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A QUALITY CONTROL MONITORING SYSTEM FOR SATELLITE TELEMETRY DATA INFORMATION SYSTEMS

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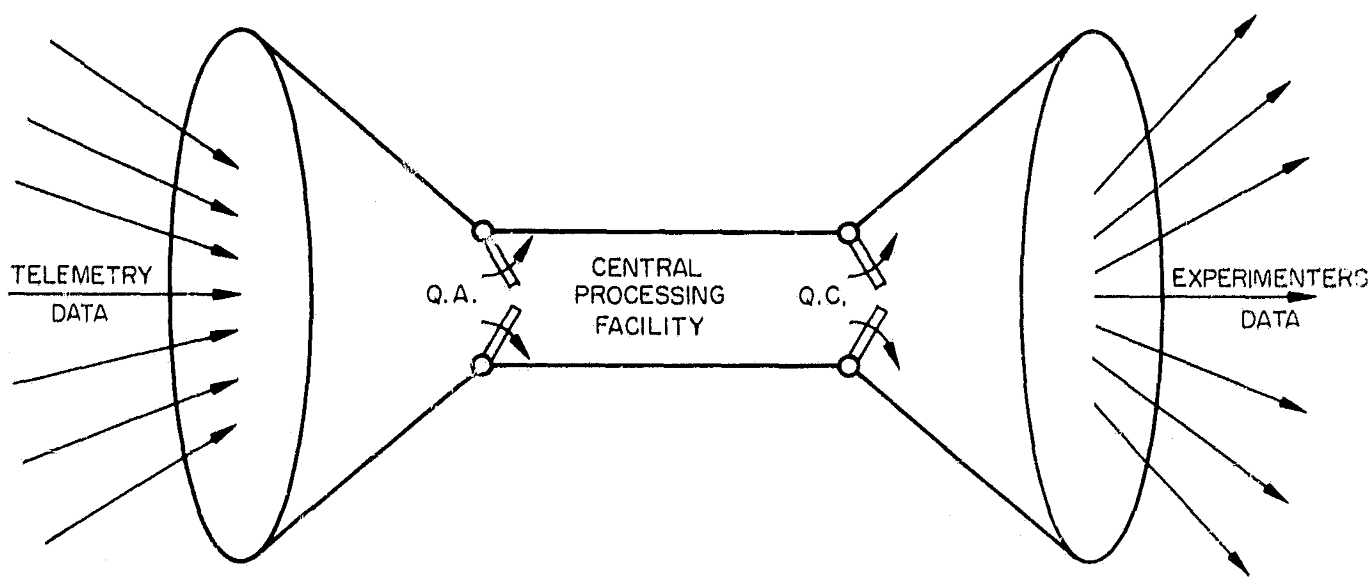

Frontispiece

CONTENTS

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ABSTRACT

A Quality Control Monitoring System for a Satellite Telemetry Data Information System is described which could provide the necessary in-depth monitoring, evaluation, and analysis capability for determining short and long term Information Systems performance characteristics.

Station environmental problems, seasonal changes, and signal-to-noise characteristics of recorded passes over time of day, time of year as a function of satellite range, data recovery, data quality, and received power could be observed with man-machine analysis in a short period of time. The station performance for a satellite recording could be viewed over any selectable range of time intervals. Time of day distribution analysis of processed data could be performed for many recorded passes to observe station-satellite environmental time-dependent problems.

Several dependent variables such as data quality and data recovery along with the STADAN stations, satellite range and signal strength, could be viewed simultaneously as a function of time over any selected month or year. This would permit analysis and correlation for determining absolute and relative short and long term station variations.

The Quality Control Monitoring System is currently under investigation using an existing R&D Data Control Monitoring Display System located in the IPD. If results prove promising then the IPD will have a quick-reaction type monitoring, evaluation, and man-machine analysis capability for a Satellite Telemetry Data Information System.

A QUALITY CONTROL MONITORING SYSTEM FOR SATELLITE TELEMETRY DATA INFORMATION SYSTEMS

I. INTRODUCTION

The Satellite Telemetry Data Information System, consisting of: (1) the spacecraft, (2) the telemetry medium, (3) the STADAN(s), (4) the Schedule Acquisition System, and (5) the Central Data Processing Facility, is a very complex and interactive system. Even though there exists one spacecraft per information system, there are as many as six data rate types modulating up to three R.F. carriers, tracked by fourteen STADAN stations, recording approximately 9000 analog tapes per month which are shipped to the Central Processing Facility (which in itself contains several data processing systems). The experimenter's data tapes are generally delivered 6 to 20 weeks after the data are recorded. Also, the STADAN and the Central Data Processing Facility services more than 30 scientific satellites and so far neither an absolute nor a relative Information Systems performance is fully available or understood, mainly due to the complexity of the required analyses.

The perturbations which affect the telemetry data en route and through to the Central Processing Facility are innumerable thereby making the actual relative and absolute performance evaluation and analysis of the Information System a difficult task.

The Information System's performance should be well understood and monitored to improve and optimize the present system and its operating procedures. A "reference" must be established to evaluate and analyze the Information Systems Performance both on a short term and a long term basis. This would provide systems designers, operational personnel, management, and experimenters with valuable information as to system behavior and characteristics, not only to improve existing systems but to provide information for specifying desirable performance characteristics of "future" systems.

The Information Processing Division (IPD) is the logical group within the Tracking and Data Systems Directorate of GSFC to evaluate and analyze the performance characteristics of the Information System. The Central Processing Facility is the focal point for all telemetry data outputs from the STADAN, contains the necessary hardware and software operational data processing systems, and has immediate access to various pertinent information to perform this evaluation.

"DB Management" is an expression which best indicates what needs to be explored along the Information System to account for each and every decibel (db) when and where possible. To properly perform this evaluation at the IPD, its own data processing facility must be well calibrated and in a state of statistical control. Work toward this end has been underway and will soon be completed (Reference 1). The IPD can then monitor and evaluate the other components of an Information System.

Work has been underway (Reference 2) in the IPD to develop the "tools" which can be used to perform the majority of quality assurance, quality control, evaluation, and analyses for the Central Processing Facility's input, internal processes, and its output. A Process Verification and Analysis System is expected to be operational by mid-1970 and the performance characteristics of the IPD facilities are presently being determined.

Work is also underway to define parameters which will provide common criteria for measuring and monitoring various performance measures within an Information System (Reference 3). A combined method for evaluating the Information System's performance based on predictions such as data coverage, probability of error, and RFI interference along with the actual measured performance parameters could refine the predicted and expected performance measures of present and future systems.

This report describes evaluation considerations of an Information System and the input requirements needed for proper evaluation of that system. Also, a Quality Control Monitoring System (QCMS) is described which will use an existing R&D Data Control Monitoring System (DCMS) display-computer complex. The QCMS could provide a quick-reaction type monitoring, evaluation, and man-machine analysis capability of the Information System for both short and long term trends. The basic DCMS/QCMS is expected to be operative by July 1, 1969.

II. INFORMATION SYSTEMS EVALUATION CONSIDERATIONS

Each satellite's information system's expected performance is predicted prior to launch. After launch, information should be made available for determining the actual performance and a reference established by which the Information System can be monitored and evaluated throughout the lifetime of the satellite. Figure 1 is a block diagram of a telemetry data Information System showing the five major components from the spacecraft to the experimenter. Figure 2 is a hypothetical plot of the five major classes of noise contributing to degradation of experimenter data recovery and data quality within the

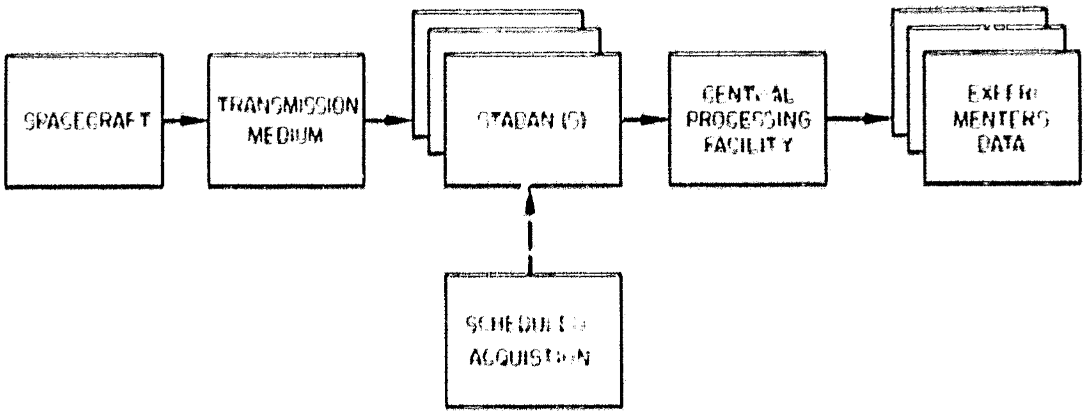


Figure 1—Major Components of a Telemetry Data Information System

Information System. These major classes of noise are those introduced by (1) the Spacecraft, (2) the Transmission Medium, (3) the Scheduled Acquisition, (4) the STADAN Stations, and (5) the Central Processing Facility. The degree to which each of these noise classes degrade the total performance of the Information System over a period of time should be well monitored and evaluated in order to optimize the system and improve the experimenters' data.

If the Central Processing Facility can be determined to be under a state of statistical control for each type of spacecraft telemetry data, then the output of each STADAN Station can be monitored and evaluated. To properly perform both an absolute and relative evaluation of each station, one needs to normalize the data quality indices by knowing the Central Processing Facilities performance characteristics, STADAN equipment and antenna types, satellite range and altitude, etc. Having done this, one is left with disturbances such as RFI, galactic noise, atmospheric variations, etc., which require a higher degree of correlation with the individual STADAN space environment as to their origin and disturbing properties.

Figure 3 indicates what the Central Processing Facility could determine by monitoring and analyzing each STADAN Station's performance. An absolute reference could be established to determine both short and long term station performance on an absolute and relative "db" basis.

Figure 4 represents several types of noise sources which affect the experimenters' data recovery and data quality. It is of extreme importance to categorize each noise source along with the amount, its rate of occurrence and its effect on data processing for each station and satellite. This would provide valuable information for use in optimizing the process through rescheduling or reconfiguring equipment.

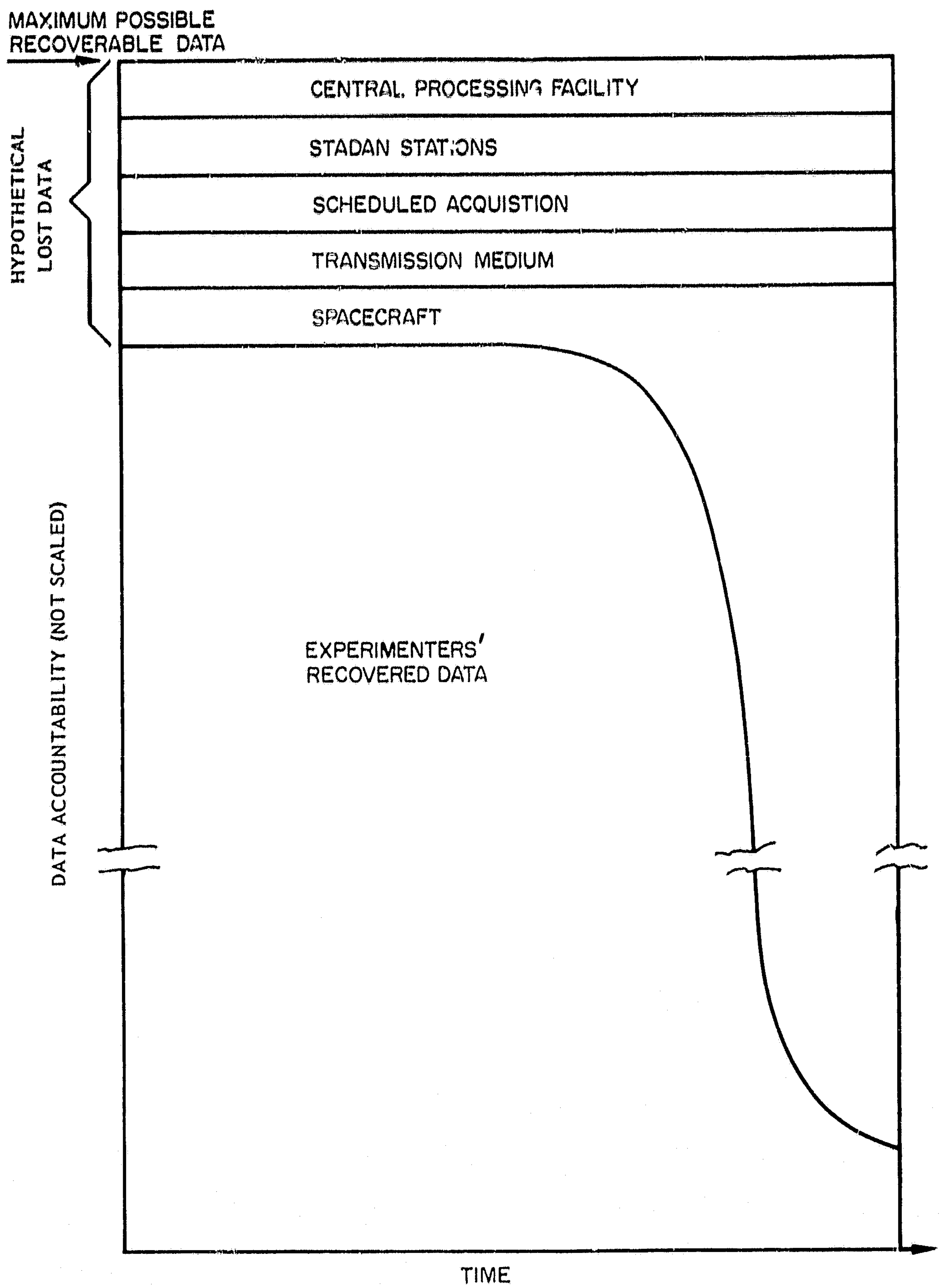


Figure 2–Hypothetical Degradation of Experimenters' Data Due to the Major Classes of Noise Sources

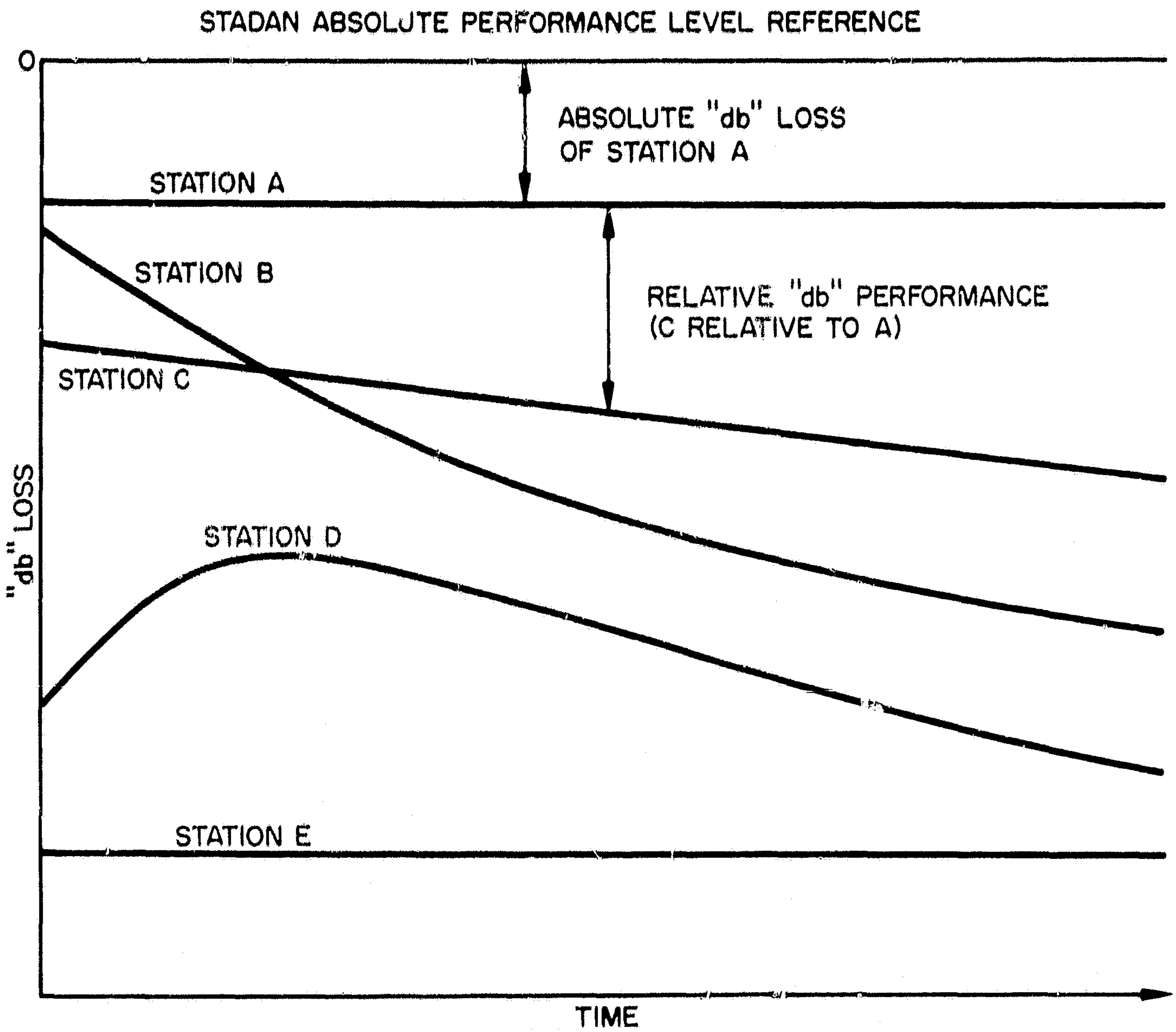


Figure 3–Hypothetical, Absolute, and Relative STADAN Performance Possibilities

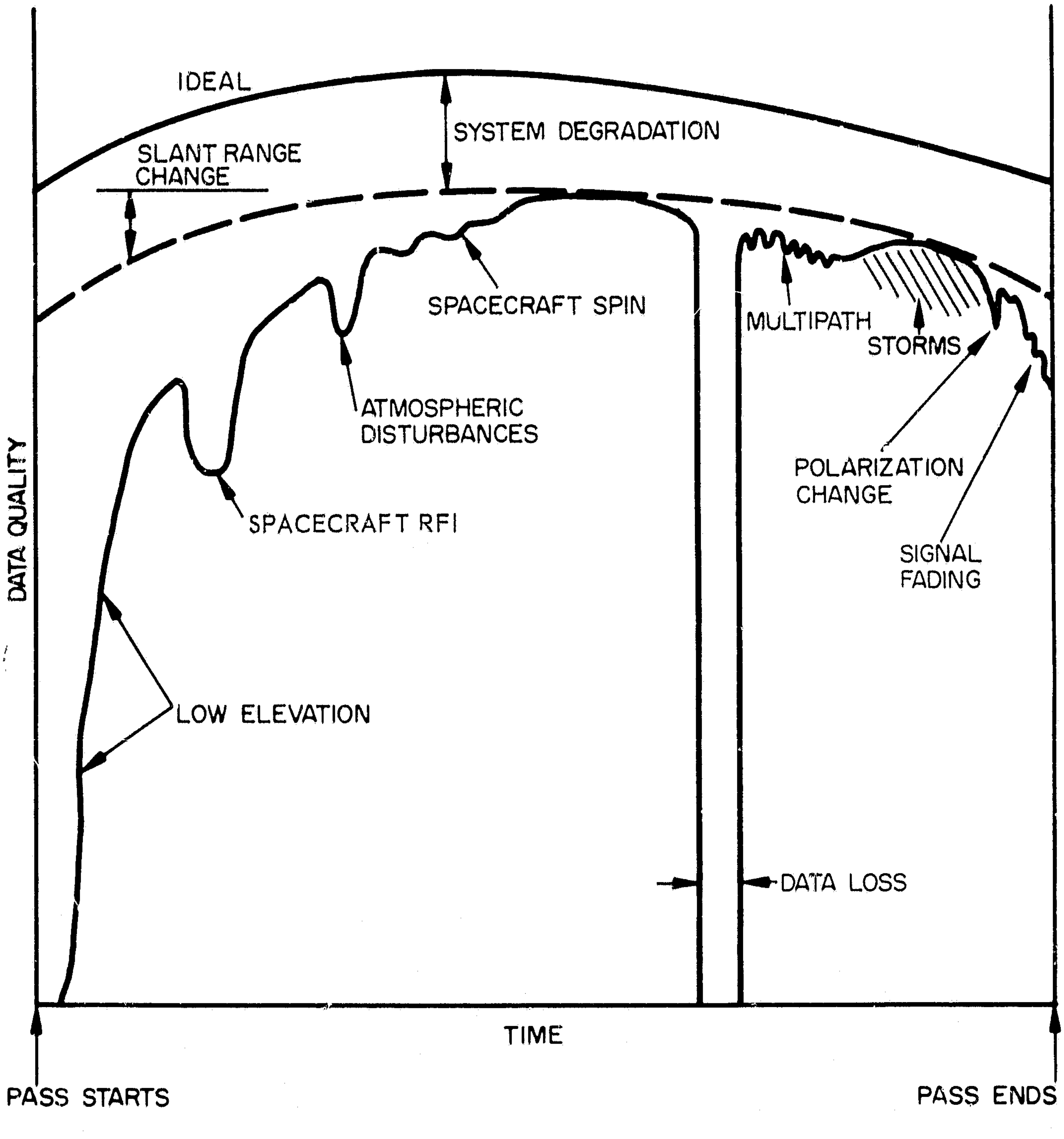


Figure 4—Several Types of Noise Sources which Affect Experimenters' Data During a Pass

III. PERFORMANCE EVALUATION AND ANALYSIS INPUT REQUIREMENTS

A perforr ıce evaluation and analysis of the Information System can be most effectively and efficiently performed at the IPD since all of the STADAN telemetry data is available as input to the IPD and the IPD contains the necessary hardware and software operational systems. Other required inputs such as station predicts, telemetry schedules, and pass summaries are also made available to the IPD. Predicted S/N, RFI, spacecraft altitude, slant range, etc. can be merged into the data processing operations.

A "reference" for the IPD of recorded data coverage and data quality can be provided by the STADAN adding a receiver-in-lock indicator and simulated data respectively on the analog tape.

The orbital information is used to predict the arrival and departure times for each scheduled pass. This information together with nominal transmitted data rates can be used to compute the predicted satellite contact data recovery interval (PDR). The station satellite contact data recovery (SDR) can be computed at the IPD by decoding the receiver-in-lock indicator and computing the maximum possible frames of data recorded on tape. The actual data recovery and its quality can be computed from the recovered frames (CDR) of data at the IPD and comparing to the SDR. Hence, the performance of ground link components of the Information System can be determined by examing the equations shown in Table I. The Information ground system performance (ISP), would be (EDR/DDR) $\cdot$ f (Pe_{EDR}) where EDR and DDR is the experimenters' useable and desired data recovery respectively and Pe_{EDR} is the data quality of the EDR. These equations are described in more detail in reference 3 and are tabulated in Table II. The computer recovery per orbit group (ODR) can be computed at the IPD by merging the CDR results of a collection of satellites passes (files) and eliminating any redundant and useable data.

Figure 5 shows the various inputs which could be used to perform a performance evaluation and analysis of the Information System. Shown is a Quality Control Monitoring System (QCMS) which could perform the required analysis and monitoring. The QCMS will be described in the next section.

Figure 6 is a detailed breakdown of the analog tapes (files) as they would be accounted for in the IPD. Table III contains the definitions and equations for the various classes of files.

Table IV contains the performance equations which would be used to compute measures of ground system performance for each data type by station.

Table I – Ground System's Data Recovery and Data Quality Performance Per Recorded Analog Pass (File)

Data Recovery Performance Per File	
Ground System	**Computation**
STADAN	S = SDR/PDR
IPD	I = CDR/SDR
STADAN & IPD Ground Link	L = CDR/PDR
Data Quality Performance Per File	
Ground System	**Computation**
IPD	FQI = I · f(CDR)*
STADAN & IPD Ground Link	LQI = L · f(CDR)*

$$^{*}f(CDR) = 1 - \frac{1}{(\log_{10} Pe_{CDR})^2}$$

Table V contains equations for computation of the ground system efficiency based on processed files by stallite and station.

IV. A QUALITY CONTROL MONITORING SYSTEM

A Quality Control Monitoring System (QCMS) could be used to monitor and compute the Information System's performance and data quality indices from the processed satellite passes and correlating this with other information such as equipment types, slant range, predicted results, etc.

The QCMS is being supported by a R&D task using the Code 563 Data Control Monitoring System (DCMS) for data display and manipulation using man-machine capabilities for on-line quick decisions.

Table II – Data Accountability of the Information System Per Orbit Data Grouping

$$\frac{\text{Data Useable (Experimenters)}}{\text{Data Desired}} = \frac{\text{Data Scheduled}}{\text{Data Desired}} \times \frac{\text{Data Recorded}}{\text{Data Scheduled}} \times \frac{\text{Data Processed}}{\text{Data Recorded}} \times \frac{\text{Data Useable (IPD)}}{\text{Data Processed}} \times \frac{\text{Data Useable (Experimenters)}}{\text{Data Useable (IPD)}}$$

(1) Information System Data Recovery Performance ISP(DR)

$$= \underbrace{\frac{PDR}{DDR}}_{\text{Scheduled Acquisition}} \times \underbrace{\frac{SDR}{PDR}}_{\text{STADAN Stations}} \times \underbrace{\frac{CDR}{SDR} \times \frac{ODR}{CDR}}_{\text{Central Data Processing Facility}} \times \underbrace{\frac{EDR}{ODR}}_{\text{Experimenter}}$$

$$ISP(DR) = \frac{EDR}{DDR} = \frac{\text{Data Useable (Experimenter)}}{\text{Data Desired by (Experimenter)}}$$

(2) Information System Data Quality Performance ISP(PQ) = Probability of error (EDR)

(3) Information System Quality Index Performance ISP(QI)

$$= \frac{EDR}{DDR} \cdot f_n\,(Pe_{EDR}) \quad ; \text{ where } f_n\,(Pe_{EDR}) = 1 - \frac{1}{(\log_{10} EDR)^2}$$

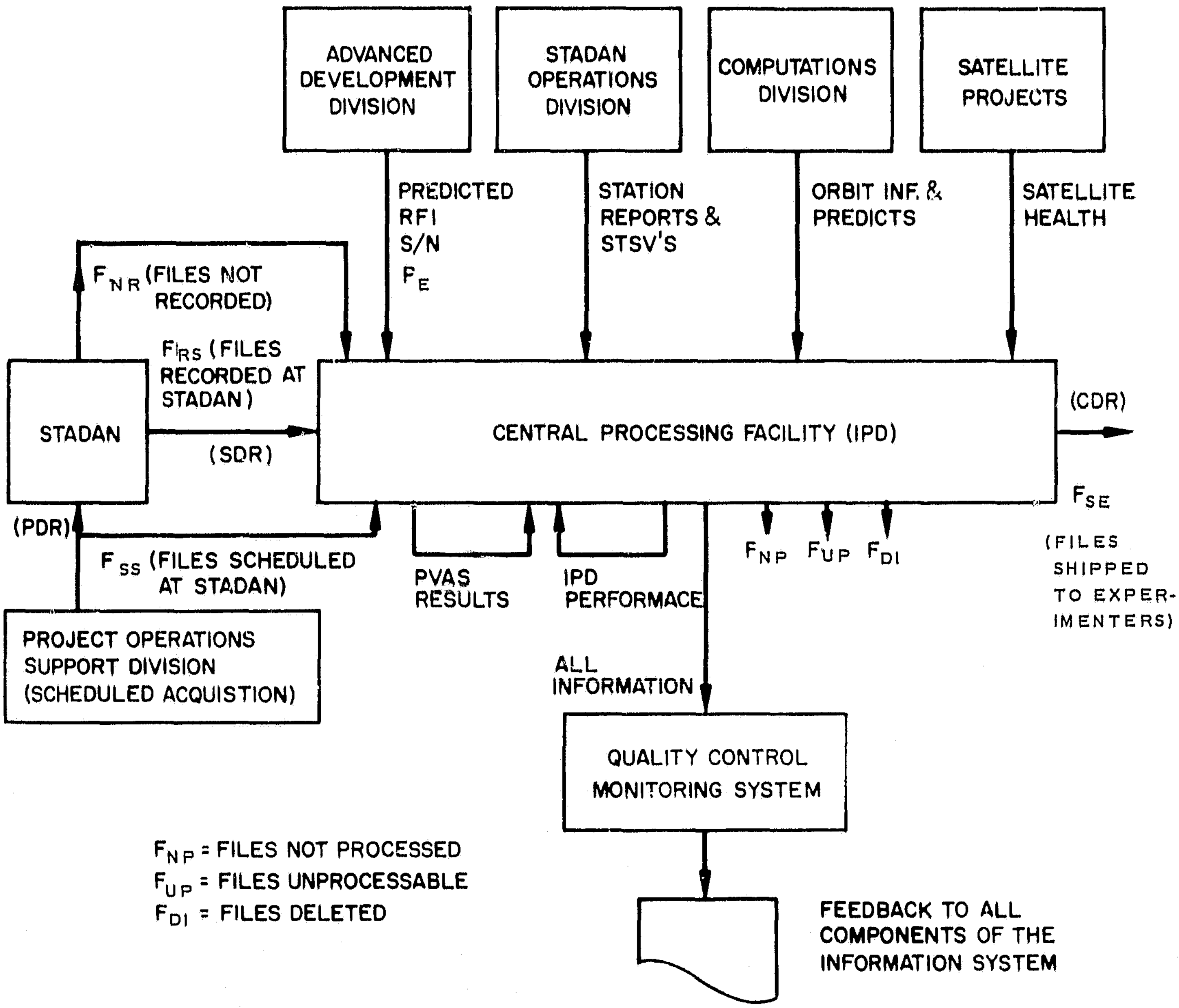


Figure 5–Proposed Information System Performance Evaluation and Analysis System

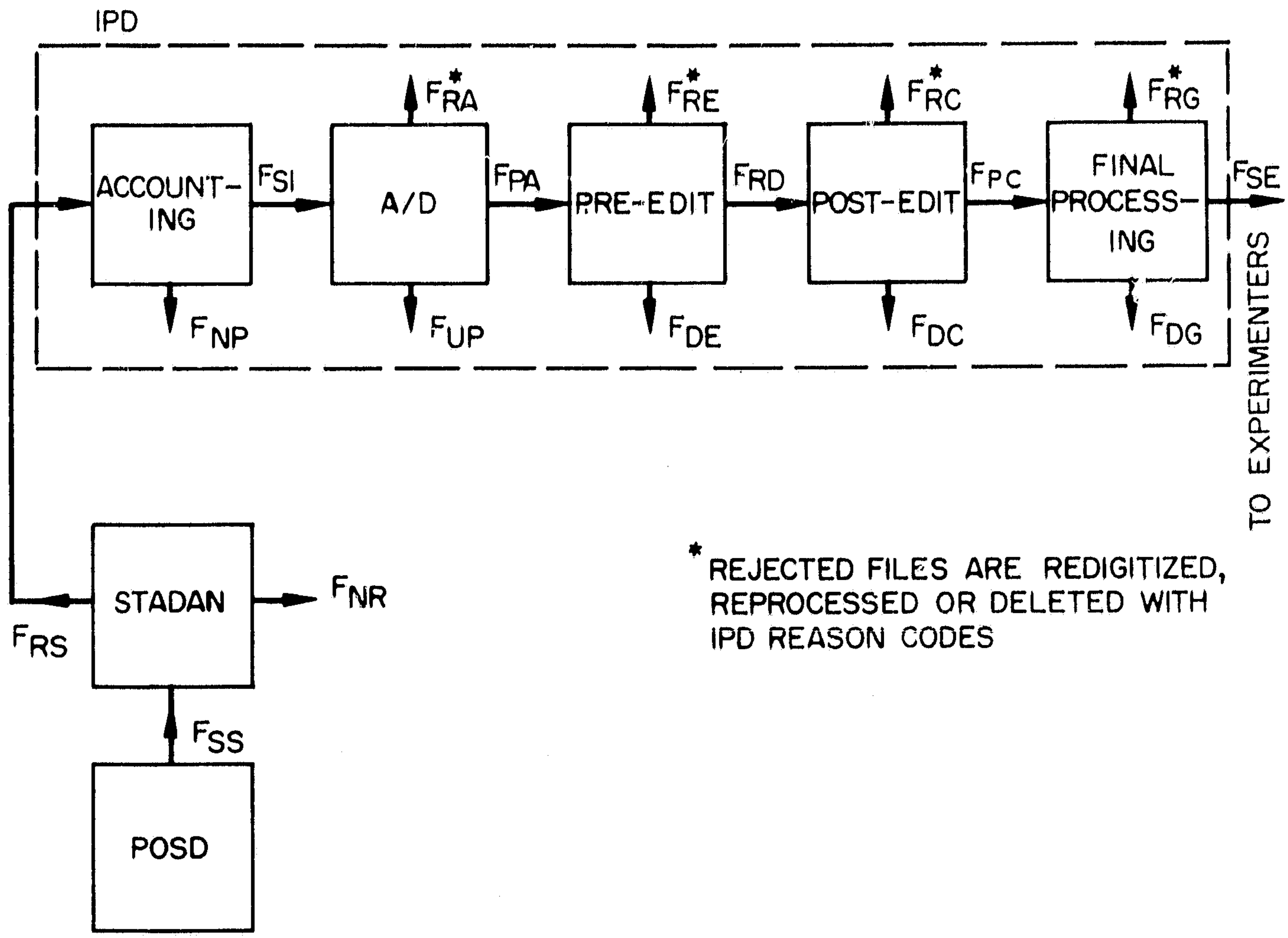


Figure 6–Flow of Analog Passes (Files) within the Ground System

Table III – Definitions and Equations of Various Files Within the Ground Information System

a - Definitions

File Type	Meaning
F	File or recorded pass on an analog tape
F_{SS}	Files scheduled for STADAN
F_{NR}	Files scheduled at STADAN but not recorded
F_{RS}	Files recorded at STADAN
F_{NP}	Files not processed at IPD by project request
F_{SI}	Files scheduled to be processed at IPD
F_{up}	Files unprocessable* at IPD due to Data (D), other (O), or Time (T)
F_{PA}	Files processed in A/D line
F_{DE}	Files deleted in pre-edit
F_{RD}	Files released to digital processing
F_{DC}	Files deleted in post edit processing
F_{PC}	Files processed through post edit
F_{DG}	Files deleted in orbit group merge
F_{SE}	Files shipped to experimenters
F_{cu}	Files culled
F_{RA}, F_{RE}, F_{RC}, F_{RG}	Files rejected (F_R) in various processing phases but would be redigitized, reprocessed, or deleted with reason codes in the analog (A), pre-edit (E), computer processing (C), and in the orbit group (G).

b - Equations

Ground System	Equation
POSD/STADAN	$F_{SS} = F_{RS} + F_{NR}$
IPD (Code 564)	$F_{RS} = F_{SI} + F_{NP}$
"	$F_{SI} = F_{PA} + F_{UP}$
"	$F_{PA} = F_{RD} + F_{DE}$
IPD (Code 565)	$F_{RD} = F_{PC} + F_{DC}$
"	$F_{PC} = F_{SE} + F_{DG}$
IPD (Code 564)	$F_{up} = F_{UD} + F_{UT} + F_{UO}$
IPD	$F_{DI} = F_{DE} + F_{DC} + F_{DG}$
IPD	$F_{cu} = F_{up} + F_{DI}$

*$F_{up} = F_{UD} + F_{UO} + F_{UT}$; called "DOT" unprocessable codes

Table IV – Ground System's Performance Per Satellite, Data Type and Station Compared to Schedule Files

Ground System and Meaning	Equation
STADAN, % files scheduled but not recorded	$\% F_{NR} = \frac{F_{SS} - F_{RS}}{F_{SS}} \times 100$
Satellite Project, % files recorded but not processed at IPD	$\% F_{NP} = \frac{F_{RS} - F_{SI}}{F_{RS}} \times 100$
STADAN & IPD, % files scheduled at IPD but unprocessable due to data, time, or other	$\% F_{up} = \frac{F_{SI} - F_{PA}}{F_{SI}} \times 100$
STADAN & IPD, % files culled at IPD due to unprocessable files and files below the processing criteria	$\% F_{cu} = \frac{F_{SE} - F_{SI}}{F_{SE}} \times 100$
Ground System's % Files Scheduled at STADAN but not shipped to experimenters (Loss Files = files not recorded or not processed or culled)	$\% F_{Loss} = \frac{F_{SS} - F_{SE}}{F_{SS}} \times 100$
% Files unprocessable due to: (a) Data	$\% F_{UD} = \frac{F_{UD}}{F_{SI}} \times 100$
(b) Time	$\% F_{UT} = \frac{F_{UT}}{F_{SI}} \times 100$
(c) Others	$\% F_{UO} = \frac{F_{UO}}{F_{SI}} \times 100$
% Files processed but deleted in IPD	$\% F_{DI} = \frac{F_{DI}}{F_{SI}} \times 100$

Table V – Ground System's Efficiency of Scheduled and Actual Files

Ground System	Equation
STADAN File Efficiency	$\mathcal{E}_S = \frac{F_{RS}}{F_{SS}} \times 100\%$
Project File Efficiency	$\mathcal{E}_P = \frac{F_{SI}}{F_{RS}} \times 100\%$
IPD File Efficiency	$\mathcal{E}_I = \frac{F_{SE}}{F_{SI}} \times 100\%$
Ground Link Efficiency	$\mathcal{E}_L = \frac{F_{SE}}{F_{SS}} \times 100\%$

Figure 7 shows the experimental QCMS which uses a CDC 3200 computer interfaced with the DCMS. The inputs to the QCMS could be punched cards or tape containing quality information (for each scheduled, recorded, or processed file) such as is shown in Table VI. A function key board or typewriter input can be used to select any satellite Information System parameters for analyses purposes. A hard copy output can be obtained by computer printout or processing an output plot type on a S.C. 4020 plotter.

Figures 8, 9 and 10 are examples of several QCMS data analysis and monitoring Information System plots which could be provided. Up to four dependent variables can be plotted and viewed simultaneously over any selected time period.

V. SUMMARY

A Quality Control Monitoring System, using an existing R&D Data Control Monitoring Display System, may provide the required monitoring, evaluation,

Table VI – Quality Information NOT Required

Items	Processed Files	Unprocessable Files	Not Processed Files	Deleted Files
1. Satellite I.D.				
2. Station I.D.				
3. Analog Tape No.				
4. File No.				
5. Data Type				
6. A/D Line No.			X	
7. Digital Tape No.		X	X	
8. Year Recorded				
9. Start Time				
10. Stop Time				
11. Data Recovery		X	X	
12. Data Quality		X	X	
13. Simulation Results		X	X	
14. Signal Strength				
15. SDR		X	X	
16. Predict(s) Az, El				
17. Predicted RFI			X	
18. Slant Range				
19. PVAS Results			X	
20. STADAN Eq. Parameters			X	
21. Satellite Housekeeping				

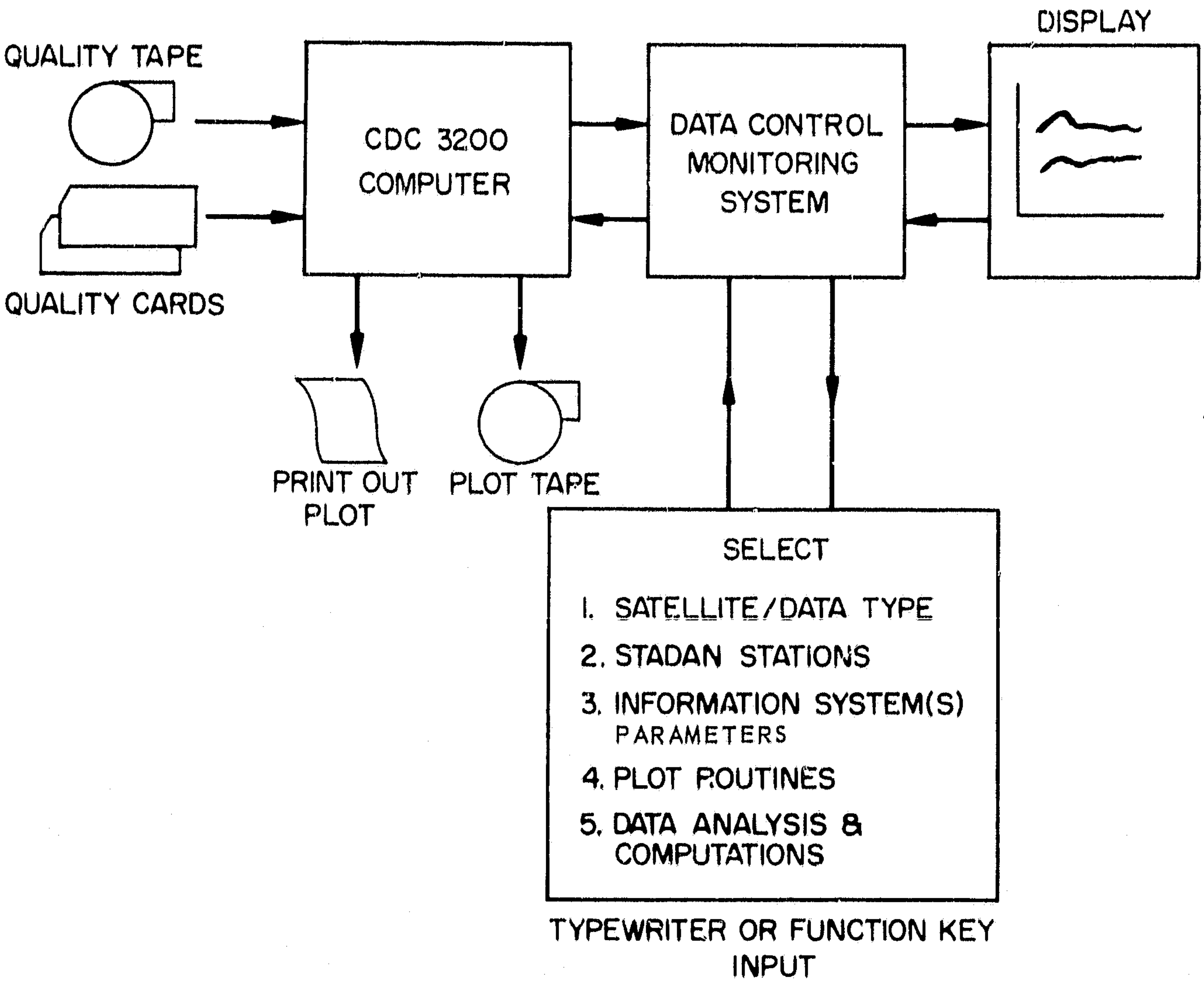


Figure 7–A Quality Control Monitoring System

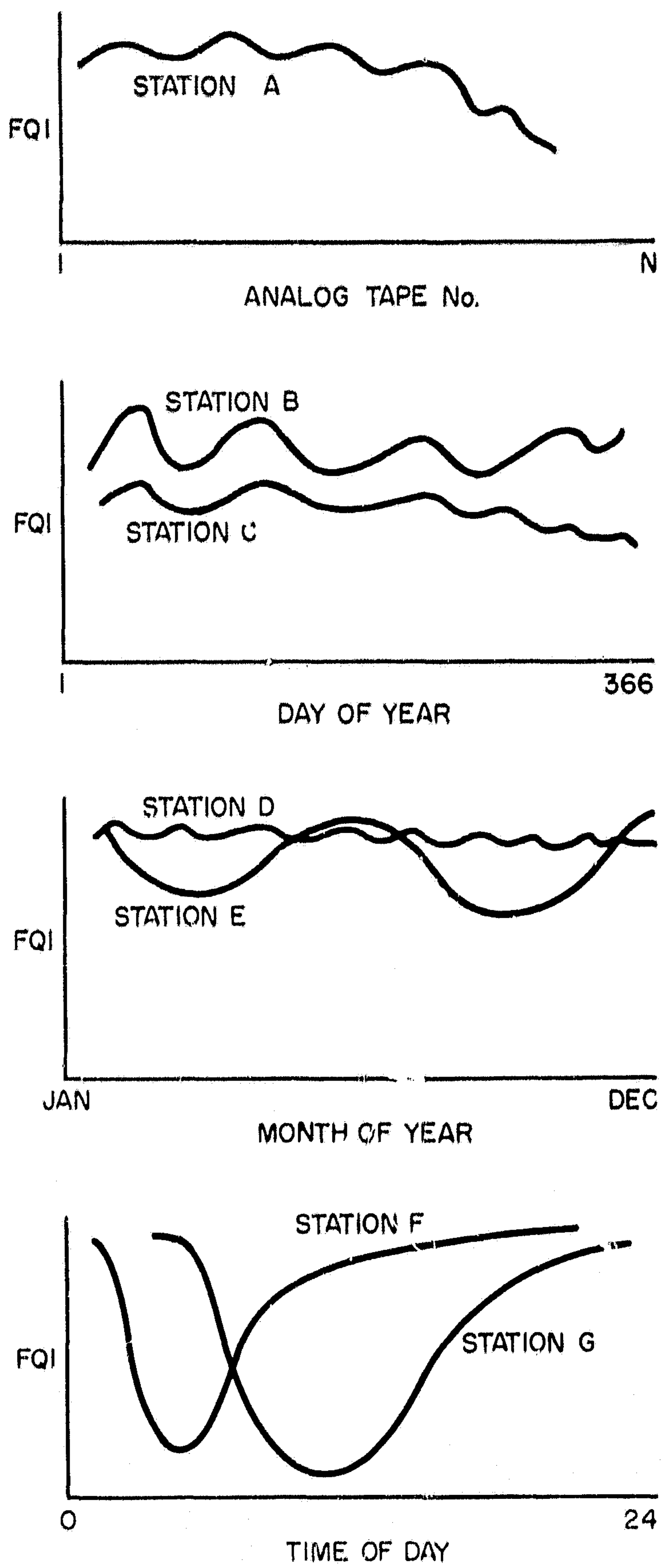
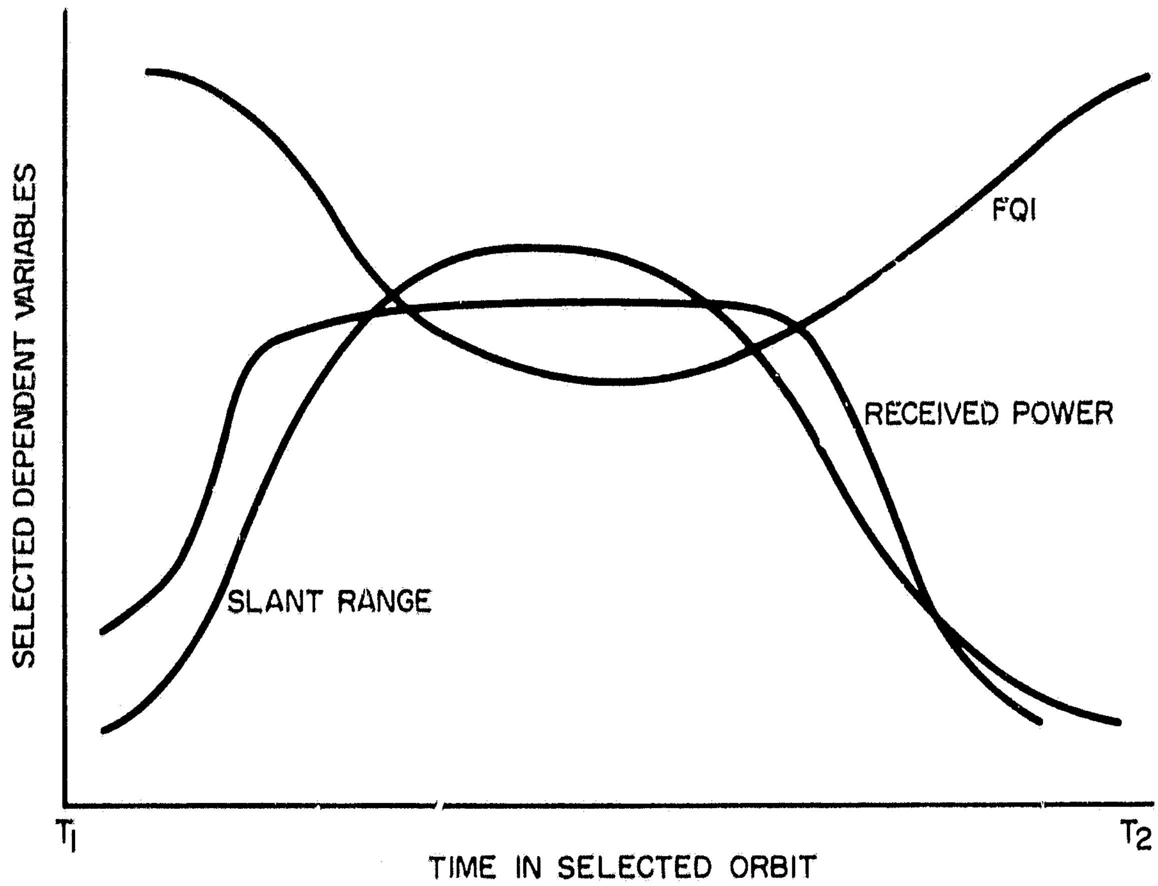


Figure 8–File Quality Index as a Function of Analog Tape No., Day of Year, Month of Year, and Time of Day



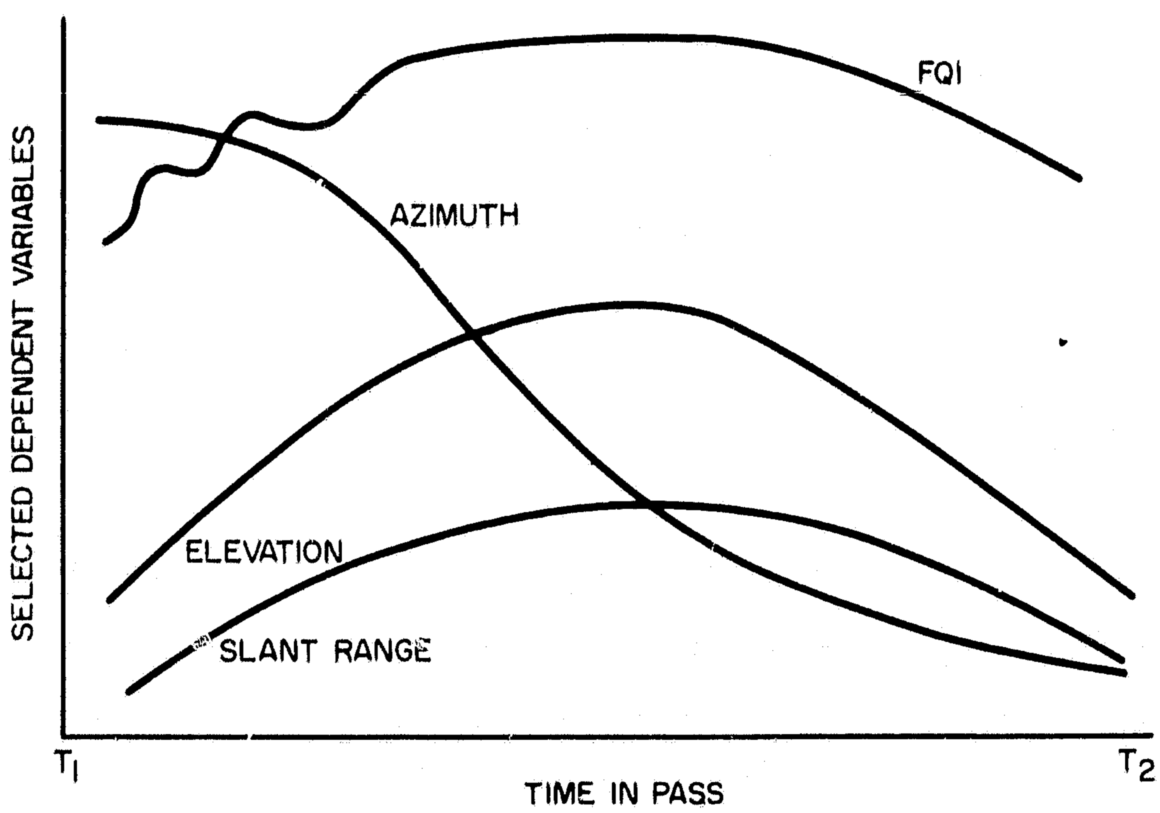


Figure 9—Several Selectable Dependent Variables Plotted Against Time

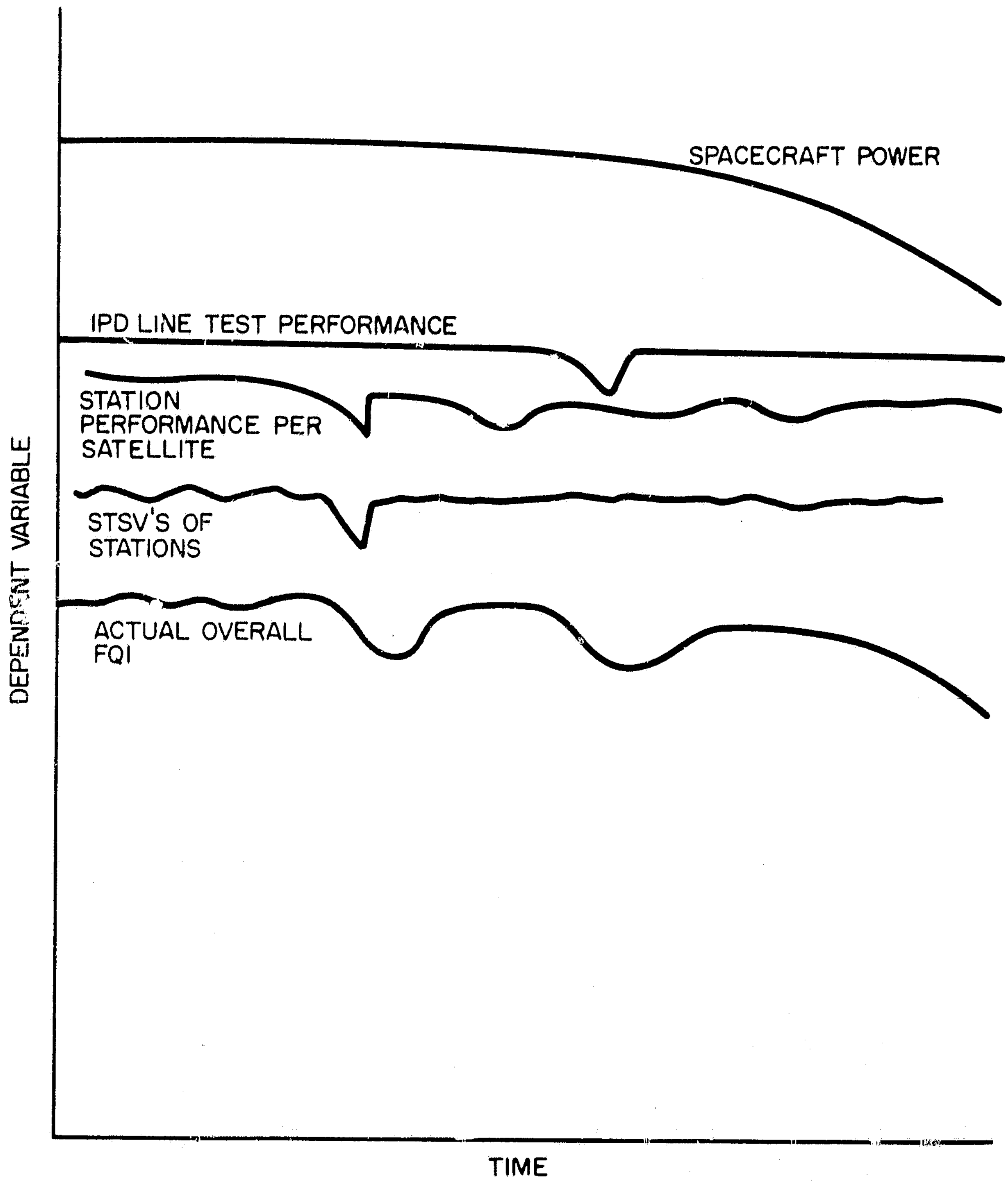


Figure 10–Information System's Evaluation Plot per Satellite Data Type

and analysis capability within the IPD Central Data Processing Facility at the GSFC for a Satellite Telemetry Data Information System quick reaction type results would be made available to interested groups regarding the Information System's performance characteristics. Both short and long term system(s) trends could be monitored for rapid detection and analysis of problem areas.

By inserting into the IPD processing and analysis QCMS programs various T&DS available information such as satellite range and attitude, STADAN predicts, STADAN equipment parameters, S/C RFI, R&RR interference, predicted S/N and signal power, etc., would provide a complete Satellite Telemetry Data Information System performance evaluation and analysis capability both on a quantitative and qualitative basis.

ACKNOWLEDGEMENTS

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