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SPACE DATA HANDLING AT GODDARD SPACE FLIGHT CENTER

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INTRODUCTION

The following is a brief, simplified, description of scientific space data handling at GSFC. This represents a system that has evolved over the past seven or more years out of an ever-growing set of operational requirements generated by the various and numerous space projects supported by the GSFC data systems facility. It should be kept in mind that this system under discussion is only one data system in a typical GSFC space project. Other systems are: the quick-look data system, the spacecraft command system, and the tracking data system. For simplicity, these systems are not included in the description below, and only the handling of the data that is recorded at the tracking station (which constitutes the largest portion of the total data volume) is described.

THE EXPERIMENTER'S ROLE IN DATA HANDLING

Simply stated, the experimenter is the key individual in the data handling and processing at GSFC. As shown in Figure 1, he stands at a crossroads in the data handling system. He originates the data requirements, receives the processed data, and then finally analyzes the processed data in the final phases of his experiment.

The "experimenter" shown in Figure 1 represents three different types of "data customers" for GSFC. These three types are: in-house experimenters, out-of-house experimenters, and sub-system engineers. The in-house experimenters are GSFC experimenters, the out-of-house experimenters are experimenters from other NASA Centers, universities, and all other scientific organizations outside of GSFC. The sub-system engineers are the spacecraft designers and builders who are responsible for the operation of the spacecraft, and in particular for the operation of the various sub-systems on the spacecraft. The larger portion of all data handling is performed for the first two experimenter types, but it should be noted that the third type, the sub-system engineer, has an appreciable data requirement and one that is growing as various satellites are becoming more complex in their operation (e.g., the Orbiting Astronomical Observatory).

PRE-LAUNCH DATA OPERATIONS

In a ground-based laboratory, an experimenter may set up an experiment, gather some data, analyze it, and then make some changes in his experimental set-up or in his data-gathering system before taking more data. The experimenter in Figure 1 does not normally have this freedom of action, and so the effectiveness of his pre-launch planning may well decide the success or failure of his entire space-borne experiment. The pre-launch data planning activities shown in the dashed boxes in Figure 1 are oversimplified, and in actual practice have a number of self-feedback loops, and inter-feedback loops in addition to the simple sequential arrangement shown.

The experiment design involves not only the actual sensor and transducer design but also associated signal conditioners, such as counters, logarithmic amplifiers, threshold detectors, to name only a few, which perform transformations on the data usually at a point before sampling, multiplexing, and modulation.

The sampling and modulation planning has an input from the experimenter, but here the experimenter must fit his requirements in with those of other experimenters on the same spacecraft. (There may be from 10 to 50 experimenters on a spacecraft.) The final sampling rate that the individual experimenter obtains is determined by the super-commutation and/or subcommutation imposed on his experiment by the time-division-multiplex telemetry format. There is usually one form of modulation used in a spacecraft, and this is typically PCM (Pulse Code Modulation) or PFM (Pulse Frequency Modulation). In some instances, special telemetry modulation may be added to accommodate certain experiments that cannot be handled by PCM or PFM, but this is more the exception than the rule.

In the phase of spacecraft design and final testing, there are often changes made in the data system parameters or hardware for the individual experimenter which are occasioned by a number of design and operating conditions, not least of which is the interference between experiment packages on the spacecraft.

Before and during the testing phase of pre-launch activity, the data-processing plan is put together. This plan covers in fine detail the operations of station coverage, recording of received data, shipment of data back to GSFC, tape evaluation, analog-to-digital conversion, quality control, time conversion, decommutation, attitude computation, orbit and attitude merge, shipment of tapes to experimenters, and storage of master data tapes. These operations are explained below, and are listed here to indicate the magnitude and complexity of this data processing plan. This plan ties into other plans for station coverage, quick-look, and spacecraft command operations for the life of the satellite (1 year, typically).

ACQUISITION AND PROCESSING OF DATA

Upon launch and injection, we have an orbiting spacecraft transmitting data to the ground-based receiving stations through the intervening propagation medium which we can generalize as the space channel. This channel has many non-constant signal-degrading features (such as auroral effects in the use of polar orbits) which may seriously affect the usefulness of the received data. The receiving stations constitute STADAN (Satellite Tracking And Data Acquisition Network), a world-wide network of over 15 stations that receive data transmitted from orbiting spacecraft, tape-record the data in analog form and ship the recorded tapes to GSFC.

Upon reception at GSFC, the raw analog magnetic tapes are put through some preliminary tape evaluation checks and then converted into computer-format raw digital magnetic tapes with data and ground time (inserted by the receiving station) appearing in serial form.

These raw digital tapes are then used as input to a quality-control and time-conversion computer program. In this computer operation, various data format characteristics are checked, such as record lengths, data dropouts, illegal tape characters, file marks, identification fields, and consistent time advance. These checks are necessitated by the finite probability of errors being introduced by the space channel, the receiving equipment, the recording equipment and the preceding analog-to-digital conversion equipment. The results of these checks are made available in a summary printout of the number and kinds of errors in given time intervals. On some satellites, it is required to correlate the spacecraft clock readout with the corresponding ground time inserted at the receiving station, and this operation is performed at this point in the processing. The output of this quality-control and time conversion program is a master digital magnetic tape with all format inconsistencies either corrected or suitably flagged, and time appearing in the desired format. This tape is saved for future reference or rerunning.

The output of the quality-control and time conversion program is used as input to the decommutation program wherein the time-multiplexed data is separated into individual experiment outputs, with each experiment written on a separate output tape along with periodic time words. An individual experiment output magnetic tape may also include various spacecraft performance data that is pertinent to the particular experiment.

One of the outputs of the decommutation program is the raw spacecraft attitude data, and this is used as input to an attitude computation and orbit merge program. This program first uses orbital information* from an orbit tape in conjunction with the raw attitude data to compute the attitude of the spacecraft as a function of time. The program then merges the computed attitude parameters with the orbital parameters and writes this combined output on one magnetic tape, the attitude/orbit tape.

The experimenter is now presented with two types of tapes: his experiment data tape, and a combined attitude/orbit tape. With this tape reception, the experimenter completes a loop, as shown in Figure 1, which may represent years of time—from initial data planning to final reception of processing data.

FINAL ANALYSIS OF DATA

At this point, the experimenter is free to further process and analyze his data as he sees fit. But his final data operations can be summarized as shown in Figure 1. In the typical case, the experimenter uses the experiment tape and the attitude/orbit tape as input to a pre-analysis program where the primary functions are: selection of data from interesting portions of interesting orbits, removal of redundant data, and scaling and unit conversion of data. The output of this edit and scale program is normally a raw data printout which is used by the experimenter to modify the program for iterative runs.

After several runs through the edit and scale program, the experimenter uses the reduced, selected raw data as input to one or more final analysis programs which provide either printouts or plots of the final data for use in preparation of a report or paper which discloses the results of the experiment.

RATES AND VOLUME OF DATA

No description of this data system is complete without some mention of the rates and volume of data it has to handle.

Data rates in satellite telemetry have been going up, particularly with the shift to larger satellites with PCM telemetry systems. If we include PFM, which has normally slower data rates than PCM, and think of equivalent bit

*The orbital information includes various orbital parameters such as a position vector and a velocity vector as a function of time.

rates for the PFM frequency pulse rates, we can say that the data system shown in Figure 1 has to handle, simultaneously, different bit rates ranging, order-of-magnitudewise, from 10 bits/sec to 10^5 bits/sec.

The GSFC Data Systems Division has made some estimates and projections of the data volume imposed on the system in Figure 1, and these numbers are presented in Table 1 below. (A data point corresponds, on the average, to 8 bits.)

TABLE 1

ESTIMATED DATA VOLUME PER DAY	
CALENDAR YEAR	DATA POINTS PER DAY
1961	0.85×10^6
1962	3.2×10^6
1963	5.8×10^6
1964	7.0×10^6
1965	34×10^6
1966	110×10^6
1967	205×10^6

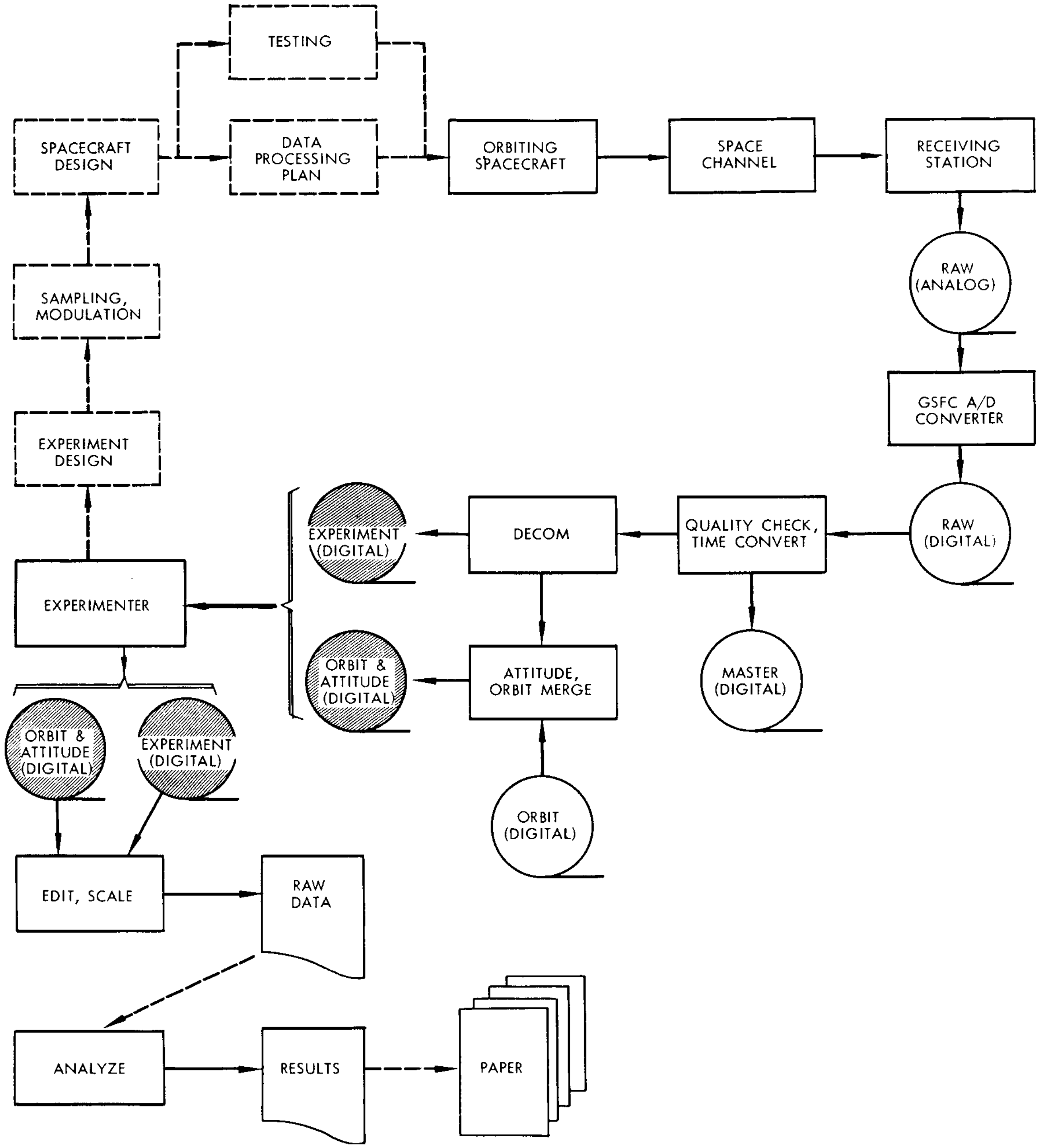

Figure 1. GSFC Space Data Handling