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STUDY AND ANALYSIS OF TELEMETRY SYSTEMS FOR THE SATURN VEHICLE

By

Marvin A. Griffin
Project Co-Director

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FINAL REPORT

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INTRODUCTION

The work accomplished under this contract and extensions has consisted of a series of investigations and analyses of Telemetry Systems used on the Saturn Vehicle.

During the performance of this contract eleven interim technical reports consisting of about 1,400 pages have been published. These reports fully document the work which has been accomplished.

This report consists of a brief summary of each of the eleven interim technical reports.

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Technical Report Number 10

TITLE: An Algorithm for Determining Program Feasibility of a Multi-Mode PAM Commutator Telemetry System

DATE: August, 1965

SUMMARY:

This is the tenth report in a series of technical reports concerned with the Telemetry Systems to be used on the Saturn Vehicle. It is concerned with the design of an appropriate algorithm for evaluating strapping arrangement programs for an All Purpose PAM Multi-Mode Commutation System.

Both manual and digital computer methods for programming commutators to the gates of the master control unit of an M Channel Multi-Mode Commutator System are included. Additionally, the algorithm has been used to determine all feasible programs for a 30-Channel Multi-Mode Commutator System and the results are summarized as an Appendix to the report.

Technical Report Number 11

TITLE: Analysis of the Linearity Characteristics, Tape Recorders and Compensation Effects in the FM/FM Telemetry System

DATE: March, 1966

SUMMARY:

This report describes a set of exploratory experiments performed on the FM/FM Telemetry System. These experiments were performed to investigate:

1. System linearity characteristics for two major sub-systems; i.e., the package sub-system and the receiving and data reduction sub-system.
2. The effects of tape recorders as a system component.
3. The effects of tape speed compensation as related to system noise.

In general, the purpose of the linearity experiments was to determine if any non-linear effects existed within the system. Overall system tests indicated an affirmative answer. The degree of non-linearity was determined and a mathematical model which describes this effect was formulated. This experiment was performed prior to that presented in Technical Report Number 9 and served as a foundation for the design of that experiment.

The experiments related to tape recorder effects resulted in the development of a methodology for isolating the errors associated with individual components of the system. This methodology is presented in detail and the isolated errors within the experimental system summarized.

A methodology for determining the error assignable to the instability of the system was also developed. This methodology is presented and the portion of instability error associated with the

various system components summarized.

Findings on the advantages offered by tape speed compensation have also been summarized. A possible explanation for the large interaction variance documented in Technical Report Number 2 is discussed as is the large contribution of the analog tape recorders to total system noise.

Technical Report Number 13

TITLE: Statistical Quality Control Applied to a Telemetry System Acceptance Procedure

DATE: June. 1966

SUMMARY:

This is the thirteenth of a series of technical reports concerned with the Telemetry Systems on the Saturn vehicle.

The purpose of this report is to develop a methodology for implementing statistical control charts as a basis for telemetry package acceptance procedures. The methodology is developed for both the control chart for mean values and for the control chart for standard deviations.

A total expected cost model which relates alpha and beta errors as well as the sample size is developed. This model is used to establish optimum upper and lower control limits for the chart for mean values. Control limits for the chart for standard deviations are then established based on this model.

An experiment that was designed and conducted for the purpose of testing the feasibility of the optimum control limits is reported. Results of this experiment confirm the reasonableness of the assumptions made in the cost model. Subcarrier oscillators in the experimental telemetry package that were intentionally maladjusted are detected by the control charts.

Estimates of the accuracy and precision of the telemetry package are obtained and ninety-nine per cent confidence limits are established for these limits.

Standards for future control chart analysis are established for both charts These standards may be used for future package check out procedures.

Technical Report Number 14

TITLE: A Model for the Determination of Optimum Sampling Rates

DATE: June, 1966

SUMMARY:

This is the fourteenth of a series of technical reports concerned with the telemetry systems on the Saturn Vehicle.

The purpose of this report is to formulate a cost model which may be used for the determination of optimum sampling rates for the Saturn telemetry system.

A total expected cost model is developed which includes equipment costs. data reduction costs, and the costs associated with inaccuracy or error. Each element of cost is expressed as a function of sampling rate. The method of least squares regression analysis is used to estimate the various functional relationships from known information.

The assumption underlying the derivation of the error sampling rate relationship is investigated. Power spectral densities from samples of actual telemetry measurements are calculated and compared with an assumed power spectral density.

An example is presented to illustrate usage of the model. Parameters from present systems are used to estimate the cost for telemetering equipment and for data reduction time as a function of sampling rate. A "reasonable" function is estimated for the cost associated with error as a function of sampling rate. An optimum sampling rate is obtained using these parameters.

Technical Report Number 15

TITLE: A Statistical Investigation of the Effects Contributed by Tape Recorders and by WOW and Flutter of Magnectic Tape on the Accuracy of a Telemetry System

DATE: July, 1966

SUMMARY:

The purpose of this report is to describe an experiment in which the effects contributed by analog tape recorders were investigated. Also, the noise contributed by the wow and flutter effect of magnetic tape was studied in relation to the accuracy of a telemetry system.

Since the data collected for this experiment did not conform to a normal distribution, a non-parametric test was employed in testing for significant difference between the tape tracks and tape recorders, in regard to their noise indexes.

The ratio of the standard deviation over the range was used as a relative measure of the error or noise effect in the system and provided the best information for ranking tape recorders and tape tracks in terms of system noise.

A secondary experiment in noise analysis was performed in order to corroborate the results obtained in the original experiment.

Technical Report Number 16

TITLE: Experimental Analysis to Determine the Number of Required Calibration Levels and Samples at Each Level for the FM/FM Telemetry System

DATE: August, 1966

SUMMARY:

This is the sixteenth of a series of technical reports concernod with the Telemetry Systems on the Saturn Vehicle.

As an extension of Technical Report Number 9, a methodology is developed to determine the mathematical model which relates input to output of a telemetry system. Since it is infeasible to develop the model under the actual environmental conditions, a simulation model reflecting the linearity characteristics of the true system is employed. Three levels of random noise are recognized as existing in the system. These three levels are respectively considered for the second, third, and fourth degree coefficients of the simulated polynomial relation.

The regression analysis, with orthogonal polynomials technique, is used to find the curve providing the adequate fit. To determine the optimal calibration levels and sample size at each level, analysis of variance in conjunction with Duncan's Multiple Range Test is employed.

Under the simulated experimental conditions, two calibration steps with fifteen samples at each step is significantly better than other techniques.

Technical Report Number 17

TITLE: Statistical Estimation of Variation Parameters on Inflight Telemetry Systems

DATE: June, 1967

SUMMARY:

This is the seventeenth of a series of technical reports concerned with the telemetry systems on the Saturn Vehicle.

The purpose of this report is to develop a methodology for estimating variation parameters on inflight telemetry systems and to apply this methodology to data available for Flights SA7, SA8, SA9, and SA10 to establish variation estimates for these systems. These estimates are made using data obtained from inflight calibrations.

Noise and drift are the variation parameters considered. Confidence limits for estimates of these parameters are given.

Technical Report Number 18

TITLE: Some Statistical Tools and Techniques Useful in the Design and Analysis of Aerospace Telemetry Experiments

DATE: July, 1967

SUMMARY:

This is the eighteenth of a series of technical reports concerned with the Telemetry Systems on the Saturn Vehicle.

The purpose of this report is to present a collection of the various statistical tools and techniques which have proven to be useful in the design of telemetry experiments and the analysis of results.

The material in this report is presented in increasing order of complexity. The techniques presented cover a wide range from the basic statistical concepts, through the more advanced analysis techniques including regression analysis and analysis of variance.

The theoretical basis for each technique is outlined and exemplified by an appropriate example. In general, these examples have been taken from analyses performed on some phase of the telemetry system.

Technical Report Number 19

TITLE: A Statiscal Analysis of Dynamic Error in the FM/FM Telemetry System of the Saturn Space Vehicle

DATE: August, 1967

SUMMARY:

This is the nineteenth of a series of technical reports concerned with the telemetry systems of the Saturn Vehicle.

The purpose of this report is twofold: first to determine what factors significantly affect the accuracy of the FM/FM telemetry system; and secondly, to estimate the accuracy of the system for a dynamic input source. The total error of the telemetry system is analyzed and then it is broken down into its static and dynamic error components.

Technical Report Number 20

TITLE: A Computer Simulation Study of Failure Behavior of Components and Their Reliability

DATE: September, 1967

SUMMARY:

The purpose of this report is to develop a methodology to generate the failure frequency curve considering the effect of chance failure, the effect of wearout failure, and the combined effect of both on components. The effect of replacements before and after the failure of components have been studied. A methodology to determine system reliability is presented.

The simulation methodology presented in this thesis can be used to study the failure characteristics and reliability of any component provided that the theoretical or empirical distributions of failures are known.

Technical Report Number 21

TITLE: Analytical Reliability Models and Specifications

DATE: August, 1968

SUMMARY:

This report presents appropriate methods for applying the analytical principles of reliability to the design, test and specification of telemetry equipment. Statistical sampling techniques are derived for estimating MTBF and for placing confidence limits on MTBF. Two Fortran computer programs are included in the report. The first program computes the reliability of series and parallel circuits. The second program simulates random failure times based on the exponential distribution.

A rapid reliability estimating procedure is presented and used to estimate the reliability of a telemetry transmitter.