording (which is one of the functions associated with data capture), the description "level zero processing" has emerged. The origins of this terminology are associated with the definition of processing levels of science data. (See Table 1 (1).) For the purposes of this paper, level zero processing will be used as a title for the data processing functions included under the umbrella phrase "data capture." Thus, a level zero processor is a computer that performs the data processing functions associated with a data capture facility. The data capture functions can be grouped into four major categories: data protection; isolation of users from data acquisition problems; data reconstruction; and provision of detailed quality and accounting information.

Table 1
Definition of Data Processing Levels

Level 0	Reconstructed unprocessed instrument data at full resolution.
Level 1A	Reconstructed unprocessed instrument data at full resolution, time referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (i.e., platform ephemeris, computed, and appended but not applied to the Level 0 data).
Level 1B	Level 1A data that has been processed to sensor units (i.e., radar backscatter cross section, and brightness temperature). Not all instruments will have a Level 1B equivalent.
Level 2	Derived environmental variables at the same resolution and location as the Level 1 source data (e.g., ocean wave height, soil moisture, and ice concentration).
Level 3	Variables mapped on uniform spacetime grid scales, usually with some completeness and consistency properties (e.g., missing points interpolated, complete regions mosaicked together from multiple orbits).
Level 4	Model output or results from analyses of lower-level data (i.e., variables that were not measured by the instruments but instead are derived from these measurements).

DATA PROTECTION

The development and operation of satellite systems are expensive undertakings, and it is important that the data acquired from such missions be protected against inadvertent loss. Therefore, a key function in the data capture process is to record the raw data as it is acquired, thus protecting against line outages between the capture point and the user and protecting against loss in the user system. Generally, raw data sets are held in a short-term storage area for a considerable amount of time (perhaps a year or more) and then sent to a long-term storage area. The short-term storage of data is generally considered a data capture function. Long-term storage is performed as a matter of policy at facilities designed specially for that purpose. Satellite data sets are archived for a minimum of 17 years under current national policy.

ISOLATION OF USERS FROM DATA ACQUISITION PROBLEMS

The end users of satellite data are often scientists at universities or other research institutions. They frequently need to perform complex processing operations on the data to analyze the content and develop (or reinforce) fundamental theories. This process, which is contemplative and analytic in nature, is not consistent with the day-to-day requirements of satellite data acquisition, Since a low Earth-orbiting body encircles the globe every 90 minutes, the data acquisition facility must be staffed around the clock to acquire all of the data that is transmitted to the ground. Furthermore, satellite-to-ground transmission schedules may be complicated by complex data acquisition requirements (imposed by the mission or science objectives) or by ground resource preemption (perhaps as a result of an emergency condition with another spacecraft). Finally, data acquisition sites must be designed for peak (e.g., tape recorder playback) data rates, and the data lines to those sites must support peak rates. Clearly, a second valuable function of the data capture facility is to isolate users of satellite data from the complexities of acquiring the data, allowing them to build systems that are staffed during normal working hours, and that need accept data only at average, not peak, rates.

DATA RECONSTRUCTION

Scientists and engineers have defined a convenient shorthand notation for describing different stages of satellite data processing. (See Table 1.) As defined, level zero processing removes artifacts of the space and ground data system from the instrument data set. For example, most spacecraft are equipped with tape recorders; to save on head wear, the tape recorders are not rewound before playback. As a result, recorded data is received on the ground in reversed time order. Data acquisition periods normally include both real-time and playback data. Thus, within the data set acquired at any given time, there may be a mixture of forward and reverse data with overlap at the beginning and end of a data pass (when the same data may be recorded on tape and transmitted in real time) and data gaps where data is lost. In addition, errors may be injected during space or ground transmission. Level zero processing removes all of these artifacts by detecting and correcting errors (within limits), noting data quality, reversing playback, deleting overlap areas, time ordering the data, providing time smoothing where necessary, and adding fill data for missing areas. These corrections are needed because of the characteristics of the spacecraft and ground data systems and the operational modes, which have no relationship to the instrument or the observations of interest. Thus, it is desirable to insulate the user from these characteristics, and since they are independent of the data source, a centralized multi-spacecraft facility can provide a cost-effective means of providing the needed corrections.

QUALITY AND ACCOUNTING

Finally, it is important for users, network managers, and system engineers to understand the performance of the overall data system. A data capture facility receives data in a variety of formats for numerous users, and it can provide a single-point source for performing a number of useful functions, such as fault isolation, performance trend analysis, data quality evaluation, and data accountability. This type of information is invaluable for maintaining effective and efficient network and system operations and for understanding the useability of the data delivered from the satellite system.

TYPES OF DATA FORMATS

There are two principle format types for satellite data: TDM and packet. TDM telemetry streams are generated by the periodic sampling of data from different instruments; instrument data words are multiplexed into minor frames, which are then grouped into major frames. The sampling sequence or frequency of one or more instruments may vary with the operating mode, so the demultiplexing system must have knowledge of particular operating modes and onboard multiplexing strategies before a TDM telemetry stream can be separated into groups of instrument data files. Figure 1 (2) shows the construction of a typical TDM major frame. The data system associated with the UARS spacecraft, scheduled for launch in 1989, utilizes a TDM format.

Packet data systems group data from different instruments individually. A data packet consists of a header with synchronization and identification information followed by data from the onboard source. All of the information needed to handle the data is included in the packet header; therefore, knowledge of the operating mode of the source instrument is not needed. Since each packet’s length is included in its header, the length may vary from instrument to instrument or even between operating modes without impacting the data handling system. For transmission to the ground, packets are broken into fixed-length

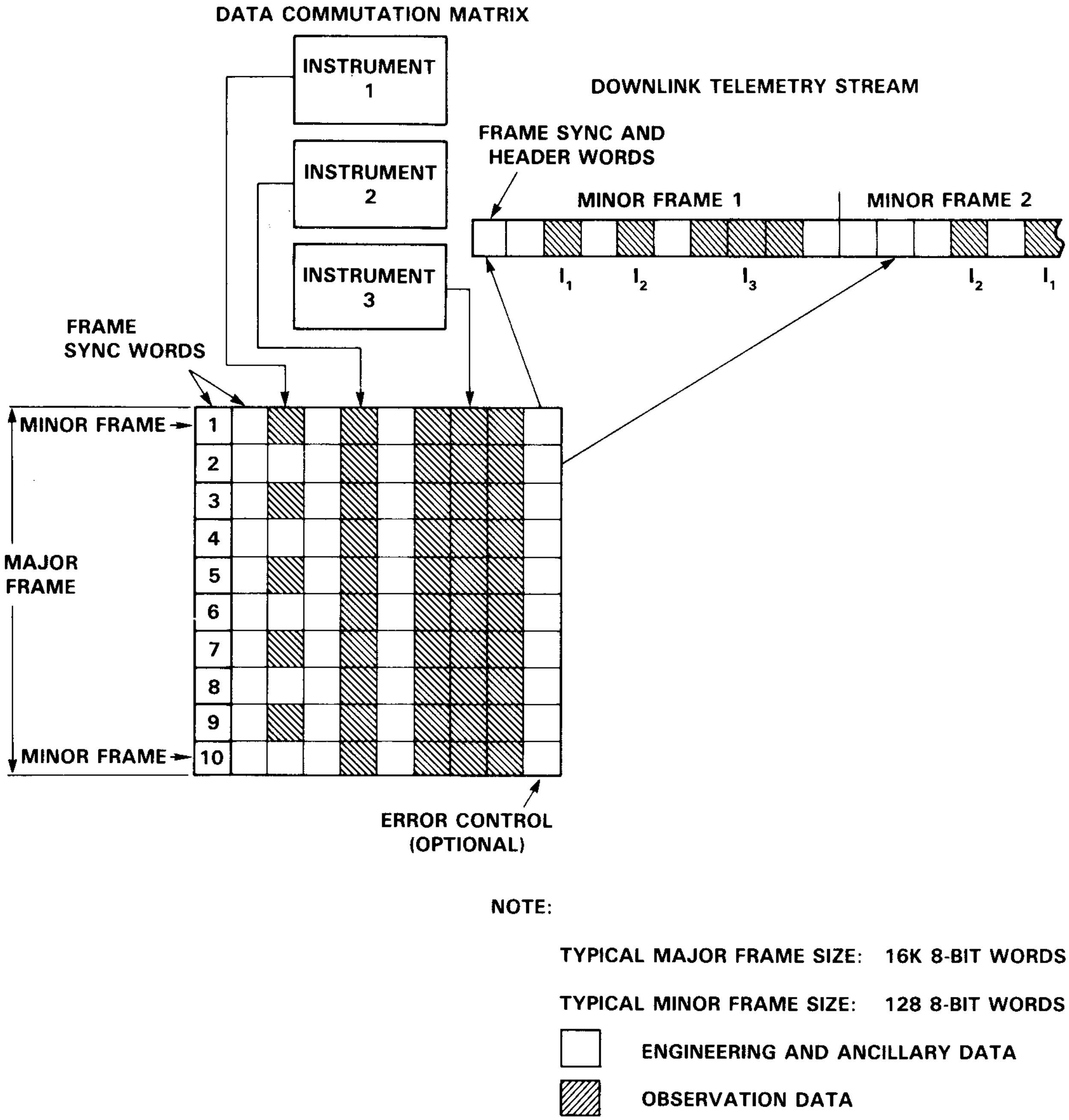

Figure 1. TDM Telemetry Data

transfer frames; this makes efficient use of the space-ground link, and it is a relatively easy task to reconstruct the original packets. Since all of the information needed to process a packet is located in its header, packet data systems are particularly amenable to automated operations and have very limited susceptibility to last minute changes in instrument design or format details. Figure 2 (Ibid) shows the relationships between instruments and data packets and between packets and transfer frames. Note that there are two different ways that spacecraft subsystem engineering data can be transmitted to the ground: as separate engineering packets, or time-division multiplexed into the transfer frame. In the example shown in Figure 2, several packets are inserted into the transfer frame; however, in general

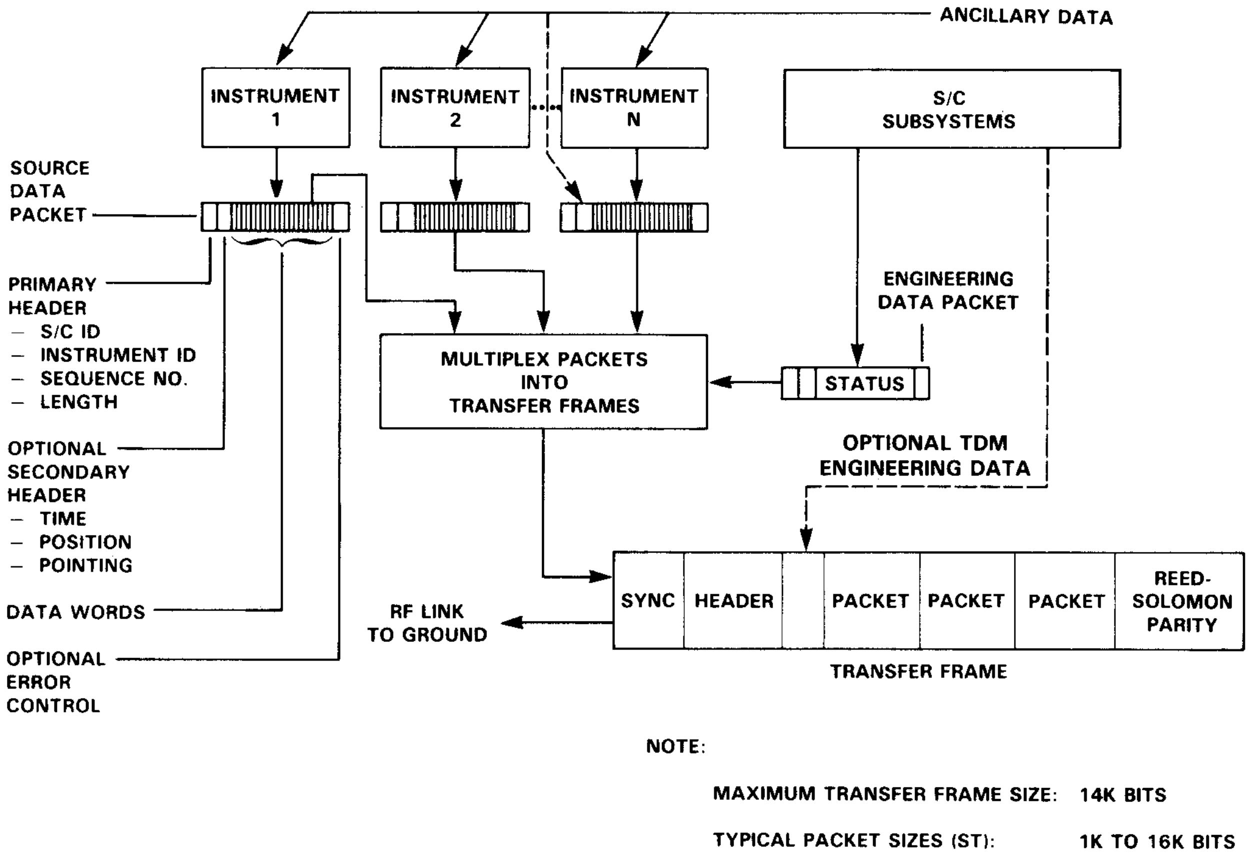

Figure 2. Packet Telemetry System

a partial packet, an entire packet, or many packets may be found in a frame depending upon the length of the particular packet. The transfer frame shown in this example (Figure 2) utilizes Reed-Solomon parity coding. This is consistent with international recommendations (3) for packet/transfer frame encoding. The GRO spacecraft, scheduled for launch in 1989, formats data in packets.

Both TDM and packet data formats impose some similar processing requirements on data capture systems; however, they each have unique requirements. Table 2 lists the functions for each format.

DEVELOPMENT OF GENERIC FACILITIES

It was recognized in the early 1980’s that available and emerging technology could support the development of a generic data capture capability, and that such a capability could provide significant cost savings by reducing the need to design, implement, test, and operate dedicated facilities. Since the data handling requirements are significantly different from TDM and packet data formats, it was decided to implement the generic capability as two separate systems. Each system’s capabilities were to be based upon the known requirements of upcoming missions, but each system would be capable of supporting

Table 2
Level Zero Processing Functions

Common Functions	• NASCOM Block Synchronization • NASCOM Block Error Detection • Minor Frame Synchronization • Data Recording • Playback Data Reversal • Time Ordering • Redundant Data Deletion • Quick-Look Data Delivery • Quality Determination • Accounting • Data Delivery
TDM-Unique Functions	• Time Correction • Time Smoothing • Minor Frame Time Tagging • Spacecraft Clock Correction • Minor Frame Counter Correction • Major Frame Reconstruction • Decommutation
Packet-Unique Functions	• Frame Error Detection • Packet Reassembly • Fill Packet Discard • Data Set Assembly

additional, new missions as long as those missions used compatible data formats. The system for supporting TDM telemetry streams, called the Generic Time Division Multiplex (GTDM) system, will support the UARS mission as well as current TDM missions. The Packet Processor (Pacor) will support the GRO mission as its first user. Both systems build upon a history of telemetry processing experience.

The GTDM system is based upon an earlier general purpose front-end system called the Telemetry Online Processing System (TELOPS). The TELOPS was developed in the early 1970's, and it has provided certain synchronization, error detection, and quality reporting functions for a variety of spacecraft. As the equipment has aged, plans for replacing it became necessary and the GTDM concept was born. A block diagram of the GTDM system is shown in Figure 3. At present, considerable analysis of the software is underway to determine which portion of the code developed for TELOPS can be reused. The desire

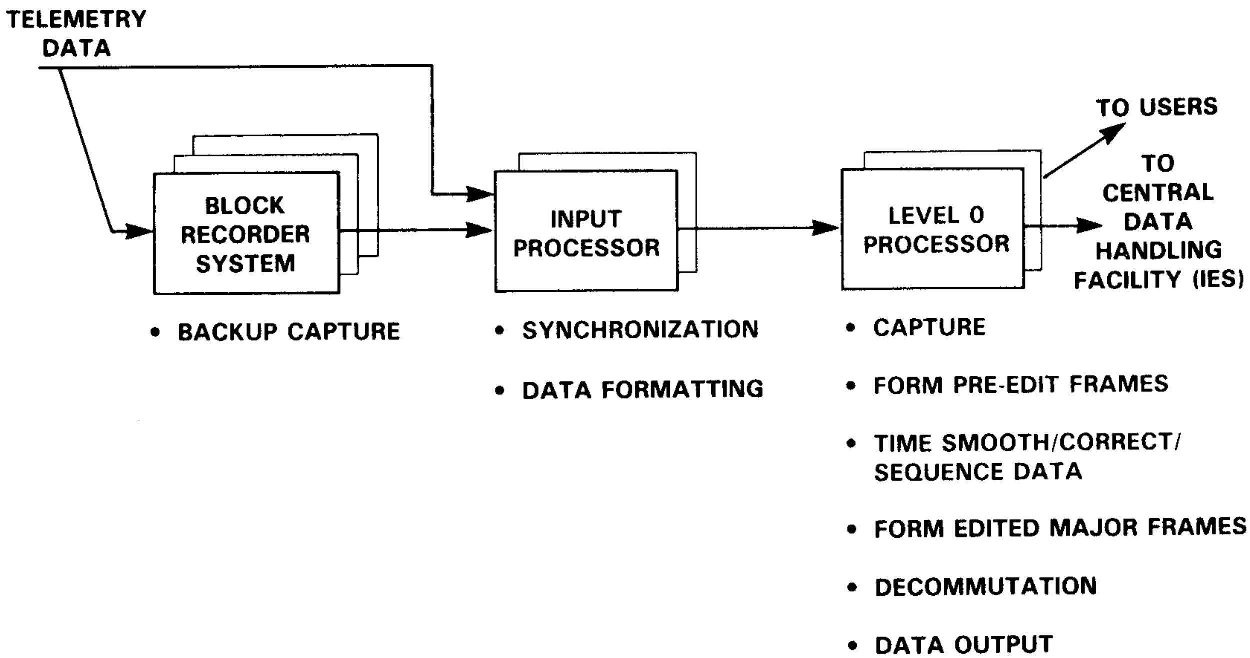

Figure 3. Generic TDM Data Capture Facility

to save implementation costs by reusing software will require that the system run two operating systems (one for the older software which ran under a specially modified operating system and one for the newly-developed software). It is anticipated that much of this software will be applicable to any new mission using TDM formats; however, certain special routines for TDM-unique functions (e.g., decommutation) will probably have to be written on a mission-by-mission basis.

The Pacor system is based upon experiences gained during the development of a test system put together as a technology demonstration and the implementation of the Space Telescope Data Capture Facility. The Space Telescope utilizes an early version of the packet format, and considerable portions of the code developed for this system (and the technology demonstration) have been applied directly to the Pacor. A block diagram of the Pacor is shown in Figure 4. The current system supports two types of packets: the special GRO format, and version 1 of the Consultative Committee for Space Data System's (CCSDS) packet telemetry format (4). The GRO format is somewhat different from the CCSDS packet because the GRO design was frozen before the CCSDS guidelines had been completed. It is anticipated that the Pacor system will be capable of supporting any future spacecraft with packetized data formats, since the packet concept allows the level zero processing system to handle data independently of instrument or spacecraft data system characteristics. The software development for the Pacor is nearly complete; in fact, work has been initiated to implement certain data handling functions in the Special Hardware Subsystem using Very Large Scale Integration (VLSI) circuitry (5). The VLSI has the potential for increasing the overall throughput capability of the system by providing

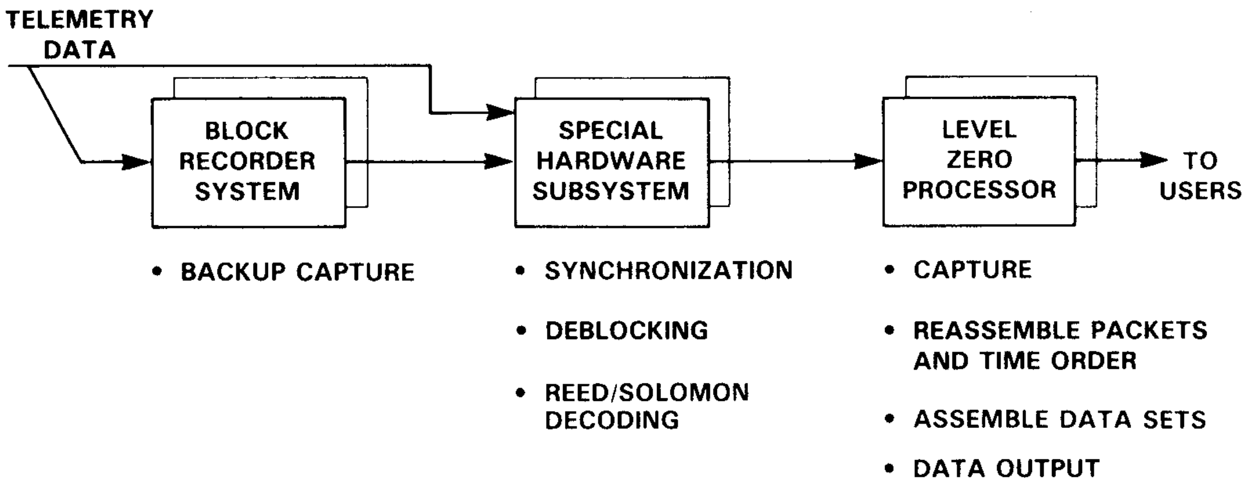

Figure 4. Packet Processor

some processing functions independent of the mainframe computer, and it therefore provides one possible growth path for higher performance.

CONCLUSION

A centralized data capture facility can provide a number of valuable services to users of spacecraft telemetry data including isolation from data acquisition problems, level zero processing, data protection, data quality monitoring, and data accounting. By careful design, it is possible to develop a generic capability that will support multiple spacecraft with minimal redesign, and one that is capable of growth as required. The Generic Data Capture Facility at the Goddard Space Flight Center is being constructed to support current and planned spacecraft in a manner that is efficient in operations, that can accommodate the fundamentally different data formats, and that has the potential to grow to accommodate increased requirements.

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