FINAL REPORT

NASA MANAGEMENT AND CONTROL SYSTEM

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CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

SECTION I

INTRODUCTION

1A. THE NASA PROBLEM

1A.1 General

The most recent and most rapidly expanding major government program in the United States is the space exploration effort. The responsibility for developing, guiding and managing this huge undertaking rests with the newly formed National Aeronautics and Space Adminstration.

Of national and international scope, this expanding program involves billions of dollars of expenditure and affects the activities and production of thousands of persons in diverse industrial and scientific organizations. Management of this program is an extremely complicated and exacting requirement.

The importance of this effort in terms of national security and the welfare of mankind makes it imperative that NASA exercise every possible means to enhance the probability of successful achievement. Since this country has a great wealth of scientific capability and physical resources, the success of the NASA effort rests on the effective employment or management of this productive capability. Hence, the most effective management system, tools, and techniques must be considered. It is recognized that such considerations must be weighed with respect to feasibility, practicability, and scope of authority.

The various major objectives of the NASA organization, which include manned exploration of the moon and of the nearby planets, have been described in a comprehensive ten-year plan[1] calling for a steady increase in the size and complexity of satellites and space vehicles launched over a period of ten years. In this plan, several specific objectives are defined and categorized within the following four groupings:

Space Vehicle Development
Manned Space Flight
Engineering and Scientific Research
Space Flight Operations

In support of these plans, a series of programs and projects has been established and scheduled. To carry out this over-all program, the National Aeronautics and Space Administration organization includes several Space Flight and Research Centers located throughout the country.

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1. "The Ten Year Plan of the National Aeronautics and Space Administration", Dec. 18, 1959 (Confidential)

Operations of NASA Headquarters and the subordinate field operations depend in large measure for accomplishment of their over-all missions and objectives on a large network of contractor organizations. This complement of in-house and out-of-house (contractor) resources which must be integrated into an effective team represents a complex, although not unique, management problem.

1A. 2 Specific

The problem of "management and control" has been recognized by NASA management as a very important factor in the success of their program. Positive steps have been taken by the installation of the Program Management Planning (PMP) system as an interim measure. There is no question that NASA operations must include an effective capability to give focus to management problems. To do this, a comprehensive system of information flow must be set up to support management in rapid and accurate decision making. The frequent occurrence of events and circumstances reflecting the dynamic character of space exploration also demands a unique "response" ability to redirect or reprogram vital resources rapidly. Also, the various levels of management and supervision must concentrate a significant proportion of their time on the creative aspects of the space exploration problem if the very difficult technical goals are to be accomplished. Those aspects of management regarding the generation of routine reports, coordination of effort, and general information dissemination must be handled through systems automation and data processing means.

During the past three fiscal years, the total NASA obligational authority has almost doubled each year over the preceding year's figure. It is anticipated that the obligational authority for the next fiscal year, FY 1962, will also double. This is one of the principal contributing factors in the increasing magnitude of the NASA management problem. NASA currently employs in its headquarters staff and its field centers (including the Jet Propulsion Laboratory) an estimated 17,000 people. Its currently approved complement is somewhere around 19,000 people. In consideration of the fact that the NASA organization is responsible for the direct consumption of only a small percentage of its total obligational authority, the total numbers of people and activities (when including all contractors) obviously are significantly large. In order to operate effectively, NASA management, at all levels, must be continuously able to assess both technical and financial status and progress with respect to established plans. The degree of accuracy which these reports reflect will have a direct bearing on the rate of progress and over-all achievement of the NASA mission.

1B. PURPOSE OF THE RAMO-WOOLDRIDGE STUDY

As a result of recognition by NASA management of the necessity and importance of effective management and program control, Ramo-Wooldridge was retained to perform a study of this problem. It was recognized that advanced management techniques, such as the PERT system employed by the Navy Department in the development of the

Polaris weapon system, could possibly have direct application to the NASA operation. It was also recognized that the PERT, and other systems, did not provide the complete function of program control desired by NASA. In particular, cost analysis and control directly relatable to technical progress and organizational responsibility were not obtainable in present systems. Hence, there was a desire and need to create a "complete" system, which at the same time would be tailored to the NASA organization. It was also recognized that PERT and other systems monolithic in nature could be adapted to NASA's problem only with great difficulty and possibly without success.

The initial study effort centered around an analysis of the organizational structure and responsibilities as related to the mission and objectives of the NASA operation, with the aim of determining the basic nature of NASA's management and program control problems. However, the specific intent of the study can best be summarized with the following statement of work documented in the contract:

1. In cooperation with NASA staff members, study the nature and flow of information to and from organizational elements of NASA required for efficient dissemination and analysis of NASA program information, and for good management and control of NASA programs.

2. Assist NASA staff members in early design and implementation of an interim system (Program Management Planning-PMP System) and an interim control center for program control.

3. Assist in preparation of a plan for the design and installation of an improved system.

4. Develop criteria, by comparative analysis, for the extent of automation, communication, processing, and display of information desirable for optimum management and program control.

5. Support NASA staff in other contract work devoted to the design and/or specification of display devices for information handling equipment for the NASA Headquarters Program and Management Control Center.

6. Assist NASA in the analysis of a control room configuration and general architectural requirements necessary for inclusion in the projected installation in Federal Office Building No. 6.

7. Assist NASA staff in an investigation of methods for integrating cost information, funding and budgetary information, and cost prediction methods into the advanced management and program control system.

8. Study the display system design criteria, outlining performance and operational procedures, and preliminary manpower requirements for system operation.

9. Develop specifications for the display equipments and for the overall control center facility.

10. Establish an early facility requirement, including facilities description and architectural layout (control center).

11. Prepare a final report which will summarize all conclusions reached during the subject study period.

12. Prepare an estimate of the level of effort, schedule, and budgetary cost estimates of the subsequent design and installation phases.

1C. RESULTS OF STUDY

1C.1. Benefits of an Automated Management System

As a result of the R-W study, an advanced management system concept, utilizing automated information processing, has been established for the specific needs of the NASA operation. This system can be generally described through design criteria for the system, stated here in terms of the benefits it offers to the NASA organization. These benefits are

Provides NASA management a uniform means for assessing the progress and status and controlling all programs throughout the organization.

Provides complete reports based on real-time information for management decision response.

Provides the capability of continuously measuring progress against plans to signal early warnings of program slippages for early corrective action.

Provides a firm basis through a comprehensive system of disciplines and policies for a significantly increased probability of meeting all performance, objectives and schedules.

Provides for sub-optimum utilization of all available resources.

Provides a uniform means of controlling and monitoring the activities of contractors.

Provides for a rapid means of preparing and documenting special reports periodically required by the executive and legislative branches of the government.

Provides top management with a tool with which they can apply war gaming techniques to rapidly determine mission and resources trade offs responsive to necessary redirection.

Provides a structure for the establishment of a uniform code of cost collection and evaluation for all NASA activities.

1C. 2 Design Criteria for an Advanced NASA Management and Program Control System

The foregoing design criteria represent a summary of the more elaborate system details which are described in Section III of this report. The system is sufficiently flexible to permit the eventual substitution and inclusion of currently foreseeable improved components. The eventual availability of improved man-machine communications and display equipments will substantially increase the usefulness of the management system. Various features, as the reservoir concept, permit organizational growth without immediate fear of exceeding major equipment capabilities or capacities. New concepts of data processing systems based on a "telephone type" switching-central, can be continuously expanded to include new "subscribers" without compromising the initial investment in equipment.

During the course of the study program, analysis effort included:

the NASA mission and objectives

the various program and projects established to realize these objectives

the organizational structure established to carry out these projects

the established authorities, policies, and rules.

In developing a broad understanding of these highly diverse functions and interrelationships, the Ramo-Wooldridge staff was able to assess the magnitude of the management problem, and consequently structure a suitable control system. In so doing, benefits of this advanced system became apparent. Each in themselves may not be considered extraordinary, but as an over-all system capability, the aggregate represents a unique and exciting contribution. These benefits, representing a practical set of design objectives, served as an important prelude in the establishment of the design criteria for an advanced management and program control system. It is emphasized that the design criteria have been established with particular consideration given to economic practicability as well as technical feasibility. They are:

(a) A network system be employed as a primary guide in the planning and scheduling of all programs. These networks are composed of basic "building blocks."

All achievements are defined as goals; all subordinate accomplishments are defined as stages

All efforts to achieve a goal are defined as tasks; subordinate efforts defined as steps

(b) A uniform machine-oriented code be used to relate all tasks and goals to the basic control parameters of management.

Technical mission
Time
Cost
Organization responsibility
Manpower
Facilities
Probability of completion

(c) Disciplines, formats, and methods for the preparation, collection, compilation, processing, etc. of data be provided for the automatic generation of reports. The coding of data will be such that a high degree of flexibility is available to management for their selection or designation of required reporting. The flexibility of the coding system will provide for the inclusion of normal, periodic schedule changes, and provide for system growth without compromising the code scheme or format.

(d) The system be predicated on a "management by exception" operation whereby deviations from pre-designated plans will be automatically reported to higher levels of management. The further capability of supplying detailed supporting reports will be provided.

(e) High capability must be provided in the system for response to changes of plans. All planning or schedule changes will rapidly reflect back into the system to determine and indicate necessary reallocation of resources and scheduling.

(f) A system of organizationally integrated data reservoirs be installed in which detailed supporting data to all management reports are maintained with an integrated file structure.

(g) Provide for dynamic re-programming capability, based on gaming techniques which would be responsive to: rebudgeting, cost overruns, technical redirection, political pressures, etc. All tasks and goals and various pertinent scheduling data would be classified with respect to their precedence relationships and with respect to necessary or required resources.

(h) A computer capability be included for the manipulation of basic data to predict trends or generate extrapolations to anticipate problems.

(i) In order to facilitate all currently available equipments and still provide a more extensive future capability, the data handling system will be adaptable to either punch card or computer operation.

(j) Provision be made for the adaptability of the data system to special reports generation techniques.

(k) A Control Center at NASA Headquarters be provided as the focal point of management action. It should serve as the main conference facility in which the total NASA effort will be coordinated. It should also provide for management briefings to cognizant legislative and executive agencies. In this Center, the problems concerning programs, schedules, funding, and general program resources requirements would be displayed to stimulate effective management response.

Similar Control Centers be provided major field centers, integrated systems-wise with the Headquarters Control Center, to filter, summarize, and otherwise maintain chain-of-command decorum in the over-all NASA information reporting system.

Provide for a system of automated report display equipments functionally compatible with the data processing system, and complying with the individual and general human factors requirements of management.

Methods of display storage be provided to permit on-demand availability of planning and scheduling data for all programs and projects.

The Control Center include a display generation and processing area to provide the work space for those personnel directly concerned with the method of production of displays. It will also provide the facilities for production of currently used chart type displays until such time that automated displays are fully employed.

Provide the necessary additional services such as teleprompter, public address, recording, etc., to facilitate briefings.

1D. RECOMMENDATIONS

The greatest single new influence on the requirements for the management decision making process is the drastic reduction in reaction time necessary to cope with a dynamic space exploration program. The complex interrelationships among operational factors, technical factors, and the organizational structure in which a management and program control system must function require communications and automatic data processing facilities with which to not only evaluate progress, but with which to rapidly feed back appropriate management influence.

In consideration of NASA's expanding scope of work and responsibilities, operations must be facilitated by integrated electronic information systems whichcollect, transmit, process and display the data required for the decision making process. These systems cannot be considered independently of specific requirements, character, and objectives of the NASA organization. Hence, a careful man-machine, or organization-machine design effort must be carried out to realize the full potential and benefits of these tools.

It should be especially noted that the tremendously fast moving field of information system technology makes it difficult, if not impractical, to progress in one step from the present NASA PMP system to what may be considered as an advanced management and program control system. Attempting to incorporate the continuously appearing new and more sophisticated equipments could be extremely disrupting in designing and implementing a working system. Consequently, it is recommended that a reasonable and practical first development step be determined and implemented. From that point on, succeeding system improvements can be planned in orderly periodic intervals to avail NASA of the most effective developments. In the ensuing sections of this report, this "first step" is referred to as the Initial Operational Capability (IOC) System.

The preceding design criteria represent the basic structure of an advanced managment and program control system. In order to fully justify the selection of these Criteria, various parts of the system were analyzed in "working" detail. By so doing, the technical feasibility of various important functions of the control system has been established. Hence, it is apparent that some extent of data processing equipments is necessary to facilitate an effective NASA management operation. Therefore, the problem reduces to a NASA decision on how extensive the first step shall be in the achievement of an advanced management and program control system.

It is recommended that:

An immediate program be adopted to design a management and program control system around the basic structure mentioned above (and described in detail in the following sections of this report) utilizing the techniques of automatic data processing for the collection, compilation, transmission, processing and display of management information.

Implement the <u>initial</u> system to extend to all organizational elements under NASA, but limited to the more major programs in the Research and Development area.

In the process of initiating an early Management and Program Control System, information reporting and processing requirements should be established and programmed for data processing equipments in the current NASA inventory. The IBM 7090, which is available at the field Space Flight Centers, should be a most satisfactory choice.

In addition to a top management Control Center located at NASA Headquarters, a subordinate control center be established at the Marshall Space Flight Center. The latter installation will not only serve as a vital adjunct to the Marshall operations, but will serve as a basis for testing and establishing Headquarters and Field Center control center system relationships.

Decision gaming techniques be established at the NASA Headquarters Control Center to prove out this vital top management planning tool.

A training program be established to indoctrinate and familiarize all NASA and associated contractor organizations with the function of the advanced Management and Program Control System. Their responsibilities and function as part of this system must be clearly defined and established.

SECTION II

DESCRIPTION OF PROPOSED NASA MANAGEMENT AND PROGRAM CONTROL SYSTEM

2A. ADVANCED MANAGEMENT SYSTEM

2A.1 System Concept

The system title "Management and Program Control", implies a two-way exchange of information. In accordance with the established mission and objectives of an organization, management creates plans and schedules which directs and integrates all of the operating levels of an organization in the performance of their responsibilities. Through a prescribed discipline of reporting, the manager is kept abreast of the performance of the organization. He is dependent on this reporting discipline to alert him to problems or exceptions that warrant his attention. Since problems must usually be dealt with as they occur, it is necessary that the flow of information be on a real-time basis so that corrective decision action by management be responsive to the actual situation. Likewise, management decisions must be communicated down into the organization on a real-time basis to maintain relevance and effectiveness.

If we conclude, therefore, that a management system is a tool with which information can be rapidly disseminated to permit the people in an organization to function effectively, then the subject system concept primarily refers to an "information system". In establishing a system concept for an Advanced Management and Program Control System, most of the emphasis is placed on the techniques of employing and fitting together various logical structures, electronic data processing equipments, communication equipments, display equipments, and special disciplines. Electronic data processing has been successfully used for many years in various routine operations such as inventory control, accounting, payroll, etc. Its full potential with regard to improved business management has not been realized because its information handling and correlating capabilities have not been operationally linked to management functions.

In most well run operations, an organization chart is normally developed which establishes divisions, departments, sections, groups, etc., with assigned responsibilities and functions which contribute to and collectively represent the total operation of an organization. Policies, procedures and other means of establishing working relationships are instituted to provide greater detail or resolution in the day-to-day activities of the people who staff an organization. The requirements for reporting are usually defined and established by each ascending level of management. A myriad of reports flow continuously to provide management with the means of evaluating over-all adherence to or compliance with plans and schedules. Reports such as: Personnel, Production Control, Inventory Control, Manufacturing and Engineering, Quality Control, Marketing

Research, Advertising, Customer Service, Credit and Collection, Balance Sheets, Income Statements, Pilot Line Progress, and many others soon fill the communication lines.

A common phenomenon among executive personnel is that of being swamped with reports. Development of procedures to filter information destined for management is an important function usually performed by staff departments. In an advanced management system, active reporting to higher management levels would be restricted primarily to exception data. Normal progress information would be filed. This information, in detailed analytical form, could be retrieved or extracted on demand to support decisions, or to provide passive reports for periodic over-all review. The organization of information will permit the development of statistical procedures for automatic correlation of data within the file. Through experience with and development of an appropriate management system, there will be an improved capability for automatically finding cause and effect relationships between various types of information in the file.

In considering, therefore, the necessary elements of the management and program control system, it is first apparent that an electronic data processing system is required which compiles, collate, files, and retrieves all types of operational information. Current data processing systems can collate, file, and report on tremendous volumes of information of all types and classifications. Equipments have long been in use which permit reports to be readily converted to machine-readable format such as punched cards, punched tape, magnetic tape, etc. This information can then be fed automatically into data storage systems which process the information in any prescribed manner. High speed printers can issue, at regular intervals of time, reports for any specific or all levels of management. Equipments have been developed, and many others are in various stages of current development, which can or will provide exceptionally effective means for communication between the man and the machine. Devices are available which will display reports in the form of tabular information, plotted graphs or charts, and in the conventional form of narrative text.

Communication equipments have been developed which can link together the various types of information input devices with remotely located data processing systems, and with various types of readout or display equipments. At this point of time, there are virtually no reasonable limitations in complying with the communication requirements of an information flow system.

As will be described in a later part of this report, a management and program control system will include a control center. This center provides a physical place for top management and staff and line supporting levels of management to review the status and progress of operations with respect to the plans of the organization. It provides a place where decisions based on real-time information can be reached and from which these decisions can be communicated back down into the organization. Through the established disciplines of reporting and generation of realtime progress displays the results of decisions can be closely monitored to determine their effectiveness. The control center communicates directly with electronic data centrals (data reservoirs) which in turn are linked to the numerous organizational echelons, each of which would have physical access to or provision for entering into the system reports on their individual accomplishments or problems. If there is an increase in the size of the organization, this information flow network can be expanded or multiplied in a manner similar to the growth of a telephone system.

In accordance with the size or the geographic distribution of an organization, various data reservoirs can be set up in different parts of the country to localize the collection, filtering, and summarization of information before being passed on to higher organization levels. Remote data centrals or reservoirs would not be established until a careful analysis of the economics and logistics of such provision is made. The operation of large field centers should be greatly facilitated through the local implementation of a control center. This would not only provide an important focal point for management of the field operation, but would also provide a functionally compatible vehicle for reporting rapidly and accurately to higher, centrally located top management operations. The costly and time-consuming requirement for lengthy, hard to read reports would be significantly, if not wholly, reduced or eliminated.

In addition to the physical equipments which could be patterned together into one effective information handling system, various techniques can be instituted to provide top management with even greater facility. In particular, we refer to what has been described in military operations as "war gaming" techniques. Since we are primarily referring to decision-making techniques, let us refer to this function as "decision-gaming techniques". Through the application of proven mathematical relationships, and with the provision of a computer capability in the electronic data processing system, very complex, diverse relationships or problems can be rapidly analyzed to determine optimum or "better" solutions. It is beyond the capability of man to analyze, compute and otherwise evaluate relationships dependent upon numerous variables, in time to make decisions responsive to current status rather than to "history". Numerous techniques related to mathematical modeling and gaming have been developed and proven in simulated and actual operations, and will be described in the succeeding section of this report.

To summarize, the "Advanced Management and Program Control System" herein discussed, consists of:

a. A Control Center (or Centers) equipped with automatic display equipment which provides an output for electronic data processing systems for timely presentation of any or all signficant management reports.

b. Electronic data processing system with computer capability to receive, compile, process, file, retrieve, and generate information, pertinent to all phases of the NASA operation, in either machine-readable or human-readable form.

c. Systems and equipments to link together the various data processing equipments required for machine-to-machine, and man-to-machine-to-man communications.

d. Decision-gaming techniques which permit optimization analysis for decision making.

e. Other techniques which greatly increase the usefulness of data processing systems in the compiling of facts for timely extraction of significant information according to subject, aspect, data, degree of specificity, and organizational unit.

The current state-of-the-art of certain types of equipment may currently limit the full envisioned capability of such a sytem. However, enough proven equipments and techniques are available to permit the gainful employment of an integrated control system to business operations. This can be done today on a technically feasible and economically practical sound basis. Obviously, weighted consideration must be given to all the factors defining the nature of one's particular operations, to determine a balanced, phased-type program for applying an Advanced Management and Program Control System.

2A. 2 Functional Requirements of a Management System

The function of the Advanced Management System is to facilitate control of NASA's far-flung and many-sided activities by the managers of the organization. Control, in turn, implies establishing plans against which events can be measured. Henri Fayol wrote, "In an undertaking, control consists in verifying whether everything occurs in conformity with the plan adopted, the instructions issued, and principles established."[2] Another authority distinguished planning and control in a useful manner: "Managerial planning seeks consistent, integrated and articulated programs," while "management control seeks to compel events to conform to plans."[3]

The somewhat negative connotation of the word "compel" in Goetz's statement should be discounted. Proper management control emphasizes these objectives:

Insure compliance with over-all objectives and policies.

Discover weaknesses or errors in the execution of a plan and prevent their recurrence.

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2. Henri Fayol, General and Industrial Management (New York, 1949), p. 107.

3. Billy E. Goetz, Management Planning and Control (New York, 1949), p. 229.

Of equal importance, discover weaknesses in a plan at the earliest possible date and alter the plan to strengthen it.

Discover and implement improved methods of operation.

Ideally, anticipate deviations from plans and take corrective action prior to their actual occurrence.

A proper management control system, therefore, is a positive force within an organization and should never be designed or used as a means of coercion or as an instrument of punitive action.

To be effective a management control system must include provision for accepting inputs, processing data, and producing usable information in at least the following areas of activity:

Planning and scheduling.
Performance evaluation.
Projected performance.
Budgeting and expenditure.
Resources utilization.

In succeeding paragraphs each of these areas is characterized with particular reference to the needs of the National Aeronautics and Space Administration as revealed by the Ramo-Wooldridge study effort. The concepts of the Advanced Management System for NASA have been developed specifically to meet these needs in ways that are not only feasible but also practical and economical.

2A. 2a PLANNING AND SCHEDULING

Although the need for detailed planning has certainly been recognized within NASA there is also an evident need for a mechanism to aid the production of the "consistent, integrated and articulated" programs described by Goetz. A proposed NASA procedure[4] for establishment of development programs details the elements of a sound plan:

a. Objectives.

b. Justification.

c. Project description.

d. History and related work.

e. Technical approach.

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4. "Proposed Procedures for Approval of Development Plans", National Aeronautics and Space Administration, Draft (source unidentified), August 5, 1960.

f. Conceptual design.

g. Schedules and significant intermediate accomplishments.

h. Resource requirements.

i. Management approach.

The proposal further outlines standard formats for presentation of these planning materials and establishes certain minimum standards for level of detail and content.

The Ramo-Wooldridge study indicates clearly that establishment of this or an equivalent procedure within NASA is a highly desirable step toward production of meaningful plans. What the Advanced Management System seeks to accomplish is to translate the plans thus prepared into a standard form throughout NASA, a form that will permit a high degree of automation to be applied to the problem of using these plans as the basis for exercising effective management control.

Not every aspect of planning is susceptible to automation. The initial presentation of items (a) through (f) in the paragraph above may require the use of English text, tabulated data, charts, graphs, models, photographs or any combination of these or other elements. The only format requirement reasonable to impose on the initial presentation of materials related to these items is brevity; brevity consistent with clarity.

On the other hand, items (g) and (h), schedules and resource requirements, can be reduced to standard formats susceptible to automation. Schedules, representing time, and budgets, representing the allocation of resources, form the quantitative aspects of the management control problem. In another sense, schedules and budgets are the quantified embodiment of the qualitiative judgments expressed in statements of objectives, project descriptions, conceptual designs, etc. The "management approach" (item (i)) is implicit in the assignment of responsibilities, in the schedules and budgets themselves, and in the procedures designed for measurement of actual events against the plan.

It is the objective of the Advanced Management System to automate this process of measurement to the greatest extent possible. How this is to be done is described in later sections of this report. In those areas to be automated, the system will be required to perform the following functions with respect to planning and scheduling:

Provide standard formats for expression of schedules and budgets.

Establish an integrated file of information related to plans and schedules.

Perform edit checks on planning and schedule data entered into the system to help insure completeness and accuracy.

Provide a means for revision of plans when necessary.

Review plans and schedules for conflicting assignments of facilities.

2A. 2b PERFORMANCE EVALUATION

Performance evaluation forms the opposite side of the management control "coin" from planning and scheduling. Measurement of actual performance provides the data for the comparison against plans that forms the basis of management control. The needs of an adequate management control system impose several stringent requirements upon performance reporting and evaluation:

Timeliness. Management is a time-related function. The operational decisions of management, like the tactical decisions of a military commander, have value in direct proportion to their ability to influence the immediate situation. This in turn presupposes knowledge of the immediate situation. In the Advanced Management System, timeliness of reports, consistent with need and economy, is a prime design factor.

Consistency. Reports must be in a form consistent with plans, so that proper evaluations may be made. Automating the management information system imposes strict requirements on consistency of form. In addition to form, reports must be consistent in source, content, and periodicity. These elements taken together form the reporting discipline that must be imposed and maintained.

Accuracy. The need for accuracy exists in high degree on at least three levels in an automated information system: (a) data recorded on documents fed into the system should be double-checked by the originator for accuracy, (b) any type of transcription of data from one form to another should be subjected to a verification procedure, and (c) any processing to which data is subjected should be verified. In terms of automated system design this implies establishment of verification procedures at all critical points.

Reduction to appropriate form. Since the Advanced Management System will be serving every level of management, from the Project Manager to the Administrator, it is essential that the System be able to provide information in forms appropriate to various levels. It is the assumption that it will be necessary to provide reports in both tabular and graphic form, with content varying from lowest level of detail to grand summary or exception information only. The processing system must also be responsive to requests for special report formats.

Variety of content. One example of the variety of content required in output formats was mentioned in the previous paragraph. In addition, the Advanced Management System must be capable of providing a wide variety of analytical reports on request. It will not be possible to anticipate every type of such report that might be required, hence the need to adapt the structure of the system to use of modern report generation techniques.

It is also of concern to note the factors to be evaluated. In general, the Advanced Management System is concerned with time, dollars, and facilities utilization as performance factors. It is possible to extend the capacity of the system to include such factors as manpower loading, if desired.

2A. 2c PROJECTED PERFORMANCE

The ideal goal of a management control system is to enable management to anticipate abberrations in the execution of a plan and take steps to prevent such abberations from occurring. Of course the future is never completely visible. But the capability of the management system to utilize trends to project or extrapolate the probable future course of events is a great step in the proper direction.

In order to respond properly to the requirement of providing such information, the Advanced Management System should incorporate these abilities:

Reflect the most current estimates of those managers and contractors closest to actual operations.

Analyze past events statistically to provide projective data.

Support the analysis of possible future courses of action before any are adopted.

The system should be capable, moreover, of performing these tasks on all levels of management and doing so in each case with an appropriate amount of detail.

2A. 2d BUDGETING AND EXPEDITURE

The function of the Advanced Management System with respect to budgeting and control of expenditures is supplementary, rather than primary. The management control problem at NASA definitely includes consideration of budgets and the status of expenditures, as well as the requirement of ability to provide meaningful cost figures for items of hardware, projects, and contracts. A proposed contractor reporting system for NASA[5] has given these uses for financial information submitted by contractors:

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5. Draft Staff Paper, "Proposed System for Financial Reporting by NASA Contractors Holding Cost-Type Contracts", dated July 19, 1960, p. 3.

1. To measure contractor performance in terms of stated financial objectives and schedules.

2. To assist in budget preparations and executions of the NASA financial operating plan system.

3. To serve as a source of financial reports to NASA management on over-all program and project status and progress. Such reports will be prepared periodically by the office of Financial Management.

4. To provide financial information required inthe formulation of long range program and financial plans.

5. To provide prompt and reliable indicators of possible contract overruns.

6. To indicate contractor expenditures and commitments for termination considerations.

Paragraphs 1, 3, and 5 above are particular objectives of the Advanced Management System as currently envisioned, while the remaining paragraphs state objectives that do not fit so clearly within the automated aspects of the Advanced Management System. The system of monthly financial reports recommended for the Advanced Management System strongly suggests that the function of the Advanced Management System is to provide timely, accurate and frequent assessments of the financial status of projects. The proposed financial reporting system for NASA contractors, cited above, aims to meet this requirement also, and hence should be incorporated with the Advanced Management System. In addition, it establishes the basis for more intensive analysis of contractor financial status, progress, intentions and commitments on a quarterly schedule. There is question that top management in NASA needs both types of reports. Exactly how the quarterly report should be integrated with the Advanced Management System, however, can only be resolved during the detail study phase leading directly to implementation of the system.

2A. 2e RESOURCES UTILIZATION

The inventory of resources available to NASA in the conduct of its missions is extremely large, complex, and in many cases costly. Launch pads, factories, engine test stands, wind tunnels, computers and like facilities represent enormous investments and, in some cases, unique items. It is essential that these facilities be utilized in the most efficient manner possible. It is also essential that projects in the planning stage have rapid access to information relating to the scheduling of required facilities, and that the availability of facilities be taken into account when changes in plans are contemplated.

The Advanced Management System should, therefore, maintain a Facilities Inventory, available to all parts of the system, containing current data on the status and schedule for each facility included in the inventory. The system will be required to provide the capability of interaction between operational plans and schedules and the Facilities Inventory, reporting potential conflicts where they exist and reporting also the availability of alternative facilities where these exist.

2A. 3 Necessity for Evolutionary Development

Installation of the Advanced Management System could, in theory, follow two possible courses of development: (a) complete specification of the entire advanced system, followed by a single implementation and change-over period, or (b) an evolutionary development, in which a carefully phrased program of development leads towards ultimately complete implementation of the Advanced System. The Ramo-Wooldridge study has led to a recommendation to follow the latter course of action. This section presents the reasoning behind this recommendation.

A major factor leading to the recommendation to follow a pattern of phased implementation for the Advanced Management System is the fact that all of the tools and techniques that could be used to advantage in the Advanced Management System do not exist within the present state-of-the-art. Under a phased program of implementation those areas that are presently fully developed, such as the use of data processing equipment in information systems, can be implemented. In other fields, such as display generation systems, there is great promise of further advance. It would seem logical, therefore, to avoid premature heavy commitment to devices and techniques that may soon be outmoded. Similar arguments apply in such areas as data transmission, techniques and equipment; mathematical modeling techniques, and storage and retrieval devices for graphic information.

Equally important is the consideration that an attempt to provide a fully automated integrated management system in one large jump generally speaking entails higher initial costs than a phased implementation and also entails a greater risk. By implementing the system piecemeal in accord with the general plan greater advantage can be taken of existing facilities and personnel and later phases can build upon experience gained during the evolutionary process.

Factors which influence the cost of system design and installation include the following that are pertinent to this discussion:

2A. 3a DESIGN EFFORT

This cost must be considered to be approximately equal in both approaches. Although it may true that the phased implementation will require design attention over a longer period of time, it is also more likely that less re-design time will have to be applied in this case.

2A. 3b PROCEDURE WRITING AND INSTALLATION

Here again costs must be considered approximately equal although the fully integrated approach entails considerable risk of incurring procedural changes and consequent additional costs.

2A. 3c TRAINING

With phased implementation training time, and hence training costs, are spread over a longer period of time than with a completely integrated implementation. Trainees are familiarized with concepts developed in one phase of implementation before being required to absorb concepts related to a new phase. Less correction and retraining is necessary since training follows a logical pattern of development. Training costs should be significantly lower under a phased system.

2A. 3d COMPUTER PROGRAMMING

The ultimate system in either mode of implementation will contain approximately the same number of computer instructions. In either case the major portion of computer programming effort will come near the beginning of the effort. Here again, however, complete implementation in a single phase entails risk of incurring considerable reprogramming cost due to system changes. On the other hand, in a phased implementation the possible need to reprogram can be evaluated during the initial effort and can be provided for through enforcement of systematic programming procedures.

2A. 3e FORMS DESIGN AND USE

Adoption of a form for any use involves certain cost. Once again the principle of avoiding changes insofar as possible through the accumulation of experience before instituting forms and procedures is applicable.

Still another important consideration is that, in a completely integrated system, programs must be run in parallel for a time, to be certain that the advanced system is accomplishing the objectives anticipated and to be certain also that should the advance system fail in any respect a backup system will be available. In a phased implementation, not only can advances be made on a sound basis, but implementation can proceed from program to program, thus reducing the amount of parallel processing effort required. The larger and more important the program, the stronger should be the consideration for placing it under the advanced management system at an early date.

NASA must further take into account the fact that final system design and installation is itself a task that requires planning, scheduling, staffing and a not inconsiderable amount of management effort and coordination. In the final analysis much of this effort must be applied from within NASA; no contractor or consultant can issue directives, make final decisions binding upon the organization, or enforce system disciplines. The R-W study indicates that NASA management is now fully burdened with on-going activities, and that the surplus management capacity within NASA to mount a massive systems effort simply does not exist.

In summary, every indication points not only to the desirability of a phased approach to system implementation, but as well to the lack of any realistic alternative.

2B. INITIAL OPERATIONAL CAPABILITY-MANAGEMENT AND PROGRAM CONTROL SYSTEM

2B. 1 Control Center and Display System

2B. 1a GENERAL

The NASA Control Center requirement arises from a need for rapid and timely dissemination of accurate intelligence information to management. This fact, and the corresponding complexity of a variety of solutions, served to crystalize the research approach which was used during the Control Center and Display System investigation. Simply stated, the research approach consisted of a two-part effort: an investigation of the immediate management intelligence requirements of NASA, and a study of those requirements which would exist in the event that NASA management should have to rapidly accelerate its efforts. The former of these two is the subject of this section. The latter is discussed in detail in Appendix B.

2B. 1b THE CONTROL CENTER

Until a more automated system becomes economically feasible, it is assumed that the prime mission of the Control Center will be to house the information generation equipment and to present management review and planning information in an efficient, flexible, and detailed manner. The proposed Control Center[6] meets this requirement. It will provide the NASA Headquarters staff with:

> A facility in which summarized or report type information pertinent to management can be stored and made readily available for review and discussion
>
> A control area in which the environment and facilities contribute to effective management decision making
>
> An integrated facility which combines the conference room capability with a supporting display generation system

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6. Described in detail in Part III of this report, p. 111.

A facility in which the design is compatible with presentation techniques currently in use at NASA, those techniques characteristic of a semiautomated system, and those features which will permit, without major redesign implications, evolutionary modifications to keep pace with the state-of-the-art.

In particular, the Control Center Conference Room and projection system will permit members of the headquarters staff to:

Display a variety of graphic media in an impromptu presentation such as that which might occur during a launch;

Prepare and conduct formal preprogrammed presentations automatically with no man-machine malfunctions;

Project immediately a full size screen display of financial or project status charts in the Conference Room or in another location (e. g., the Administrator's office); and

Exhibit, on a 6-foot x 21-foot screen, a program status display that would reveal scheduling information, cost analysis data, coordination and contractor responsibility, and project objective information, all at the same time.

2B. 1c THE DISPLAY SYSTEM

The interim display system, discussed in Part III, has been designed to provide NASA management with an acceptable semiautomatic link between a comparatively inefficient manual system and the more refined computer-actuated display generator techniques. The system will meet the immediate requirements of information presentation with a minimum of expense and of personnel addition. It will also blend with an advanced system with no loss in capital expenditures.

The system proposed for implementation consists of three major areas of effort: format generation, display preparation, and slide presentation.

The first of these items, format generation, serves a two-fold purpose in that it produces display slide format originals and printing master originals as a part of a common effort by using an automatic typewriter. [7] Utilizing the output of a tabulator or computer, the automatic typewriter will, by accepting a preprogrammed tape, print on opaque originals the intelligence information which will be displayed for management review. Subsequently the automatic typewriter, using identical or related information, will prepare a multilith master for reproduction in a matter of minutes without xerographic processing.

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7. The automatic typewriter generator process lends itself equally well to the proposed system or to an automated system since it is an acceptable link in a data processing system.

The preparation of the display slide has been automated to some extent by the use of particular components (e. g., the microfilm camera and the semiautomatic processor); each of these facilitates the rapid generation of management review information. In this instance, speed was considered essential to the over-all effort.

Finally, the slide projection techniques and equipments which have been recommended are automated in the sense that a user can, by preprogramming, select slides without requiring the services of a projectionist. This capability has been developed to eliminate confusion, to give a lecturer full command of his presentation, and to reduce manpower requirements.

Certain manual steps remain in the semiautomated system. However, it is assumed that the system will absorb an increase in production with no increase in personnel after the interim system is established.

In summary, the interim display system provides:

> The method and equipment needed to prepare accurate display slides and printed "hard copies" which contain information pertinent to the decision making process.
>
> A method of producing automatically a variety of infomation formats (e. g., Gantt charts, curves and tabular data).
>
> Systems and techniques which can be revised to incorporate automated processes without attendant equipment obsolescence.
>
> A display system which can be electronically linked to field installations by teledata connections.

2B. 2 Information System

2B. 2a RELATION TO ADVANCED MANAGEMENT SYSTEM

In the discussion of the Advanced Management System and the necessity for an evolutionary development, it was pointed out that the general functional requirements of the information system are well understood. Information processing and communications technology has developed at a rapidly increasing rate during the past ten years; particularly in the field of data processing, machines unheard of in 1950 grind routinely through clerical tasks of unprecedented size and complexity.

This advance in the area of information systems, coupled with the development of sound information processing concepts for the IOC-MAPCS, has led the Ramo-Wooldridge study team to the conclusion that the information system described in this and later sections provides not only a workable system for the IOC-MAPCS but also a sound structure upon which to base the Advanced Management System as its phased implementation proceeds.

The information system is in a very real sense management's intelligence arm, performing the vital functions of collection, processing and dissemination of information. The information system not only supports the control center and through the control center presents information of vital importance to the NASA top management, but in addition is designed to provide vital management control information to all levels of NASA management from the administrator down through the project manager and his assistants. Further, the information system is designed to provide to each level of management information in the degree of detail appropriate to that level. The design of the information system extends its capabilities beyond mere parroting of facts to the ability to derive important extrapolations and projections of current trends so as to give management at all levels an indication of future events. Finally, the information system is designed to support the decision gaming capability discussed in the succeeding section.

This section of the report will be devoted to a general discussion of the findings of the Ramo-Wooldridge study with respect to the requirements of the information system for the collection, processing and storage, and dissemination of information. These requirements are stated in terms of the IOC-MAPCS, but apply for the most part to the Advanced Management System as well.

2B. 2b FUNCTIONAL DESCRIPTION

2B. 2b. 1 System Inputs

Inputs to the IOC-MAPCS information system may be broadly classified as (a) plans and (b) operational reports. Under the heading of plans come both the development plans or initial plans for a project and the revisions to plans made from time to time by NASA management. In terms of the information system, approval of the development plan requires establishing a project file. Changes in plans call for a file revision. The Ramo-Wooldridge study indicates that within the IOC-MAPCS information system it will be convenient to consider the project as the basic file unit. In other words, all subordinate file elements will be considered as belonging to a project file and larger file units will be made up of groups of project files. Tasks not related to a specific project can be grouped in an artificial "miscellaneous" project file for convenience in handling.

The over-all information system must provide adequate procedures for the establishment of project files. Specific recommendations concerning these procedures are contained in later sections of this report. In general, they combine the functional requirements of:

Insuring that adequate authority for establishment of the file has been granted.

Checking to assure that all information required in the establishment of a file is actually present.

Specification of formats in which information of an initial planning nature is to be presented to the information system.

Insofar as possible, within the limitations of the state of the data processing art, automated checks covering these functional requirements will be built into the information system.

The same statement holds true for plan revisions as they are entered into the information system. Here, again, the system must provide for an automated check of the authority to revise, formats must be specified and appropriate procedures devised for checks of reasonability and accuracy.

The second broad class of system inputs covers operational reports developed by contractors and from in-house operations. The information system is required to accept these inputs, match the information against plan data contained in the file and prepare meaningful sequences of management reports. The system is also required to respond to revisions of such reports as various levels of management review them in their progress up the management ladder.

2B. 2b. 2 File Structures

The exact file structure built into the IOC-MAPCS information system will require careful study of NASA's needs. In general, however, the Ramo-Wooldridge study indicates the desirability of utilizing a fully integrated file structure for the information system. In this type of file structure all information related to a basic organizational element is grouped together in a single file or record. Thus the automated data processing system would contain in a record relating to a contract such information as contractor name, contract number, total dollar amount of contract, length of time of contract, the issuing agency, detailed plan for execution of the contract, reporting requirements, delivery dates, relationship to other contracts, etc. Later sections show in detail how it is proposed such integrated files should be established and maintained and show also how through the use of a sophisticated coding system information can be filed and retrieved with maximum efficiency. The coding system recommended is described in full in a later section.

The basic file structure within the information system is never changed. All items within the file are always identified in exactly the same way to facilitiate information retrieval. Modern file maintenance techniques are employed to update the file as required without necessitating expensive re-sorting or maintenance of redundant information in the files.

2B. 2b. 3 Data Processing and Computation

The IOC-MAPCS information system can be operated most effectively and most efficiently through the use of electronic data processing equipment. Preliminary studies indicate that equipment already on hand within NASA could be made available for this purpose. Should this prove to be the case, the information system files could be maintained on magnetic tape, allowing further economies through the physical compression of information in the file.

Use of modern automatic data processing equipment increases tremendously the scope and flexibility of the information system. The logical and arithmetic capabilities of such machines allow for virtually unlimited manipulation of raw data and conversion of these data into the type of analytical report highly desirable in a management control system. In later sections of this report examples of the use of automatic data processing equipment for such purposes is illustrated by specific examples. Only such an automated system can support the decision gaming system described in the next section.

2B. 2b. 4 System Outputs

Outputs of the IOC-MAPCS information system are based on the use of modern report generation techniques. Such techniques allow the requestor of a report from a given file to specify the format of the report and the data from which it is to be derived. At this point the automatic data processing system takes over, prepares a computer program to develop the required report and processes the file specified to produce the end result. Such techniques can be utilized either for recurring or for special reports with equal facility. For the preparation of analytical reports beyond the scope of a reports generation system more sophisticated handwritten computer programs can be inserted directly in the report generator format to provide virtually any desired report construction.

The capability of the automatic data processing system recommended for use with the IOC-MAPCS information system extends to the ability to prepare reports in graphic format by the use of cathode ray tube display equipment that is computer controlled. Analytical reports for example can be prepared in graphic form utilizing this capability. These graphs can be photographed and reproduced in any desired size or manner.

2B. 2b. 5 Communications

Specific recommendations for communications links have not been formulated by the Ramo-Wooldridge study team. The determination of specifications for these links must depend upon conclusions reached in the final design phase regarding volumes, speed requirements, and formats of data transmissions.

Figure 1 illustrates the IOC-MAPCS data flow as it has been visualized in the preliminary design phase. Analysis of the diagram discloses five major types of communications links[8] within the system:

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8. Various communications systems and equipments suitable for this purpose are listed and discussed in some detail in Section 3A. 3d of this report, beginning on page 10 .

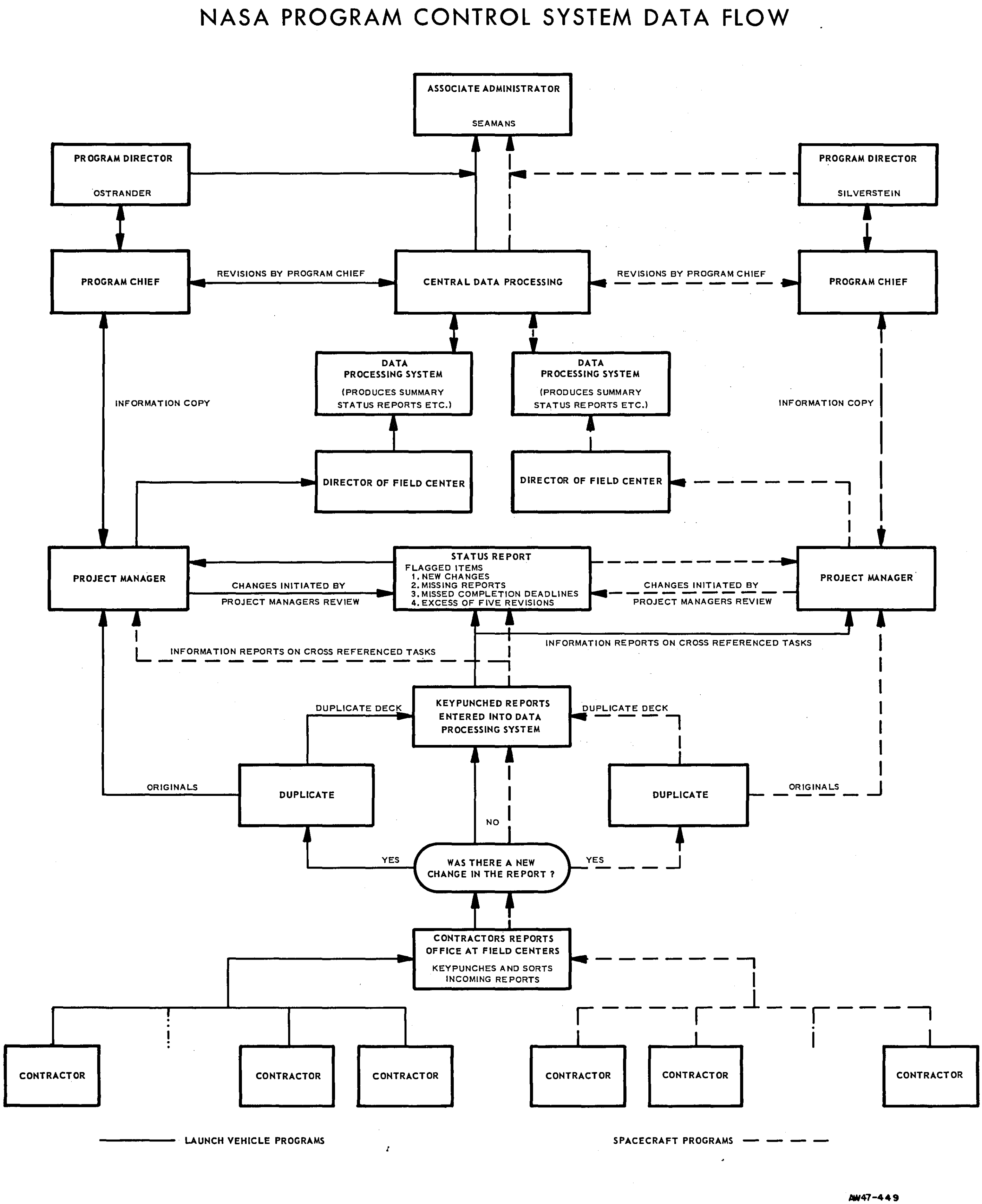

Figure 1. NASA Program Control System Data Flow

Contractor to field center. IOC-MAPCS reports from contractors to field centers have been visualized as utilizing U. S. mail as the primary means of communications, although other systems might be used as alternatives.

Internal field center communications. Internal mail should prove adequate for this purpose.

Interfield center communications. Reports being transmitted from one field center to another will normally be for information purposes. If this is the case, U. S. mail, supplemented where necessary, should prove adequate.

Field center to headquarters (inter-reservoir communications). The exact means of communications between reservoirs cannot be specified until final system study reveals the detailed system requirements. The preliminary study indicates the desirability of establishing communications in machine-readable form (i. e., punched-card to punched-card or magnetic-tape to magnetic-tape transmission).

Headquarters reservoir to display generation room in the Control Center. The primary requirement here would appear to be for transmission of 5-, 6-, or 7-channel data to be converted into punched paper tape. Existing systems should prove adequate.

In summary, the communications requirements of the IOC-MAPCS appear to be well within the current state-of-the-art in every respect, and they do not appear to involve unusual or expensive installations. Final communications specifications cannot be made until the detail system study has revealed communications parameters.

2B. 2b. 6 Display Generation

The IOC-MAPCS information system must be capable of supporting the display generation requirements of the Control Center. In general, this implies:

That the central reservoir processing system must be capable of manipulating information in the reservoir in ways not predictable in every case, in order to be able to respond to requests for newly developed reports.

That the central reservoir processing system must be capable of formating reports in any desired fashion.

That the system must have the capability of arranging and transmitting data and control information to the specifications of a Flexowriter or similar device.

That the system must be capable of responding to the data arrangement and control requirements of automated display generation equipment not yet specified.

The pattern suggested by these requirements is one that can best be fitted by the integrated file structure and advanced programming techniques recommended for use with the IOC-MAPCS information system. The use of large-scale general-purpose electronic data processing equipment, also recommended in this report, further establishes the capability of the system to meet these requirements.

2B. 3 Decision Gaming System

2B. 3a BRIEF DESCRIPTION OF DECISION GAMING

The proposed NASA Decision Game will be played by the NASA Administrator, Deputy Administrator, Associate Administrator, the principal directors and a chosen staff. By playing the Decision Game these executives will be presented a panorama of plans and programs which can be improved step by step until a final acceptable plan is reached.

The NASA Decision Game will be played by executives whenever:

> A new mission is to be established and, therefore, a new program has to be initiated.
>
> A program is to be accelerated or stretched out and the rest of the NASA program must be accordingly modified.
>
> A program is to be cancelled.
>
> Problems arise that require the reprogramming of the NASA effort.

The NASA Decision Game will assist executives in making the various decisions required in reprogramming, but the primary emphasis of the Gaming System is on financial and cost control. Whenever there is a change in budget, whether an increase or decrease, or whenever it is revealed that more funds are required to complete a program, the Decision Game will be played. Whenever problems arise in prototype production or in the Test Vehicles Programs, by playing the Decision Game NASA executives will be furnished with important information making it possible to make fiscal decisions quickly, accurately and to the best advantage.

The NASA Decision Game will be played in three steps. As the first step of the Game, the executives gathered in the Control Room will inspect a set of displays prepared in advance. These displays will be presented on either cathode ray tubes or screens. The material presented will contain all the important factors necessary to develop NASA programs. The time phasing of various missions and goals and the associated loading of various facilities and field installations will be displayed. The associated financial information will also be displayed with sufficient detail so that reprogramming decisions can be made. Provision will be made for retrieval and display of backup information from the computer files so that whenever executives require further details, these details can be furnished.

The second step in playing the game will be the making of a "move" by the NASA Administrator. Such a "move" will consist of a "suggestion" or tentative shift of some of the missions and goals in time. In some instances the time of completion of certain goals will be delayed, whereas some others will be accelerated. When such a suggestion is made in the rephasing of missions and goals, this information is transmitted to an operator who translates the suggestion into machine code and informs the computer of the change to be made.

Step 3 of the Game is carried out by the computer and associated equipment. Within a time span of the order of one minute, the computer will prepare a new NASA program and compute the financial, manpower, and facility loading implications of the suggestion made by the players. As the computer determines the new program new displays are prepared automatically. The third step in the Game completes the cycle: now the players are offered a new set of displays depicting the essential information on NASA programs associated with the suggested new program.

It is visualized that in most situations the first suggested program will result in conditions that are not acceptable to the players of the game. Therefore, after considering the material presented and discussing further implications of the data, a new proposal for reprogramming will be made and a new cycle of the gaming system will be entered upon. By a series of steps it will be possible to develop a reprogramming plan for NASA which will be acceptable.

As a final phase of the Gaming System the equipment will be directed to recompute with greater detail all the implications of the plan accepted. It is expected that this recomputation will not result in any major changes, but it will provide more accurate and detailed plans. Results of these final computations then will form a new program for the NASA effort.

2B. 3b OBJECTIVES OF GAMING TECHNIQUE

The Decision Gaming System to be described here is primarily designed to meet the following four objectives.

Objective 1 - Programming

Develop efficient program plans compatible with resources.

Objective 2 - Reprogramming

Develop efficient program modifications compatible with resources.

Objective 3 - Early Warning System

Indicate automatically when progress deviates from plans.

Objective 4 - Status Report

Provide visibility on the progress of programs and projects.

The Decision Gaming System will also aid executives materially in determining money, manpower, facilities and other requirements associated with the changing needs and missions of NASA.

2B. 3c MAN-MACHINE RELATIONSHIPS

Preparation of a NASA Program requires much human judgment and executive know-how. The Gaming System proposed in this report does not aim to replace human judgment, but it is designed to amplify and strengthen executive capability.

This increased management planning and control capability is achieved by a detailed analysis of the tasks involved in planning and control and by assigning to the computer those routine tasks that it can accomplish more quickly, more accurately and more economically.

It is common knowledge to managers that in order to make decisions a great deal of detailed work must be performed. Past financial records must be examined, various alternatives reviewed and thousands of details attended to. Much of this data is for the purpose of summarization and not for detail presentation for executive decision making. These are precisely the data processing tasks that we must delegate to the computer.

On the other hand, the weighing of various alternatives and selection of the most acceptable plan requires human judgment that cannot be coded and programmed on a computer. These are then the tasks that we assign through the Decision Gaming System to executives.

One further aspect of the NASA Decision Gaming System is worth mentioning here. Some aspects of the NASA programming problem are unsolvable by conventional management techniques, and therefore better and more advanced techniques must be made available. During the last few years great advances have been made in the use of mathematical techniques and models to program problems related to the NASA situation. In order to play the NASA game in the most effective fashion it is necessary to develop a system of mathematical models, describing the NASA programming problem.

With the aid of modern computers and display equipment and using mathematical programming techniques, it is possible to furnish NASA with a Management Decison Gaming system, that will materially aid NASA executives in developing efficient programs.

SECTION III

INTERIM OPERATIONAL CAPABILITY— MANAGEMENT AND PROGRAM CONTROL SYSTEM

3A. SYSTEM DESCRIPTION AND PRELIMINARY ASSESSMENT OF REQUIREMENTS

Design of the IOC-MAPCS for NASA has required development of several basic concepts especially tailored to meet the needs of the NASA situation. This section of the report is devoted to an exposition of these concepts and the manner in which they are integrated to form the IOC-MAPCS. The first subsection is an explanation of the concepts themselves, together with an analysis of the supporting organizational requirements. The second subsection describes the development of planning documents for initial inputs to the IOC-MAPCS. A third subsection outlines the design of a data processing and information system to support the IOC-MAPCS. The final subsection describes in detail the Control Center and display generation and processing system recommended to NASA.

3A. 1 Basic Concepts

3A. 1a TASK AND GOAL NETWORKS

TASK

Analysis of the contracting structure of NASA revealed that NASA contracts follow a distinct pattern that may be characterized as "many-small". That is, NASA projects, particularly in the spacecraft programs, tend to be made up of many small contracts ("small" in general connoting contracts under $1,000,000 in dollar volume) . A notable exception is the prime contract for Project Mercury. Table A illustrates this finding with selected data for fiscal year 1960.

This contracting structure, which we assume will continue to be the pattern within NASA, lends itself ideally to the TAG concept. Within this concept each contract (or separately costed and scheduled elements of contracts) may be identified as a "task". The formal definition employed by the IOC-MAPCS is:

> TASK - A task is defined as a discrete assignment of responsibility and funds for the accomplishment of a specified goal within a specified period of time. A task is an element of a mission, a project, or a program, or of two or three of these classes of activities.

The definition of the task is a key to successful operation of the IOC-MAPCS. It is at the task level that the initial opportunity exists to relate schedules, technical objectives and funds in a rational manner. In the normal course

TABLE A

Contracting Structure of Selected Programs, FY 1960

Source: National Aeronautics and Space Administration Financial Report, May 31, 1960

Selected programs[a]	Excluding misc. contracts under $50,000					$ value of misc. under $50,000
	# contracts	# over $1 mill.	Total $ value	Average $ value	$ value, largest contr.	
Sounding Rockets	23	1	7,150,000	311,000	2,650,000	830,000
Scientific Satellites	40	5	17,390,000	497,000	5,060,000	1,420,000
Lunar and Planetary	15	4	26,370,000	1,758,000	13,880,000	340,000
Meteorology	21	1	6,420,000	306,000	1,430,000	420,000
Communications	9	1	1,730,000	192,000	1,000,000	190,000
Manned Space Flight[b]	25	3	22,570,000	903,000	10,550,000	1,240,000
Vehicle Systems Technology	4	1	3,970,000	992,500	3,750,000	50,000
Solid Rockets	8	1	3,240,000	405,000	2,060,000	330,000
Liquid Rockets	7	4	29,990,000	4,284,000	23,000,000	20,000
Nuclear Systems Technology	14	2	4,600,000	329,000	1,470,000	140,000
Space Power Technology	6	1	2,480,000	413,000	1,060,000	1,620,000
Scout	17	2	7,330,000	431,000	1,650,000	380,000
Delta	8	1	12,280,000	1,535,000	10,440,000	70,000
Supporting activities	17	4	12,640,000	744,000	2,920,000	420,000
Totals	214	31	158,160,000	739,065		7,470,000

Notes: (a) Programs excluded are Vega (cancelled), Centaur, Saturn and Vehicle Procurement. The latter three were brought under direct NASA control with Marshall Space Flight Center at the beginning of FY 61. All other Research and Development programs are included.

(b) Excludes McDonnell contract for $51,640,000.

of events it should be possible to relate tasks directly to contracts, as well.

Note the use of the word "discrete" in the task definition. The implication here is that the task can be separately identified, and is, in fact, a unique element. The goal that is the endpoint of a particular task is the endpoint of that task and no other. The dollars assigned to a task are assigned to that task and no other. And the schedule for a given task relates to that task and no other. The task, then, becomes the basic building block of a mission or project. Later in this section it will be shown how tasks may be divided into logical elements for control purposes. Still later it will be shown how a single task may become an element of more than one project, through the cross-referencing (synonym) capability of the IOC-MAPCS information system.

GOAL

Normally the task will be the lowest level of detail with which NASA top management will be concerned. Under usual circumstances, the end-point of the task, the goal, will represent a significant technical accomplishment. In the IOC-MAPCS, goal is defined as follows:

> GOAL- A goal is defined as the end-point of a task. A goal is considered to have been reached when its accomplishment has been reported by the responsible NASA officer. Goals should be stated in terms that are unambiguous, and should be chosen where possible in such a manner that their accomplishment represents a definable point in time.

The goal, then, is the result of the effort applied in the task, and the dollars and time assigned to the task are objective measurements of this effort. Additionally, when tasks are contractually related, or when a task is related to an assignment of funds to an in-house agency, responsibility for the accomplishment of the goal is also completely defined.

To recapitulate this discussion of task and goal:

(a) A goal, usually representing an intermediate technical objective of a project or mission, is established. Examples: Design and construct a guidance system to control a launch vehicle for a Mars Impact mission. Prepare specifications for instrumentation to measure the density and composition of the Martian atmosphere from within that atmosphere.

(b) The time and dollars estimated to be required for the accomplishment of the goal must be established. This is the first step in development of the task. Examples: The design and construction of the guidance system mentioned above might require eighteen months and cost $500, 000. The instrumentation study might require two years and cost $150, 000.

(c) Once responsibility for accomplishing the goal has been assigned, a task has been created. With the assignment of responsibility go concomitant assignments of time and funds, usually through the medium of a contract.

MAJOR GOAL

For convenience, the concept of goal has been extended in two instances. A major goal is defined as follows:

MAJOR GOAL - A major goal is defined as the representation of a culmination of a group of tasks, as for example the launch of a mission vehicle.

Although any goal may be selected as a major goal, its definition as a culmination of a group of tasks suggests that major goals should be used to represent only the most significant events of a project or mission. In a vehicle program, for example, a major goal might be reached each time a vehicle is launched. A mission, on the other hand, might have only one major goal, that is, launch of the mission vehicle.

The purpose of the major goal is to furnish a point of reference for all subsidiary tasks and goals, and also to serve as a major summary point for project management and analysis. In the IOC-MAPCS information system, major goals are coded in a distinctive manner.

TERMINAL GOAL

A third type of goal is the terminal goal, defined as follows:

TERMINAL GOAL - A terminal goal is defined as the end-point of a mission, project or program. Terminal goals may be major in nature, but more frequently will not be.

The terminal goal is the final event in a project or mission. One reason for making a distinction between major goals and terminal goals is that frequently a mission will culminate in a major goal, i.e., a launch, but if successful the mission will not be completed until all data of immediate importance to the mission has been reduced and analyzed. One test for determining whether or not a goal is a terminal goal might be, "Are there unaccomplished tasks outstanding that were originally part of this mission or project?"

The purpose of the terminal goal is to furnish a reference point for budgetary and other types of planning in which it is necessary to establish definitive end-points for projects.

NETWORK CHARTING

A basic tool for management control made possible through the task and goal concept is the network chart, showing in a graphic manner assignments of responsibility, funds, schedules and interrelationships among tasks and within tasks. In its most complete form the network chart may be used directly by Project Managers and subordinate managers as a day to day record of and check on project progress. Network charts may also be created which show only task summary information or which may show only the relationship of projects within a given program.

Development of the detail network chart begins with the definition of tasks. Consideration of the task by itself may be sufficient detail or even more than sufficient detail at the top management level. At the Project Manager level, however, greater detail is required for effective control. Therefore, the concepts of stage, step, path and link have been developed for use within tasks and a coding system appropriate to the automated information system has been designed.

Reduction of a task into its component stages, steps, paths and links is accomplished through a careful analysis of the task, most usually done in conjunction with the agency responsible for carrying out that task. Ideally, construction of the network for a given task will be done during the negotiation period before a contract for the task is issued. Definitions and explanations of these elements follow:

STAGE

Stages are identifiable points in time. The formal definition:

> STAGE - A stage is defined as a single instant in time at which progress toward a goal can be measured. The name is suggested by the words "steps taken to achieve a goal." A stage is an element of a goal.

On a network chart stages are represented by inverted triangles (See Figure 2) located at appropriate points in time. Associated with each stage is a code number to be explained later, a date representing the planned date for accomplishment of that particular stage and a description which should state concisely and unambiguously the nature of the accomplishment represented by that stage. Only the code number appears on a network chart. The date is represented by the position of the stage with relation to a time scale and the description is carried only in the accompanying documentation.

STEP

Whereas stages are points in time, steps are periods of time accompanied by estimates of funds. The formal definition:

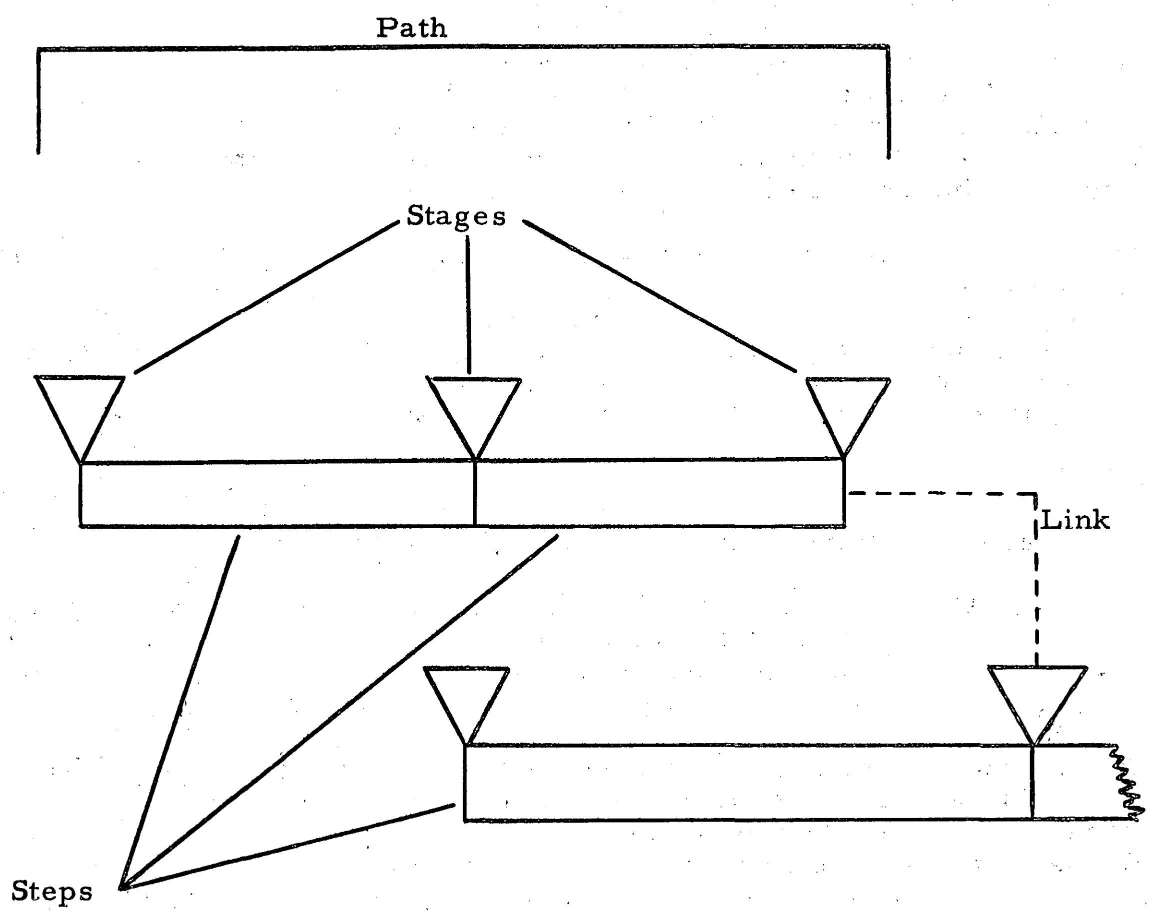

Figure 2. Elements of the Network Chart

STEP - A step is defined as the interval between stages, representing an estimate of the funds and time required to progress from one stage to the next. A step is an element of a task.

A step always begins with a stage, as it must since it is defined as an interval. Similarly a step must end either in a stage or a goal. Associated with each step are a time estimate and an estimate of the dollars required to accomplish the step. A description of the work to be performed during the step is also an integral portion of the information required for each step. As with the description of a stage the description should be stated concisely and unambiguously. The graphic relationship between stages and steps is also shown in Figure 2.

The time estimate associated with each step is given as a planned time stated in standard time units, accompanied by an estimate of the possible variance (plus and minus or tolerance factors) from the plan estimate. Use of the variance factor is discussed in a later section.

PATH

PATH - A path is defined as a completely unique sequence of stages and steps within a given task.

A path(shown on Figure 2 as a sequence of three stages separated by two steps) is a logically ordered sequence of events related by their nature. Paths may proceed in a straight line so long as the funds and schedules involved in the stages and steps do not overlap and as many paths may proceed in parallel during a given task as are required. No infallible rule can be derived to guide planners in making a decision to begin a new path at a specific point. However, in general it will be found convenient to create new paths whenever logically different blocks of activity are encountered. For example, within a hardware task the preliminary design and final design phases might form separate paths or might be combined into a single path depending on whether or not these phases overlap. Most certainly however, design phases would be separated from fabrication by employing separate paths and in all likelihood fabrication of individual components proceeding in parallel but involving different organizational components would be shown as individual paths.

LINKS

LINK - A link is defined as the indication of a precedence relationship between stages of separate paths. No times or funds are associated with links.

On the network chart a link is shown as a dashed line proceeding from one stage to another. Frequently an arrowhead will be included to show the direction of flow and hence the precedence relationship. This is a desirable practice but not necessary, of course, where one stage precedes another in the time scale. Where a link exists it has the meaning that the stage from which the link proceeds must be completed before the stage to which the link proceeds can be completed. Stages may be linked to other stages or to goals. The logical role associated with a link is that if the end point of a path is not the goal of a task then that stage which is the end point of a path must be linked to a stage in another path or to the goal. Links serve not only the purpose of illustrating the interrelationships graphically but are used in the automated system to trace interdependencies within the file of information regarding tasks and projects. It should be noted in this regard that links may extend beyond individual tasks or in fact beyond projects.

SUMMARY

To recapitulate this discussion of stages, steps, paths and links:

1. A stage is an identifiable point in time shown on the network chart as an inverted triangle. Associated with the stage are a code number, a description and a date. A stage is a recognizable event marking measurable progress towards a goal.

2. Stages are separated by steps. Since it is defined as an interval between stages, a step must always begin with a stage. Steps represent not only intervals of time but also amounts of money. Hence estimates of time and dollars, a description and a code number are associated with a step.

3. A path is a unique sequence of stages and steps. A path represents a logical block of activity but is not described apart from the stages and steps that make up the path. The code number that identifies the path is also an integral part of the code number for the stages and steps that make up the path. Hence no separate number is required for the path. A path must terminate in a goal or else the terminal stage of a path must be linked to a stage of another path or to a goal.

4. Links are indications of precedence relationships between stages. A link is indicated on the network chart by a dashed single line and code numbers are associated with links. These will be explained in detail later. Links may join stages within tasks, may join stages of separate tasks or may extend to any other project. No times or funds are associated with links.

5. The network chart, then, is an assemblage of stages, steps, goals and links. The amount of detail included on the network chart and hence the amount of detail included in the planning process depends upon the level of management requiring use of the particular chart and the degree of control that is desired to apply to a given problem. In the IOC-MAPCS management has complete flexibility in determining these factors. Both the network charting technique and the IOC-MAPCS information system are sufficiently flexible to handle the problems at any degree of detail.

THE IOC-MAPCS CODING SYSTEM

In previous discussion it has been implied that the IOC-MAPCS incorporates a coding system by which information contained on the network chart and other information developed during the planning process can be translated into automated form and manipulated readily in accord with modern data processing techniques. It is the purpose of this section to show the derivation of the coding system and to explain it in detail.

At present the research and development activities of the National Aeronautics and Space Administration are organized into broad programs under the direction either of the Office of Launch Vehicle Programs or the Office of Space Flight Programs. The IOC-MAPCS has been designed around this organizational format, but in such a manner that changes in organization can be easily accepted by the system, rather than requiring extensive system changes in response to organizational changes. All coding for the IOC-MAPCS has been chosen in an "arbitrary" manner; that is, the coding system does not depend on any outside logical structure, but is completely integrated and independent of non-system structures. The arbitrary principle in coding systems is an important one, and will be discussed in further detail.

Almost everyone is familiar with derivative coding systems, the opposite of arbitrary coding. In a derivative system, the code designation for an object, place or idea is drawn from the full name of the item or from the nature of the item itself. Abbreviations, for example, form a derivative coding system, as, "AOMC" to designate the Army Ordnance Missile Command, or "NASA", the National Aeronautics and Space Administration. Frequently such coding is convenient and highly mnemonic. Consider the situation, however, in which a derivative code becomes part of a large and complex information handling system. Rarely is it possible to impose a consistent classification structure upon derivative codes, and such a structure is essential in an automated information system. Further, concepts and even names change with time, requiring either a system change or embedment of an anachronism within the system. With an arbitrary system, however, changes can be made at will without either systemic or psychological effect.

An arbitrary system, simply, is one in which the symbols used to code information have no meaning beyond the arbitrary meaning designated by the system for the moment. Thus, in the IOC-MAPCS the letter "E" occuring as the first symbol in a code designation could indicate the Planetary program (This is an example use only; this study makes no recommendations concerning the actual symbols to be used to designate specific programs). Such use would bear no relation to the fact that E is the fifth letter of the English alphabet, that the letter E occurs in the word Planetary, or that planetary objects are Extra-terrestial.

The arbitrary coding system proposed for the IOC-MAPCS is based on the use of a six-group code to represent the most detailed elements of the system. The organization of this code is shown by example in Figure 3.

Prefix	E - Program (Single alphabetic character) 55 - Project (Two decimal digits) S - Section (Single alphabetic character) 01 - Task number (Two decimal digits)
	. - Decimal point (Prefix - Suffix separator)
Suffix	00 - Path number (Two decimal digits) 01 - Stage/step/goal number (Two decimal digits)

Figure 3. IOC-MAPCS Code Breakdown

The elements of this coding structure have the following meanings:

PROGRAM

This letter designates the broadest organizational breakdown within one of the major organizational units of NASA. Eamples of current programs are Sounding Rockets, Satellite Applications, Vehicle Development, Space Power Technology, etc. In its current form the system allows for simultaneous operation of up to twenty-six such broad programs. If more programs are instituted, double letters may be substituted for the single letter designations.[9]

PROJECT

A project is the next largest organizational element within a program. Examples of projects are the Orbiting Astonomical Observatory (S-18), Lunar Spacecraft Test (P-32), Echo II, Centaur Vehicle No. 1, etc. The coding structure provides for arbitrary serial numbering of projects within programs, and allows for up to 99 projects (or 100, if the number 00 is used) within a single program. A summarized list of NASA projects (as of June, 1960) is given in Section 3A. 3b.[10]

SECTION

Frequently projects will be so organized that while project management will the responsibility of a single individual, a portion of the project will be under the direct control of another person, located perhaps at another field center. In such a case project management responsibility will be coordinative for those portions of the project, and direct for the remainder. It will frequently be found convenient, therefore, to divide the project into sections. A typical space probe launch mission, for example, might be divided into the spacecraft (S), vehicle (V), launch

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9. It is recommended that the letter designations I, O, and Q be avoided in any case. These letters are susceptible to ambiguous interpretation. If the number of program exceeds twenty-three double letters should be adopted.

10. Figure 27, page 91.

facilities (F) and ground support (G) sections. Although the letter designations chosen here are mnemonic, they need not be and therefore do not violate the stricture against derivative coding. There is no general rule for establishment of sections, but it will be found convenient to divide projects into sections along organizational and functional ines, for the most part. The section designation must be present, it should be noted, even in projects which are not divided. In such cases the section and the project will simply be congruent.

TASK

Tasks are numbered serially within sections. The coding structure allows for up to 99 (or 100, if task number 00 is used) tasks within a single section.

The portions of the code thus far described constitute the prefix portion of the coding system, and are so labelled in Figure 3. Figure 4 further illustrates these concepts as they relate to one another. It should be noted that the code for each element incorporates the code of the preceding elements. In other words, a particular task will always be referred to as "E55S01", and not simply "01" or "S01". Similarly, a given project should always bear the program designator; it is "E55" and not just "55". Exceptions to this rule may be made where there is no opportunity for confusion, as, for example, on a clearly labelled network chart, where the program and project numbers may be omitted on details of the network for sake of brevity.

The prefix portion of the code and the suffix portion are separated by a decimal point, primarily for convenience in reading.

The suffix portion of the code refers to sub task elements. The suffix consists of four (or five, as later explained) decimal digits that identify path and stage, step or goal.

PATH

The leftmost two digits of the suffix identify path. Path numbering begins with 00 and extends through 99, allowing for up to 100 separate paths within a single task. The order in which paths are numbered is not material, although in general it will be found convenient to apply path numbers in ascending order by starting date (date of initial stage), with the earliest beginning path given the lowest number. Figure 5 demonstrates this principle, and also illustrates the path number concept.

STAGE-STEP-GOAL

The remaining two (or three) digits of the suffix identify the stage, step or goal. On the original network chart numbering of stages and steps always begins with the designation 01 for the initial stage of a path and proceeds by increments of one along the path, with steps and stages being numbered as encountered. By this scheme stages will always

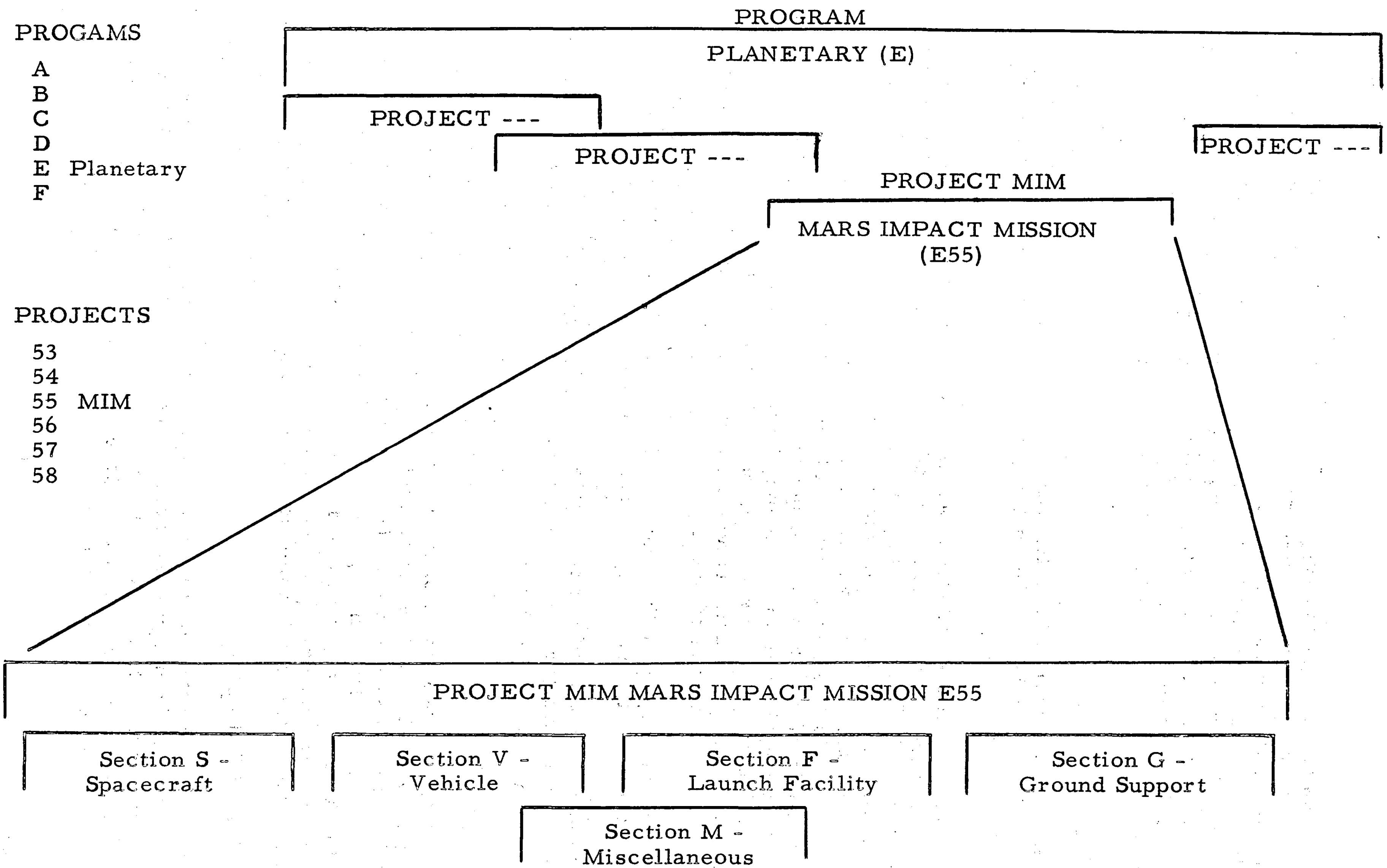


Figure 4. Project Coding Example

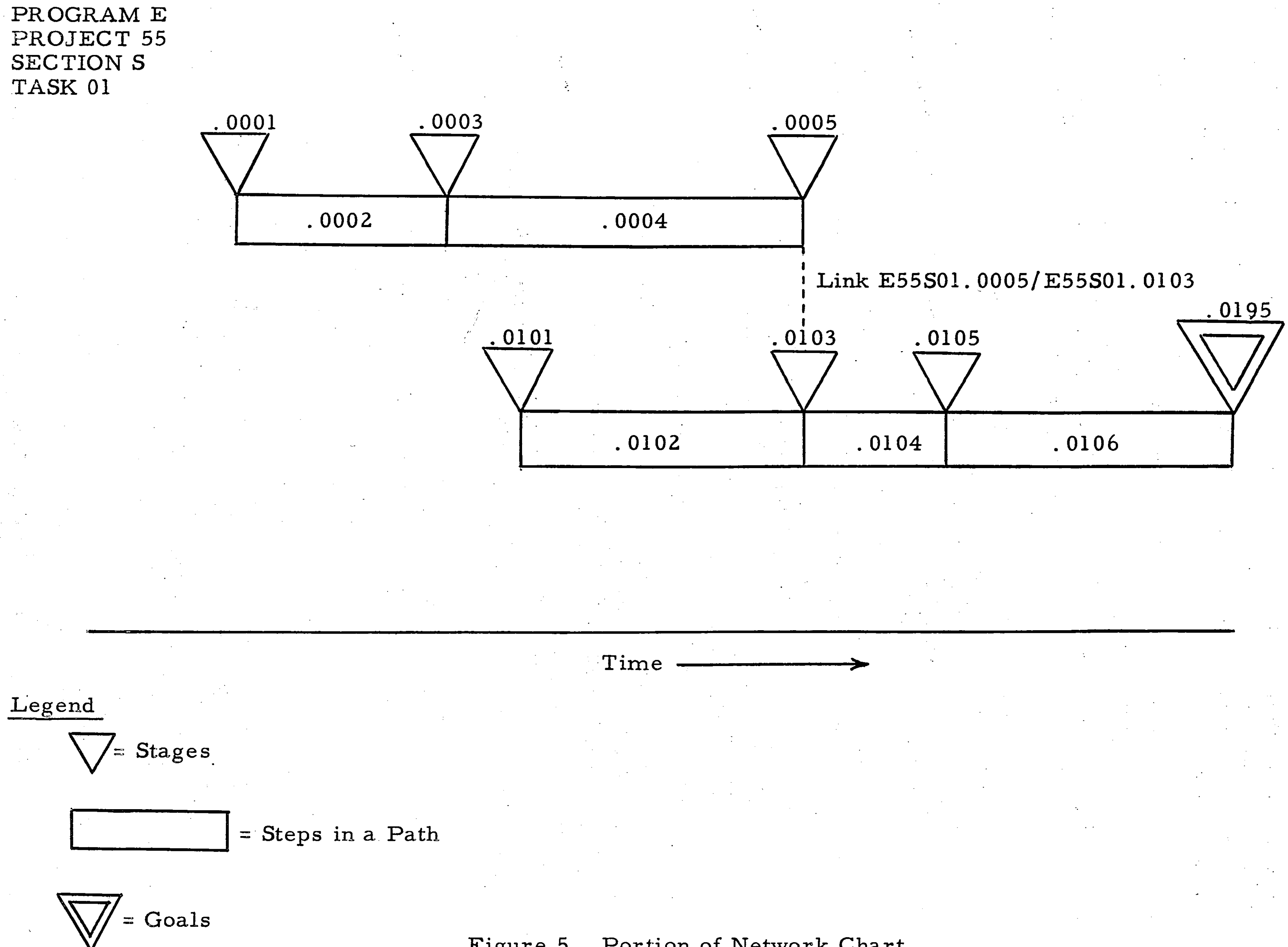


Figure 5. Portion of Network Chart

receive odd numbers and steps will receive even numbers. No break in the continuity of a path is permitted; if the situation appears to indicate that a step should be omitted from a path, then the next stage should begin a new path.

The coding rules for stages, steps and goals are as follows: (See Figure 5 for Example)

1. Numbering within a path begins with the initial stage numbered 01 and proceeds consecutively along the path from left to right.

2. Stages will always have an odd digit in the fourth position to the right of the decimal point.

3. Steps will always have an even digit in the fourth position to the right of the decimal point.

4. Task goals are always identified by the number of the path in which they occur and the digits "95" in the stage - step - goal positions.

5. Major goals are always identified by the digits "97" in the stage - step - goal positions.

6. Terminal goals are always identified by the digits "99" in the stage - step - goal positions.

7. Links are not separately coded. The link code is an ordered pair of stage codes, the code of the stage (or goal) <u>from</u> which the link proceeds appearing first.

SYMBOL CONVENTIONS

Symbol conventions for network charts are illustrated in Figure 6.

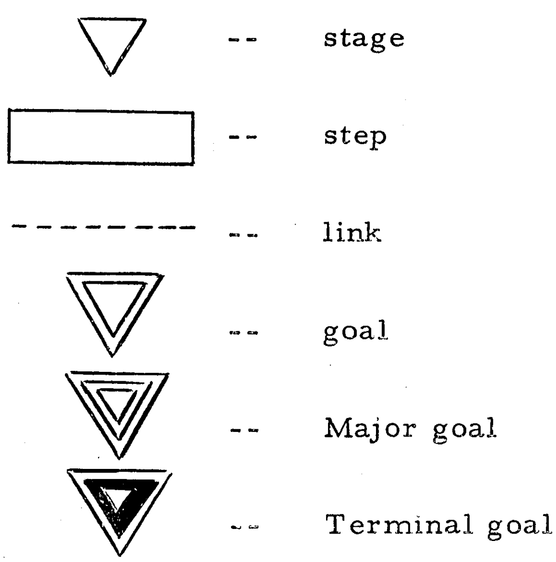


Figure 6. Network Chart Symbols

OTHER RULES FOR NETWORK CONSTRUCTION

(See Figure 7 for illustrations of these rules)

1. All paths of a task should be grouped within a single vertical span of the chart.

2. Conversely, the vertical span encompassing all paths of a given task should not contain any paths of another task. In other words, tasks should not overlap on the vertical scale. The vertical separation between tasks may be indicated by an appropriately drawn dashed or dotted horizontal line. The background of different tasks may be shaded in different colors where desired.

3. The horizontal dimension of the network chart is a time base and may be drawn to any appropriate scale. Dashed or dotted vertical lines may be used to indicate points in time (e.g., beginning of fiscal year, starting point of each quarter, etc.)

4. Points on the timebase should be labelled clearly.

5. Titling and marginal information:

   a. All charts should be appropriately titled. At minimum, titling information should include:

      (1) Program designation and code.
      (2) Project designation and code.
      (3) Legend showing the meaning of all symbols used on the chart.
      (4) Identification (name and location) of originating authority.
      (5) Identification (name, position and location) of approving authority.
      (6) Date of origin or revision.

   b. Marginal information for each task might include:

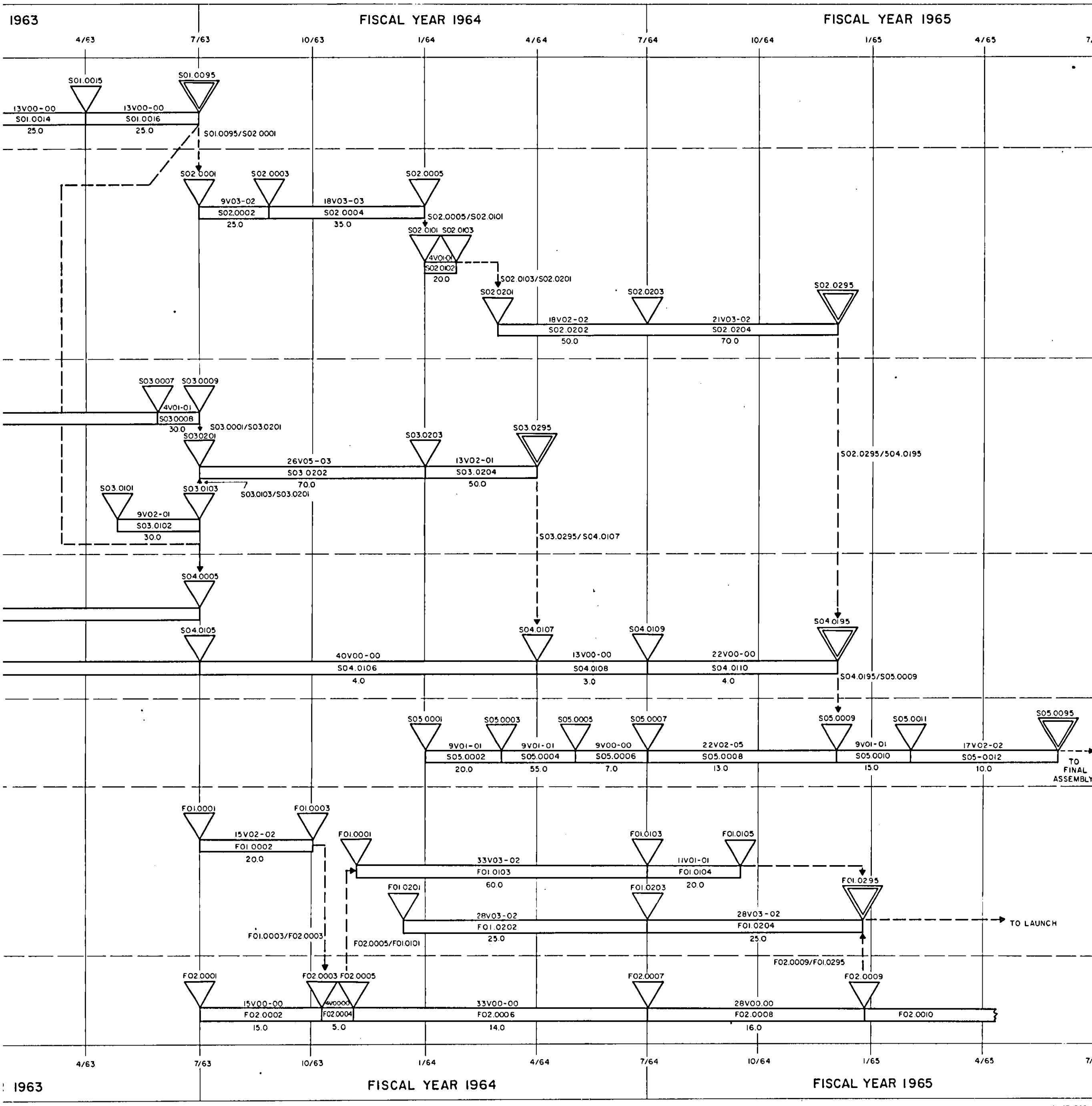
      (1) Section name
      (2) Responsible field center
      (3) Contract number
      (4) Contractor name
      (5) Any other appropriate information, e.g., name of responsible NASA monitor.

6. Steps, stages, goals and links are labelled on the network chart as follows:

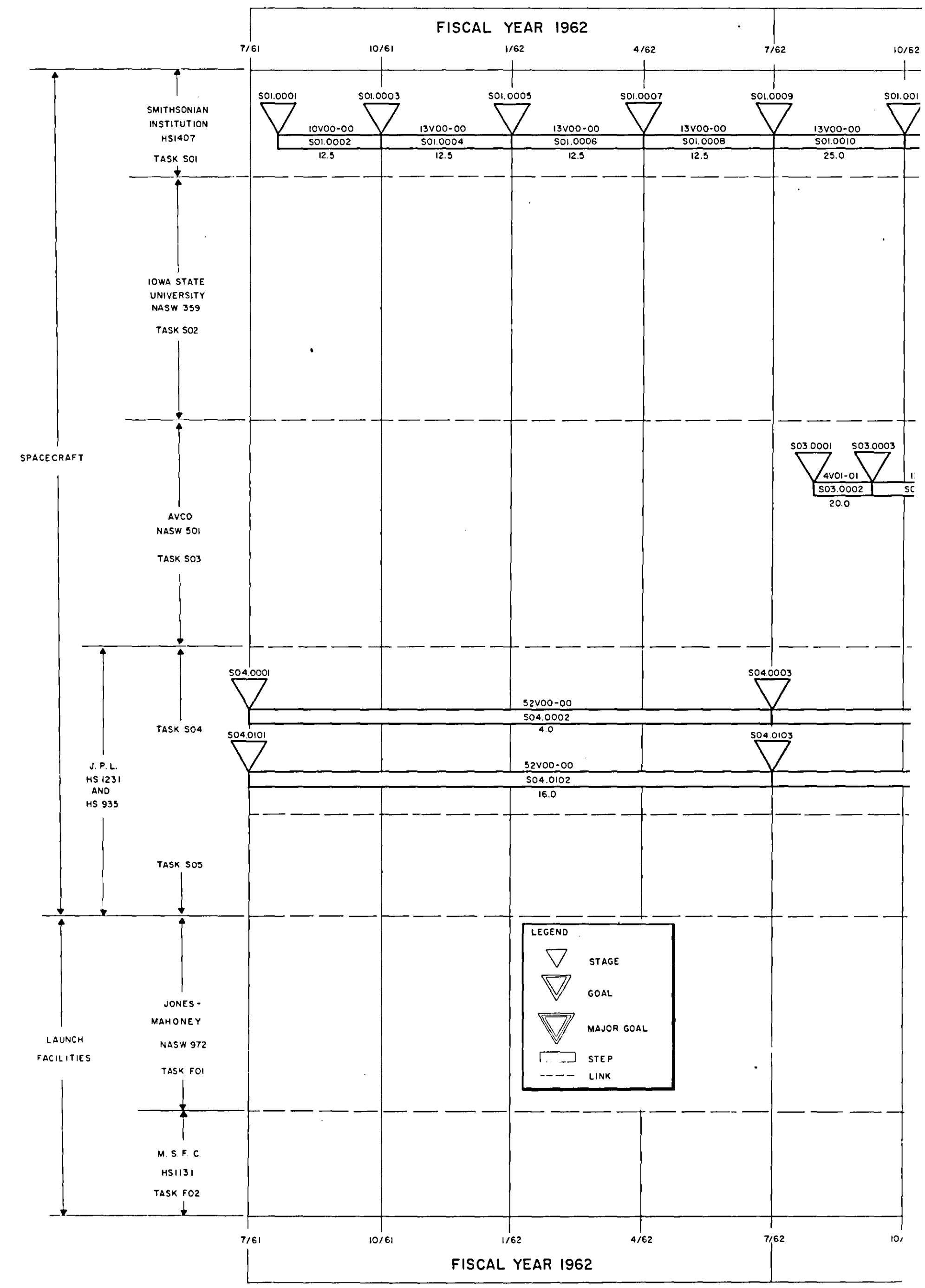
   a. Stages and goals are labelled with the code number <u>only</u>.

   b. Steps are labelled by code number within the hollow bar symbol, by the time estimate in weeks (another unit might be chosen) above the hollow bar, and the dollar estimate below the hollow bar, as shown in Figure 8.

IM PLAN E-55 (PARTIAL)



Project MIM, Partial Network


FISCAL YEAR 1962
7/61
10/61
1/62
4/62
7/62
10/62
SPACECRAFT
SMITHSONIAN INSTITUTION HS1407
TASK S01
S01.0001
S01.0003
S01.0005
S01.0007
S01.0009
S01.001
10V00-00
S01.0002
12.5
13V00-00
S01.0004
12.5
13V00-00
S01.0006
12.5
13V00-00
S01.0008
12.5
13V00-00
S01.0010
25.0
IOWA STATE UNIVERSITY NASW 359
TASK S02
AVCO NASW 501
TASK S03
S03.0001
S03.0003
4V01-01
S03.0002
20.0
J. P. L. HS 1231 AND HS 935
TASK S04
S04.0001
S04.0003
52V00-00
S04.0002
4.0
S04.0101
S04.0103
52V00-00
S04.0102
16.0
TASK S05
LAUNCH FACILITIES
JONES-MAHONEY NASW 972
TASK F01
M. S. F. C. HS1131
TASK F02
LEGEND
STAGE
GOAL
MAJOR GOAL
STEP
LINK
FISCAL YEAR 1962

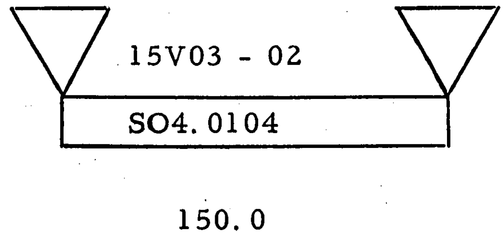


Figure 8. Step Labelling

The time estimate associated with the step includes a variance estimate. In the example above, the estimated length of time for completion of the step is 15 weeks. The numbers following the V are tolerance estimates; completion of this step may require as long as 18 weeks, or may take only 13 weeks. In general terms the expression

$$N_o \text{ V } N_1 - N_2$$

may be translated as "the step will most likely require N_o time for completion, but it may be done in as little as $N_o - N_2$ time or it may require as long as $N_o + N_1$ for completion".

Dollar estimates could be shown similarly, if required.

PLAN REVISIONS

It is unrealistic to assume that an initial version of any plan will survive unchanged. Both the network chart and the information processing system resulting from the task and goal concept have been designed to provide a maximum of flexibility in accepting changes to plans.

Four basic methods are provided for revising plans:

1. Changes that do not require alteration of the basis network outline. Revisions in definitions of stages, steps, or goals may be made at any time in the information system without affecting the network chart. Revisions in the dollar amounts or tolerances associated with steps may similarly be made at any time, but should be made on the network chart at the same time such changes are entered into the information system. Changes of this type will be reflected in periodic reports and in change notices generated by the information system.

2. Insertion of additional paths. Because of the flexibility of the link concept new paths may be added to a task network at any time without further change of the original task network, by simple addition of links and the new path. Because path numbering is arbitrary, old

paths do not have to be renumbered when new paths are added. Uniqueness of link coding is assured by its nature.

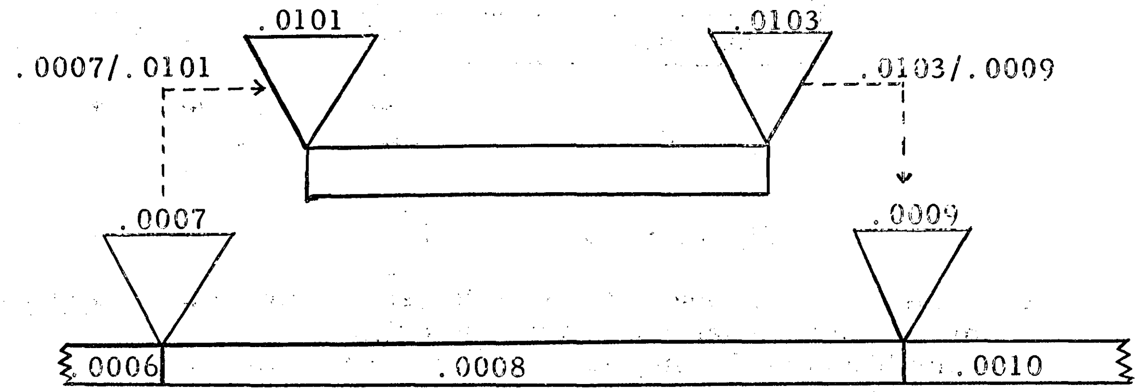


Figure 9. Insertion by Path Linkage

3. Insertion of additional stages and steps. A method is provided in the information system for insertion of additional stages and steps between existing stages. To illustrate the method, assume two stages 0.0005 and 0.0007 and the intervening step, 0.0006. The method is based on addition of a fifth digit to the code for the stages and steps to be inserted. The original situation is shown in Figure 10.

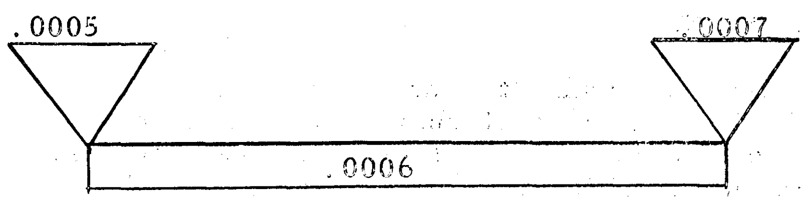


Figure 10. Stage Insertion, Before

Now add a stage between 0.0005 and 0.0007. By definition, this requires division of step 0.0006 into two steps. The rule for addition states that each addition should be identified by a digit chosen from the set 1, 2, 3, ... 7 in such a manner that the digit chosen is 1/2 the difference between the preceding and succeeding digits. For example, insertion of a stage between 0.0005 and 0.0007 would result in the situation shown in Figure 11.

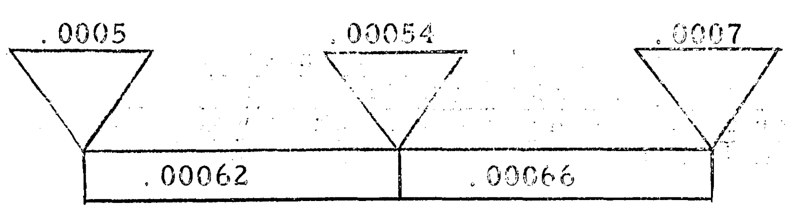


Figure 11. Stage Insertion, After

Addition of the fifth digit does not affect the odd/even identification of stages and steps, since the fourth (and identifying) digit remains unchanged. The scheme suggested allows for insertion of up to sixteen stages and steps between existing stage pairs.

4. Deletion of existing elements. Any stage, step, goal, path or task may be deleted from the plan without prejudice to the system. Within a task, the system requires only that the code number suffix for a stage or step be numerically larger than the code number suffix for the preceding step or stage. For example, assume that in the diagram below it is desired to eliminate stage 0.0007 without changing stages 0.0005 or 0.0009. The suggested procedure is to combine steps 0.0006 and 0.0008 under either number (in most cases the lower number would be chosen), as illustrated in Figure 12

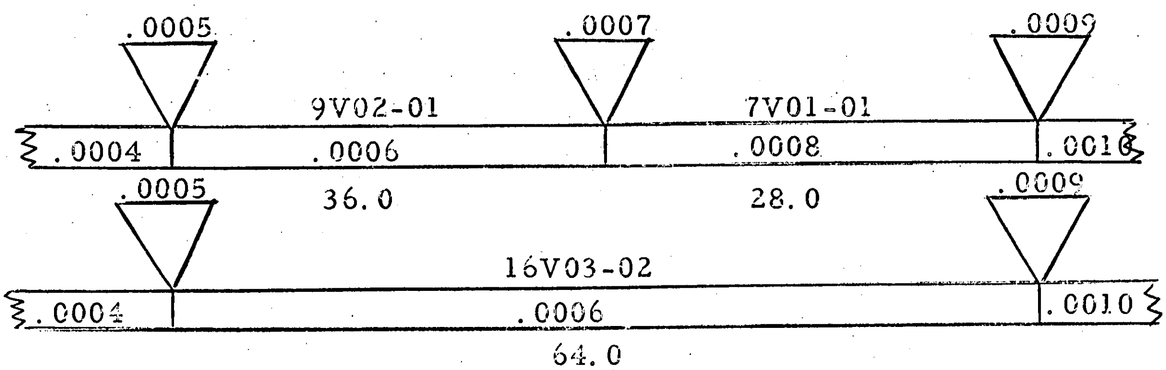


Figure 12. Step Elimination

Elimination of a path or task simply involves erasure of that path or task from the network chart and from the data file, with erasure of corresponding links in remaining paths and/or tasks.

SYNONYMS

To permit manual and automatic interrelation of projects the prefix portion of a task code relating to one project may be established as a synonym for the prefix of another project code. The processing system will carry a synonym table for each project, in which will be shown the prefix synonyms for each project task that is under the direct management control of a different project manager. The table also will show the prefix synonyms of tasks under the direct control of that project which are of concern to the manager of another project.

The primary purpose of the synonym table is to show routing of information copies of system reports. Assume, for example, the existence of two projects, E55 and N34, which are related in that task N34V01 involves production of a launch vehicle for use in project E55. In the initial planning for E55 this task was given the code number E55V02. Then the prefix codes N34V01 and E55V02 are said to be synonyms. In the synonym table for project E55 would be found the entry

N34V01/E55V02

indicating that reports for E55V02 are to come from project N34. The identical entry in the file for project N34 will indicate that N34V01 reports are to be sent to Project E55. The synonym table can be expanded to include name and address of the project manager who is to receive the reports, if desired.

USES OF NETWORK CHARTS

The network chart is an integral part of the detail planning procedure. The primary purpose of the detail project network chart is twofold:

a. To impose a systematic and logical discipline upon the organization and planning of tasks.

b. To provide a graphic display of the organization of effort and of the interrelationships between elements of tasks and among tasks.

The detail task network chart is a working tool of project management. The project manager of his staff should be responsible for initial layout, reproduction and distribution of the network chart for tasks under his direct control, and should be responsible as well for making revisions and distributing revised charts as required.

Higher levels of management, such as field center directors, program chiefs and program directors, will want to have detail network charts available, but in all likelihood will not regard these detail charts as working tools. For these and higher levels of management summary network charts can be prepared, showing only tasks or projects, without inclusion of sub-task or sub-project detail. Various types of display formats for top management use might be based upon such networks, utilizing either an overlay principle or the method of filling in the hollow bars of steps and triangles of stages to indicate completion. Color might also be used to emphasize significant factors, to separate portions of network charts, or to outline completion rates.

The range of possibilities for use of network charts is so broad that no attempt has been made in this initial study phase to list them exhaustively. It is the conclusion of the Ramo-Wooldridge study, however, that this technique for approaching management control can be of great significance to NASA.

3A.1b Project-Oriented Staffing

Assignment of responsibility for the accomplishment of specific objectives is a fundamental principle of management control. The manner in which this fundamental principle has been built into the Task and Goal concept has already been described; in fact, it will be recalled that the definition of the term "task" itself incorporates this principle.

For effective control and for logical consistency the principle must be extended beyond the Task and Goal concept. Tasks, and the assignment of responsibility for tasks, include only those aspects of projects concerned with the immediate objectives of research, design, production and operation of space programs. The project-oriented staffing concept relates directly to internal NASA management of tese efforts.

The NASA project-oriented staffing concept states that every project manager and higher official of NASA who is involved with one or more projects should be provided with a clear picture of the organizational relationships bearing upon that project. This is especially important in cases where direct responsibilities for a project are divided among two or more field centers.

Figure 13 illustrates the project-oriented staffing concept as applied to a hypothetical example, Project MIM, in which direct responsibilities are shared between JPL and Marshall Space Flight Center.

Under the project-oriented staffing concept it is the intent that existing organizational relationships would be stated and charted for each project. It is not the intent that new organizational elements should necessarily be created or that any presently existing units should be disbanded.

The organizational charts produced under the project-oriented staffing concept should reflect all project responsibilities and should be widely-distributed. Preparation and distribution of the charts should be the responsibility of the program chiefs. Information derived from the project-oriented staffing charts may be entered into the information system for retrieval as appropriate.

3A.1c DATA RESERVOIRS

A management control system can be only as effective as its "intelligence" arm permits it to be, in the last analysis. The Intelligence portion of the NASA IOC-MAPCS has been described in this report heretofore simply as the information system, an all-inclusive term intended to apply to the functions of collection, processing, storage and dissemination of management control information.

Other sections of this report deal specifically with the collection and dissemination functions. It is the purpose of this section to describe the conceptual foundation of the portions of the system designed for information processing and storage.

The basic concept involved in the NASA information processing and storage system has been designated the "Reservoir" concept. This concept projects the establishment of single, integrated management control data reservoirs at each major NASA field center and at Goddard Space Flight Center for NASA Headquarters. Each reservoir would contain all pertinent information required for management control purposes for those projects whose direct control falls within the purview of the particular field center.

PROJECT STAFFING

MISSION : IMPACT SHOT TO MARS
PROJECT: MIM (MARS IMPACT MISSION)

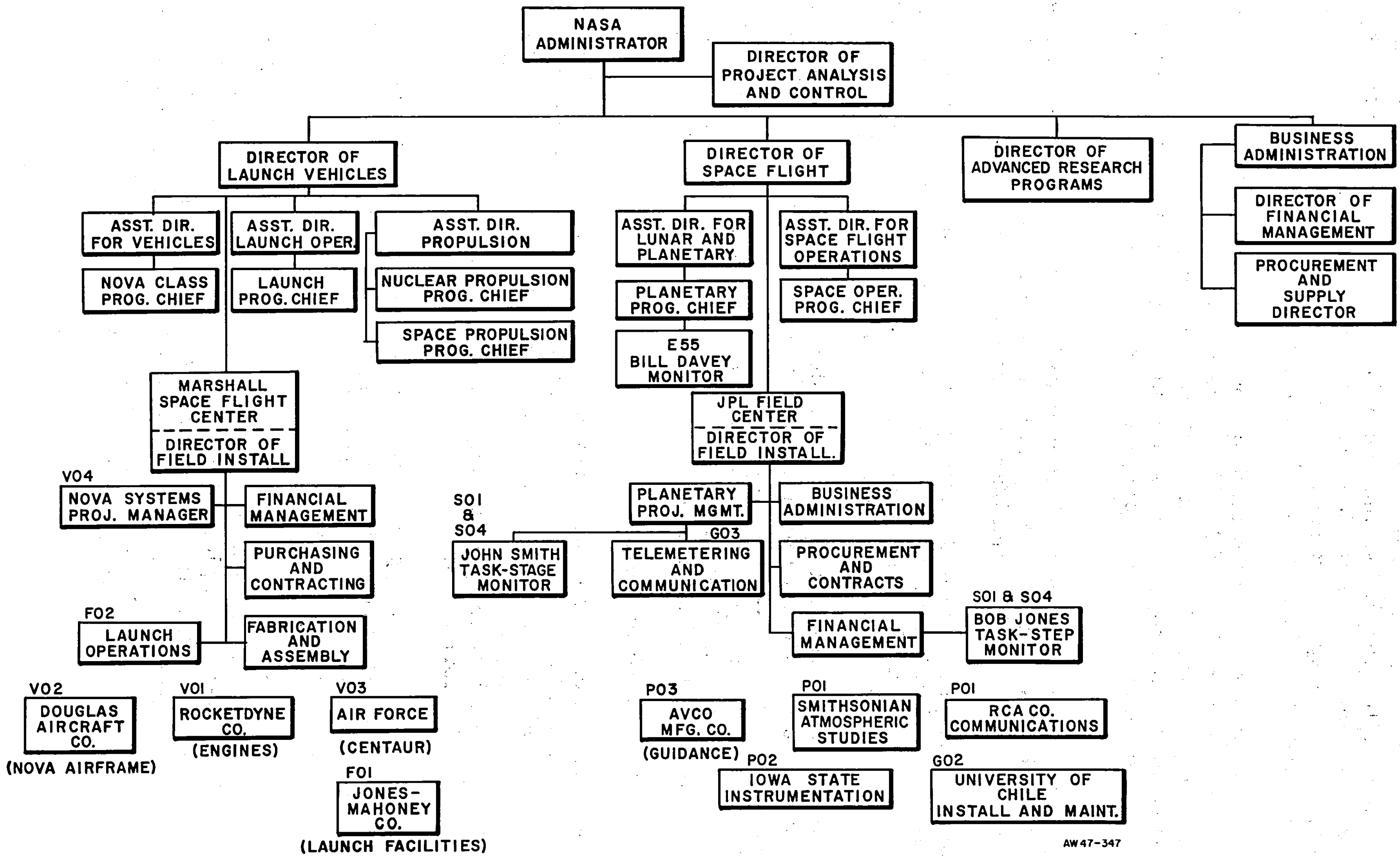


Figure 13. Project Staffing

The Headquarters reservoir would contain summary level information for all NASA projects covered by the IOC-MAPCS. Direct communications would be established between the field center reservoirs ("sub-reservoirs") and the Headquarters reservoir.

Other sections of this report discuss the physical makeup of reservoirs in detail. In general, the reservoir concept calls for an organizational pattern illustrated in Figure 14 for the hypothetical Project MIM. Within the field center the reservoir should be under the management of the Director of Business Administration, and similarly for the Headquarters reservoir, since the reservoir is essentially a management service.

Each reservoir would maintain its files of data in a uniform manner, described in a later section. This integrated file concept has several important advantages in the NASA situation:

> All information relative to a given project can be maintained in and retrieved from a single file, offering the advantage of a single source from which all information is available.
>
> Uniformity of file structure throughout NASA offers important savings in programming costs, particuarly since the same type of data processing equipment is available at all field centers and for the Headquarters reservoir. Further, such uniformity greatly simplifies inter-reservoir communication.
>
> The integrated file structure allows specification of various types of special reports at any time, without the necessity of considering whether or not the information required is available. (It is assumed that the reservoirs will contain all pertinent information).
>
> Updating and revising files requires access only to two files throughout NASA, the field center reservoir and the central reservoir. With access to all data in a central reservoir the tendency of subordinate managers to build partial files of redundant information should be discouraged. Further, all managers will be working with the same set of facts relating to a given problem.
>
> Maintenance of files by use of high-speed data processing equipment helps insure both timeliness and accuracy of available information. File maintenance runs can be scheduled as often as necessary to insure that these factors are given proper weight.
>
> As shown in a later section, the reservoir system can be so designed as to assure that only those persons authorized to do so may have access to any given file.

As outlined in this section the reservoir concept can be implemented by NASA utilizing existing equipment. Figure 15 shows the presence of IBM 7090 data processing machines at the three major field centers

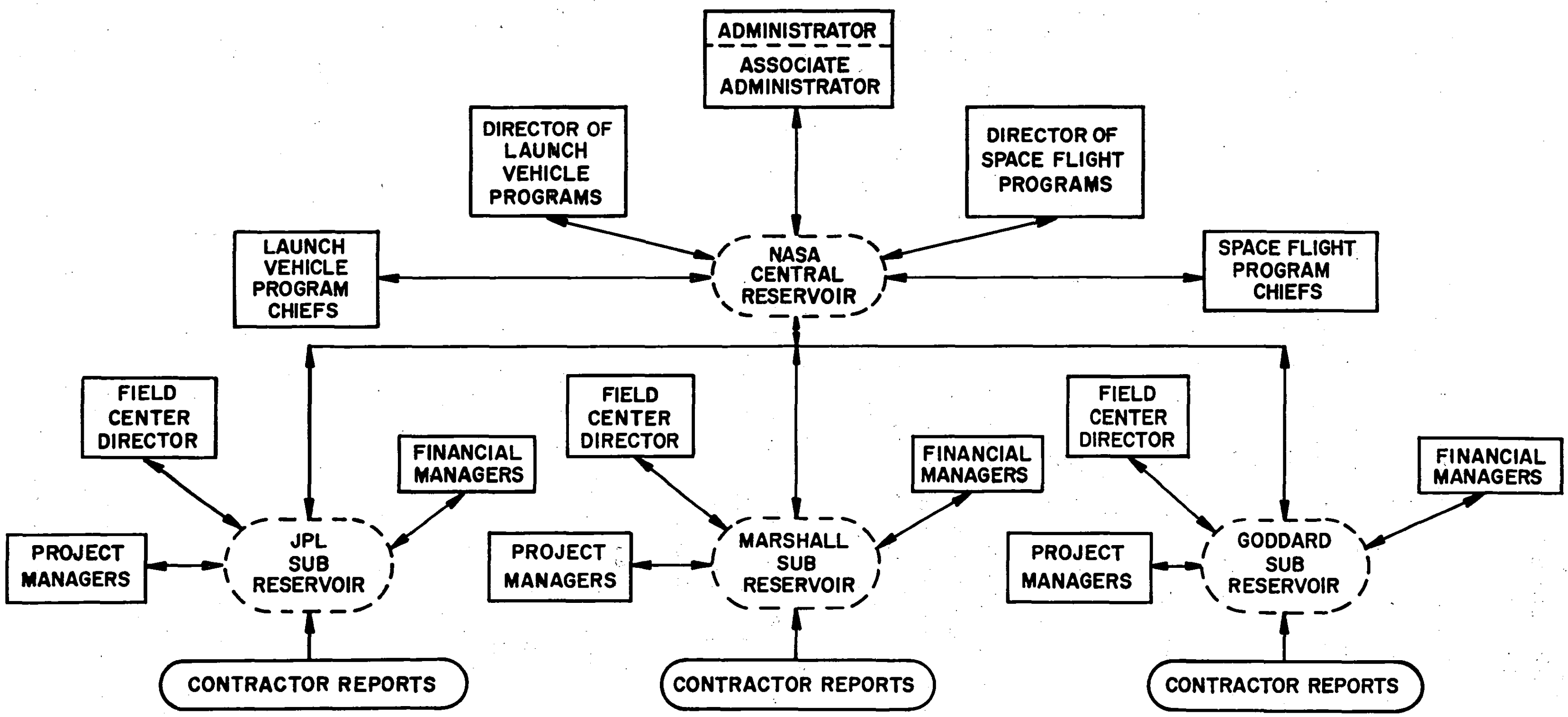


Figure 14. NASA Reservoir Concept

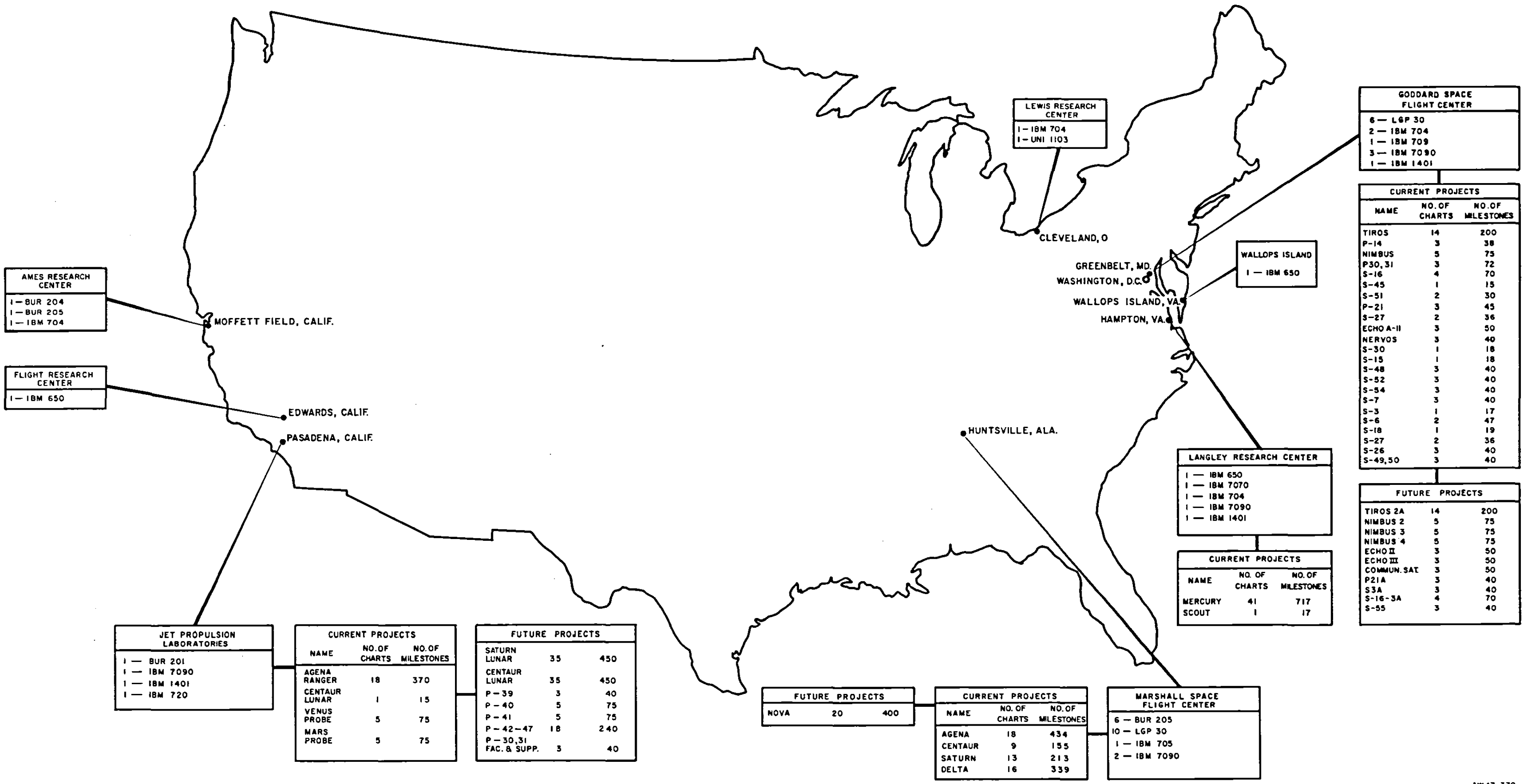


Figure 15. Available Computers and Current Projects

concerned with research and development projects, Goddard, Marshall and Jet Propulsion Laboratory. Further, it is our belief that the equipment at Goddard is sufficiently close to NASA Headquarters to be able to serve effectively as the processing machine for the Central Reservoir.

Not only are 7090's available in strategic locations, but their speed and flexibility suit them admirably for the data processing task involved in the reservoir concept. A later section of this report develops the parameters of this problem more fully. There is still another important factor, and that is the availability of a set of computer programs, known as "9PAC", specifically designed for file maintenance, report generation and sorting, for the 7090. Ability to adapt the reservoir files to the 9PAC system could mean savings of thousands of dollars in programming costs.

3A. 1d EARLY WARNING

A major objective of the NASA IOC-MAPCS is to provide early warning of situations that are potential management problems. This early warning concept has been reflected both in the basic philosophy of the system—to provide timely, accurate and meaningful management control information—and in specific features of the system's construction. These specific features of the system designed to provide early warning are detailed below.

> Positive reporting from the source. The IOC-MAPCS requires affirmative reports from each contractor concerning both technical progress and financial status for each reporting cycle. (A later section specified these cycles). This fact does not mean that the IOC-MAPCS denies the principle of exception reporting. However, for reasons set forth in the next section, exception reporting is not in general applicable to contractors. Positive timely reporting from the source establishes confidence in management control reports, and, equally important, firmly fixes responsibility for the accuracy of currently available information and avoids the ambiguity of "no report".

> Simplified report structure. Contractor reports for the IOC-MAPCS have been simplified as greatly as possible in order to encourage compliance with reporting disciplines and to hold the volume of information processed to a reasonable level while including all essential data. The aim is timely reporting and speedy processing, consistent with provision of all necessary information.

> Fully automated data processing. NASA has the opportunity to employ the most modern electronic data processing equipment in the IOC-MAPCS at relatively small incremental cost. These devices offer maximum speed and accuracy in processing at reasonable cost.

Reporting structures geared to plans. With a reporting structure geared directly to planning structures, meaningful direct comparisons of reports and plans can be made. The IOC-MAPCS has been designed with this capability firmly in mind as a sound basis for early warning.

Requirement of estimates from the sources. The IOC-MAPCS requires each contractor report to affirm an existing estimate or to provide a new one, both for time and dollars. Deviations from plans are thus signalled from the source.

Outstanding flexibility in processing. The IOC-MAPCS information processing system, based on the use of electronic data processing equipment, possesses tremendous logical power and flexibility. More and more meaningful comparisons of results and estimates against plans can be made than can be done in either a manual (because of data volumes) or a punched card (because of lack of flexibility) system.

System design to fit the early warning requirement. The "end-product" elements of the IOC-MAPCS have been designed specifically to emphasize the early warning capability. This is particularly evident in forms design, where every effort has been made to provide management control information in formats that facilitate management use. Graphic analytical reports for all management levels further emphasize this aspect of the system.

No system can outguess the future. An information system that provides management with early warning of deviations from plans, however, can assist management to apply effective controls.

3A.1e EXCEPTION REPORTING

Where applicable, the IOC-MAPCS incorporates the principle of exception reporting as a basic system concept. Simply stated, the concept of exception reporting is that "no news is good news." Only significant deviations from plans are reported to management under this scheme.

Successful operation of management by exception imposes several requirements upon an organization.

Subordinate managers must have a clear understanding of the plan to be carried out.

Delegations of management authority must be clear and unambiguous.

The circumstances under which exception reports are to be made must be thoroughly understood by subordinate and higher echelon managers alike, in order to avoid recriminations of either type: "Why bother to report this?" or "Why wasn't I told that?"

Higher level management must have assurance that failure to report is not due to lack of information.

Higher level management must have the ability to hold subordinates completely responsible for failure to report in exceptional cases.

It is the contention of this study that these requirements can be enforced only within a single organization, where the degree of control by higher level managers over subordinates is sufficient to insure compliance. Specifically, the exception reporting principle is not applicable to the relationship between NASA and a contractor, since the requirements stated above obviously cannot be met. For this reason the IOC-MAPCS specifies affirmative periodic reports from contractors.

Within NASA, however, increasing levels of summarization as information proceeds upward in the organization constitutes a form of exception reporting. The principle adhered to throughout the system is that so long as the overall picture is within predetermined bounds, and so long as no special problems requiring high level management attention exist, reports will be confined to broad summaries. Detail information will be reported to top management only when such information reflects a problem of sufficient magnitude as to require top management attention.

No attempt beyond the statement of general principles has been made in this study to spell out in absolute terms the level of detail information appropriate to a given level of management within NASA. Such specification can only be made after a detailed systems analysis which takes into account the requirements of individual managers. In its basic design, however, the IOC-MAPCS is flexible enough to respond to any reasonable requirement of this nature.

3A. 2 Development of Planning Documents

3A. 2a SPECIFICATIONS FOR ORIGINATING AND INTRODUCING PLANNING DOCUMENTS INTO INFORMATION SYSTEM

At the time an idea is conceived for a development project, it will be the responsibility of the Field Center Director to prepare and submit a "NASA Development Plan" for approval.[11] A development project is a spacecraft, space probe, launch vehicle or Advanced Development project, the responsibility for which falls under the jurisdiction of the National Aeronautics and Space Administration. The primary purpose of a Development Plan is to secure the approval of the Administrator on new projects, to secure approval for major revisions to plans

11. The development plan set forth herein follows the outline of the development plan proposal cited earlier.

previously approved, and to apprise management of the objectives, responsibilities, necessary resources and required scheduling milestones to effectively manage the project to accomplish the desired result. The secondary purpose of the Development Plan will be to notify the Program Planning and Evaluation Group that detailed planning efforts on the subject project will be necessary as soon as required approvals are obtained. In the preparation of the development plan, the following information will be required:

Name of project (or mission, if it is the desire of management to establish a control plan on this type of activity).

Objectives of the project which, in narrative form, describe the purpose of the project, number of shots to be made, and broad parameters of effort which will be required as far as Field Center activity and out-of-house contractor activity. Also included should be a justification of the project indicating why it is necessary and how it will fit into the National space effort.

Responsibilities, including Field Center, Headquarters organization (Space Flight or Launch Vehicle) and names of the Project Manager and Program Chief.

Major project elements, indicating Field Center or Contractor having responsibility for performance of each element. For example, elements might be spacecraft structure, telemetry system, television system, and vehicle.

Funding requirements. This would involve the estimated porjection of dollars required for the accomplishment of the mission by fiscal year, broken down by Research and Development funds, salaries and expenses funds (by Field Center) and construction and equipment funds.

Action by Program Director and by Administrator. Field Center Directors submit the plan to the appropriate Headquarters Program Director who, following his approval, forwards it to the Associate Administrator who in turn routes it to the Administrator.

Development Plans are required whenever a new project is proposed; whenever a major revision is proposed to a previously approved plan, or whenever changes are necessary to conform the proposed plan to the conditions specified by the Administrator's approval.

After approval of the plan by the Administrator, it will be the function of the Program Planning and Analysis Staff to develop the detailed planning which will be required to effectively manage and control the progress of the project or mission. This detailed planning effort will be done, by necessity, through coordination of members of the project team at the Field Center level which has primary responsibility for the project, with

Field Center Directors, Program Chiefs and Program Directors at the Headquarters level. Before a plan can be implemented and control established it must have the approval of and be meaningful to all levels of management who will be in a position to evercise control over the project. Also since valid control over the project will be in direct proportion to the validity of the original plan and the establishment of realistic "yardsticks" of measurement, it is imperative that all levels of project management, including working levels, be consulted and be actively involved in formulating the initial plan.

The first step in documenting the plan is to establish the project staffing. (Figure 13) This will consist of an organization chart designation the offices responsible for the activities of the project. Beginning with the lowest level and working up, the first groupins will be the major contractors, indicating the name of each contractor and the task he will be performing. These will be grouped in such a manner as to fall beneath the activity of NASA which will have the overall responsibility of their efforts, such as the Office of Launch Vehicles or Office of Space Flight. The next level will be the particular office of the field center having direct supervision of the contractor's activities. These boxes will indicate the name of the organization (Planetary, Satellite Applications, Nova vehicles, etc.) and the name of the Project Manager responsible. Also included would be Offices of Financial Management and Procurement and Contracts since people in these areas would be directly involved in project management activities. Above these would be Field Center Directors leading directly to either Director of Launch Vehicles or Director of Space Flight at Headquarters. Also, at Headquarters, the responsible Program Chief office will be indicated as will the person from this office having primary responsibility. Also included will be Business Adminstration Offices at Headquarters having an interest in the progress of a project, such as Financial Manager and Procurement Offices. At the top of the chart, of course, will be the NASA Administrator and Associate Administrator. The basic purpose of the Project Staffing chart is to fix responsibility at the commencement of a project to insure the effective accomplishment of the mission, and to establish control points at the proper levels of management so that persons at these levels will receive data properly summarized to perform the control activity within that level.

The next step is the formulation of the project or Mission Plan (Figure 16). By coordination with the field centers of the Office of Program Planning will establish the broad parameters of effort necessary to accomplish the desired goal of the project or mission. This will , by necessity, be done also in coordination with the contractors which have been selected by NASA to perform work on the project. These broad parameters of effort are designated as tasks, the definition for which has been explained elsewhere in this report. The primary breakdown in the plan will be to define the Sections involved in performing the requirements of the project or mission. A possible breakdown is: Spacecraft, Vehicle, Launch Facilities and Ground Support. By definition the next breakdown is by task. It should have been determined by this time which portions of the

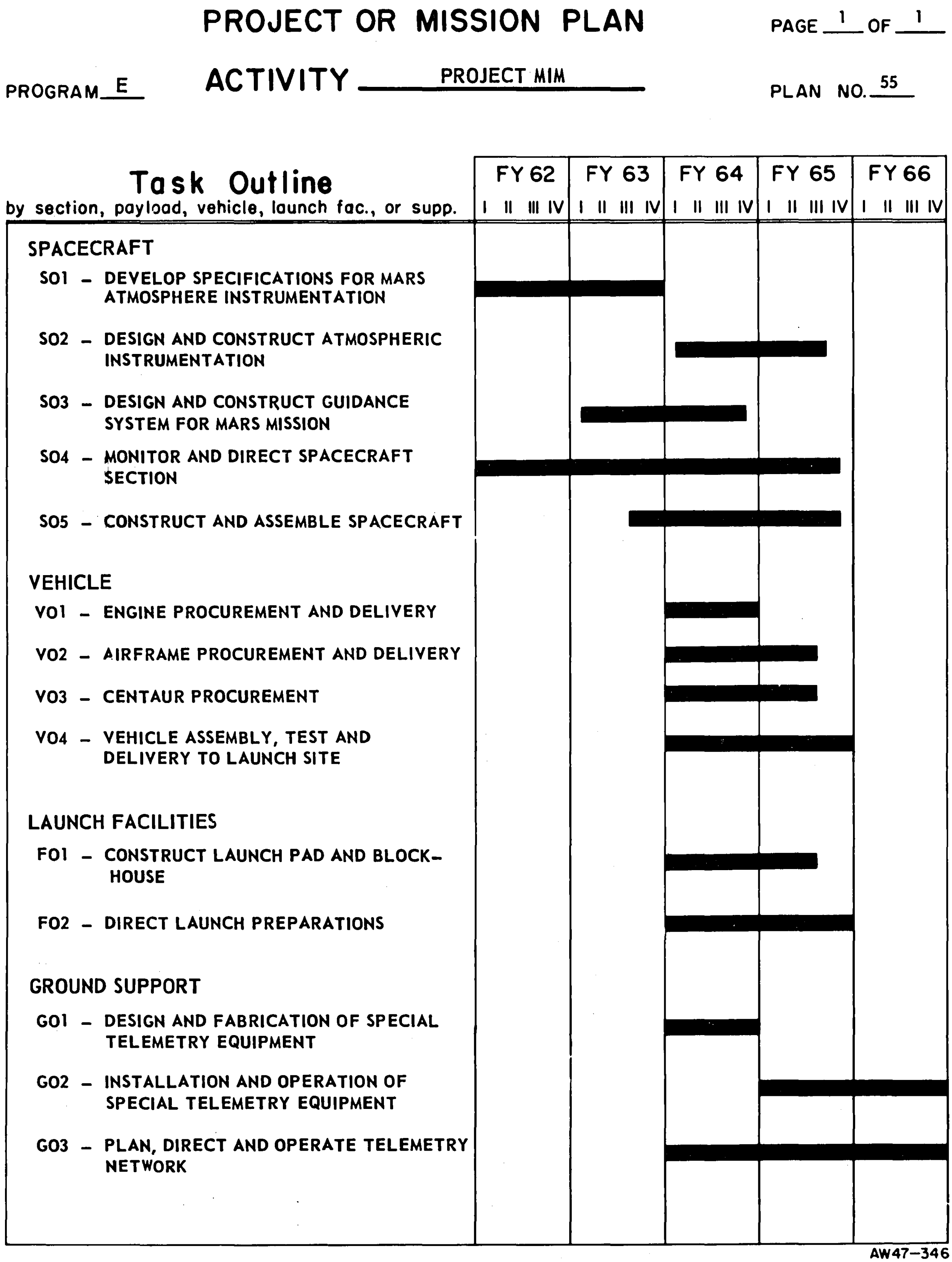


Figure 16. Project or Mission Plan

project will be performed within the NASA Field Centers and which portions will be performed out-of-house by private contractors. Knowledge of this information should, then, automatically provide the proper sub-division of the Sections into tasks. Included on the Project or Mission Plan are columns for fiscal years during which it is proposed that the project will run. These columns are sub-divided into four quarters each. After the establishment of the Sections and Tasks, the anticipated duration of time required to complete the task is entered on the plan by drawing a line through each of the fiscal years and quarters affected. It must be assumed that schedules should be reasonably firm for approximately the first two years. However, it is presumed that subsequent dates will be somewhat flexible due to the high degree of unpredictability of this type of operation. In conjunction with the Project or Mission Plan, a schedule of dollar allotments is made (Figure 17). This is a summarization of the way in which it is anticipated that funding will be required. The schedule provides for the contractor's name and contract number and the proposed allotment in millions of dollars (or thousands in the case of smaller projects) subdivided by fiscal year requirement and the total for each contractor. Also included will be the funding requirements for each field center which will contribute manpower or facilities directly to the project.

3A. 2b NETWORK CHART CORRELATION WITH OVER-ALL MISSION, CONTRACT OBLIGATIONS, AND RESOURCES ALLOCATION

Following completion of basic planning documents as described, it will become necessary to construct a detailed Network Chart. The construction of this chart will serve to graphically portray the logical sequence of events, the scheduled start and completion times of these events with allowable tolerances and the budgeted funds allocated to perform the required work. Once the tasks have been defined, contractors chosen, and funding allocated to both out-of-house and in-house activities, the people responsible for planning take each task and subdivide it into workable segments of effort with which time and dollars can be associated. It will be necessary, of course, to work in close cooperation with each contractor in order to insure that steps and goals established are realistic because the effective control of progress on the project will be in direct proportion to the validity of the original planning effort. The culmination of each task is a goal which means, in effect, that each contract has a task goal which must be met at a particular point in time and must be accomplished with a specified amount of money. The construction of the chart then proceeds on the assumption that a contractor will be able to identify the paths of activity, the resources he will require for these activities, and the length of time necessary to perform. Each path begins with the establishment of a stage which signals the commencement of effort by the contractor. Along each of these paths it will be necessary for the contractor to estimate as closely as possible the length of time he feels it will take and the estimated expenditures he will make to arrive at the next stage (the point at which he has determined a particular amount of technical progress has been made). It will also be necessary for him to establish points in time along these

DOLLAR ALLOTMENTS

WORK ASS'MTS AND CONTRACTS (CONTRACT NO.)	NAME CONTRACTOR & DESCRIPTION	ALLOTMENTS $ (MILLIONS)						
		FY 62	FY 63	FY 64	FY 65	FY 66	TOTAL $	MONITOR
HS 1407	SMITHSONIAN ASTROPHYSICS	.05	.10				.15	JPL
NASW 359	IOWA STATE			.15	.05		.20	JPL
NASW 501	AVCO		.25	.25			.50	JPL
HS 1231 } HS 935 }	JPL	.01	.02	.03	.10	.15	.31	JPL
	ROCKETDYNE			7.5			7.5	MSFC
	DOUGLAS			5.0	3.0		8.0	MSFC
	AIR FORCE			3.0	3.0		6.0	MSFC
	MSFC			.20	.50		.70	MSFC
NASW 972	JONES-MAHONEY			.10	.05		.15	MSFC
HS 1131	MSFC			.01	.04		.05	MSFC
	RCA			.20			.20	JPL
	UNIVERSITY OF CHILE				.05	.02	.07	NASA HQTS.
	JPL			.03	.03	.03	.09	JPL
	TOTALS	.06	.37	16.47	6.82	.20	23.92	

AW47-319

Figure 17. Schedule of Dollar Allotments

paths which are dependent upon the completion of another activity (Links). Obviously, a certain amount of flexibility will be built into the later stages of a task because of the nature of most of the projects, but the early stages of performance should be reasonably well established. Each field center contributing to the project will also establish its paths of activity in a manner similar to the out-of-house contractors. As the detailed network chart takes shape based on information gathered from contractors and field centers, the coding of each of the stages, steps, goals, and paths will be established. This detailed data will be the initial input to the system. The reservoir at the field center having direct responsibility for the contract will file all the detailed planning data. The reservoir at Marshall Space Flight Center will contain all the data on vehicle development. The information resulting from the preparation of the Network Chart, Project or Mission Plan and other planning documents will be punched into IBM cards, the sorting and printing of which will produce the initial listing of the project plan (Figure 16). This will contain the following information:

Field Center having direct responsibility for the project

Contract number of out-of-house contractor, or number assigned to field center directly contributing to contract.

Funds allocated to each step

Code numbers of step, stage, link or goal.

Brief description of step, stage, or goal.

In the case of stages, date of expected completion; in the case of steps period of time expected to take for completion of step (usually weeks) and tolerable variances (usually plus or minus x weeks).

Once the planning data is on file, it is possible to sort and print the information in a variety of ways to suit whatever purposes management may desire. It is also possible to summarize the information for use by various levels of management.

3A. 2c CONTRACTOR STATUS REPORTS

Once the planning phase of project control is established and filed, the actual control on the progress of the project or mission is exercised by periodically measuring the performance of the contractor or field center against what was originally planned. The physical accomplishment of this effort will be executed through various reporting formats disseminated to various levels of management requiring them in order to properly guide the activities of contractors and field centers, and in order to take corrective action (in re-programming, etc.) as it becomes necessary. To prepare these reports, input data must be introduced into the system based on the periodic information that can be gathered from the contractors. In order to facilitate the handling of this data, and in order to make it as easy as possible for the contractor to meet this requirement, it is proposed that the use of pre-punched IBM cards be used. As soon as the network chart is completed and coded and the detailed plan is complete, a set of cards title "Stage Report" (Figure 18) will be punched for each stage for which a contractor will be responsible. The program, plan, task, path and stage numbers and contract number will be pre-punched into the card and interpreted along with the planned date for completion of each goal. The deck of cards for each task will be mailed to each contractor having a contract on the particular project along with a set of specific instructions for completing the form and required dates of reporting. The contractor will be sent a sufficient number of cards with which to meet the reporting date for each stage within his area of responsibility. The reporting requirements for stages will be as follows:

> Bi-weekly on alternate Wednesdays under normal conditions.
> Between reporting cycles if a change in completion date is anticipated.
> Within four days following the completion of a stage.

Two pieces of information are required on every form submitted: Reporting date (date mailed), and the name of the contractor along with the signature of an authorized representative.

Of the remaining three boxes on the card, one must be completed: If there has been no change in the original plan, an X is placed in the first box. If there has been a change in the planned date, this new date should be entered in the second box. Changes can be initiated by the contractor, or can be initiated through a revision in the plan periodically made by NASA. The first time a change in planned date is made, the reverse side of the Stage Report (Figure 19) must be filled in describing in sufficient detail the reasons therefore so that NASA management may act appropriately. In addition to a narrative explanation, the contractor is required to indicate what future goals and stages will be affected by his slippage. If a contractor indicates that a slippage will result in a like slippage on all stages along that path, he should list just the effect on the terminal stage. It must then be assumed that all intermediate stages will slip. If, however, the contractor feels he can make up the schedule prior to this, he should list the last stage which will be affected by the current slippage. If a goal will be affected, this should be noted. Upon the completion of a stage or goal, the third box should be filled in with the appropriate date and submitted within four days following the date so entered. Stage Reports will be submitted at the time a path is activated indicating the planned start date. Subsequent to this, a report is due as described above for each of the next incompleted stages in turn until that stage is completed, at which time the next stage is reported on until its completion, etc., until the goal is reached.

Another set of pre-punched cards will be used, entitled "Step Report", (Figure 20) for purposes of reporting financial information on the project. The program, plan, task, path, and step codes will be pre-punched and interpreted in the card along with the contract number and the planned cost of the step rounded to the nearest thousand of dollars. The reporting

STAGE REPORT

DUE BIWEEKLY
OR
UPON STAGE COMPLETION

PROGRAM - PLAN - TASK	PATH STAGE	CONTRACT NUMBER	PLAN DATE

☐ (X) NO CHANGE FROM ORIGINAL OR REVISED APPROVED PLAN

☐ CURRENT ESTIMATED COMPLETION DATE IF DIFFERENT FROM PLAN DATE
(COMPLETE REVERSE IF NEW CHANGE)

☐ STAGE OR GOAL COMPLETED (DATE)

☐ REPORTING DATE

SUBMIT TO:
CONTRACTOR REPORTS
JET PROPULSION LAB.
4800 OAK GROVE DR.
PASADENA, CALIFORNIA
MAIL NO LATER THAN
ALTERNATE MONDAYS
OR WITHIN TWO DAYS
OF STAGE COMPLETION

____
CONTRACTOR

BY: ______________________________
CONTRACTOR REPRESENTATIVE

Figure 18. Stage Report, Front

REASONS FOR CHANGE IN SCHEDULE DATES:

FUTURE STAGES AND GOALS AFFECTED

Figure 19. Stage Report, Reverse

PROGRAM PLAN TASK	PATH STEP	**STEP REPORT** DUE MONTHLY OR ON COMPLETION OF STEP	CONTRACT NUMBER	PLANNED COST (IN THOUSANDS)
				$

[ ] (X) COMPLETION REPORT

$ [ ] EXPENDED TO DATE OR TOTAL COST FOR STEP (IN THOUSANDS)

$ [ ] ESTIMATED COST TO COMPLETE (IN THOUSANDS)

[ ] NO. WEEKS REQUIRED TO COMPLETE (FROM REPORT DATE)

[ ] DATE OF REPORT

SUBMIT TO:
CONTRACTOR REPORTS
JET PROPULSION LAB.
4800 OAK GROVE DR.
PASADENA, CALIFORNIA
NOT LATER THAN 5th
DAY OF EACH MONTH OR
WITHIN 5 DAYS FOLLOWING
STEP COMPLETION.

____
CONTRACTOR

BY: ______________________________
CONTRACTOR REPRESENTATIVE

Figure 20. Step Report

requirement for Step Reports is on a monthly basis instead of bi-weekly. It is expected that this report will be sent within five days following the end of the month being reported. The following information should be included on the report:

If this is a report being made due to the completion of a step, this information is noted in the first bos.

If this is a completed report, the total cost expended to complete the step should be inserted in the second box. If the step is still in process, the amount of funds expended to date will be inserted. This will include all elements of cost to NASA including materials used, direct labor, and appropriate overhead application, sub-contract costs incurred, other direct costs incurred, appropriate additional overhead applications and a pro-rata portion of fixed fee earned.

Estimated cost to complete should represent the most realistic estimate obtainable of the funds required to complete the step in the scheduled time.

The number of weeks it is anticipated it will take to complete the step measured from the date of the report is entered in the fourth box. This should be an accurate and realistic estimated and not a figure resulting from subtracting the report date from the planned stage completion date.

The date of the report will normally be the last day of the preceding month being reported.

The report must also contain the name of the contractor and the signature of an authorized representative.

3A. 2d FIELD DIRECTOR REPORTS

Periodically, it will be possible, by utilizing the cards as they are returned from the contractor, to up-date and print out a tabulated listing of the information contained on the Stage Reports and Step Reports. The Schedule Status form (Figure 21) will be used to summarize the data contained on the Stage Report. The information shown on this report is as follows:

The field center having direct responsibility for project performance.

The contract number of the reporting contractor.

The person in NASA management, based on the Project Staffing Chart, who has immediate responsibility for that particular stage.

Stage code number.

Brief description of the stage.

SCHEDULE STATUS PROGRAM: PROJECT: DATE: PG:

RESPONSIBILITY			STAGE-GOAL DESCRIPTION		DATES — TIMES				FLAG	COMPLETION DATE
DIR	CONTRACT	PERSON	CODE	DESCRIPTION	PLAN	APPROVED REVISED	# REV	PLANNED ACTUAL	**	

AW47-344

Figure 21. Schedule Status Form

Planned date of stage completion based on the original plan, unrevised.

The approved revised date of stage completion, if appropriate.

Revision number, based on the number of revisions made since the original planned date was established.

The actual planned date of stage completion, if different from the original planned date.

If the actual completion date varies substantially from the original or revised completion date by some predetermined length of time, there will be a print-out of two asterisks in the "flag" column to visually indicate a problem area.

The Financial Status form (Figure 22) will be used to summarize data submitted on the Step Reports from the contractors. The following information will be shown on this report:

The month and year indicating the date at which that step is reported on.

Field center having direct responsibility for the step.

Contract number of the reporting contractor.

Code, number of step.

Brief narrative description of the step.

Planned cost of the step, in thousands of dollars, as indicated on original unrevised plan.

The approved revised cost, if appropriate.

Revision number, based on the number of revisions made since The original planned cost was established.

Costs expended to date including all costs incurred as previously described to cut-off date as indicated in column 1.

Variance from plan is the result obtained by subtracting the amount in the Expended to Date column from the amount in the Planned Cost column for each line item.

"Weeks to complete" is the contractor's best estimate of the number of weeks he feels will be required to complete the step.

Rate to complete is the result obtained by dividing the amount to complete by the number of weeks to complete.

FINANCIAL STATUS PROGRAM: PROJECT: DATE: PG:

RESPONSIBILITY						IN THOUSANDS OF DOLLARS							
DATE	DIR.	CONTRACT	PERSON	TASK, PATH STEP, CODE	DESCRIPTION	PLANNED COST	REVISED	REV #	EXPENDED TO DATE	ESTIMATE TO COMPL	VARIANCE FROM PLAN	WEEKS TO COMPL	RATE TO COMPL
						$	$		$	$	$		$

AW47-345

Figure 22. Financial Status Form

The original print-out of data in complete detail on the status reports as described above will serve the purpose of providing the project manager at the field center level with the complete unedited picture of the status of his contract at a given point in time. The basic premise of a sound control system would require that each level of management exercising control over a project be in a position to receive information affecting his projects rapidly and unaltered by anyone else within the agency having management authority. Facts are facts, and sound management techniques dictate that all levels of management receive these facts, even though consolidated and summarized for various levels, without having been previously watered down by lower levels of management in order to obscure the true picture. A program chief at Headquarters, for example, should be in a position to exercise his own prerogatives in making decisions based on current factual data, unchanged by people at the field center level. Field center directors should see facts as they exist, without benefit of a project manager's changes based on his own whims. To operate in any other way would vitiate the purpose of the system, which is to disseminate information rapidly and accurately to all levels of management in order to optimize the ability to make valid and justified decisions. However, the study conducted at NASA indicates that the policy which will be followed requires that after the project manager has had an opportunity to see the reports, he may edit the data, after which a summary will be prepared for the field director's approval. Following his approval, a further summarization will be made for the Program Chief at Headquarters. When he has had a chance to make changes he feels are required, a summary will be made for the Program Director at Headquarters. Finally, after the Program Directors' approval, top summaries will be made for presentation to the Administrator's office.

It should be pointed out that reporting cycles can vary between projects. Some smaller projects may be reported on once a month for schedule status and once a quarter for financial status. The capability of the system is flexible, and can be adjusted to meet whatever requirements are demanded of it by NASA management.

3A. 2e DETAILED ANALYTICAL REPORTS

One of the many benefits of the system will be its ability to generate several types of analytical reports. An example of one of these reports is the "Stage Schedule Analysis," (Figure 23). This report will provide the observer with an immediate assessment of the schedule status of all stages and goals. Its value lies in its ability to give broad visibility to the over-all project at a glance without wading through volumes of detail. The information contained on this report is as follows:

Field center exercising direct responsibility.

Code number of stage or goal.

Description of stage or goal.

STAGE SCHEDULE ANALYSIS

V - TO BE COMPLETED
▼ - COMPLETED

PROGRAM E   PROJECT 55   DATE 2/64   PG. 1
CURRENT MO

DIR	CODE	DESCRIPTION	PLAN DATE	FISCAL YEAR 1962 JFMAMJJASOND	FISCAL YEAR 1963 JFMAMJJASOND	FISCAL YEAR 1964 JFMAMJJASOND
MSFC	F01.0101	START CONSTRUCTION OF BLOCKHOUSE	11/15/63		▼	
MSFC	F02.0005	APPROVE SPECIFICATIONS	11/15/63		▼	
MSFC	F02.0005	/E55F01.0101	11/15/63		▼	
MSFC	F01.0201	START LAUNCH PAD CONSTRUCTION	12/16/63		▼	
JPL	S03.0203	ADVANCED TEST SERIES COMPLETE	12/31/63		▼	
JPL	S02.0005	FINAL DESIGN APPROVED	12/31/63		▼	
JPL	S02.0005	/E55S02.0101	12/31/63		▼	
JPL	S02.0101	START COMPONENT DEVELOPMENT	01/01/64			▼
JPL	S05.0001	BEGIN FINAL CAPSULE DESIGN	01/01/64			V
JPL	S02.0103	REPORT COMPONENT TEST SUCCESSFUL	02/01/64			▼
JPL	S02.0103	/E55S02.0201	02/01/64			V
JPL	S05.0003	FINAL DESIGN APPROVED	02/29/64			▼
JPL	S02.0201	START FABRICATION OF INSTRUMENT P	03/01/64			V
JPL	S03.0295	DELIVERY TO JPL	04/01/64			V
JPL	S03.0295	/E55S04.0107	04/01/64			V

Figure 23. Stage Schedule Analysis

Planned date at which time it is expected to complete the stage or goal.

The current month will be illustrated with a series of dots in the appropriate column in the month in which the report is issued. The symbol V will be printed in the column headed by the month and year in which the stage and goal was or is scheduled to be completed. If the stage or goal is completed, an overprint of an asterisk over the V will be made (V̄*) to indicate this fact. An open V in any column to the left of the dots indicates a schedule slippage. An overprinted V in a column to the right of the dots would indicate a situation where the contractor is ahead of schedule. An indicated problem on this report would serve to actuate further interrogation of the system on the part of the observer.

Another type of analytical report available would be the report and chart displaying financial information (Figures 24 and 25). The report would consist of indicating the planned, actual and projected costs, time, and related rates of expenditure and variances. The explanation of this report is as follows:

Step code is self-explanatory.
Planned cost in thousands of dollars for completion of step.
Planned weeks anticipated to complete step without variances.
Rate of expenditures which can be made to complete the step for the planned length of time indicated and the amount of planned funds.
Actual expenditures made based on contractor's step report.
Actual weeks which have elapsed since commencement of work on step.
Rate variance is the difference between the planned rate of expenditure in column 4 and the actual rate arrived at by dividing the actual expenditures by the actual elapsed time in weeks.
Weeks to complete is based on the contractor's estimate on his Step Report.
Rate to complete is arrived at by dividing the estimated total cost to complete by the estimated weeks to complete.
Total cost to complete is based on the contractor's estimate from his Step Report.
Projected total cost is the total of the actual expenditures to date (column 5) and the estimated cost to complete (column 10).

All steps in a given task are sub-totaled by task to present statistical data for the task as a whole.

The financial analytical chart is a graphic presentation of the data contained in the Analytical report. The horizontal scale on the chart is time, the vertical scale, dollars. The first line to be plotted is a solid line representing the cumulative expenditure curve. The coordinates

FINANCIAL STATUS

PROGRAMS: E PROJECT: 55 DATE: 6/63 PG: 1

TASK PATH					IN THOUSANDS							
DATE	DIR.	CONTRACT	CODE	DESCRIPTION	PLANNED COST	REVISED	REV #	EXPENDED TO DATE	ESTIMATE TO COMPL.	VAR. FROM PLAN	WKS. TO COMPL.	RATE TO COMPL.
9/62	JPL	NASW501	E55S03.0002	DEVELOP MODIFICATION SPECS	$ 20.0	$		$ 20.0	$	$		$
12/62	JPL	NASW501	S03.0004	COMPONENTS DEVELOPMENT EFFORT	50.0			55.0		5.0-		
4/63	JPL	NASW501	S03.0006	FABRICATION AND ASSEMBLY	250.0			240.0	15.0	5.0-	8	1.9
5/63	JPL	NASW501	S03.0006	FABRICATION AND ASSEMBLY	250.0			250.0	10.0	10.0-	4	2.5
6/63	JPL	NASW501	S03.0006	FABRICATION AND ASSEMBLY	250.0			265.0		15.0-		

Figure 24. Financial Information Report

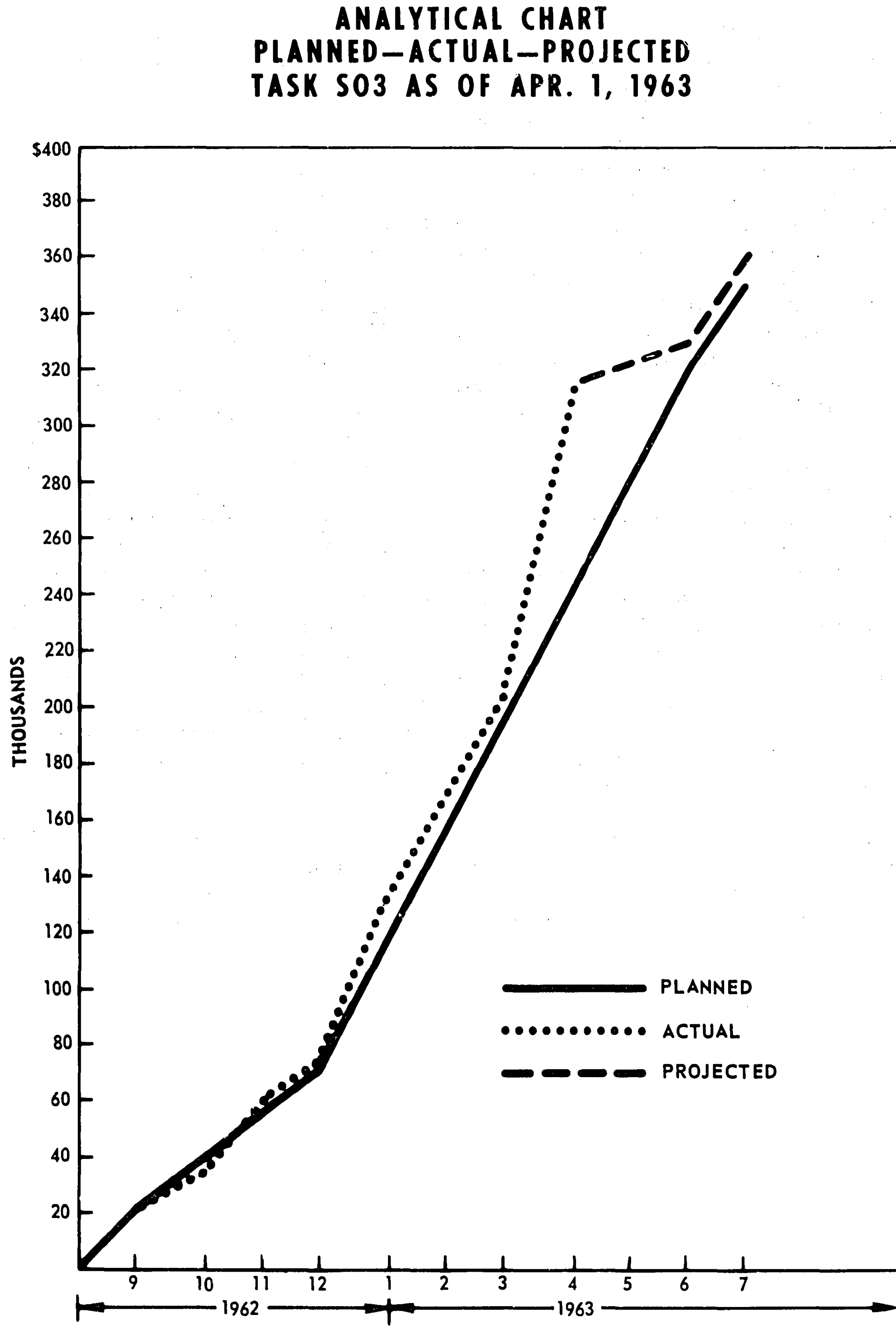


Figure 25. Financial Information Chart

used in plotting this curve have the cumulative weeks as their absicissa, and cumulative expenditures to that number of weeks as their ordinate. Each month a chart is prepared to correspond to the reporting cycle of the contractor having the responsibility for that task. The planned expenditure curve is drawn first. Then by the use of a different type of line the actual expenditures are plotted. This line is drawn by plotting the appropriate coordinates at the end of each reporting period for the amount of cumulative expenditures made at each of those periods. A third type of line is then plotted, projecting the estimated expenditures to be made to reach the end of the current step, then projecting this line through to the end of the task using planned expenditures on all subsequent steps. The effect of viewing this chart will be to graphically display immediately the finanical progress of a contractor. Naturally, this chart must be used in conjunction with reports showing technical progress. The fact that a contractor is "on target" financially does not obviate the possibility that he may be in trouble from a scheduling standpoint. It may also appear that a contractor is over-expending in the early stages of a contract, but if he anticipates completing the contract within the alloted funds (assuming adequate technical progress) then there is no reason for alarm. There will be times, however, where he may be over-expending early in the contract, but his rate of expenditure will follow the planned rate in the future. This will indicate, then, the necessity for possible future funding to compensate, or a possible schedule revision in order for him to "live with" the original fund allocation. A flexibility should be built in to allow for variances within tolerable limits. In other words, since actual and projected expenditures will rarely follow exactly the planned curve, a predetermined amount of variance should be considered normal, and a warning flag raised only when the actual-projected curve is outside these variances.

It should be borne in mind that the data within the system is highly flexible; that the system has the capability of producing a variety of analytical reports and supplying a readily available mass of data suitable for use in charting techniques bound only by the imaginative confines of the users.

3A.3 System Design

In order to facilitate the installation of the Interim Operational Capability Management and Program Control System, serious consideration has been given to all aspects of data processing, including data formats, data volumes, and organization of reporting requirements. In addition, to effect the transition from a manual through a semi-automatic to a fully automatic system, utilization of existing and available electronic data processing equipment and computers in the present NASA inventory has been proposed.

The proposed data processing system would consist of one large central reservoir, for use by NASA headquarters, with three major sub-reservoirs located at the key field installations: Marshall Space Flight Center, Goddard Space Flight Center and Jet Propulsion Laboratories. The central reservoir would utilize equipment at Goddard, linked to Washington through a high-speed communications network.

Data flow would be initiated by contractor reports submitted bi-weekly on technical progress (stage and goal information), and every four weeks on financial progress (step information). These reports would be forwarded to the Contractors Reports Office located at the respective field centers, where they would be keypunched and sorted into proper sequence. Next each report would be examined for possible changes in schedule dates, variances, slippages, money allocations, etc. For all items on which there existed any changes of the above nature, the original keypunched cards would be duplicated and the original deck of cards on which narrative reports occurred would then be submitted to the responsible project manager for review. The project manager would now evaluate the change information submitted to him and would either validate it or initiate additional modifications of dates, monies, etc. on his own, to be introduced into the status report described below.

Meanwhile the duplicate deck of keypunched cards will have been entered into the data processing system, from which the status report will be issued. This status report, reflecting both the contractor's report information and the project managers' modifications will consist of a series of flagged items, including the following:

New Changes
Missing Reports
Missed Completion Deadlines
An Excess of two Revisions

These status reports are then submitted to the respective project manager for his final review and approval. In addition to the status report, the data processing system will generate additional information cross-reference type reports which will be issued to those project managers having indirect responsibility for a given project or mission. These will assist each project manager in his evaluation of the project over which he has direct responsibility.

Once he has approved the status report, he then submits it to the director of the field center for final approval, with an information copy being submitted to the program chief at NASA headquarters. Upon approval by the field director, the status report and all related information would then be submitted to data processing for producing summary status reports, etc. In addition, all data contained in the field center's sub-reservoir would be updated.

From the sub-reservoir the information is then transmitted to the central reservoirs at NASA headquarters. Additional inputs and modifications to the central reservoir may also be initiated by the program chiefs and program directors at headquarters. The data processing system at headquarters then further summarizes the information and issues finalized top level reports to the director, associate director and program directors. Since the central reservoir contains a complete file of all top level information, the Administrator, Associate Administrator or program directors will at any time have immediate access to all summarized top level information. If at any time they should desire information of a more detailed nature, it is merely a matter of the central reservoir requesting this information from the appropriate field sub-reservoir, which contains all of the detailed information. Since the requirements for this detailed information will be on an exception basis, there will be no need for expensive high-speed communication links between the central reservoir and each sub-reservoir. Actually the capability to transmit within a two or three hour cycle would be more than adequate.

3A.3a DATA FORMATS

Data communication between the central reservoir and each of the field centers major sub-reservoir and data extraction by the various levels of NASA management will best be accomplished through the use of a standard identured file arrangement in each reservoir. For the two types of reservoirs the arrangement will be similar to those shown below:

Record No.	Central Reservoir	Sub-Reservoir
1	Identification Label	Identification Label
2	Program No. 1	Project No. 1
3	Project No. 1	Task No. 1
4	Task No. 1	Path No. 1
	Task No. 2	Stage No. 1
		Step No. 1
	Project No. 2	Stage No. 2
	Task No. 1	Step No. 2
	Task No. 2	
		Path No. 2
		Stage No. 1
	Program No. 2	Stage No. 2
	Project No. 1	
	Task No. 1	
	Task No. 2	Task No. 2
	Project No. 2	
	Task No. 1	
	Task No. 2	
		Project No. 2
		etc.
	etc.	

Thus, it will be seen by examining the above file arrangement, that all data necessary for Program, Project and Task reporting will be immediately accessible to top management from the central reservoir and that data necessary for Project, Task, Path, Stage and Step reporting will be available to field center management from its own respective sub-reservoir.

In general this means that the data files for the central reservoir will have just five basic types of records, namely 1. Project type, 2. Task type, 3. Path type, 4. Step type and 5. Stage type which is the same for Goals and Links. The actual format of each record together with the character requirements for each field in the record are shown in Figure 26.

The following is a brief description of each of the items listed in Figure 26.

1. Record Type Code Designation is merely a one character alphabetic or numeric designation to be used internally for program identification in either a manual or an automated system.

Item	Field Definition	Program	Project	Task	Path	Step	Stage	Goal	Link
		Field Size (Number of Characters) (V = Variable length)							
1.	Record Type Code Designation: 1, 2, 3, etc.	1	1	1	1	1	1		
2.	Network Code Number: ESS, ESSS01, etc.	1	3	6	8	10	10	10	10
3.	Title of this element: MIM, Spacecraft for MIM, etc.	50	50	50					
4.	Description: Variable length - special code tells length	V	V	V	V	V	V	V	V
5.	Program Chief: Name and NASA address	50							
6.	Title or Organizational Responsibility	50							
7.	Project Manager: Name and NASA Address		50						
8.	Title or Organizational Responsibility		50						
9.	Contractor/sub-Contractor: Names and addresses	V	V	V					
10.	Contract: Number, Type, Description, Etc.			V	V				
11.	Direct Responsibility: Which field center	5	5						
12.	Synonym designation (Tasks only)			10					
13.	Link Tie-In Coding								10
14.	Times: Starting Date	8	8	8	8	8			
15.	Original or Revised Planned Completion Date	8	8	8	8	8	8	8	8
16.	Current Report Date	8	8	8	8	8	8	8	8
	Next Report Date					8	8	8	8
17.	Number of Weeks Estimated to Completion	3	3	3	3	3			
18.	Total Estimated Time in Weeks	3	3	3	3	3			
19.	Variance in Weeks				3	3			
20.	Funding Information:								
21.	Total Dollars - Initial Planned or Estimated	36	36	32	32	28			
22.	Current Revised Estimate	36	36	32	32	28			
23.	Actual Cumulative to Date	36	36	32	32	28			
24.	Estimated to Complete	36	36	32	32	28			
25.	Rate of Dollar Expenditure - Overall planned or estimated	24	24	20	20	20			
26.	Estimate - Previous Report Period	24	24	20	20	20			
27.	Current Report Period	24	24	20	20	20			
28.	To Completion	24	24	20	20	20			
29.	Actual - Cumulative to Date	24	24	20	20	20			
30.	Previous Report Period	24	24	20	20	20			
	NOTE: All funding information to be gathered for each of the following categories: 1. Direct Labor 3. Materials 2. Overhead 4. Other								
31.	Hourly Information:								
32.	Total hours - initial planned or estimate	24	24	21	21	18			
33.	Current revised estimate	29	24	21	21	18			
34.	Actual - Cumulative to date	24	24	21	21	18			
35.	Estimated to complete	24	24	21	21	18			
36.	Rate of hourly utilization - overall planned	18	18	15	15	15			
37.	Estimate - previous report period	18	18	15	15	15			
38.	Current Report Period	18	18	15	15	15			
39.	To completion	18	18	15	15	15			
40.	Actual	18	18	15	15	15			
41.	Previous report period	18	18	15	15	15			

NOTE: All hourly information to be gathered for each of the following categories:

1. Direct Labor
2. Indirect Labor
3. Total Numbers of Manpower

Figure 26. Record Format

2. Network Code Number is the full code designation to identify a specific part of a given network scheme whether it be a program, project, task, path, step, stage, goal or link. The definition of each part of the network code number is indicated in general as follows:

Program Code	Project Code	Task Code	Path Code	Step, Stage or Goal Code
E	55	S01	01	04

Under this system only one character is needed to identify a specific program, while three, six, eight and ten characters are needed to uniquely identify a project, task, path or step (stage, goal or link) respectively.

3. Title of this Element is a non-coded descriptive name which easily identifies a specific element. Its main purpose in the record is merely for report title generation.

4. Description is self explanatory as to content. However, since the description is always variable in length, a count only will be indicated in the first fixed part of the record which will tell where the description starts at the end of the record and how many characters in length it is.

5. through 9. The names, addresses and titles of the program chiefs, project managers and contractors and/or sub-contractors will be used for identification of responsibilities, for routing, for checking on delinquent reports, etc. and also for proper identification of all source action and summary reports.

10. Contract data will show all necessary information pertinent to this specific contract as to type of contract - cost plus fixed fee, fixed price, etc. and will also show a complete description of the items or items to be delivered under the contractual requirements.

11. Direct responsibility merely designates which field center will be in charge of this specific project, usually Goddard or Jet Propulsion Laboratories for the spacecraft portion and Marshall Space Flight Center in the case of vehicle development and construction.

12. Synonym designation merely gives the network code number for this task's designation within another project. For example this task may be coded as E55S01 under a network system at Goddard where the direct responsibility is held and might be

coded N34 PO1 under an entirely separate program at Marshall where it exists only as an indirect responsibility on their part. One main purpose of this type of cross referencing is to permit the proper referencing and distribution to all project managers whether they hold a direct or indirect responsibility for this item.

13. Link tie-in coding merely shows the code designation for the two stages and/or goals which have an interdependency. This will indicate which stages and/or goals in one path are dependent upon the completion of a stage and/or goal in another path.

14 through 19. Times here refer to all the various scheduled starting, completion and reporting dates as well as the elapsed times and variances in weeks. These dates and times will be used to measure actual technical progress and financial status against the original estimates or latest revised plans in order to enable NASA management to initiate corrective action where difficulties, resulting in scheduled slippage or over-expenditure of funds, appear to be probable.

20 Through 30. Funding information will show available figures both as to total dollars as well as the rate of dollar expenditure. The total dollars figures will indicate the original or revised planned amount for the completed job, the cumulative totals to date and the estimated total dollar amount to completion. This will enable the NASA managers to evaluate their financial position at any given report date, and judge whether or not the contract will be expected to overrun. The rate of dollar expenditure will be of additional assistance in telling NASA in which direction the project has been heading, what total figure will result if this rate continues and what actual rate of expenditure is necessary in order to fulfill the contract within the specified dollar amounts. Rather rigid boundary limits may be set around the anticipated, estimated or planned rate of expenditure, either as an absolute rate over or under, or as a percentage over or under plan. The rates will be studied both for very short periods, such as the current or previous report periods, as well as for the overall study on a cumulative-to-date or estimated to complete basis. Actually there should be incorporated into the control system not just one set of funding information figures, but rather a breakdown into the four major categories for which funding information is applicable, namely for: (1) Direct Labor, (2) Overhead, (3) Materials, and (4) Other, so that when difficulties arise within a given path, task or step that the source of the difficulty may be pin pointed.

31 through 41. Hourly information shown will be very similar to funding information contained in items 20 through 30, except that it will indicate a measurable level of effort in absolute units rather than in dollars. Here again to pin point where the source of difficulty may lie, the hourly figures should be summarized into one of three categories: (1) Direct Labor, (2) Indirect Labor, and (3) Total Numbers of Manpower.

3A. 3b. DATA VOLUMES

In order to properly project the total volume of data which would be handled under the Initial Operational Capability - Management and Program Control System it is necessary not only to look at all existing and anticipated programs and projects, but also to study the anticipated number of steps, stages, and goals which will be developed under the network system, as well as the average reporting cycle for each type.

In examining the overall listing of NASA programs and projects, we see that there are approximately eight major programs listed under the cognizance of its Office of Space Flight and there are five major programs listed under the cognizance of the Office of Launch Vehicles.

On first investigating the Space Flight Programs we might classify them as follows, showing the number of PMP's and milestones for each:

SPACECRAFT PROGRAMS	No. of PMP's	No. of Milestones
Scientific Satellites	39	590
Scientific Satellite Probes	6	85
Lunar and Planetary Exploration	60	930
Satellite Applications-Meterology	34	485
Satellite Applications-Communications	15	250
Manned Space Flight	58	1012
Centaur Lunar (Surveyor)	36	465
Saturn Lunar	36	465
Spacecraft Program Totals	284	4255

The first six of these programs are well defined and practically all documented and being managed under the present PMP system, while the last two programs, the Centaur Lunar and the Saturn Lunar, are still in the formative stages so that the number of PMP's and milestones shown are projections based on comparisons with the other well-defined programs.

By next investigating the Launch Vehicle Programs we see that they fall into five major programs we are showing below, together with the corresponding number of PMP's and milestones:

VEHICLE PROGRAMS	No. of PMP's	No. of Milestones
Scout	1	15
Agena	18	434
Centaur	9	159
Saturn	19	333
Nova	21	420
Vehicle Program Totals	68	1361

Of these five major programs, the first two are well defined and documented, while the third and fourth are well defined, but only partially documented, and the last one, Nova, is still in the formative states, again giving rise to a projection based on a study of the other major Vehicle Programs.

Analysis of the figures shown above for all current Program Management Plans (PMP's) and the number of milestones contained on each indicate that there are approximately 350 PMP's either in existence or anticipated in the near future, and that there are some 5600 or better milestones listed on these PMP's. Further analysis of the types of milestones shown on the PMP charts and the nature of the stages, steps and goals which would be required for a network system indicate that approximately 18,100 steps, 21,000 stages and 2000 goals would be necessary. This means that approximately three to four times as much definition for a project would be required in defining the specific tasks and paths involved under the network system of control, which would also tie in much more closely to actual contractual specifications. A detailed analysis of all of the current and anticipated PMP's, milestones, together with the projected number of stages, steps and goals necessary for the network system is shown in Figure 27.

Having once reached this level of total projected numbers of stages, steps, and goals, it is next necessary to translate this massive quantity of reporting elements into a meaningful rate of flow for each reporting period, so that data processing requirements for the system can be calculated.

	NUMBER OF PMPS	NUMBER OF MLSTNS	PROJD NUMBER STAGES	PROJD NUMBER STEPS	PROJD NUMBER GOALS
Spacecraft Programs					
Scientific Satellites	39	590	2240	2015	204
Scientific Satellite Probes	6	85	325	290	29
Lunar and Planetary Exploration	60	930	3290	2950	318
Satellite Applications—Meteorology	34	458	1475	1320	153
Satellite Applications—Communications	15	250	700	625	85
Manned Space Flight	58	1012	4105	3445	358
Centaur Lunar (Surveyor)	36	465	1100	825	165
Saturn Lunar	36	465	1100	825	165
Spacecraft Program Totals	284	4255	14335	12295	1477
Vehicle Programs					
Scout	1	15	100	75	15
Agena	18	434	2122	1910	166
Centaur	9	159	805	700	67
Saturn	19	333	1650	1420	129
Nova	21	420	1940	1700	160
Vehicle Program Totals	68	1361	6617	5805	537
Totals All Programs	352	5616	20952	18100	2014
Totals By Field Center					
Goddard Space Flight Center	94	1383	4740	4250	471
Langley Research Center	59	1027	4205	3520	373
Jet Propulsion Laboratories	132	1860	5490	4600	648
Marshall Space Flight Center	67	1346	6517	5730	522

Figure 27. Current and Future PMPs and Milestones Compared to Proposed Network System

STEP DATA VOLUME CALCULATION

First, the total number of 18,100 network steps was analyzed in the following manner. This total level represented all the known active or anticipated steps which would be contained in the overall NASA plan for the next five fiscal years starting with fiscal 1962. It was assumed that whatever level of effort was to be required to complete this total of 18,100 steps would hold approximately constant for the first fiscal year and that then it would fall off gradually in a linear fashion until all steps were completed at the end of fiscal 1966. This is not to say that the total network system requirements would be less for the second, third, fourth, and fifth years, but rather that any slack which might result would immediately be used up by new projects and programs which had not as yet even been contemplated.

With this type of relationship we may now assume that each financial step would require reports only once each month. The average length for each step would be approximately five to seven months in duration. We now have all the basic parameters and can make a reasonable projection of the number of steps to be reported on during the typical reporting period.

Graphically, we may represent the problem somewhat along the lines shown in Figure 28 where the total of the 18,100 steps is represented by the large trapezoidal area to the left side of the chart. Next, the time interval for the five fiscal years 1962 through 1966 is divided into equal blocks of twenty four weeks each (with the partial blocks falling to the left or beginning of fiscal 1962). These twenty four week blocks represent six reporting periods of four weeks each for an unknown number of steps. To determine the number of steps associated with each block, one has merely to determine the number of blocks in the trapezoid and divide this into the total 18,100 steps.

The total number of blocks in the system is calculated in the following manner. First, the number of blocks in each row is established starting with the bottom row, which has eleven blocks, up to the top row, which has three blocks. The shortening of the time interval by one reporting cycle causes the total number of blocks per row to decrease by one every sixth report period. Therefore, our equation to determine the total number of blocks in the trapezoid is:

Bottom 5 Rows - All other rows

$$(5 \times 11) + 6^{3} \sum_{i=10} i = 55 + 312 = 367 \text{ blocks}$$

Where i represents the number of step blocks in the time interval, therefore, since we have 367 blocks and 18,000 steps in total, each block equals approximately 50 steps.

NASA NETWORK SYSTEM—STEP DATA FLOW RATE

The chart shown below represents the level of effort which would be required to maintain the NASA network system for all steps in the over-all NASA program for the next five fiscal years. The detailed area on the left side of the chart represents the current known and projected activity planned through fiscal 1966. The blank area to the right represents new programs and projects not as yet even contemplated. The area to the left corresponds to the 18,100 steps expected for spacecraft and vehicle programs, where each block is equivalent to approximately 50 steps of activity. The average length of these 50 steps will be six reporting cycles of four weeks each, or 24 weeks total. Based on this level of activity, approximately 2,650 steps will be reported on during each four-week reporting cycle.

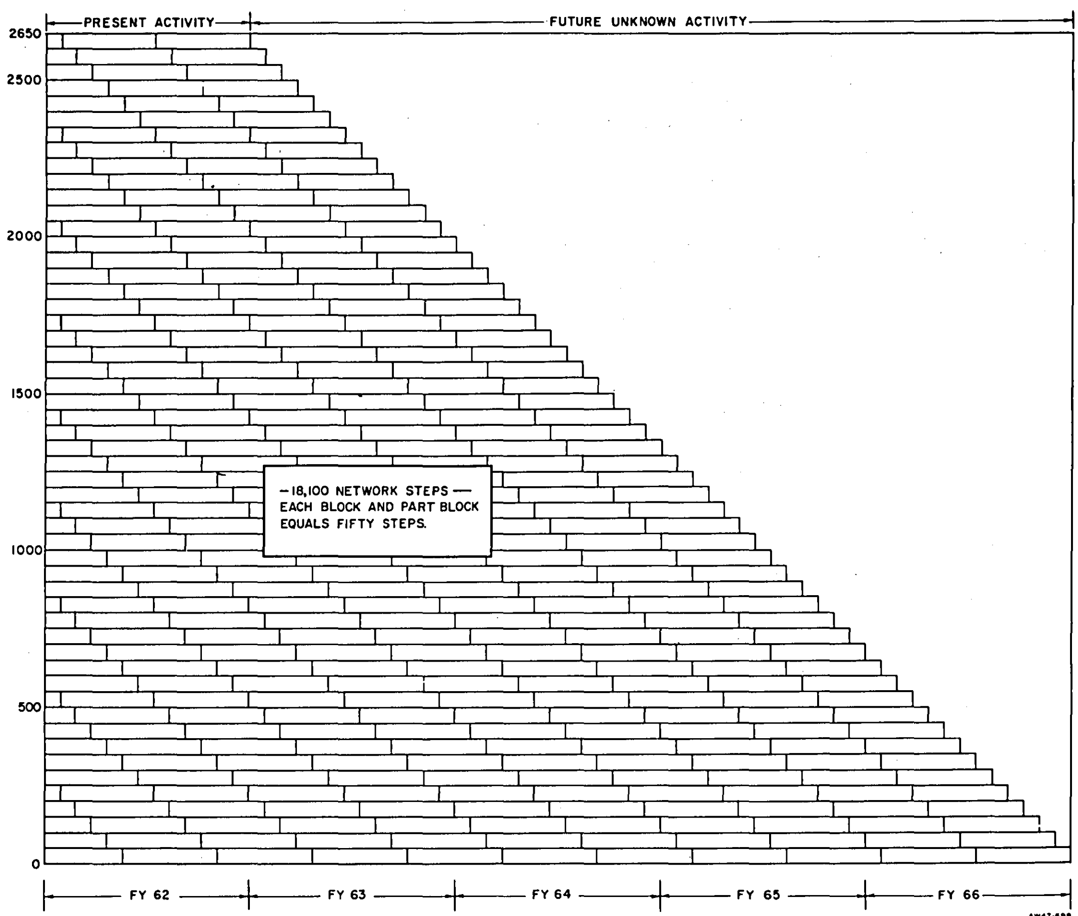


Figure 28. Effort Level Determination – Steps

Next, to establish the number of steps during one report period, we merely count the number of rows which is:

$$5 + 6 (10 - 3 + 1) = 5 + 48 = 53 \text{ rows}$$

Therefore, the level of effort stepwise is 2650 steps for each four week reporting period.

STAGE AND GOAL DATA VOLUME CALCULATION

Since stages and goals represent a measure of technical progress and possibly need closer management control, it is advised that the reporting period for stages and goals be every two weeks exactly the same as with milestone technical reporting on the PMP system. This change in the basic parameters leads to a slightly different solution for the total number of stages and goals for each report period. Also, since goals are actually just a specialized form of stages, for purposes of calculations, we have combined the 20,952 stages and the 2,014 goals to a total of 22,966 stages and goals. The average number of weeks between two successive stages and/or goals is the same as for the step length. However, since the stages and goals will be reported upon every two weeks, this means there will be twelve reports over the time interval between two stages. Here the number of blocks in each row is established the same as in the step calculation. However, the shortening by two weeks each report period causes the number of blocks per row to decrease by one only every twelfth report period. Therefore, our equation for the calculation of the total number of blocks in this trapezoid is:

Bottom 10 rows   Middle rows   Top 11 rows

$$(10 \times 11) + 12 \Sigma i + (11 \times 3) = 110 + 588 + 33 = 731 \text{ blocks}$$

Where i represents the number of stages and goals blocks in the time interval. Graphically we may show this problem in a manner similar to Figure 29 where the 22,966 stages and goals are represented by 731 blocks in the cut-away trapezoid, dividing the 22,966 stages and goals by our total of 731 blocks gives us an average of approximately 32 stages and goals for each block.

Next to establish the number of stages and goals during one report period, we merely count the number of rows which is

$$10 + 12 (10 - 4 + 1) + 11 = 10 + 84 + 11 = 105 \text{ rows}$$

Therefore, the level of effort stagewise is 3300 stages and goals for each two week reporting period.

In summary, then we may say that the total number of 2,650 steps to be reported upon each four weeks, plus 3300 stages and goals to be reported upon each two weeks represents a fairly close approximation

NASA NETWORK SYSTEM—STAGE AND GOAL DATA FLOW RATE

The chart shown below represents the level of effort which would be required to maintain the NASA network system for all stages and goals in the over-all NASA program for the next five fiscal years. The detailed area on the left side of the chart represents the current known and projected activity planned through fiscal 1966. The blank area to the right represents new programs and projects not as yet even contemplated. The area to the left corresponds to the 23,000 stages and goals expected for spacecraft and vehicle programs, where each block is equivalent to approximately 32 stages and goals of activity. The average length of these 32 stages and goals will be 12 reporting cycles of two weeks each. Based on this level of activity, approximately 3,300 stages and goals will be reported on during each two-week reporting cycle.

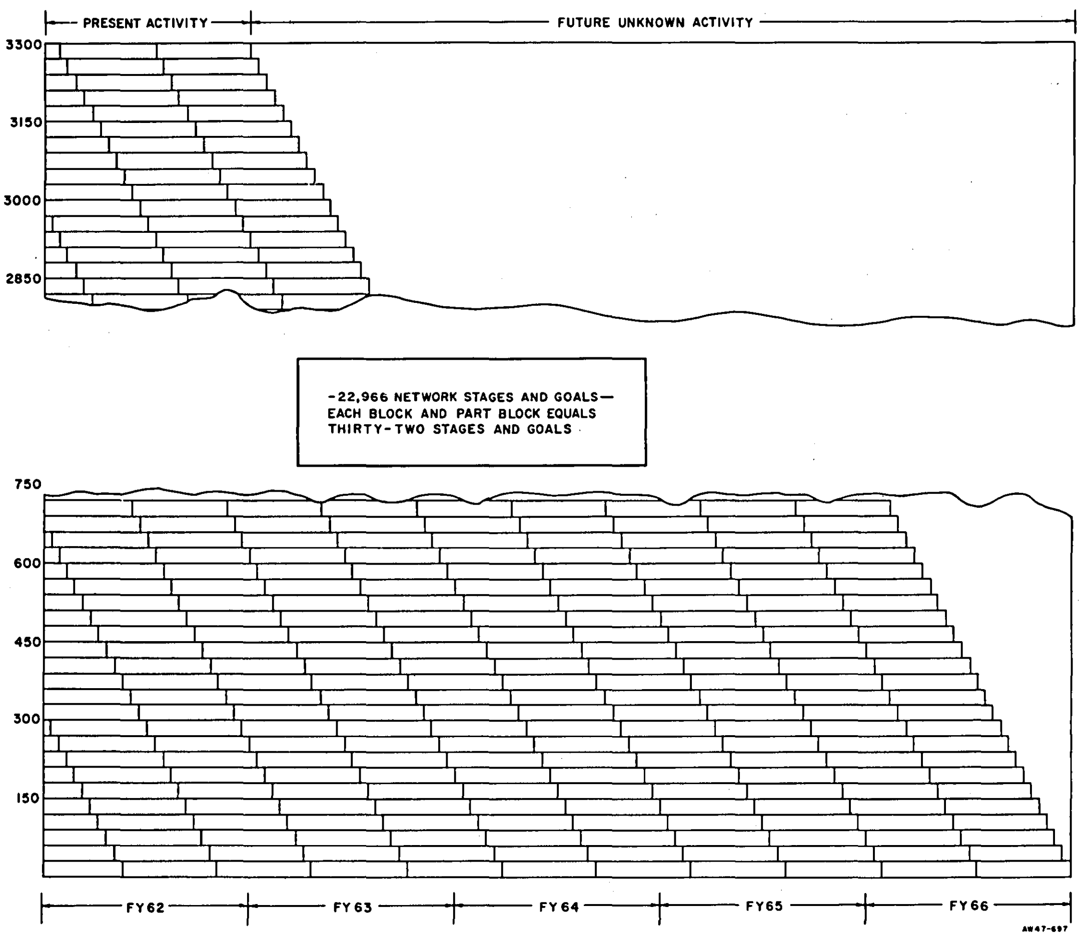


Figure 29. Effort Level Determination – Stages and Goals

of the magnitude of NASA's management problems. This also assumes a level of effort approximately consistent throughout the next five years, when in all probability the actual rate may appreciably increase.

3A.3c. ORGANIZATION OF REPORTING REQUIREMENTS

The Initial Operational Capability - Management and Program Control System has as its basic capability, the ability to develop necessary management reports to all levels of NASA, with sufficient detail for each specific management level and on such a schedule as to give meaningful import to management decisions. It insures consistent information flow from the contractor reporting level all the way up to the administrator's level with sufficient detail at each level for management decision and summarization to the next higher level. It also screens the precedence relationships of all levels of management and reports so that only authorized personnel shall be able to request certain levels of information. To see just how this overall system of precedence checks and controls will work, we will describe the Precedence Relationship Factor make-up of the reservoirs. We will describe the file as it would exist on a single reel of magnetic tape, which of course is expandable to an unlimited number of tapes as the system grows in volume or complexity.

On this reel of tape, which we will call the Master Record File, is contained all the necessary data and information necessary for generating practically any type of required report, plus the ability to maintain and update the file either at regular intervals or upon special request. Before commencing with the layout of the file itself it would be well to describe the basic philosophy underlying the need for a file of this nature.

PRECEDENCE RELATIONSHIP FACTOR

Let us assume for the moment that all NASA data and information can be assigned levels of security classification, namely: 1) Unclassified, 2) Confidential, 3) Secret, 4) Top Secret, 5) Super Secret. These then refer to the level of security placed upon each report, portion of a report, and even each single element of information. If, for example, a report were generated which was to be classified secret, then each piece of information contained therein would necessarily have to carry a classification of secret or less. This means that if someone were to try to generate a secret document containing top secret or super secret information, then those fields which contained the higher classified information would automatically be censored out of the report and an error warning or flag would be indicated.

The same type of situation would arise if the various levels of NASA management were assigned a level of security classification for calling out information from the central reservoir. For example, a project manager might be assigned a top secret classification for his own project, but might be given only a confidential clearance for all other projects. (The same procedure could be followed for field center directors, program chiefs, etc.) Now if this particular project manager wished to interrogate the reservoir, his name would be keyed into the system for investigation and display purposes. The computer would then check his name in the personnel table, and extract only those reports which he was eligible to withdraw from the file. If the request were valid, he would then be given the information from the computer's reservoir. However, if the request were invalid, then his request would be denied, and the fact that he had requested would be indicated by the computer.

In other words, all levels of NASA management as well as all documents, partial documents, and single pieces of information would be assigned a security classification. Only the permissible pairing of personnel and information would be allowed to communicate.

DETAIL LEVEL NUMBERS

Various management levels of NASA would also be assigned detail level numbers in reverse order, so that the project managers would be given the highest detail classification (indicating that they were to receive the most detail) while the administrator would have the lowest detail classification (indicating that he would receive the least amount of detail). This designation would in no way be associated with the security classification, but rather would deal with the level of summarization which would be necessary for each management report.

This summarization concept would be carried out in somewhat the following manner. Let us assume there were ten levels of report summarization in the overall management system where level number 1 represented the top level and number ten the bottom level. Figure 30 indicates the level of summarization which might be presented to each level of management.

Management Level	Detail Level Code	Detail Levels Shown Level Numbers
Administrator	1	1, 2, 3, 4, 5
Program Director	2	2, 3, 4, 5, 6
Program Chief	3	3, 4, 5, 6, 7
Field Director	4	4, 5, 6, 7, 8, 9
Project Manager	5	5, 6, 7, 8, 9, 10

Figure 30. Summarization Levels

This, of course, does not say that if the administrator wished to look at detailed levels 6, 7, 8, 9, and 10 that they would be unavailable, but rather that in routine day-to-day processing he would not be buried in this lower-level detail.

Now that the basic philosophy underlying this system of file interrogation, file maintenance, and report generation has been determined, we will show the layout of the file to accomplish it. The first record contained in the file would be the File Label which would contain the following elements:

Executive Code
Reel Number
Writing Mode
Dictionary Attached
Block Size
File Name
File Code and Application Code
Purge Data

The Executive Code is the number assigned for use by the top level executive routines such that when the executive routine calls out this code, that this specific file is called for as opposed to some other file. This eliminates the possibility, for instance, of data from one program or project from being updated by the wrong input data.

The Reel Number merely tells which reel (in the case of a multiple reel file) is now being processed. This enables the computer to check for sequence of the file, so that none of the file is inadvertently passed over by mistake in processing. Writing Mode merely tells the computer in which type of machine language, binary, B. C. D. or other, this file is written. The binary mode normally is used for most arithmetic type files, where the B. C. D. is usually given prior consideration for prose type information.

Dictionary Attached requires a "yes" or "no" answer and tells whether the information contained in this file is of sufficient complexity and variety to require the use of a dictionary table to define each of the records.

Block size merely indicates some economical or convenient chunk of data for processing purposes. This enables the computer to read in a constant number of words of data at each reading cycle without regard to the actual number of words contained in one logical record.

File Name is self explanatory and is usually associated with consistency of data, report titling, etc.

File Code and Application Code are also self explanatory where the File Code is used for checking consistency and the Application Code tells for which reports this file is to be used as a source document.

The Purge Date merely tells when this file can be destroyed, so that the magnetic tape reel may be re-used for another purpose or for subsequent processing by the same file. Usually a file may be purged after two or three subsequent files are created, thus relieving the need for this superseded information.

Additional information may be contained in this File Label, and possibly some may be deleted, but in general the File Label should contain all or most of the eight fields described above.

Following the File Label is the Dictionary Section of the file, where each dictionary entry defines the format for given records in the Text portion of the file. The Dictionary Section will contain as many separate and distinct Dictionary entries as there are record types contained in this file. For this reason, it is therefore possible to place as many different types of records into one file as are necessary for the overall system. Each dictionary entry contains the following information:

Dictionary Label
File Code
Record Type
Record Length
Group Header
Parent Code

The Dictionary Label is the identification matching a Text Record field contained in the body of the file, used to identify which dictionary entry is to be selected.

The File Code is the same code as was described under Section 7 of the File Label and is used here also to check consistency of input and processing.

The Record Type is actually the portion of the dictionary entry which defines all the field of the record in question. In the actual Text portion of the file, a word is designated as the record type number and this is the same number shown here in the dictionary section. The Record Type portion of the dictionary entry is broken into the following particulars: field number, field mode, field size, record increment (beginning word and number of bits), field name, authority to change, authority to look, sequence level (for indenturing), replace only designation, allowable range (minimum and maximum), file maintenance and date of last dictionary change.

The Group Header merely tells the indenture level of this particular record in the file, so that it may be sorted into proper sequence and/or summarized with the records in the file.

The Parent Code tells to which other record type that this specific record type is subordinated, so that summaries and other groupings of information and data may be accomplished.

The Record Name is self explanatory and is used for referencing and report generation.

With the file set up in the manner described above it would now be possible to generate any desired number and variety of management reports. To extract information from the file it would require definition of only a small number of parameters together with the format desired. Another feature of a file set up in this fashion, is the ease with which file maintenance and file processing may be accomplished. Several options are available under the file maintenance program. The file may be either up- dated record-for-record or for selected records, records may be changed, deleted or expanded, certain records may be completely deleted or new ones added or the entire format of the file may be expanded. All this may be effected by any member of the NASA management team that has the authority to change the file. However, if someone not having the authority to change the file were to attempt a change in any manner whatsoever, the computer would merely reject the request and leave the file unchanged, thereby assuring complete assurance of reliability of the data held in the file.

In order to maintain a meaningful schedule for both the schedule status reports and the financial status reports it will be necessary that reports be generated, reviewed and forwarded with a minimum of delay. The whole system of status reports, reviews, approvals and summarization is predicated on the following sequence of events.

The initial input to the system consists of the step reports and stage reports submitted by the various contractors to the respective field centers where the project is being supervised. The reports, which will be forwarded to the field centers on punch cards, should be filled in by the contractors on Friday for technical and financial information completed through the Wednesday of the same week. These cards are then forwarded Friday evening to the field centers. On Monday morning the cards are punched, verified and entered into the data processing for calculating. By Monday afternoon the computer will have completed the first-level status reports which will be reviewed by the project manager on Tuesday morning. The project manager may initiate any changes he deems necessary, or may release the report if there are no changes. The data then is resubmitted to the computer. The second-level status reports are finished Tuesday afternoon and are submitted to the field director for review and approval. The data is now introduced a third time and summarized for the program chiefs at headquarters, and the summarized data is also forwarded by the sub-reservoir to the central reservoir at headquarters. On Wednesday morning the program chief reviews the status reports, approves or initiates changes, and sends them back to the computer to summarize to the fourth level for the program directors. This fourth-level report is completed Wednesday afternoon and is reviewed by the program director on Thursday morning. On Thursday afternoon the data is resubmitted for the fifth and final time to the computer, and summarized for the administrator's status reports, which he may then review on Friday morning.

Admittedly this is a very tight schedule, especially when one considers the four levels of report review and approval which are currently required. If these reviews and revisions could be eliminated (or at least compressed into a lesser number) then the system could work on the same schedule, but with much more flexibility. Probably the best compromise would be a single unified review at the field headquarters by the project manager and field director at the same time and another combination program chief-program director review at headquarters, this cutting the number of summarizations and reviews from four to two levels.

Of course by far the simplest, most streamlined and very possibly the best system would be a single review by the project manager and then immediate summarization and reporting directly all the way up the management line to the Administrator in one pass through the computer. This looks especially attractive, especially considering that practically everything shown on the report is already historical fact and therefore is not subject to revision. The only elements which are actually subject to revision are those pertaining to future estimates, such as "time to complete" or "money to complete". In this way also, the possibility of intermediate censoring of important information would be greatly reduced.

In addition to all the various leveled status reports, various stage, step, goal, task, etc., analysis and exception reports would be generated to assist management in determining just where problem areas exist or where they are likely to occur.

With the above outlined system of reporting, automatic processing, and file maintenance, NASA management will have a dynamic tool with which it may more closely exercise its management prerogative and will automatically be made cognizant when danger areas start to form.

3A.3d. EQUIPMENT REQUIREMENTS

All of the system design, data format and volume, reporting requirements detailed in the four sections above are predicated upon the utilization of sufficient numbers and proper types of data processing equipments. If only a semi-automated system is to be installed, then only electronic accounting machinery, such as key punches, sorters, collators, printers and possibly the simplest of computers such as an IBM 604, would be required. However, to realize maximum utilization and full automation a somewhat larger complement of equipment would be necessary, especially in the area of computers. For this purpose, a limited number of hours on a large scale computer such as the IBM 7090 or IBM 705 would be required at each of the field centers having a data sub-reservoir.

In analyzing the available computer equipment in the present NASA inventory, which includes all computers either currently installed or to be installed in the near future, we find the following complement of equipment at the major field centers:

Goddard Space Flight Center	Marshall Space Flight Center
6 - LGP 30	6 - BUR 205
2 - IBM 704	10 - LGP 30
1 - IBM 709	1 - IBM 705
3 - IBM 7090	2 - IBM 7090
1 - IBM 1401	

Jet Propulsion Laboratories
1 - BUR 201
1 - IBM 7090
1 - IBM 1401

With this total capability, it can be seen that at Goddard Space Flight Center a total of three IBM 7090's are available for computing, at Marshall Space Flight Center, a total of two IBM 7090's and one IBM 705 and at Jet Propulsion Laboratories, one IBM 7090. Since a maximum of only about three to four hours a week would be required at each field center on a large scale computer, each then has the capability to readily handle all of the programs in the sub-reservoirs operating under the Management and Program Control System. Also, if the Manned Space Flight Program at Langley were to be included, this field center also has an IBM 7090 and an IBM 7070, both capable of maintaining a sub-reservoir of information. This means that in the over-all NASA computer equipment inventory, each major field center has the potential capability of maintaining a major sub-reservoir and issuing all the necessary financial and schedule status reports pertinent to its own activities, without seriously curtailing its current utilization of electronic data processing equipment.

COMMUNICATIONS LINKS

With the over-all Initial Operational Capability - Management and Program Control System, consisting of the center reservoir and three or four sub-reservoirs, various methods of data and information transmission must be supplied to facilitate the movement of this data from one part of the country to another. In general, there are three major categories of communication of data and information:

Facsimile Transmission
Closed Circuit Television
Data Transmission

The first of these, facsimile transmission, deals with the ability of an output device, at the receiving end of the system, to be able to exactly reproduce what has been transmitted by the input device, at the sending end of the system. Currently, there are several such devices on the market including the following:

Electronic Messenger Facsimile, by Electronic Communication, Inc., which transmits and receives copies of documents over communications circuits; it can be used over telephone, microwave or internal lines—copy size 8-1/2" x 14" or smaller.

Datafax Transmission and Receiving, by Datafax Corporation, which transmits and receives copy up to 9-1/2" wide and any length at 4 inches by minute. It operates on any voice communication equipment, namely telephone lines, private wire, leased lines or radio links.

Deskfax, by Western Union, which actually sends and receives facsimiles of telegrams directly to and from Western Union offices.

Intrafax, by Western Union, which is similar to above, except that it is for intra-Company communication over leased Western Union wire circuits.

Faxwriter, by Times Facsimile Corporation, which sends and receives over leased private wire or radio circuits, copy which is 8.3" x 13".

Alfax Facsimile Systems, by Alden Electronic Company, which has a whole series of facsimile sizes all the way from outdoor displays down to 19" copies.

These various facsimile transmission devices would be particularly useful where exact reproduction of the original data and information had to be reproduced in kind.

The second of the categories, closed circuit television, would be used to link the central reservoir with the administrators office, and whichever other offices could gainfully utilize the system. It might also be given consideration for sub-reservoirs and various offices at the field center. Closed circuit television operating over a coaxial cable hookup is widely used by many companies today. Among the leading manufacturers of these systems, we have General Precision Corporation, Ling-Altec Electronics, Thompson Products, Dumont, Remington-Rand, RCA, and others. The use of closed circuit television would afford the administrator the opportunity to exercise dynamic control over the various program and project inputs and outputs.

The last category and by far the largest, data transmission, deals with transfer of information contained on punched cards, paper tapes, magnetic tapes, teletypewriters, computers, keyboard devices, etc., both to and from like devices as well as different ones. Some of the major devices in this area are included in the following list which is in no way exhaustive:

1. IBM Data Transceiver, which transmits IBM cards, up to eleven 80-column cards per minute, over wire or radio communications without having to convert cards to punched tape or vice-versa. They can be transmitted over telephone and/or telegraph wires.

2. Telescriber, by TeleAutograph Corporation, which transmits hand-written messages instantly while they are being written to one or many stations.

3. Dataphone, by Western Electric Company, which transmits data at high speeds over telephone lines. It can be operated with teletype-writers, punch tape readers and perforators, card readers, card punches, card-to-tape or tape-to-card converters. The transmission provides for 5, 6, 7, and 8 channel punched paper tape or magnetic tape.

4. Cardaphone, by Western Electric and IBM, an experimental device for inserting IBM card into telephone set equipped to accept it. Data is transmitted over telephone line. It is a variation of the Dataphone input devices.

5. Kineplex TE-206 Data System, by Collins Radio, which is used with Kinetape or Kinecard Converters, will transmit and receive information from teletypewriters, punched cards, computers, magnetic tape, facsimile, etc.

6. Collins 768-G-1 Kinecard Converter, by Collins Radio, which transmits and receives IBM punched cards at 100 cards per minute. It is used with IBM 523 card reader/punch unit and Collins TE-206 Data System.

7. Collins 768-H-1 Kinetape Converter, by Collins Radio, which transmits and receives magnetic tape data at maximum rate of 300 seven-bit characters per second, is used with Collins TE-206 Data System.

8. High-speed Teleprinter, by Burroughs, which is a page-receiving keyboard sending device, using technique of electrostatic recordings, at recording speed of 1000 to 3000 words/minute. It translates electronic impulses over voice lines, microwave circuits on computer output with printed alphanumeric characters.

9. Telepunch, by Systematic, is an intercoupler for cable, connecting IBM keypunch machines with Teletype for data transmission or receiving.

10. Teledata, by Friden, is a transmitting and receiving unit for punch tape data, which can produce identical tape at a distant point.

11. Teletype Model 28-KSR, by Teletype Corporation, is a keyboard sending and receiving page teletypewriter.

12. Teletype Model 28-RO, same as item 11, except it is receiving only. It is equivalent to Model 28-KSR without keyboard.

13. Teletype Model 28-ASR, same as item 11, plus facilities for (1) perforating paper tape via keyboard; (2) tape transmission; (3) tape reception; (4) producing perforated tape as by-product of incoming and outgoing message; (5) typing on tape; (6) combining tape and keyboard operation for handling fixed and variable data; (7) translating electronic impulses from business machines for printout or transmission to other locations. It uses fully perforated or chadless 5-unit code tape.

14. Collectadata, by Friden, transmits edge-punched or tab card data to central data collection location where information is assembled in 8-channel punch tape for further processing. Variable data may be entered at transmitting end by 18 manually adjustable dials.

15. IBM 357 Data Collection System, by IBM, is an in-plant communication system with strategically located input stations equipped with card readers, which can be equipped with keyboard for variable data, and centrally located output station with a card punch. Input station can be located up to one cable mile away from output station. Up to 20 input stations can feed into each output station.

16. Univac BPTM Tape Converter, by Remington-Rand, converts punched paper tape to magnetic tape or vice-versa. As an off-line peripheral device, it can translate information from a wide variety of common and native language machines to electronic computers. It can duplicate from one paper tape to another without involvement of magnetic tape. Its reading rate is 200 to 240 characters per second; paper tape punching rate, 60 characters per second.

17. Tapes Perforator and Automatic Graphotype, by Addressograph-Multigraph, is a four-row keyboard machine which produces five or six unit code punched tape. The tape can be transmitted by telegraph or fed directly into Automatic Graphotype which produces embossed metal addressograph plates or plastic credit cards.

18. Sensimatic Control Input Equipment, by Burroughs, via adding machines type keyboard, data can be printed and as by-product produce IBM card or perforated tape.

19. Clary Print-Punch Combination, by Clary Corporation, enables data entered through Clary adding machine to produce as a by-product a printed and perforated tape up to eight channels at a punching speed of 20 characters per second.

20. Comptotape Data Preparation System, by Comptometer Company, is a programmed device for automatic production of 5, 6, 7, or 8 unit code punched paper tape as a by-product of normal Comptometer computation or verification operation.

21. Flexowriter, by Friden, is an electronic 5, 6, 7, or 8 channel, paper tape producing typewriter. It punches paper tape as a by-product of typing and reads tape for automatic typing, as well as reproduces tape. It can control other tape operated transmitters in communications systems. It reads tape at 100 words per minute, reproduces at the same speed, and originates tape at speed of typist. Auxiliary tape punch and tape reader can be cable connected to produce additional tapes or typing efforts.

22. Friden Tape Converter, Model 26S, by Friden, is a device used to convert 6-unit code tape into an equivalent S-unit code tape for data transmission with existing S-unit code transmitter distribution and reperforation equipment. Converter operates at 1000 characters per minute.

23. Dataflow System, by Underwood Corporation, is a basic system consisting of an electric typewriter and a tape punch. It can include three electronic typewriters, two tape readers, two tape punches, two adding machines, a card punch and a programming device that integrates and automatically controls all units. The system provides for manual typing of original or variable data, automatic typing of constant or previously used data from punched tape; automatic typing of selected data in a different format on another typewriter; automatic punching of selected data in punched paper tape of 5, 6, 7, or 8 unit code into punched cards.

24. Data Punch, by Victor Equipment Company, is a full keyboard adding machine that actuates a separate motorized tape punch using 5, 6, 7, or 8 unit code paper tape. Data punch produces two records simultaneously, a detailed printed tape and a punched paper tape which can later be converted to punched cards or used directly as input to the other data processing equipment.

25. Class 100 and Digit-Matic Analysis System, by Victor, are two systems which are the same except for speeds, that provide an automatic recap, distribution or analysis of data in punched paper tape previously prepared on tape producing equipment. The Digit-Matic is cable connected and is capable of adding, subtracting and multiplying. Reading tape at 1000 digits per second, the system selects and adds related figures, then transmits them electrically to Digit-Matic where a printed record is prepared.

26. Model 173 Tape-Ard-Punch, by California Technical Industries, provides for manual recording of data in 8-unit code tape via push buttons which illuminate when depressed.

27. Model 174 Tape-Ard-Duplicator, by California Technical Industries, coordinates a tape punch and reader to automatically reproduce, edit and revise old tapes for other uses. Continuous punching speed is over 900 characters per minute. Duplication can be stopped for manual insertion of new data.

28. IBM - 884 Typewriter Tape Punch, by IBM, is an electric typewriter and cable connected tape punch, producing 8-unit code tape as a by-product of typing function.

29. Typatape Recorder, by National Data Processing Corporation, is an attachment which makes it possible for adding machines, accounting machines, cash registers, etc., regardless of make and whether electric or hand operated, to generate special coded tape as a simultaneous by-product of the regular operation of the machine. The Typatape can then be converted automatically into punched cards or other numeric IDP media. A 5-unit alphanumeric code is under development.

30. National Adding Machines with Punched Tape Recorder and Card Punch, by National Cash Register, is an adding machine capable of producing by-product 5, 6, 7, or 8 channel tapes in any code.

31. High Speed Perforated Tape Reader, by Ferranti, is a machine which senses holes in tape by photo-electrically permitting reading speeds up to 400 characters per second versus 100 words per minute by conventional means. This increased speed is especially desirable when reading perforated tape into computers. The machine can read either 5 or 7 unit code tape.

32. Model 903 High-Speed Reader, by Potter Instrument Company, can read 5, 6, 7, or 8 unit coded tape at speeds of 150, 300, or 600 characters per second.

33. Model 909 Perforated Tape Strip Reader, by Potter, provides a method for processing information on perforated tape strips into digital-data computer systems at speeds up to 1000 characters per second. It reads 5, 6, 7, or 8 unit code tape.

34. Perforated Tape Read, by Burroughs, is a high speed photo-electric perforated tape reader at speeds of 1000 characters per second of 5 to 8 unit code tape for reading into control and computer systems.

35. Synchro-Tape Typewriter, by Remington Rand, automatically produces punched tape or edge punched cards as original documents are typed; it also types automatically from punched tape or edge punched cards at 120 words per minute. Five, 6, 7, or 8 unit code tape or edge punched cards may be read or punched.

36. Tape-To-Card Converters - C749, by Systematics Inc., converts 5, 6, 7, or 8 unit code tape into punch cards by a removable plug board and a program card in the IBM 024 or IBM 026 card punch at essentially the same speed as the card punch.

37. Model I - 170 Card-to-Tape Converter, by Systematics, interconnects on IBM 024 or IBM 026 Card Punch to 5 or 8 unit numeric or 8 unit alphanumeric Friden Tape Punch and under control of master program, can select information from cards to be converted to punched tape.

38. PDP/Data Integrator, by Taller and Cooper, is a machine which produces punched paper tape from alphanumeric punched cards and variable numerical data by means of standard 10 key full keyboard. The 5, 6, 7, or 8 unit code chadded or chadless output tape may be fed into the computer automatically or used for data transmission. There is also a provision for remote operation.

39. Justowriter, by Friden, is a paper punched tape activated and producing machine which provides justified right-hand margin copy for printing purposes. The machine is composed of two proportional spacing units, 1) Record, and 2) Reproducer.

40. Friden Add-Punch, by Friden, is a ten key, punched paper tape producing adding machine, which can produce 5, 6, 7, or 8 unit code tape.

41. Solenoid Input Add-Punch, by Friden, is a device to accept data from digital converters, control equipment, scales, flow meters, temperature and card punch machines, which can list, add and subtract the numeric information received as well as punch a common language paper tape.

42. Computyper Model C, by Friden, has a tape-punching and read-out feature using a Flexowriter. It is primarily a billing machine for preparation of orders or invoices. Through control programming, it is capable of automatic extension per unit, per hundred, or per thousand, discounts, taxes, etc.

43. Selectadata, by Friden, is a unit used in conjunction with Flexowriter for high-speed selection of pre-coded alphanumeric data from punched tape.

44. IBM 63 Card-Controlled Tape Punch, by IBM, reads alphabetic and numeric information punched in IBM punched cards and perforates five-unit code telegraphic tape. The machine consists of a card reading and tape punching unit.

45. Kleinschmidt IDP Equipment, a division of Smith Corona Corp., has four machines, namely, 1) Model 120 Typing Reperforator-Tape Transmitter, 2) Model 140 Tape Transmitter, 3) Model 112B Receiving Typing Reperforator, and 4) Model 150 Teleprinter. These are common language machines for transmitting and/or receiving five unit code tape. They transmit and receive at pre-set speeds of 60, 66, 77, or 100 words per minute, depending upon the motor drive gear used. They are usually used in private lines of wire circuits, radio-teleprinter networks or microwave relay apparatus and are widely used by the USA Armed Forces, but Western Union and Bell Systems have standardized on teletypewriters.

46. Synchro-Monroe Adding Machine, by Monroe Calculating Corp., is a full keyboard adding and listing device with a tape punch producing 5, 6, 7, or 8 unit code tape as an output.

47. NCR Class 31 and 32 Accounting Machines, by National Cash Register, are paper tape producing, card punching general purpose accounting machines.

48. NCR Paper Tape Reader, by National Cash Register Corp., is a high speed photoelectric punched paper tape reader which can convert data from paper tape to magnetic tape at a rate of 1800 characters per second. The reader will accommodate 5, 6, 7, or 8 unit code tape. This unit is a part of NCR's 304 Data Processing System but may also be used off-line.

49. NCR Multi-Purpose Converter, by NCR, transcribes information from one form to another, i.e.: Magnetic tape to high speed printer, magnetic tape to punched paper tape, magnetic tape to punched cards, punched paper tape to magnetic tape and punched cards to magnetic tape. It is an off-line unit of the NCR 304 Data Processing System.

50. IBM 382 Paper Tape Input, by IBM, is an auxiliary 5 and 8 unit code paper tape input device for the IBM 305 RAMAC at a reading rate of 20 characters per second. Paper tape input may be used separately or in combination with card input for RAMAC.

Once the method of data processing has been determined for each of the major field centers, the main problem which remains is the selection of the proper system of communication links, closed circuit TV's, convertors, etc., to move the data between the various sub-reservoirs, the central reservoir and NASA headquarters. Since NASA does not currently have a centralized data processing installation at headquarters, it is felt that this function could best be served through utilization of the data processing center at Goddard since they have a total of three 7090's which should give that field center tremendous data processing capabilities.

Under this system, the Goddard data processing center would then serve as a sub-reservoir as well as the central reservoir, with Marshall and Jet Propulsion Labs forwarding information from their respective sub-reservoirs to the central reservoir at Goddard. The information from the central reservoir could be processed at Goddard and then forwarded to NASA headquarters through means of a high speed communication link, data link, closed circuit or some other telemetric or visual means of direct communication, to be displayed at headquarters in the form of displays, network charts, bar graphs, television pictures, etc.

The communication link between Goddard and Marshall or JPL or Langley, of course would not have as stringent a requirement since a slower method of data transmission would suffice. For all intensive purposes it is felt that a transmission rate of two to four hours for major portions of the field center data would be sufficient, since normally it would not be a headquarters requirement to see the quantity of detail contained at the field sub-reservoir other than on an exception basis.

Therefore, the over-all data processing system for NASA might be summed up as follows:

Sub-reservoirs at: Goddard, Marshall, JPL and possibly Langley.

Center reservoir at: NASA Headquarters (however, physically located at the Goddard site with direct line communication with headquarters).

All sub-reservoirs are to be linked to the central reservoir through communication links, or data links of moderate capability. With this arrangement and capability of equipment, NASA will then have the capability and potential of realizing maximum utilization of the Initial Operational Capability - Management and Program Control System and will thus be in a far better position to control the scores of projects and millions of dollars under their jurisdiction.

3B CONTROL CENTER AND DISPLAY SYSTEM

3B.1 Control Center

3B.1a DESIGN CONSIDERATIONS

Certain basic facts determined the details of facility design which have been recommended for the IOC-MAPCS Control Center. Each of these, important in its own right, was given exhaustive attention by Ramo-Wooldridge scientists, engineers, industrial designers, and technicians, who analyzed the Control Center requirements, studied many configurations (see Figures 31 and 32), and developed the detailed facility specifications (Figure 33) which are described in this portion of the report. A few of the more important factors which received consideration in the preparation of the final Control Center plan are listed below.

Space and Architectural Restrictions

a) The location of the Control Center and its relative position to that of the prime users, the Headquarters Staff, had been determined when the study was begun. Also, the over-all space allocation was accomplished prior to the completion of the design study. Consequently, all design efforts were conditioned by these occurrences.

   The proposed facility meets the first requirement of a Control Center in that it is immediately adjacent to the personnel who utilize it. Its size is adequate for the functions which it will contain, although somewhat small in terms of possible expansion. Its over-all dimensions (shown in Figure 34) are 48' by 58' 6". The specific measurements of each of the areas are given below.

Area	Dimensions
Control Center	48.00 x 58.50
Entrance and Reception Room	16.00 x 16.25
Reception Room Closet	7.25 x 3.00
Conference Room Storage Closet	5.25 x 9.00
Conference Room	25.75 x 36.00
Projection Room	25.75 x 22.00
Display Generation Room	22.00 x 35.75
Display Generation Room Entrance	7.50 x 10.50
Dark Room	14.25 x 7.00
Dark Room Entrance	3.50 x 6.00

b) Plumbing outlets for hot and cold running water are required for the Dark Room. For this reason, the Dark Room had to be placed somewhere along the East wall of the area, adjacent to rooms into which plumbing had been planned by the architect.

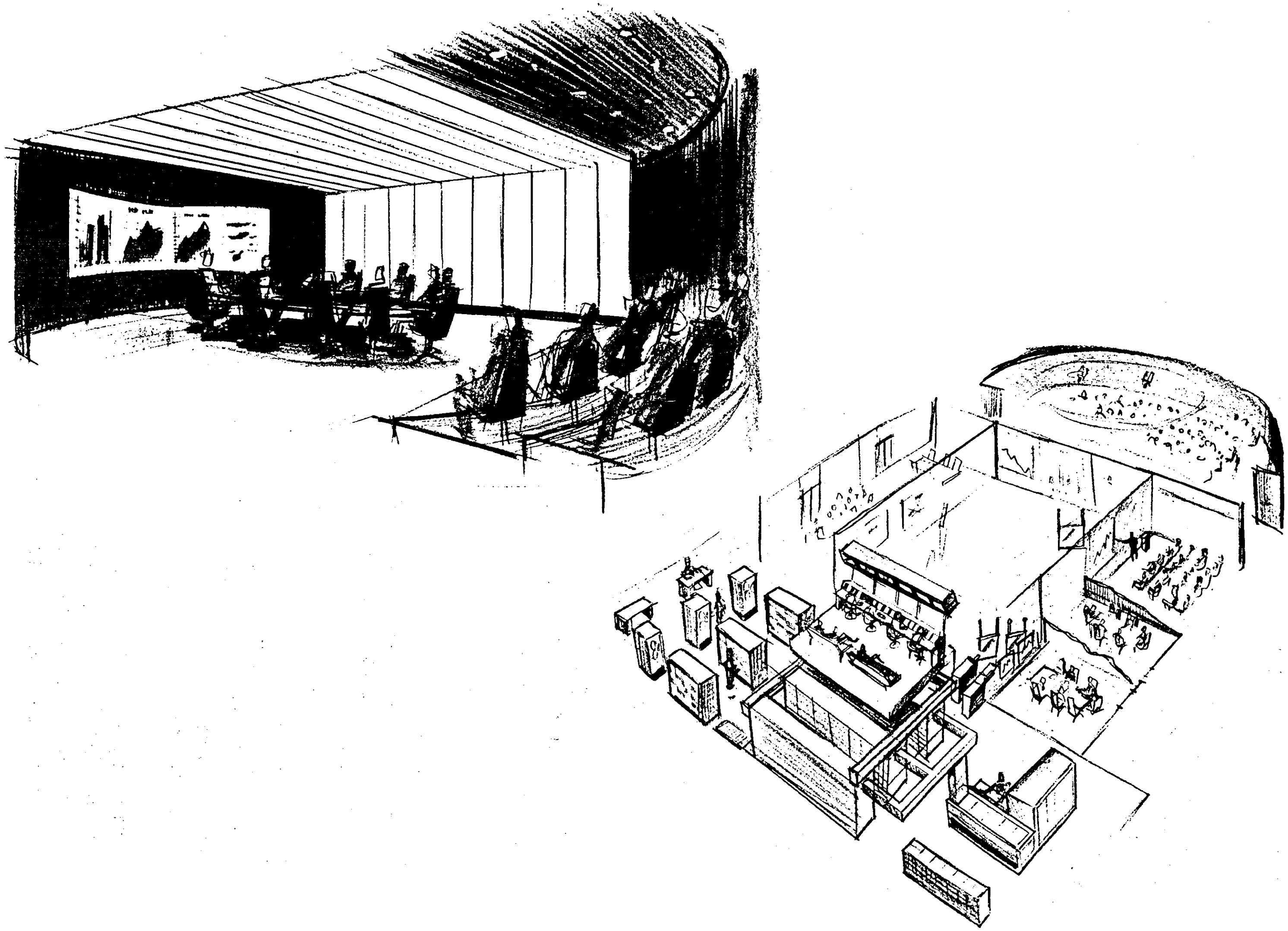


Figure 31. Early Conceptual Studies

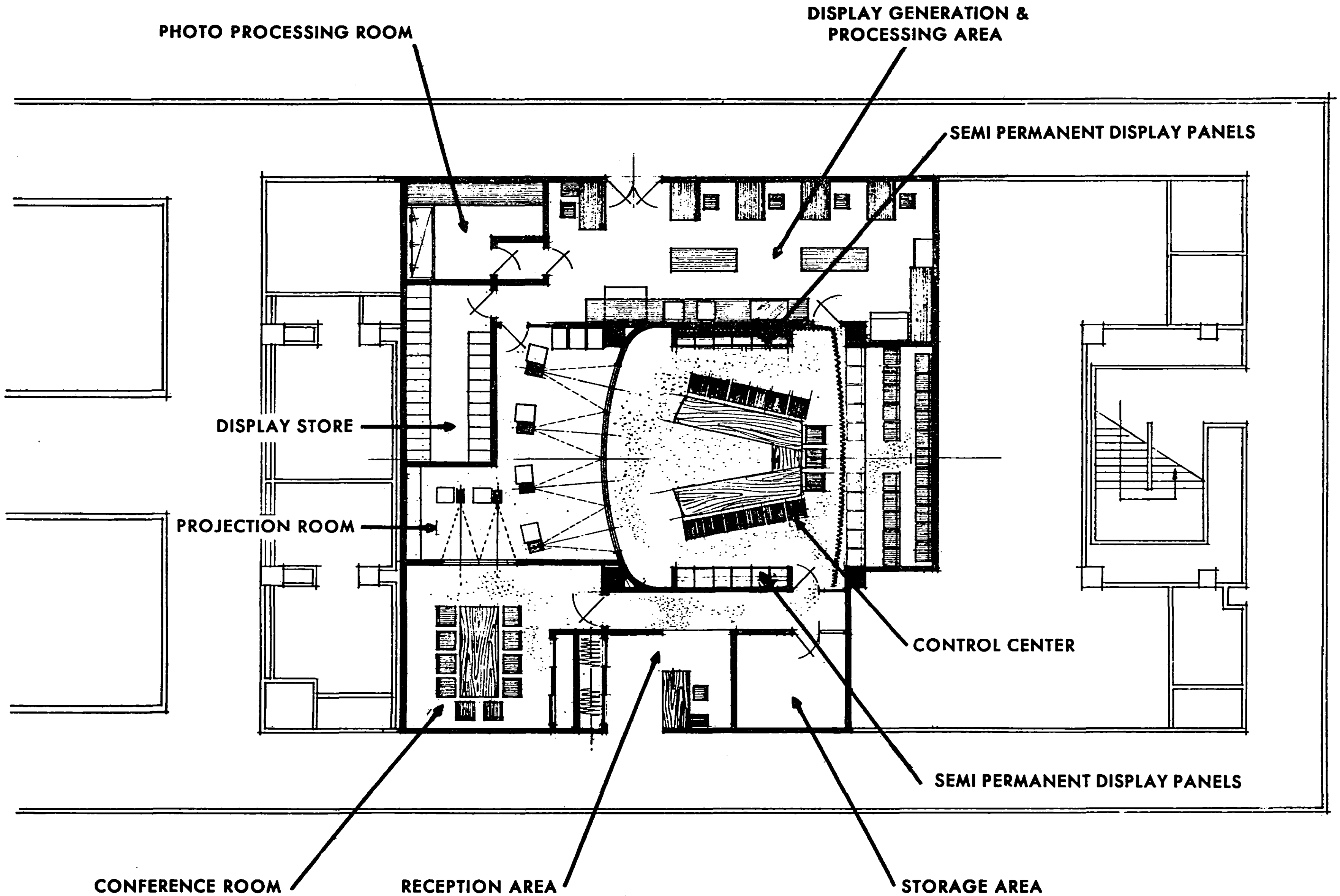


Figure 32. Preliminary General Plan

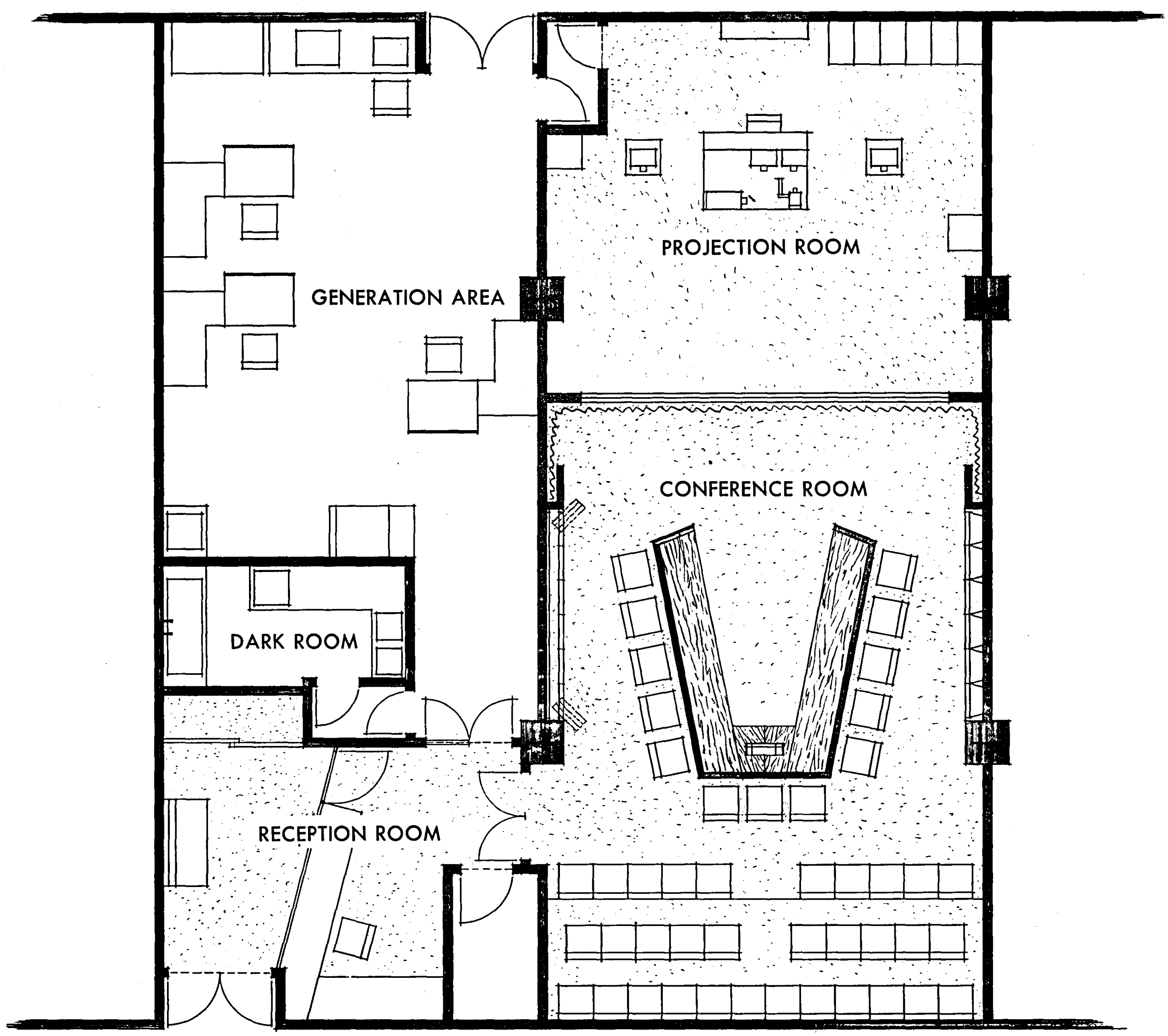


Figure 33. Facility Layout

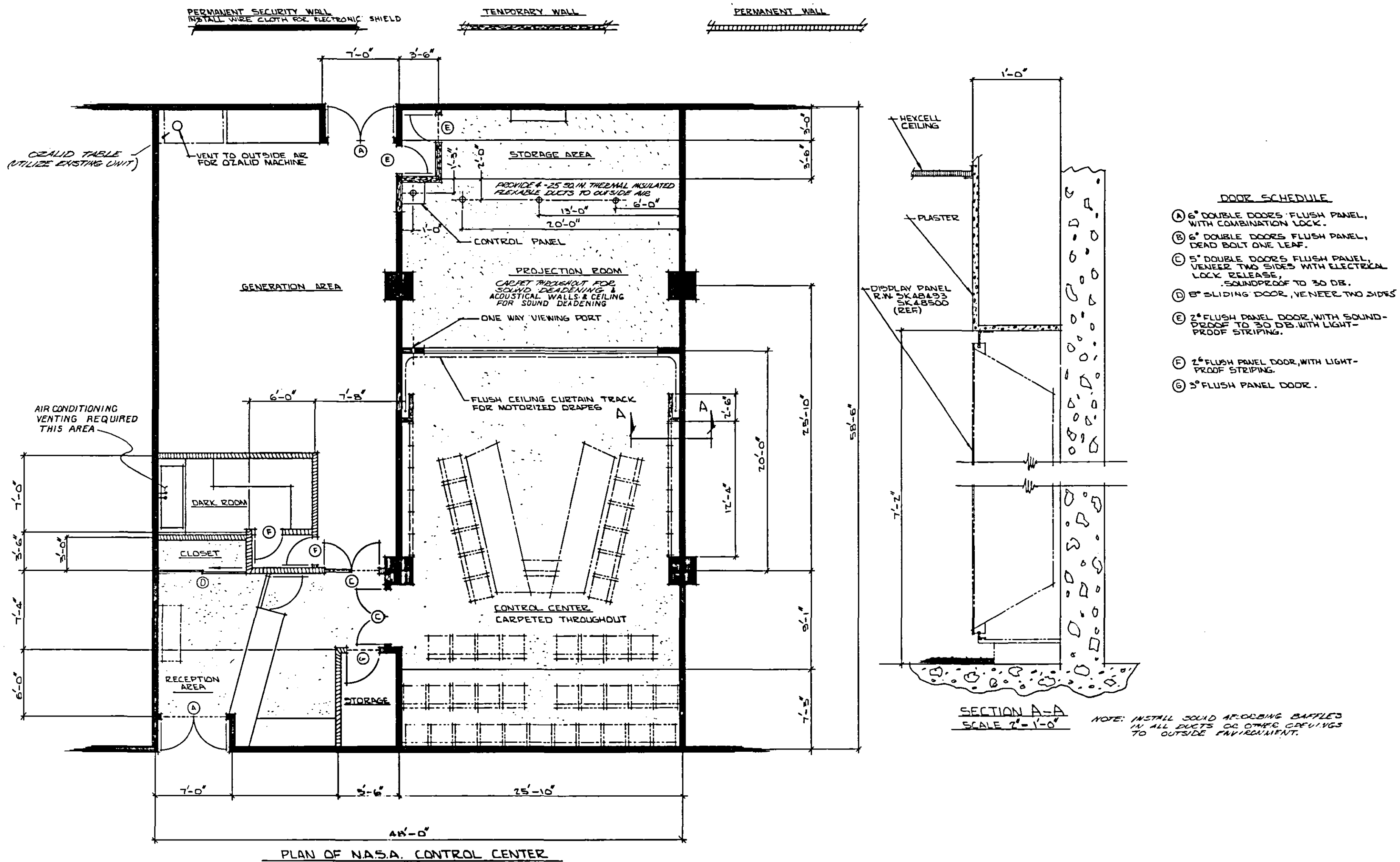


Figure 34. Final Architectural Drawing

c) Existing architectural restrictions, the four pillars in the allocated area, dictated the selection of a rectangular room which would allow space for rear projection facilities behind one of the narrow walls.

d) Fire regulations specified that all exit doors opening into hallways must be recessed and that doors to areas which would house many people must open outward into natural exit avenues.

Operational Requirements

a) The Conference Room seating requirements (40-50 people), as well as the stipulation that all should be able to view the display products, necessitated a large room which tended to focus upon the screen.

b) The Display Generation Room placement and design resulted from the requirements for a rapid generation of support for a briefing session, ease of access for supplies and support services, and centralized positioning within the Control Center.

c) The Reception Room location was determined by the fact that that it must be near the Administrator's office and yet centrally placed so that the Receptionist could provide support to the other areas within the Control facility.

d) Security considerations dictated that all problems concerning sound transmission to areas outside the facility, and control of traffic entering the facility, must be solved and that the solutions must meet the accepted standards of facility security.

Human Factors Considerations

a) Special attention was given to environmental conditions within the facility during the design study. In every instance, an attempt was made to provide: an area which is conducive to full production by support personnel; a Conference Room which is stimulating and practical; and equipment and facilities which permit more efficient and rapid utilization of information required for effective management planning, review, and control.

b) Acoustic noise control analyses for all areas within the NASA Management Control Center were developed during the study. The acoustical qualities of the Center were reviewed from the standpoint of Noise Criterion (NC) Values which take into account the sensitivity of the human ear to auditory stimulation at different frequency bands throughout the spectrum. The NC values used were those which had been found to represent the maximum permissible level of extraneous noise in an environment for the tasks to be accomplished. Proper interior construction and sound-deadening materials will be used to insure that these NC values are met.

3B. 1b. ARCHITECTURAL AND FUNCTIONAL DESCRIPTION

3B. 1b. 1 Reception Room

The Reception Room (Figure 35) will provide:

A single controlled entrance to the Control Center.

A working area for a Stenographer/Receptionist.

A place for visitors and conference attendees to store their wraps and belongings, make telephone calls, and wait in comfort for a conference.

The Stenographer/Receptionist will:

Control the access into the Control Center so that security requirements regarding "need to know", clearances and other related items will be implemented.

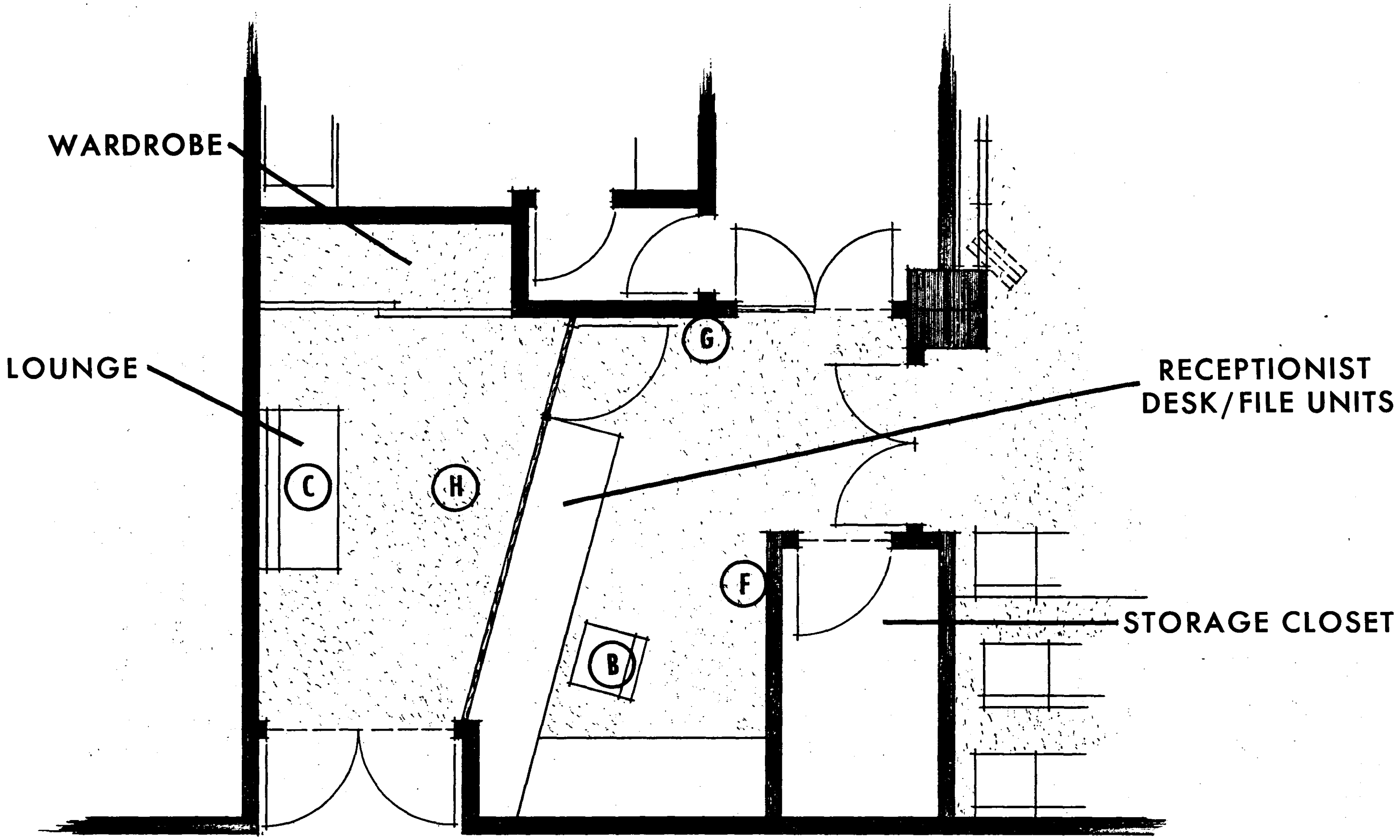
Act as a telephone monitor and assist conference attendees as required.

Maintain working files for the personnel in the Display Generation Room, prepare correspondence, and perform other clerical duties as required.

Maintain a schedule of the conference room use.

The Reception Room has been planned as a functional and decorative adjunct of the Control Center. Because of space restrictions, it has been made small and compact. As shown in Figures 36 and 37, no major construction modifications or installations (other than those required to install the access controls and telephone monitoring system) have been planned for this room.

The receptionist will have the equivalent of five two-drawer file cabinets, a center desk drawer for supplies, a lowered desk surface for her typewriter, and built-in hidden controls for the Conference Room and Display Generation Room (electric door locks; see Figure 36). Although it is recommended that the receptionist's desk and file compartments be designed and constructed to fit the decor of the room, standard off-the-shelf pieces of equipment may be used. It might be mentioned, however, that the modular design (shown in Figure 38) will cost no more than standard items which do not lend themselves to the setting. Finally, the chairs and guest lounge have been chosen to match the decorating scheme of the room. They are shown in Figure 39.



NOTE Encircled letters refer to decorating plan which is shown in color in Figure 47, page 132.

Figure 35. Reception Room

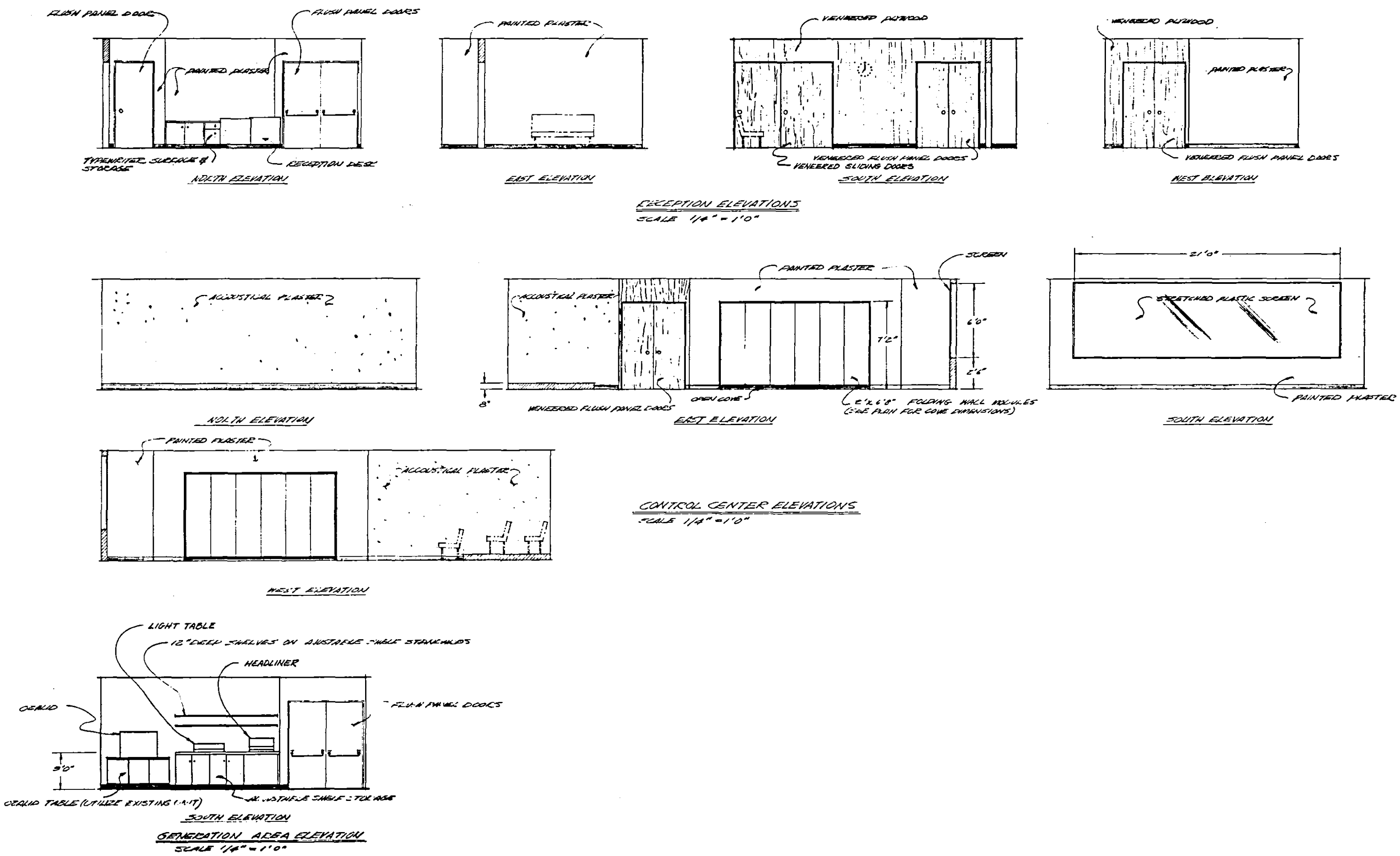


Figure 36. Architectural Elevations

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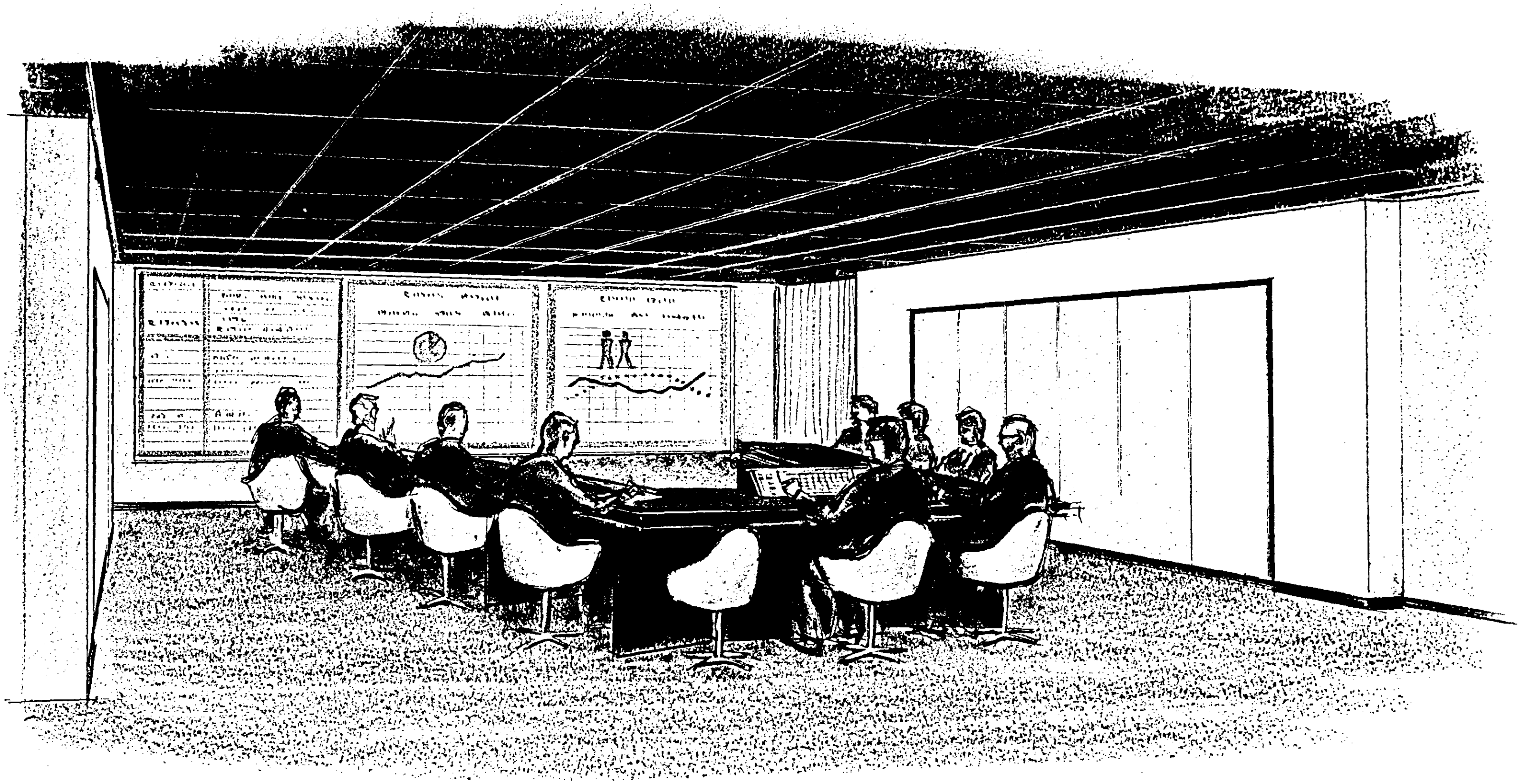
"Conference Room"

Figure 37. Wall Finish and Decor



CONFERENCE ROOM

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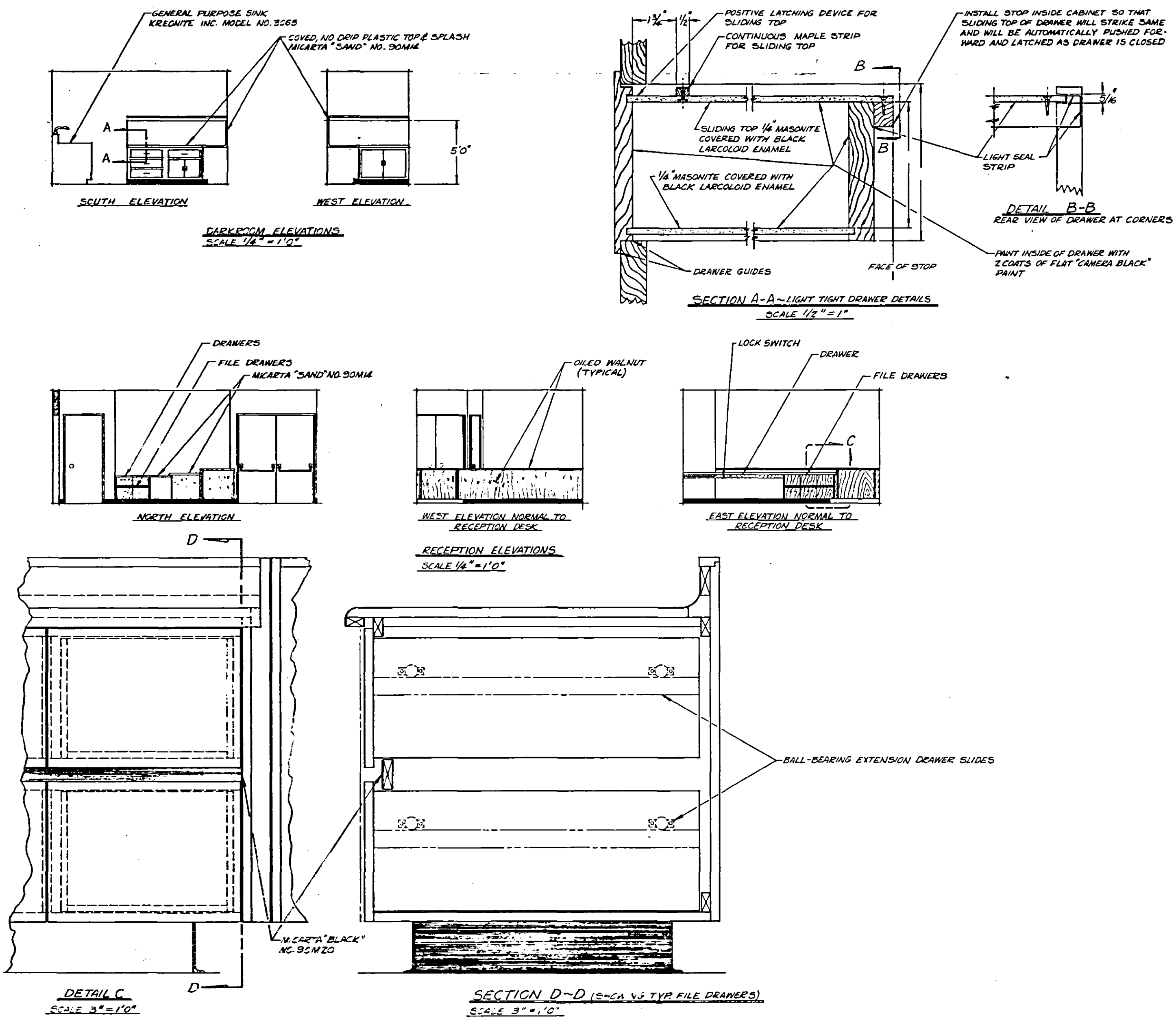
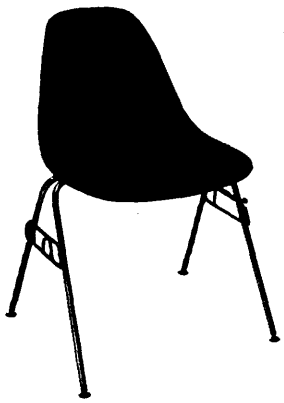
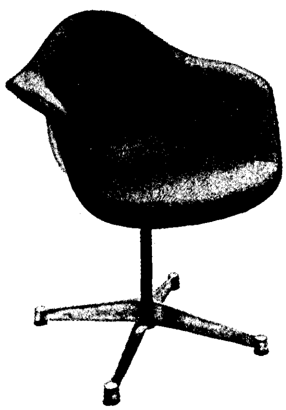


Figure 38. Cabinet Details



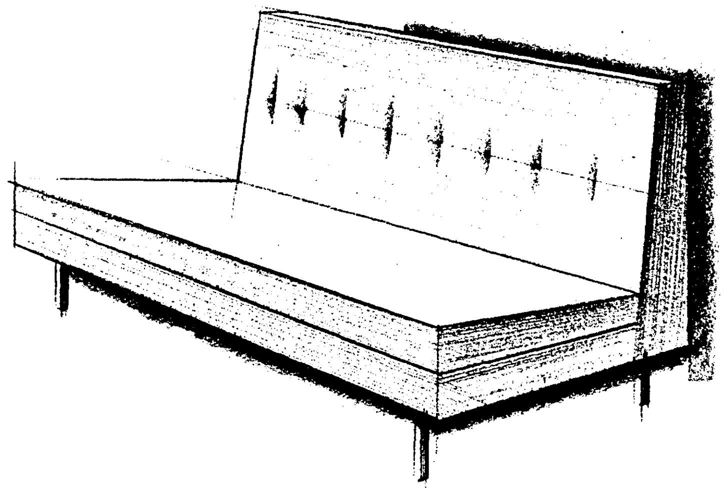
STACKING CHAIR

DSS-1

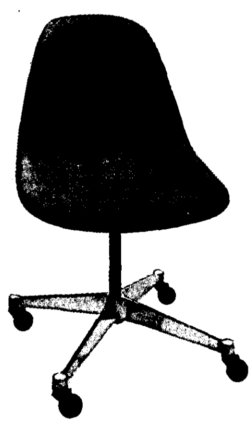


CONFERENCE CHAIR

PAC-1



RECEPTION ROOM LOUNGE



RECEPTIONIST'S CHAIR

PSCC-1

CONTROL CENTER FURNITURE

Figure 39. Furnishings

The receptionist normally will handle incoming and outgoing telephone calls, and will also have direct intercommunication with certain areas in the Control Center. A full description of the communications system is contained in paragraph 3B. 1d. 4, including descriptions of facilities provided in the reception room.

A storage closet has been provided for the storage of extra chairs and supplies for the Control Center. It is accessible to all rooms which may use it and provides overflow storage for wraps and belongings if required.

A standard closet unit is also provided. It has sliding doors to conserve space, and can be used without disrupting the routine of the Reception Room.

Lighting for the Reception area will be provided by the standard fluorescent lamps specified. An illumination level of 50 foot-candles at desk level will be maintained.

Lighting in the Storage Closet will be supplied by a standard incandescent lighting fixture with an ON/OFF switch located on the South wall (see Figure 40).

Reception area power outlets for the operation of office machines are available in standard wall-mounted two-place outlets. One each of these is mounted on the North and West walls and two are mounted on the East wall. An additional outlet on the South wall for an electric clock has been provided (see Figure 41). Standard wall plug outlets are specified for the East and South walls of the storage closet.

Provisions for security and emergency exits have been made within the area. Security will be guaranteed for the Center by electrically controlled locks for the doors to the Display Generation area and the Conference Room. The switches for the locks will be concealed in the Receptionist's desk. The controls may be overridden from the inside of each of these areas to permit emergency exit.

3B. 1b. 2 Conference Room

The Conference Room (shown in Figure 42) has been designed to serve as the focal point of management action and specifically to meet the briefing room requirements of the IOC-MAPCS. It will provide a modern and complete conference facility in a setting which is pleasing and stimulating. In it, an audience can observe any type of standard display projection on a full 6' x 21' screen or a segment thereof, and any type of presentation can be conducted. For example, by removing the conference table (which will be collapsible), the room can be used as an auditorium; if a staging effect is required, the rear platform may be used; the conference table can be reversed so that a panel of contributors can give a presentation to a selected audience seated in the rear. Furthermore, in the event that a "chalk talk" is anticipated, full greenboard space is available for a lecturer's use, as are the static display

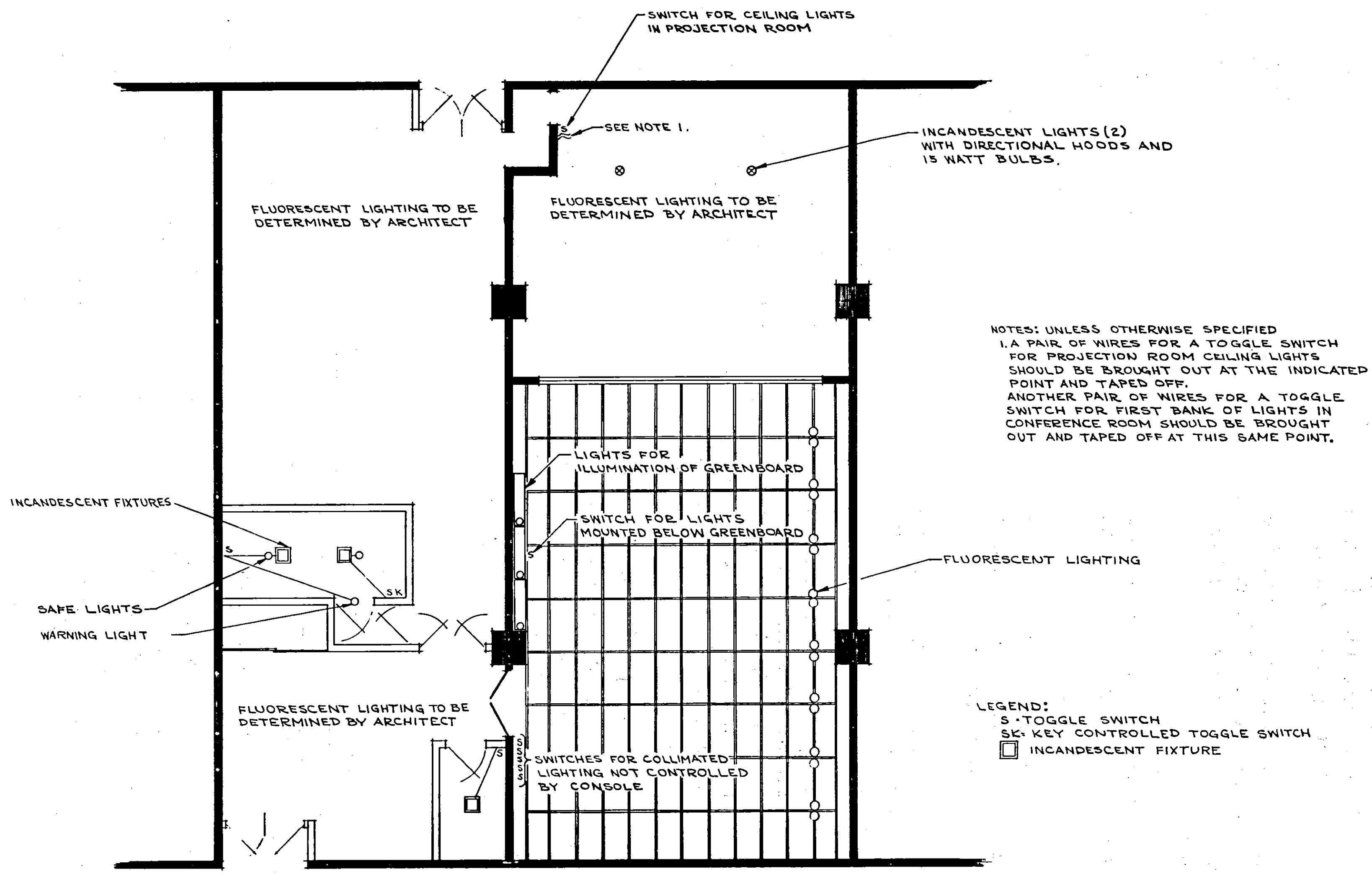


Figure 40. Lighting Plan

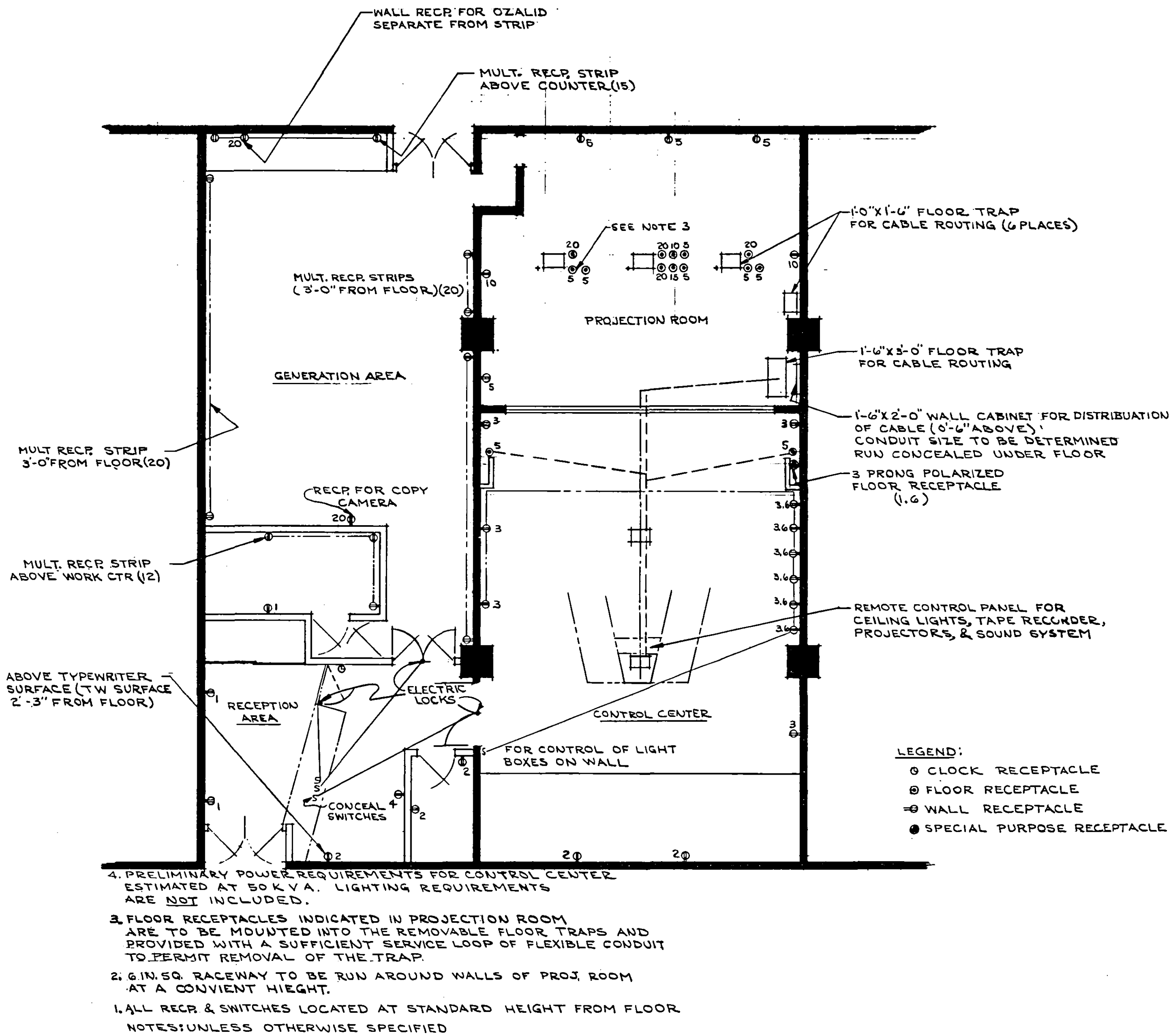
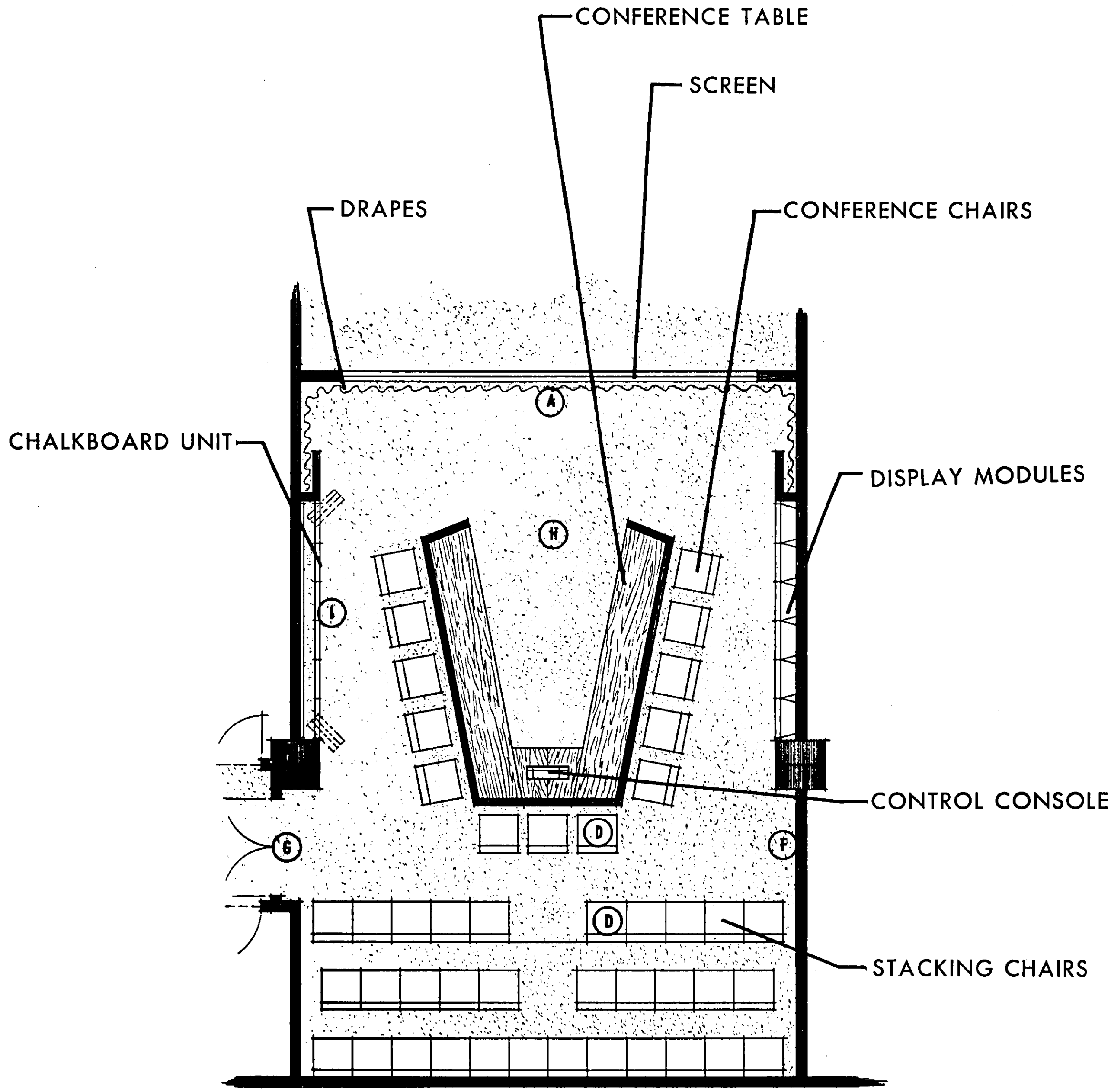


Figure 41. Power Requirements



NOTE Encircled letters refer to decorating plan which is shown in color in Figure 47, page 132.

Figure 42. Conference Room

panels which may contain transparencies depicting trajectories, vehicles, facilities or other data.

Finally, full public address and recording capability is available on an "as desired" basis by actuating the switches set in the table and lectern control consoles.

Concrete block walls on the North, East, and West eliminate the possibility of sound transmission to areas outside the Control Center. The South wall which contains the screen is not soundproof; however, the Projection Room behind it is secure.

The surface of all walls will require acoustical plaster application in the areas which are open to observation. Sound-proofing tiles and acoustical reflectors are not required.

The East wall will contain a twelve-foot-wide enclosed cabinet which will house the greenboards required for briefings (see Figure 43). The folding doors which conceal the greenboards will be constructed of the same material as that which will be used to face the display light boxes on the opposite West wall, thus insuring uniformity of wall surfaces.

The South wall of the room will contain a 6' x 21' seamless screen, mounted in the wall, and provision has been made for the insertion of a viewing port in this wall on the eastern side of the screen.

The West wall will contain the static display light boxes detailed in Figures 44 and 45. The boxes will be installed directly opposite the blackboards and will cover a wall area measuring 12' x 7'6".

The entrance door for the Conference Room will be a 40 decibel, soundproof type with rubber weatherstripping attached to the door frame. This will insure against sound transmission from the Conference Room to other areas.

A cabinet to house the draperies will be installed on the East wall, just south of the greenboards, and on the West wall, just south of the display light boxes. Each of the cabinets will contain one-half of the drapes which are used to cover the screen on the South wall (see Figure 46).

In keeping with the over-all tone of the Center, the interior decoration for the Conference Room has been designed to fit the environment. Wall treatment, carpeting and upholstery recommendations are shown in Figure 47.

Ceiling construction is explained in the lighting and power description which follows.

The ceiling lighting plan was prepared after a review of the operational and environmental requirements of the IOC-MAPCS had been accomplished. Major items which conditioned the decisions were:

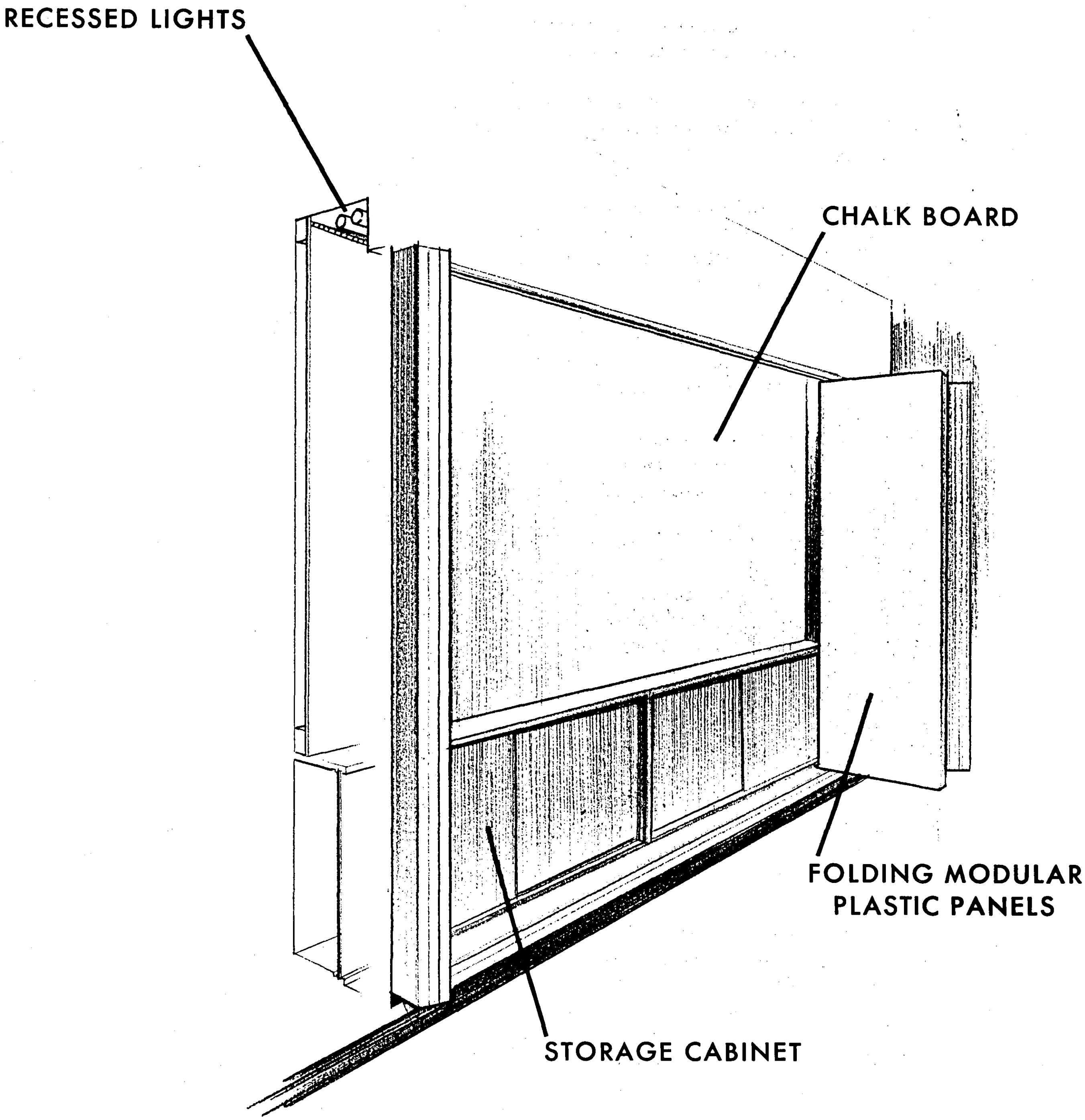


Figure 43. Greenboard Installation

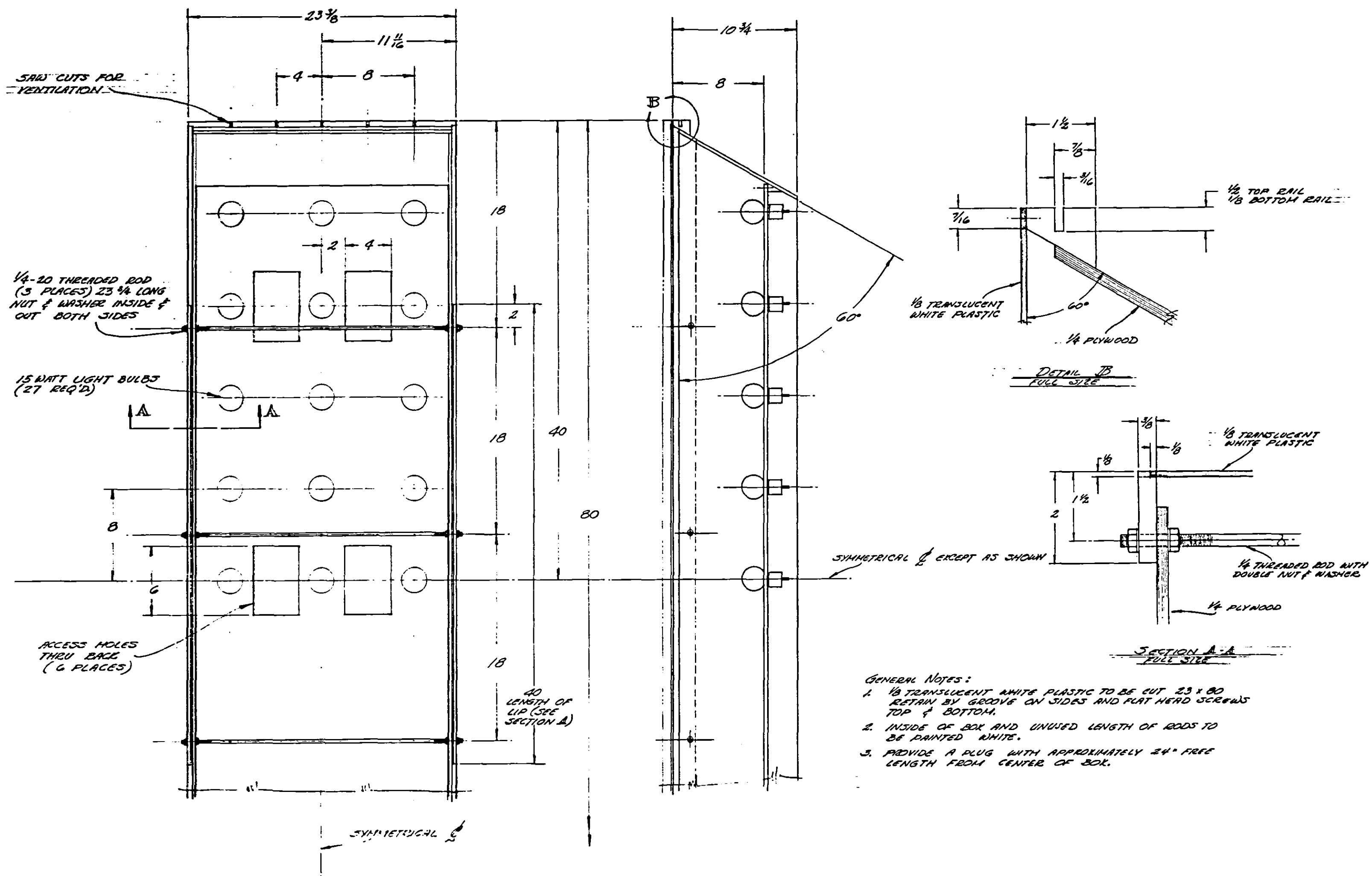


Figure 44. Light Box Module

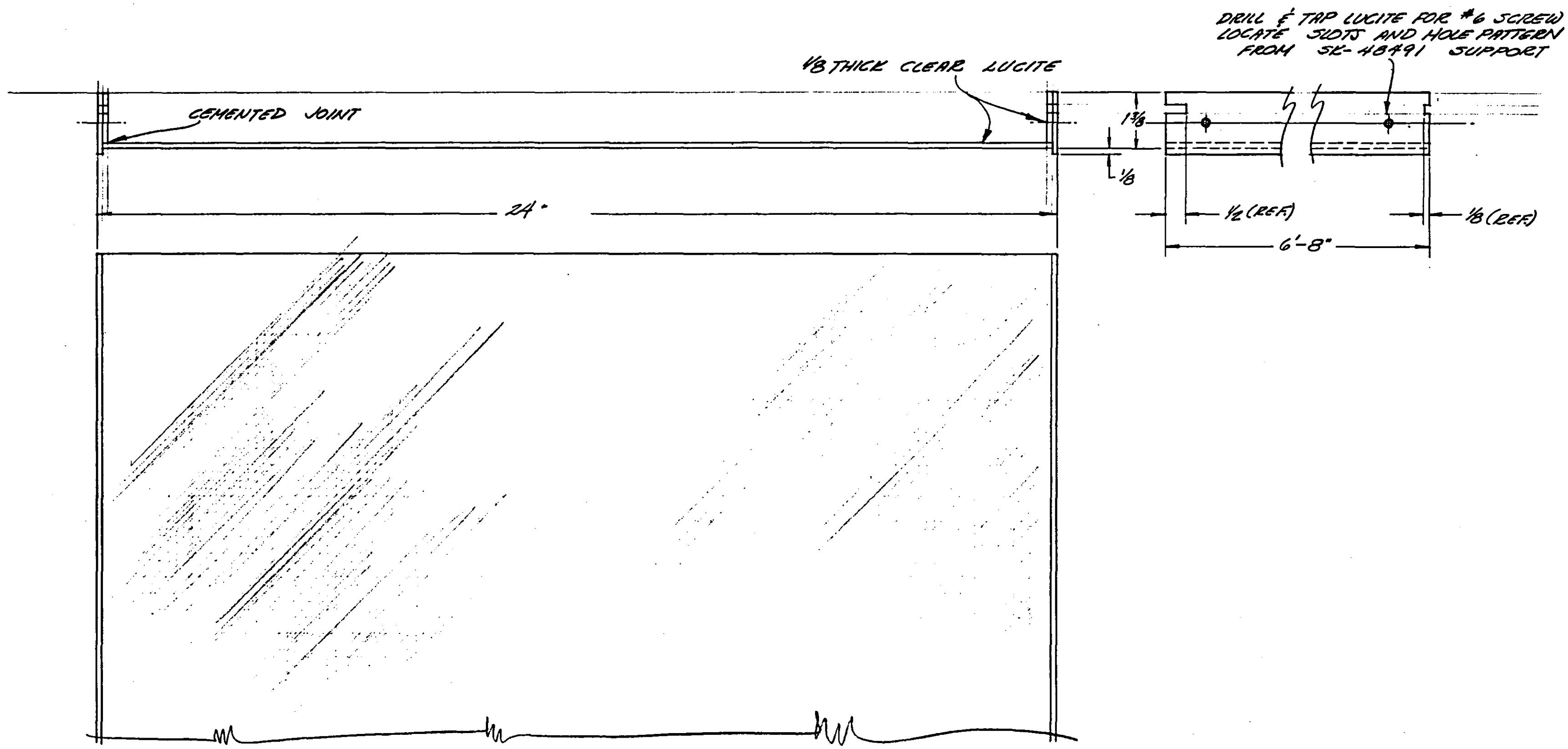


Figure 45. Light Box Module, Front Cover

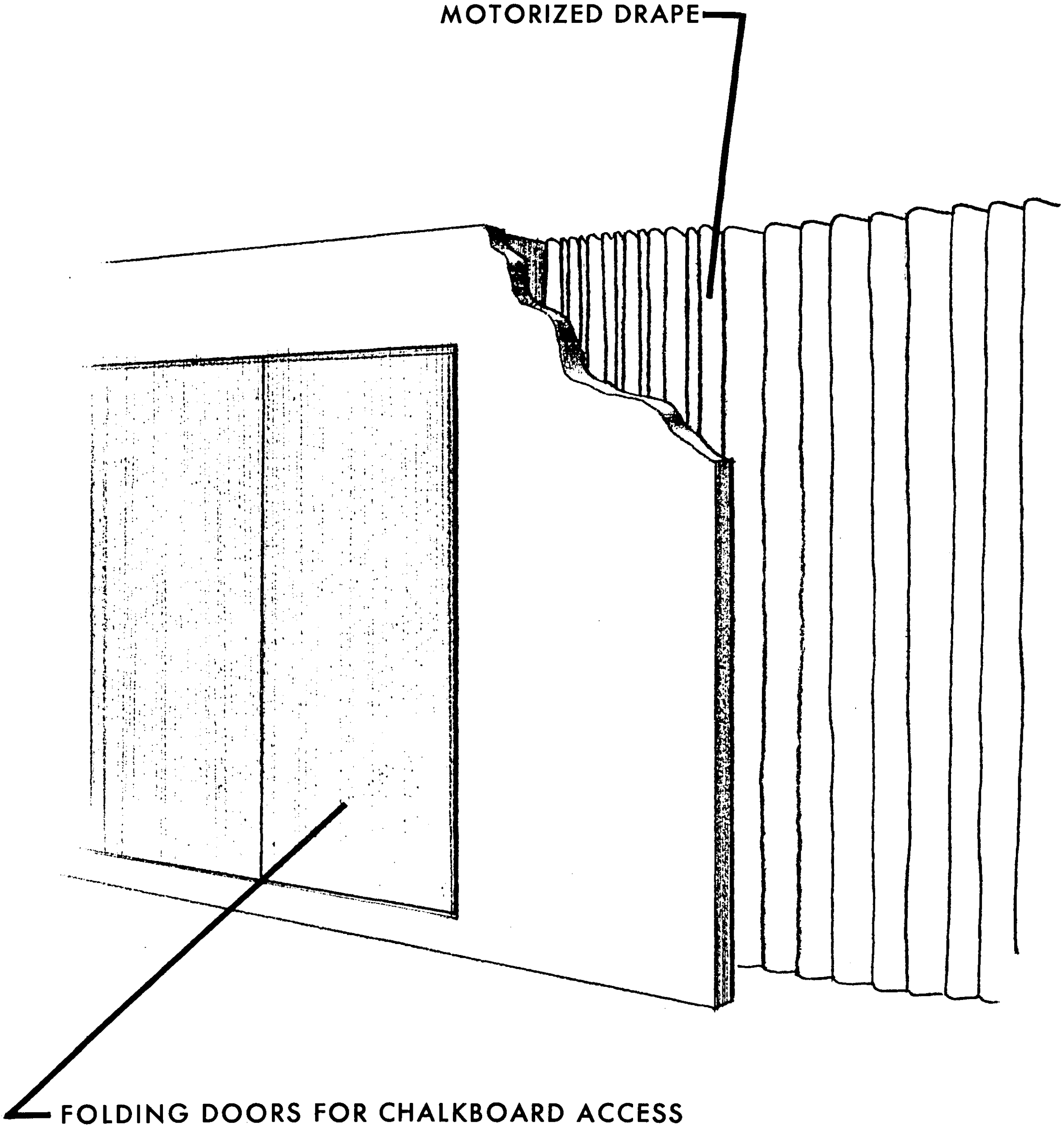


Figure 46. Drapery Recesses

Tip in Color Print

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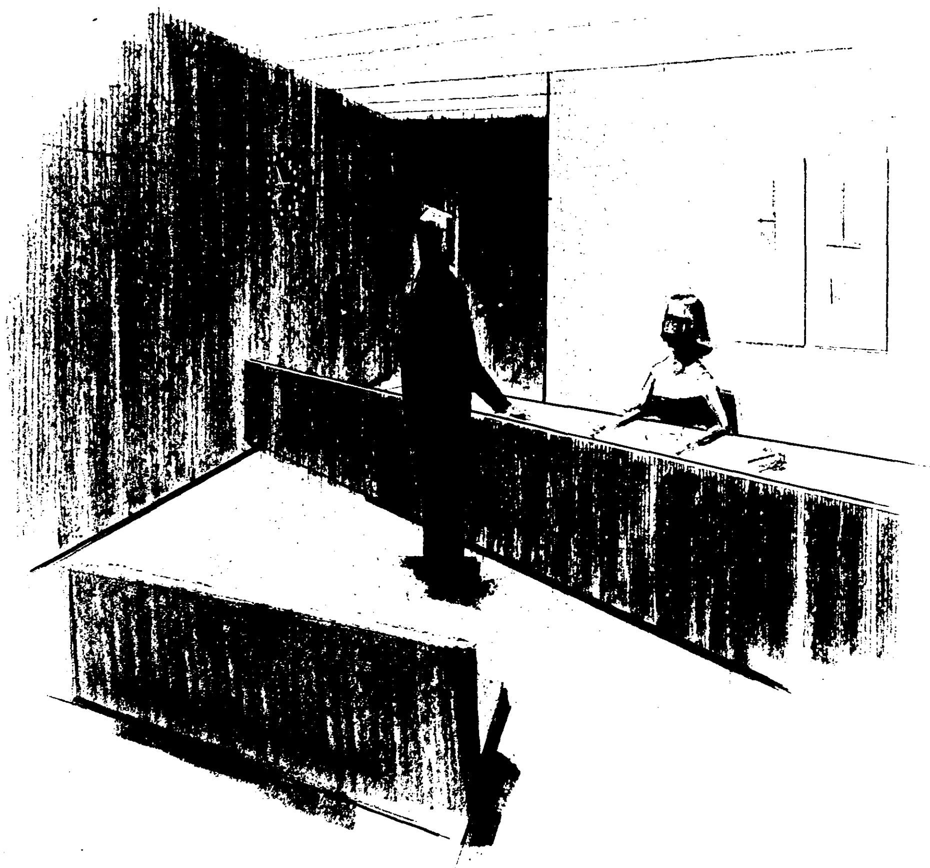
"Reception Room"

NOTE: If color print is absent from this file copy, the original transparency may be obtained from Mr. F. Lopresto, Ext. 1587, for reference purposes.

Figure 47. Decor Exhibit



RECEPTION ROOM

A CONFERENCE ROOM DRAPERY

B RECEPTIONIST'S CHAIR UPHOLSTERY

C RECEPTION ROOM SOFA UPHOLSTERY

D CONFERENCE ROOM CHAIRS UPHOLSTERY

E ACCOUSTIC WALL COVERING PROJECTION ROOM

F PLASTER WALL PAINT COLOR

G OILED WALNUT PANELED WALLS

H CARPETING

I MODULAR WALL PANELS

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Room occupants must be able to read and write while a display slide is being projected. This entailed the installation of a lighting system which would not impair a person's view of the projected image and also give him complete freedom of action.

Room lighting must also provide the type of light that would not interfere with the display projection techniques; i. e., the light path could not fall upon the screen.

The necessity of having a high ambient illumination together with projected displays in the same room has been, until recently, a serious problem to illumination engineers. However, the problem has now been solved satisfactorily by the use of ceiling fixtures which effectively collimate the light in the room, preventing any significant portion of it from reaching any vertical surface such as the display screen. This solution was chosen over others for the NASA Control Center because it is well within the state of the art and is relatively inexpensive. Drawings for this installation are shown in Figures 40 and 48. Preliminary estimates indicate that the overhead lighting will consist of continuous rows of four-foot fluorescent fixtures located on centers to be determined after completion of design. It is estimated that approximately 120 tubes arranged in 30 rows of 4 tubes each will be required. The first tube in each of the 30 rows will be controlled by the various projector controls. Because of the proposed Hexcell finish ceiling, the rest of the lights may burn continuously, even during projection, with no adverse effects. However, a group of switches will be provided just inside the door to control the lights if desired.

To arrive at an estimate[12] for the power required for ceiling lighting, it was assumed that the lamps to be used are the 96T12 Slimline. The total power required per lamp is 88 watts (including half the power required by a two-lamp ballast). A two-lamp ballast results in a power factor in excess of 90 percent, as opposed to a one-lamp ballast resulting in a power factor of 50 percent. The power required for 120 lamps is approximately 10,560 watts. There are 30 lamps associated with the projector controls. They will require 25.5 amperes. To conform to the National Electric Code, this circuit must be on two 20-ampere breakers. The remaining lamps will require 76.5 amperes. Splitting this into four 30-ampere circuits will conform to the National Electric Code.

Other lighting within the Conference Room will provide three dual fluorescent lamps to illuminate the greenboards. A switch located under the greenboard will actuate lights.

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12. An additional study of the illumination problem will be required when construction on the center is begun. At that time, accurate measurements of light requirements and reflective surfaces can be accomplished.

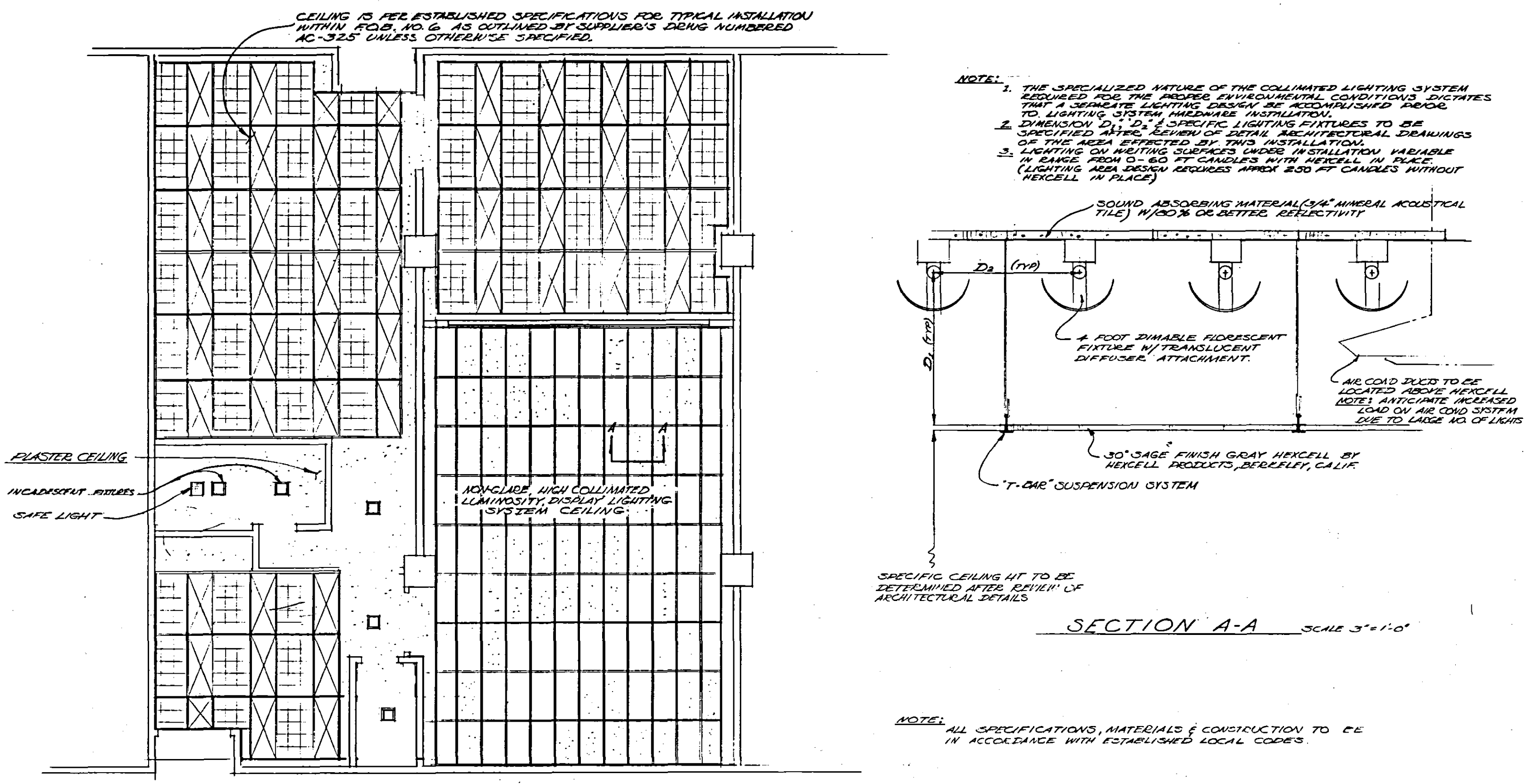

Figure 48. Hexcell and Fluorescents

Power outlets, switching panels and special installation within the area are described below.

(1) Overhead light switches (see Figure 40) are located just aft of the entrance door on the East wall as are the switches for the static display light boxes.

(2) Two convenience outlets are located on the South wall, three are on the East wall, and two are on the West wall.

(3) Six wall receptacles on the West wall, controlled by a switch just inside the door, provide power for a bank of semi-permanent display panels. Each of these display panels is illuminated by twenty-seven 15-watt incandescent bulbs. This leads to a receptacle loading of approximately 3.6 amperes each.

(4) A three-prong polarized floor receptacle is located at one side of the screen to provide controlled power for operation of the screen curtains. The curtains in front of the projection screen will be electrically-driven by a fractional horsepower motor and will open when a projector is turned on.[13] So long as any projector is on, the curtains will remain open. In addition, the controls will open the curtains a pre-set amount, depending on which projectors are turned on. For example, they will open approximately 1/3 for the movie and random access projector, and all the way for the serial projectors. Only when all projectors are turned off will the curtains return to their closed position.

(5) Conduit (see Figure 41) for the electronic console and lecturn will be run under the floor into the Conference Room from the control panel in the Projection Room. The conduit will carry control leads to two floor-mounted power receptacles located at each side of the screen which will provide power for the speaker's lectern and associated equipment. In addition, two small traps will be required to facilitate wiring of projector controls to the console which will be mounted in the table.

(6) The interlock between the electrical components and the audio units is explained in paragraph 3B.1c, which presents a description of the Control Center audio capabilities.

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13. Curtains will not be actuated when a projector is turned on for use with the video system.

The special items which will be purchased, modified, or built for use in the Conference Room include:

A portable control console (Figures 49 and 50) which will contain controls for projectors and auxiliary equipment.

A lectern (Figure 51) which will contain projector controls and other presentation aids.

A "V"-shaped conference table (Figure 52).

A chart easel.

Chairs.

Carpeting (Figure 47) for sound-deadening and appearance.

3B. 1b. 3 Projection Room

The Projection Room (see Figure 53) has been designed to house all equipments which will be used to service the conference room. Additionally, all files of display slides will be housed in the rear of the facility for ready access by the projectionist.

The projectionist within this area will have full command of all equipment. In the majority of instances, however, the prime missions of the projectionist will be to monitor the presentation, set up pre-programmed slides for showing, and service the audience as required.

This room is situated to the south of the conference room in keeping with the rear projection requirement which was chosen for large scale displays in the NASA Management Control Center. The basis for this choice was the fact that it is then considerably less difficult to maintain display contrast in an environment of high ambient illumination. Using conventional front projection techniques, when a high room illumination is desired, special screen materials must be used in order to get a display which is not completely washed out, and these screens may impair both the resolution and the quality of the image.

No sound transmission problem from this room to outside areas will exist because of the concrete block wall construction; however, because of the movement of sound through the screen from the projection room into the conference room, the floor should be covered with inexpensive carpeting and sound-deadening acoustical tile should be installed on the walls. The tile best suited for this purpose is a hard finish "Curon" polyurethelene foam which can be painted.

The north wall will contain an aperture into which the 6-foot x 21-foot screen and a viewing port will be installed. The recommended screen material is listed with the equipment recommendation, in Appendix B.

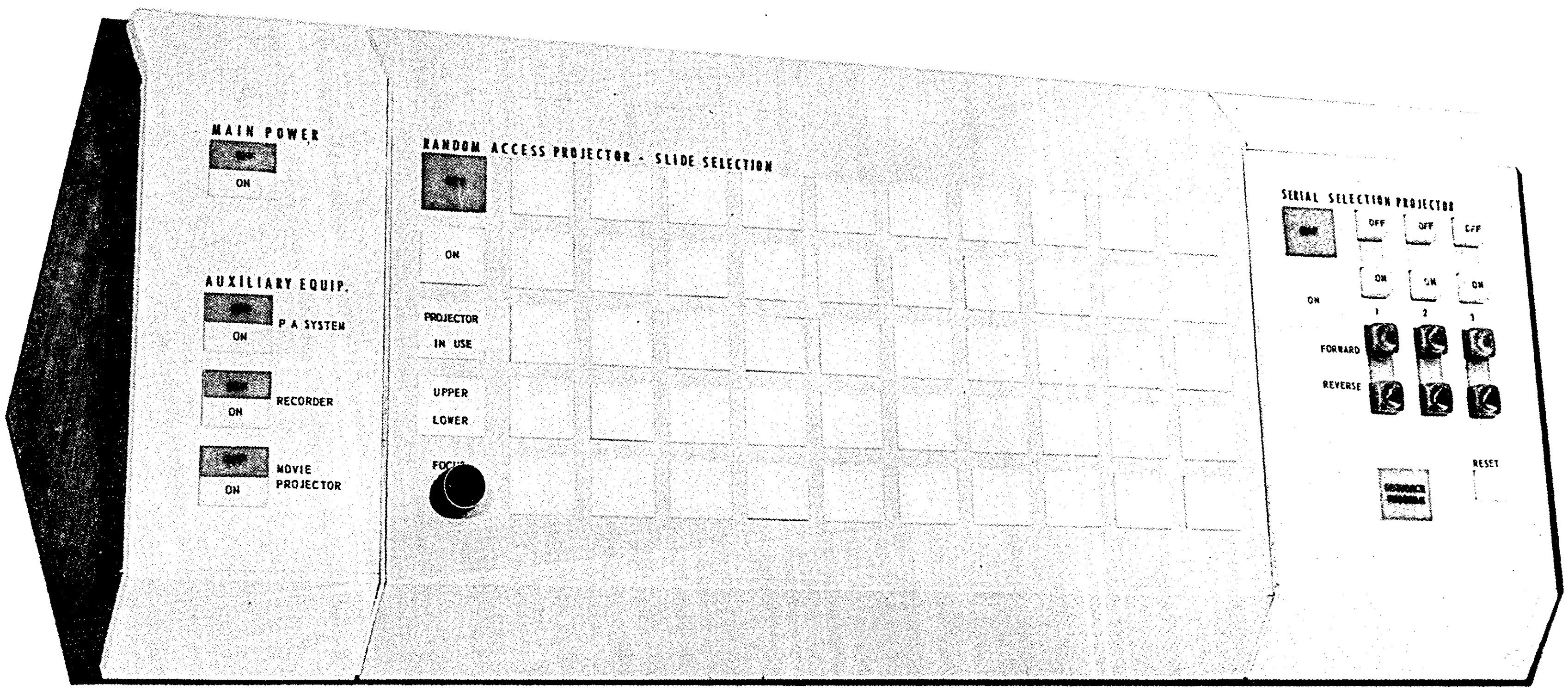


Figure 49. Control Console, Photo

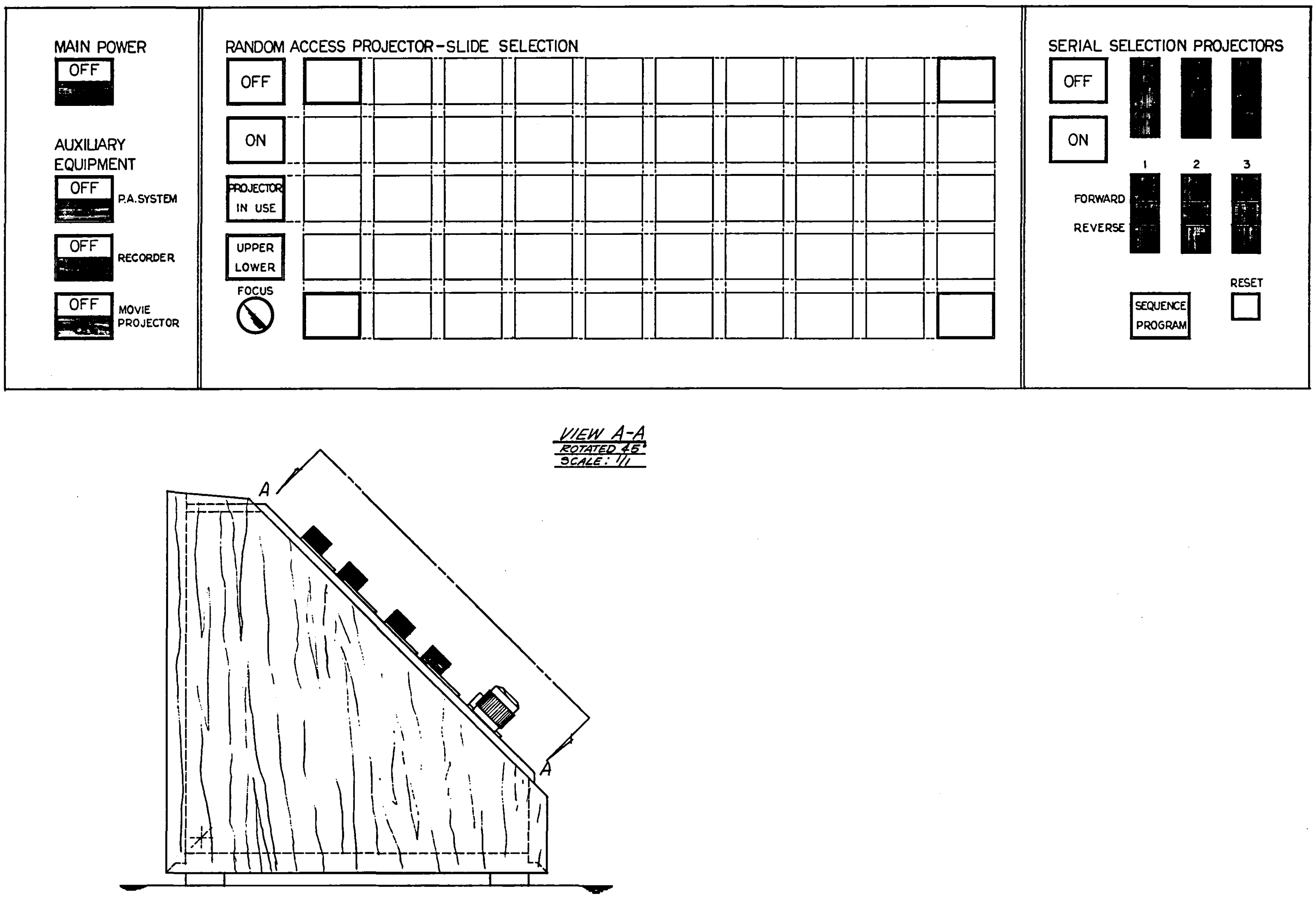


Figure 50. Control Console Panel

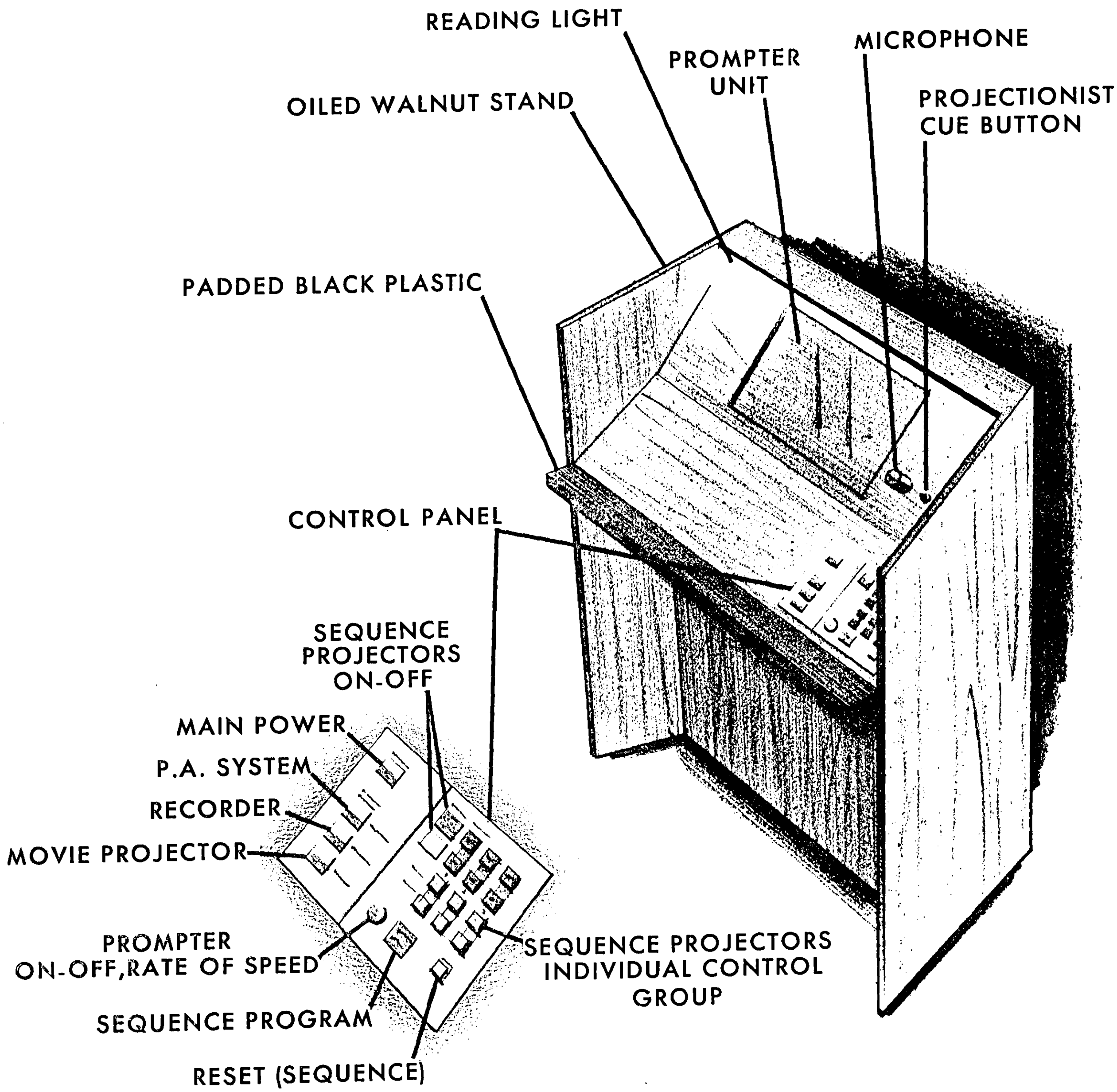


Figure 51. Lectern

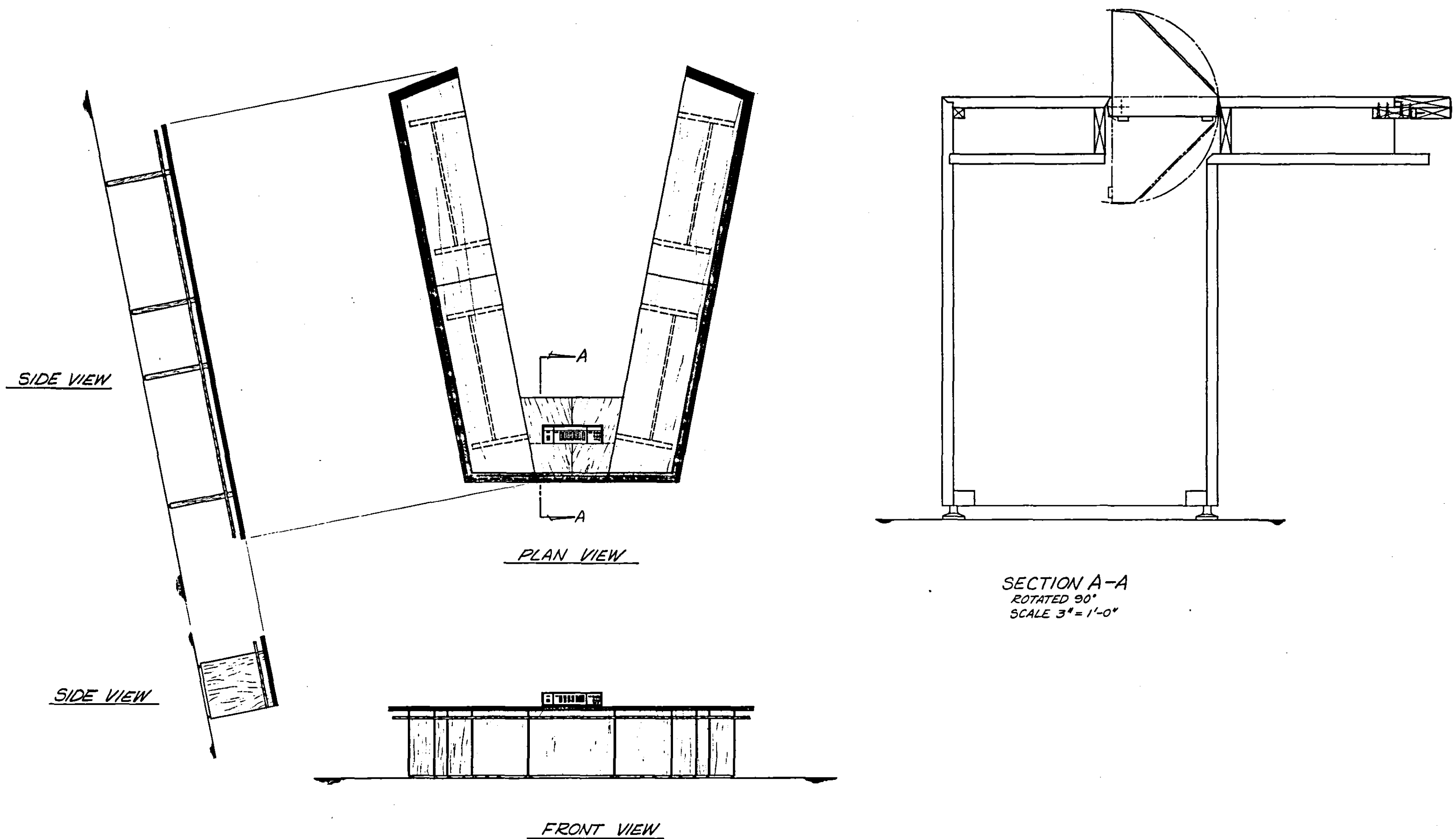
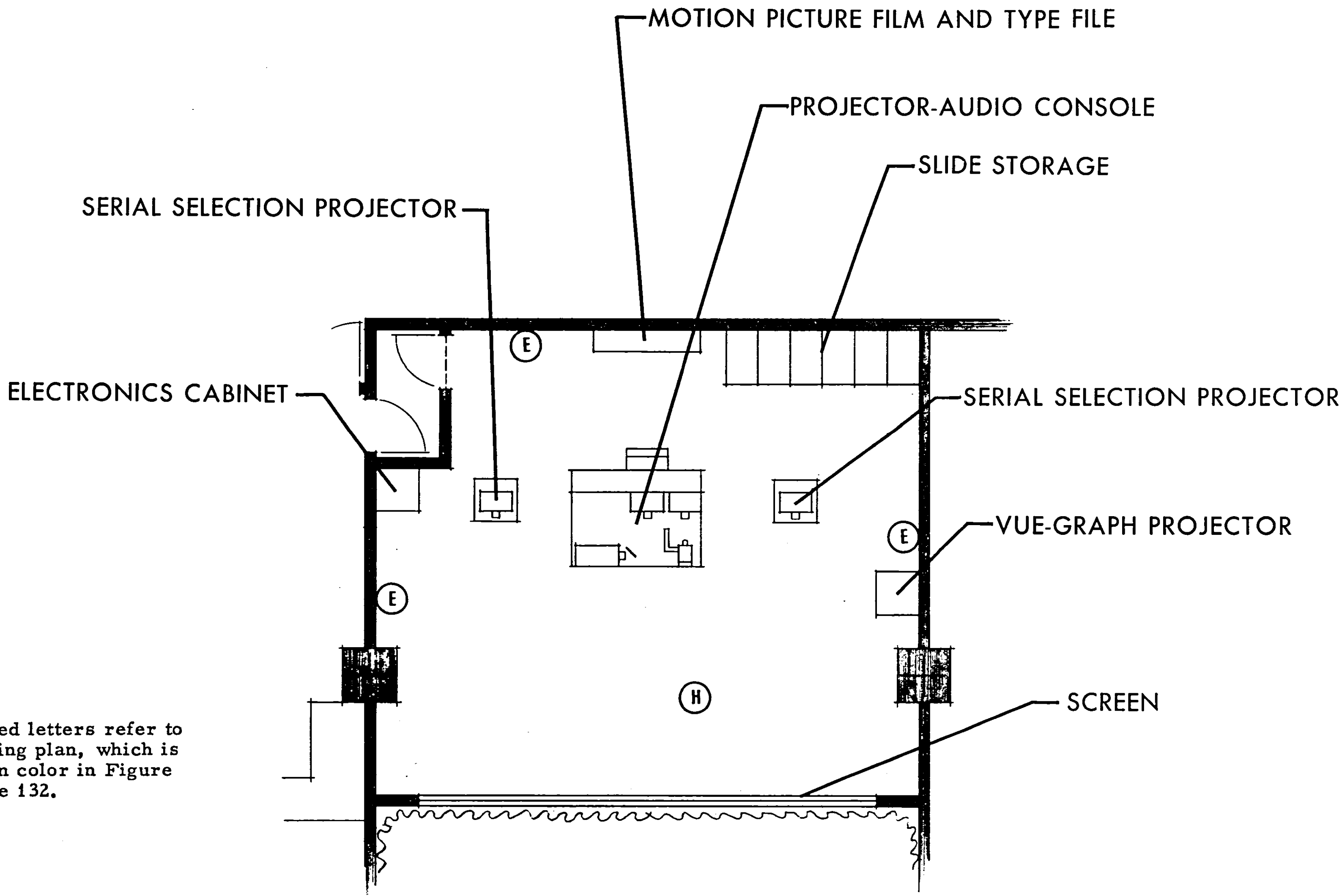


Figure 52. Conference Table



NOTE

Encircled letters refer to decorating plan, which is shown in color in Figure 47, page 132.

Figure 53. Projection Room

A light-trap-door arrangement will be required on the east wall of the room. The outer door (that which separates the Projection Room from the Display Generation Room) should be a weather-stripped 40 decibel door which will keep inside sound from filtering out and vice-versa. A second or inside door will be required to create a light trap so that an opened door will not let in light that will flood the screen while a display is being exhibited.

Above each projector, thermal insulated ducts will be installed. (See Figure 34) Each of these will lead to the outside air. These three ducts are deemed necessary for the elimination of heat from the projection area because each projector, while in use, will be generating heat into a closed area which will place an undue load on the air-conditioning system. If the architect deems these unnecessary, by reason of the fact that the air-conditioning system will handle the load, the ducts may be eliminated.

In addition to the items described above, it may be necessary to raise the floor level six inches to permit cable installation, repair, and revision. However, a detailed architectural review may prove that this will not be required.

No other special construction will be required for the Projection Room. Painting recommendations are included in Figures 37 and 47.

Lighting and power for the Projection Room (see Figure 40) will include:

a) Standard fluorescent lighting which will provide an illumination of 20 foot-candles at desk level and will be controlled in conjunction with the first bank of lights in the Conference Room. Additional supplementary lighting will raise the illumination level at selected spots to 50 foot-candles.

   During projection, the ceiling lights will be turned out, and floor lighting providing an illumination of 3 foot-candles at floor level will be turned on automatically. In addition, three 15-watt hooded ceiling lights, directed at the storage area in the rear of the projection room, will be turned on automatically, to provide sufficient light to identify objects which may be required by personnel working in the Display Generation Area.

b) Four floor receptacles will be loaded to approximately 40 amperes each. These receptacles will provide power for the three serial projectors and the random access projector. Floor-mounted convenience receptacles will provide power for the movie projector and any other pieces of system and test equipment. Additional convenience outlets (two on the east wall and one on the west wall) will provide power for the control rack and supplementary lighting.

c) A wire raceway installed at a convenient height around the walls of the projection room will facilitate the control wiring of the various items of equipment.

d) Traps located in strategic locations will permit interconnection between the projection room and conference room to be made easily. A wall-mounted junction box will provide a convenient point for making interconnections.

Controls and other power considerations are explained more fully in paragraph 3B. 1c of this report.

Items of equipment for the Projection Room include: four 35 mm slide projectors, one 16 mm sound on film motion picture projector, a 10 x 10 vue-graph projector, tape recorder, sound amplifier equipment, electronic control panel (see Figure 54), intercommunications equipment, slide magazines, storage facilities, projector lenses, closed circuit television camera and screen and other minor equipment items.

Two serial selection 35 mm slide projectors will be mounted in movable racks (see Figure 55) which can be locked in place if desired. These will be laterally dispersed across the projection room about fifteen feet from the screen. Another rack, in the center of the projection room however, will house a serial selection 35 mm slide projector, a random access 35 mm slide projector (which will provide a display capability to replace the 30 x 40 charts) a 16 mm motion picture projector, a closed circuit TV camera, and audio system components. Each of these will be so mounted that automatic usage and control can be accomplished with no difficulty.

The center rack will provide for a unique mounting so that projected images from each projector will appear properly oriented on the viewing screen. In this same rack, a video camera will be mounted to view the output from the random access projector for subsequent display on the TV monitor in the Administrator's office.

A detailed description of each piece of equipment may be reviewed in Appendix B while a complete explanation of the intercommunication system and audio equipment can be examined in Section 3B. 1d.

3B. 1b. 4 Display Generation Room

The Display Generation Room (see Figure 56) will house four to five persons, who will prepare display slides and other communications media required for use in the conference room. The personnel in this area will operate the automatic typewriter and photographic equipment which will be utilized to prepare the formats for display and the hard copy masters for reproduction, and will prepare other briefing aids of a more conventional nature. In addition, they will provide back-up support to the projectionists and to conference attendees.

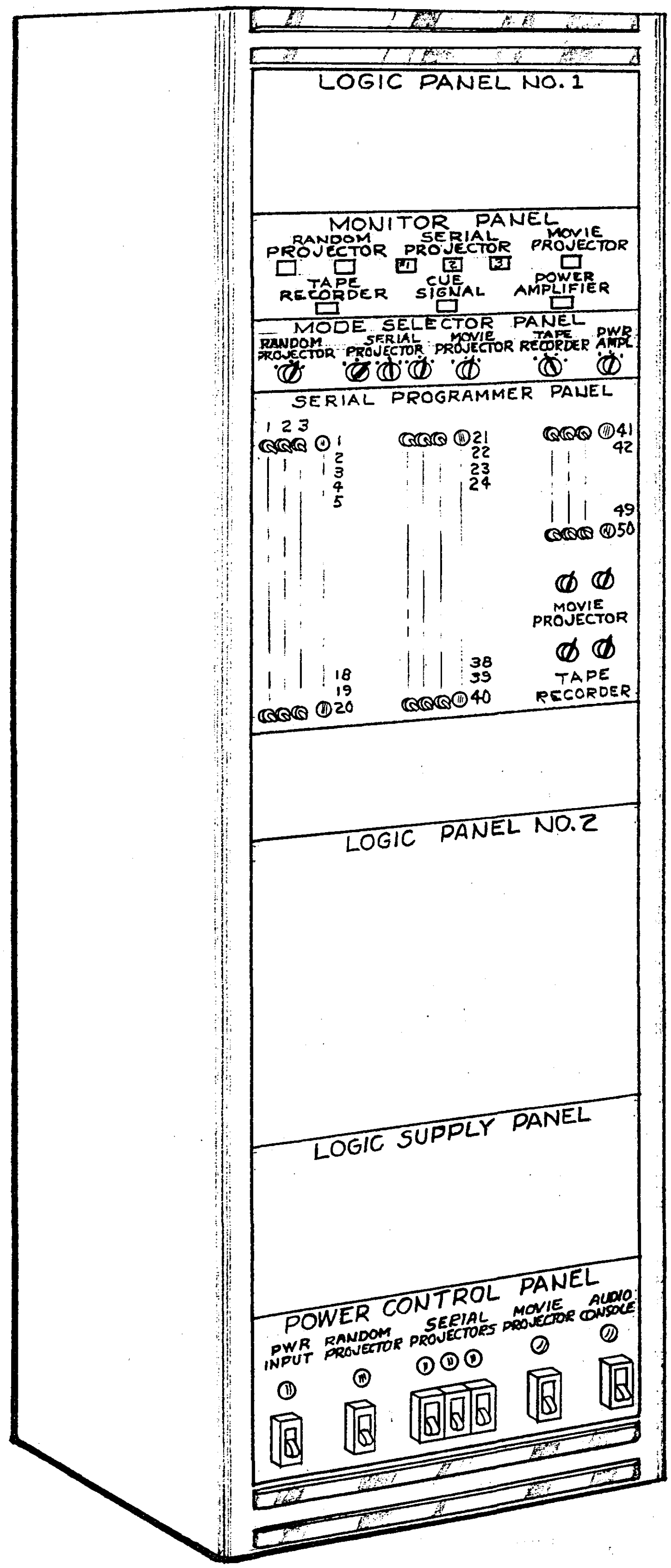


Figure 54. Electronic Control Panel

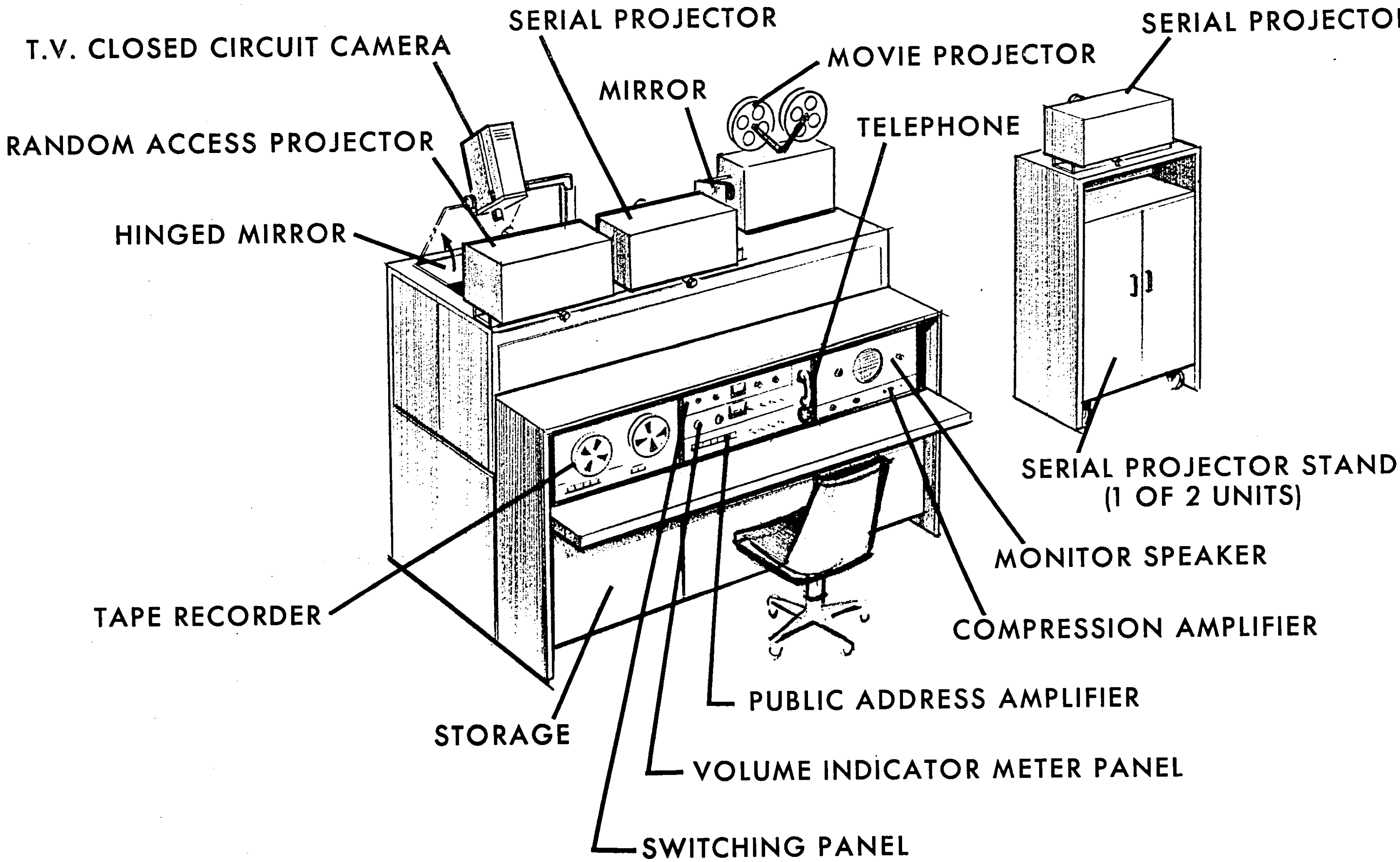
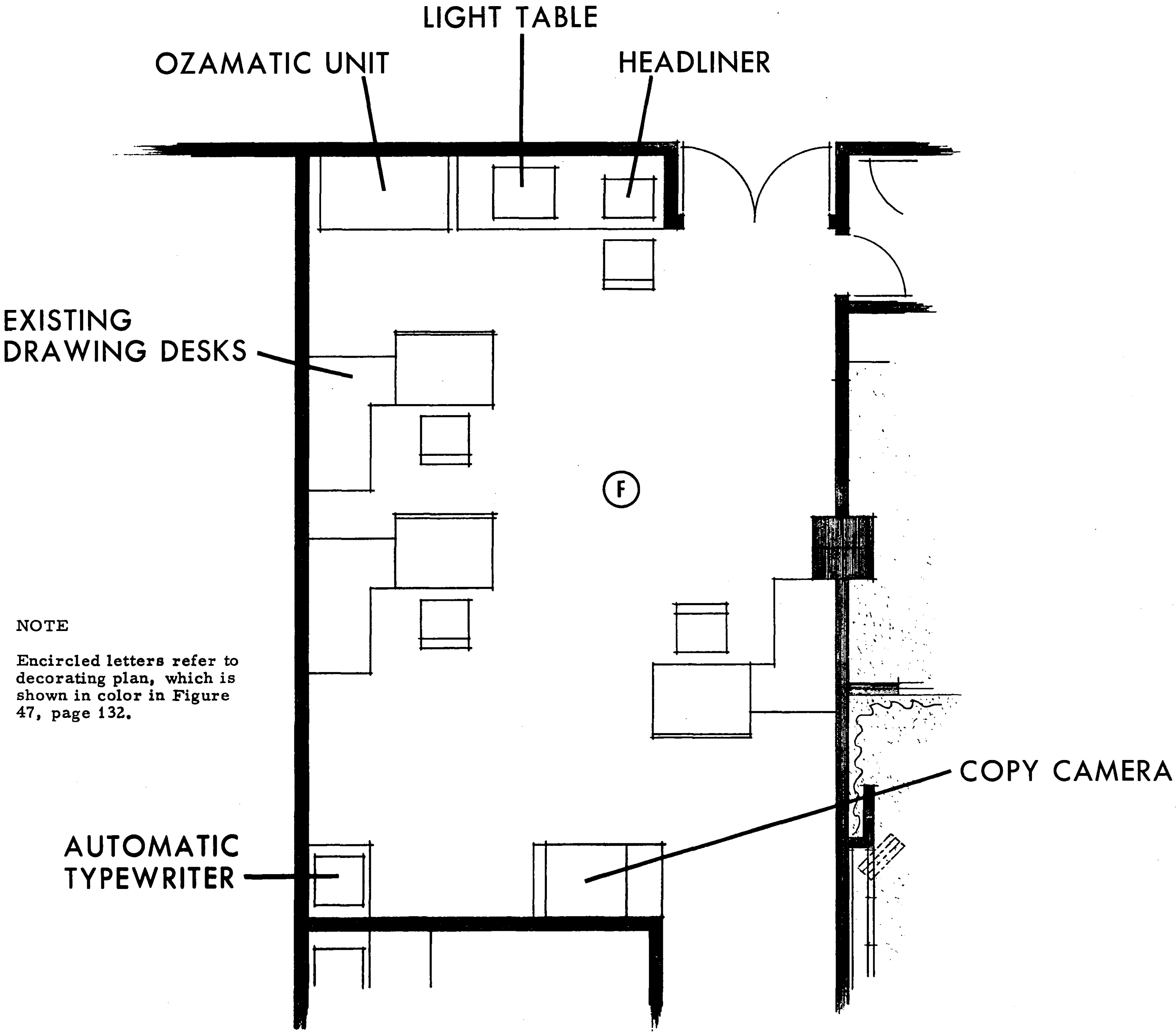


Figure 55. Projector Racks



NOTE

Encircled letters refer to decorating plan, which is shown in color in Figure 47, page 132.

Figure 56. Display Generation Room

The Display Generation room presents the least of the architectural problems. Basically, the walls will be of the same plaster as that which has been specified for FOB No. 6. The only construction modification which is required is the placement of an exhaust duct to the outside air in the ceiling adjacent to the south and east walls of the rooms. This will provide an outlet for the Ozamatic machine presently owned by NASA (see Figure 34).

Lighting fixtures will be the same as those specified for FOB No. 6. In addition, they will provide an illumination level of at least 50 foot-candles at desk level.

As can be noted from Figure 40, extensive use of multiple receptacle stripping has been recommended for installation on each wall of the room. This will provide adequate outlets for lights, light boxes, electric erasers, slide viewers, and other small items requiring electricity.

In addition to these, a separate receptacle for the Ozamatic will be installed on the south wall and another for the copy camera will be placed in the north wall.

The Ozamatic machine and Headliner which are presently owned by NASA will be placed adjacent to the south wall of the room. In the center area will be placed the artists' desks and work tables. The copy camera and automatic typewriter will be placed adjacent to the north wall.

3B. 1b. 5 Dark Room

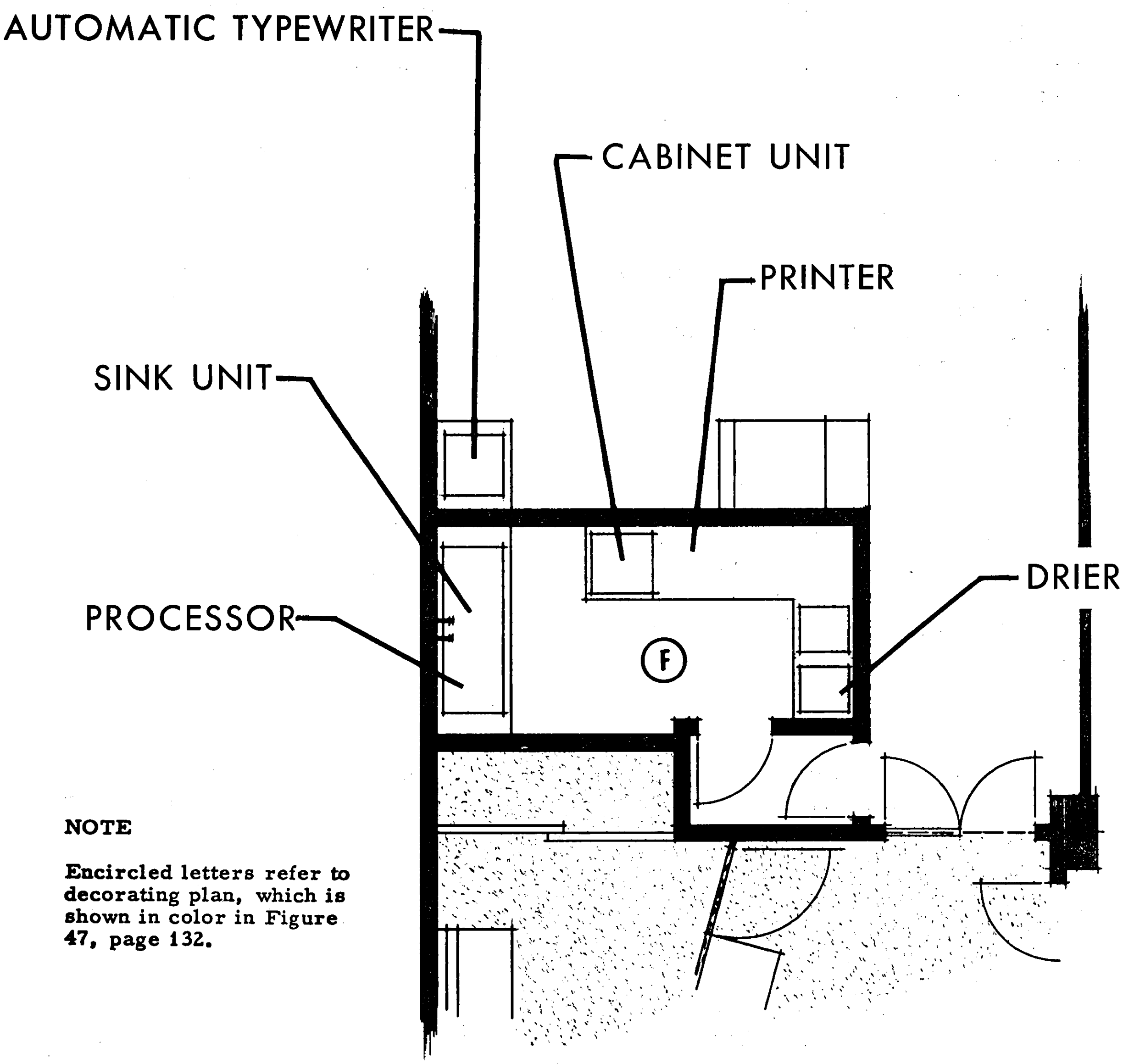
The dark room (see Figure 57) has been designed to provide full film processing capabilities with all pertinent controls, such as light-tight doors, safe lighting, and cabinetry installations.

Personnel using this area will process and develop standard formats and other display media (i. e., special briefing aids and standard still pictorial products).

This area, shown in Figures 38 and 57, is unique within the center since it requires plumbing installations for the sink, special doors to trap light, built-in cabinetry for storage of supplies (Figure 38) and incandescent lighting rather than fluorescent lighting. No special wall finish, other than the painting recommended in Figures 37 and 47, is required.

Power requirements for the room will be supplied by multiple receptacle plug strips mounted on the south and west walls above the work tables, and a standard two-place wall outlet installed on the north wall.

A key switch just inside the door will control incandescent lighting capable of providing an illumination of 20 foot-candles at desk level. Two safe lights controlled by a switch over the developing sink will be used for working light during photo-processing. In addition, while the room is in use, a warning light will be lit outside the dark room area.



NOTE

Encircled letters refer to decorating plan, which is shown in color in Figure 47, page 132.

Figure 57. Dark Room

Equipment used in the area includes a Kreonite sink, a printer, semi-automatic processor, dryer, and light-tight drawers in the built-in cabinetry.

3B. 1c DISPLAY CONTROL REQUIREMENTS

3B. 1c. 1 General Description

The installation of the display control system is divided into three sections: projection room, conference room, and interconnections.

Projection Room

The projection room will contain a cabinet, approximately 90" H x 22" W x 22" D, powered by 115 volts 60 cycles and requiring approximately 100-ampere circuits. (See Figure 54.) In addition to housing the electronic circuitry used in the display system, this cabinet will have facilities for monitoring and controlling certain of the display system functions. The cabinet will have no special cooling requirements and will be provided with proper input and output circuit protection.

Conference Room

Two remote control units will be provided in the conference room, one at the head of the conference table and the other built into the speaker's lectern. (See Figures 49, 50, and 51.) Both of these units will plug into the floor and derive the necessary power from the cabinet in the projection room. Paragraph 3B. 1c. 3 lists the control functions available on each of these units. All controls on both units will operate from 28 volts D. C. They will generate no audible noise.

Interconnections

Interconnection of the control console, lectern, and control rack will be accomplished with wiring concealed in conduit under the floor. Traps located at strategic places in the area will facilitate wiring (see Figure 40). A junction box in the Projection Room will provide a central point for tying control locations to the control rack. A wire raceway located around the wall of the projection room will facilitate wiring the various items of display equipment.

The concealed wiring will be installed so as to permit the conference table to be reversed and also move the lectern from the left or right side of the screen and still maintain full operating capability.

3B. 1c. 2 Control Panels

Five control Panels will be provided with the Display System. They are the conference table console, lectern control panel, administrator's control panel, projection room monitoring control panel and the audio control panel which is described in Section 3B. 1d.

Each of these five panels has its own unique requirements; therefore each is regarded as a separate control problem.

Control functions have been selected carefully to provide the maximum in flexibility with the minimum amount of human effort. Wherever possible, control functions have been combined to operate with one switch or pushbutton. The control buttons have been placed so as to minimize the possibility of human error. Untrained personnel should have no difficulty operating the Display system after a brief explanation. The function of each control console is described in detail in Appendix B.

3B. 1c. 3 Electronic Controls

The controls have been so designed as to permit the lecturer to present a complex presentation involving the three serial projectors, a motion picture projector, playback recorder, room lighting, and curtains, using only one pushbutton during the presentation. If individual equipment operation is desired at any time, the controls include manual over-ride, interlocking, and a memory for returning to a planned program.

In order to obtain optimum use of all audio and visual equipment provided as part of this planned control center, the equipment and controls have been either designed or modified to operate in the modes and from the locations as depicted by the following tables.

Equipment	Modes and Control Locations
1. Serial Projectors	1. 1 Manual - Projection Room
	1. 2 Remote Manual - Conference Table
	1. 3 Remote Manual - Lectern
	1. 4 Semi-automatic - Projection Room
	1. 5 Semi-automatic - Conference Table
	1. 6 Semi-automatic - Lectern
2. Random Projector	2. 1 Remote Manual - Conference Table
	2. 2 Remote Manual - Administrator's Office
3. Motion Picture Projector	3. 1 Manual - Projection Room
	3. 2 Remote Manual - Conference Table
	3. 3 Remote Manual - Lectern
	3. 4 Semi-automatic - Projection Room
	3. 5 Semi-automatic - Conference Table
	3. 6 Semi-automatic - Lectern

Equipment	Modes and Control Locations
4. Public Address	4.1 Remote Manual - Projection Room 4.2 Remote Manual - Conference Table 4.3 Semi-automatic - Projection Room 4.4 Semi-automatic - Conference Table 4.5 Semi-automatic - Lectern
5. Tape Recorder	5.1 Manual - Projection Room 5.2 Remote Manual - Conference Table
6. Playback Tape Recorder	6.1 Manual - Projection Room 6.2 Semi-automatic - Conference Table 6.3 Semi-automatic - Lectern
7. Conference Room Overhead Lighting	7.1 Manual - Conference Room 7.2 Automatic - When any projector is in use
8. Projection Room Overhead Lighting	8.1 Emergency Manual - Projection Room 8.2 Automatic - When any projector is in use
9. Projection Room Storage Lighting	9.1 Manual - Projection Room Circuit Breaker Panel
10. Screen Curtains	10.1 Manual - Projection Room 10.2 Automatic - When any projector is in use (except with video system)

3B. 1d AUDIO REQUIREMENTS

3B. 1d. 1 Description

Three major objectives were considered when this part of the system was designed. They are:

Maximum effectiveness with greatest simplicity of operation.
Maximum flexibility to minimize obsolescence.
Reliability and trouble-free operation.

In order to achieve these objectives in a satisfactory manner, the three basic functions were considered as separate entities, but arrangements have been provided for combining certain of these as required. The three basic functions are:

Public Address
Recording and transcription
Communications

Each of these functions will be described in turn.

3B. 1d. 2 Public Address System

While the primary function of the Public Address system (see Figure 58) is to amplify sound from the sound track of the motion picture projector, it will also provide speech reinforcement capability. In addition, it can be used to amplify messages recorded on magnetic tape.

Due to the relatively small size of the conference room it is not expected that the Public Address system will be needed for speech reinforcement except when large numbers of people are present or if the speaker should have an unusually weak voice.

When any system of this type is used to reinforce speech, acoustic feedback (evidenced by a howling or ringing effect) will always be encountered if the amplifier gain is set too high. Acoustic feedback can be minimized by careful selection of microphone types and locations, and by carefully monitoring and adjusting the amplifier gain. Generally speaking, the smaller the volume of the room (in which both microphones and speakers are connected to the same amplifier), the greater the tendency for acoustic feedback which means that the amount of speech reinforcement obtainable is consequently limited. Fortunately, however, the amount of speech reinforcement required is much less for smaller rooms as compared to large ones. It should be noted that acoustic feedback will not be a problem when the public address system is used to amplify sound on film or tape recordings.

Three different types[14] of microphones will be provided for public address sound pick-up as follows:

a. Lavalier (all directional)
b. cardioid (undirectional)
c. varacoustic (poly-directional - 3 selectable patterns).

By judicious selection of the right type for a particular purpose, good results can be obtained. For example, the microphone to be used at the head of the conference table (in its normal position) is probably the most critical. This is because the loudspeakers will be directing a considerable amount of sound energy toward the microphone. The use of a microphone with directional pickup capability (such as a cardioid) facing away from the loudspeakers, is extremely necessary in order to avoid severe acoustic feedback with even moderate gain settings of the amplifier. The lavalier microphone cannot be used satisfactorily in this location since it picks up sound from all directions. With the conference table reversed, the problem is not quite so severe and other types of microphones could possibly be used here. It would be desirable, however, to use a directional microphone in this case too.

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14. Items a. and c. are available at NASA.

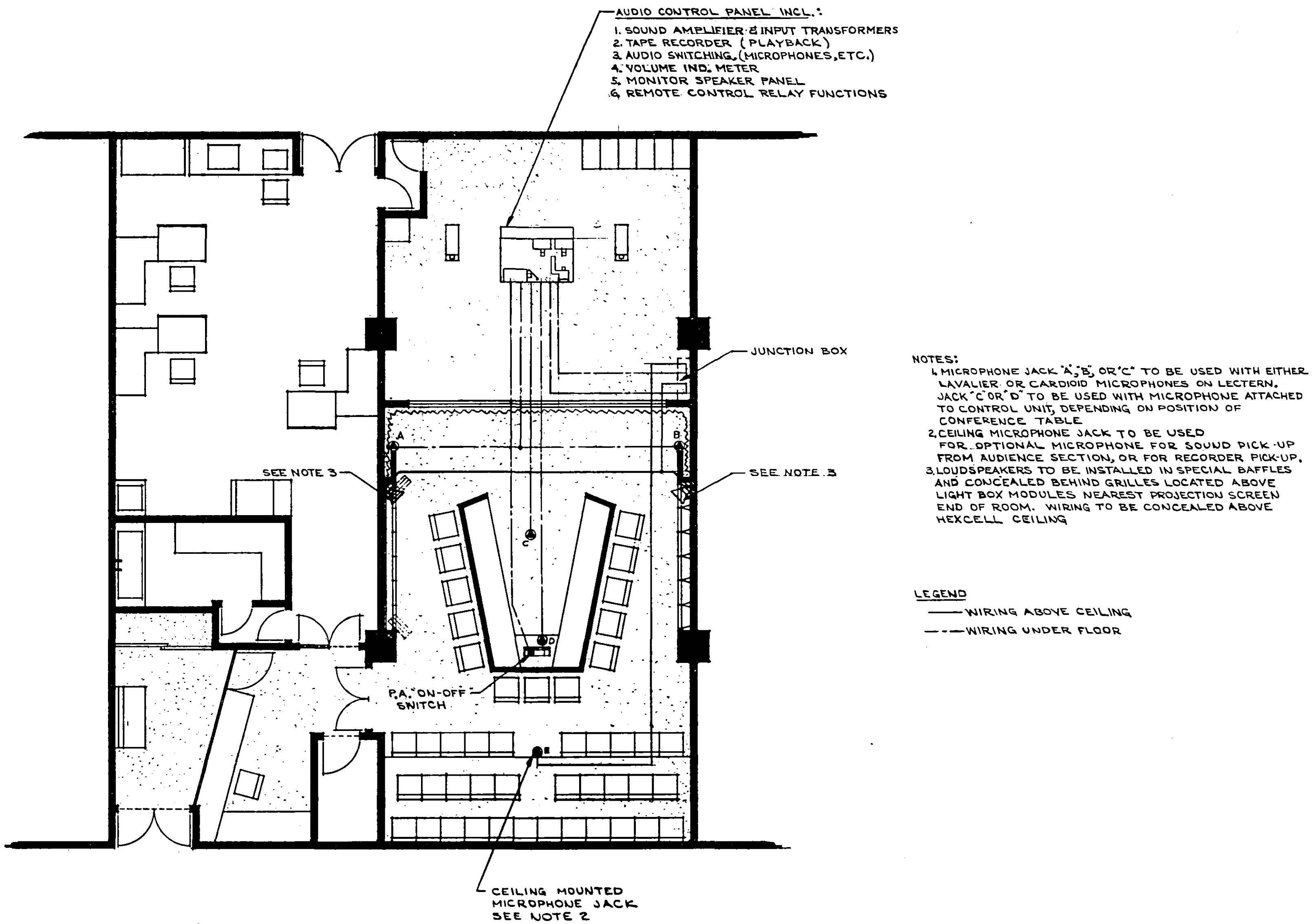


Figure 58. Public Address System

Any of the three types of microphones supplied can be used on the lectern when it is located in either corner of the conference room (nearest the screen) since the amount of sound energy from the loudspeakers reaching the microphone is less than in the previous case. Floor jacks are provided for making connections to the lectern microphone.

Microphone jacks are connected to shielded cables which all terminate at the audio switching panel in the control room. This makes it possible to select any microphone or combination of microphones necessary to satisfy any normal or special requirement without the need for long exposed cable runs.

The public address system will be controlled from the control panel located in the projection room (see Figures 49 and 50). A manually operated input switching panel will permit selection of any of a number of inputs including microphones, sound channel from motion picture projector, tape recorder, plus other sound sources as required. This arrangement makes for maximum flexibility.

The master gain control plus tone controls for the public address system are located on the main power amplifier panel (see Figure 55). Individual gain controls for each channel are also provided so that the input levels can be equalized. The operator who will be located in the projection room will operate all public address system controls.

A 35-watt power amplifier (available at NASA) will be used to provide the necessary sound reinforcement capability. While a considerably smaller amplifier could be used, the negligible distortion produced by a large amplifier operating at lower power output levels reduces listening fatigue to the vanishing point. Additional speakers can be connected to the amplifier without fear of overloading.

Plug-in impedance matching transformers provide the capability for using any standard type of microphone in an efficient manner, regardless of its impedance level.

The output from the amplifier will be coupled by means of line matching transformers to two 8" high fidelity loudspeakers. These speakers will be concealed behind grilles located above the light boxes and green boards near the viewing screen. Specially designed baffles will be used to provide good sound reproduction quality and adequate coverage. Mounting the speakers near the Hexcell ceiling (see Figure 48) will also provide maximum intelligibility since the high frequencies will not be absorbed to the same extent they would be if the speakers were mounted near the floor.

3B. 1d. 3 Recording System

The primary function of the recording system (see Figure 59) which will use a high quality tape recorder, is to provide the capability for

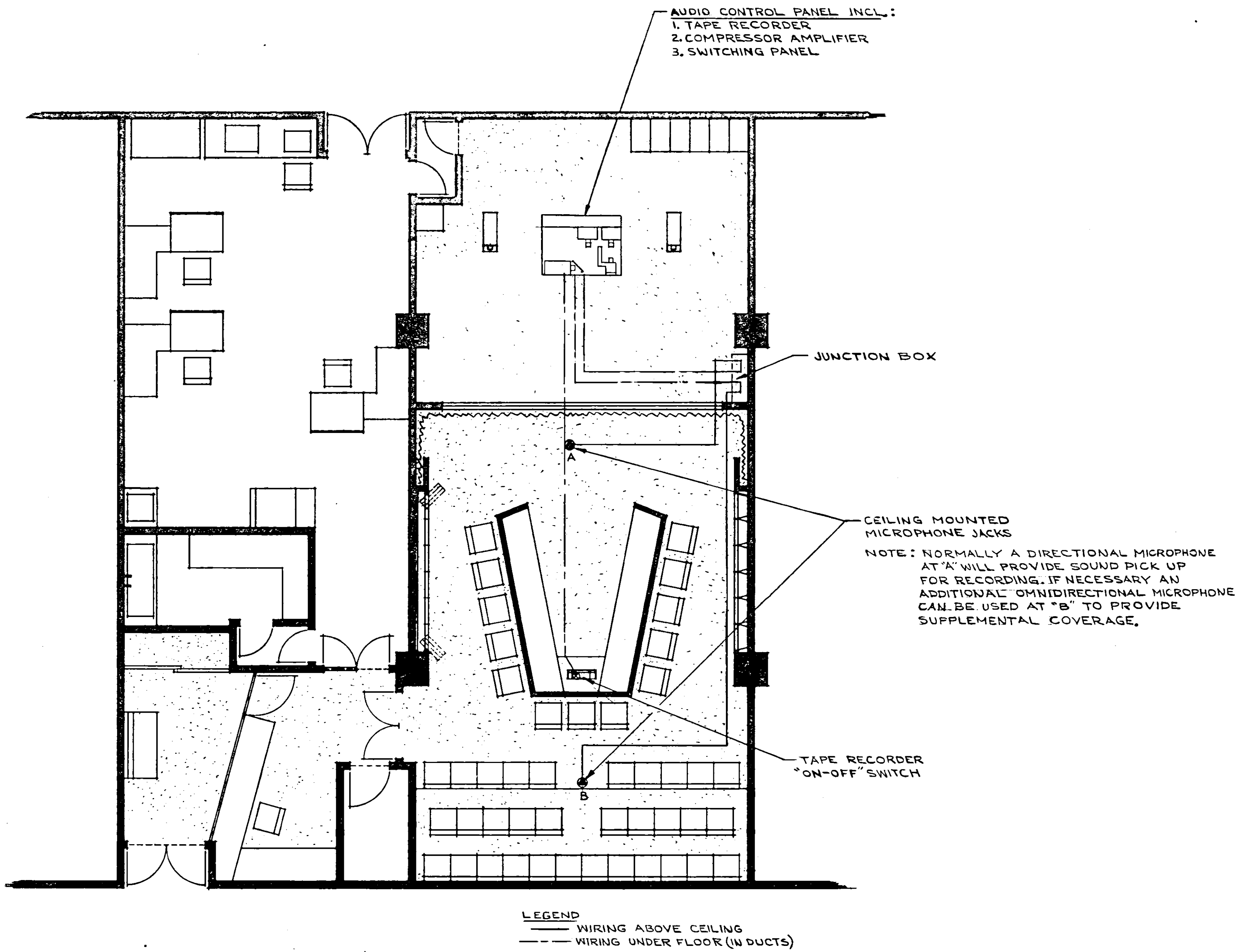


Figure 59. Recording System

recording the proceedings of a meeting for later transcribing as required. A second function is that of playing back pre-recorded tapes through the public address system as part of a presentation.

A remote control will be provided on the conference table control panel (see Figure 50) for starting or stopping the tape recorder. In this way, the Administrator will have control of information to be recorded or excluded. This control will provide only a "start-stop" function. It will not provide the capability for remote rewinding and playing back of a previously recorded section of a conference. However, the operator in the projection room can do this on request.

Recording will be done at a standard tape speed of 3-3/4 inches per second. Using a 7-inch reel of long-playing tape, uninterrupted recording for a period of over two hours can be made. By simply turningthe reel over, an additional 2 hours of proceedings can be recorded. This means that a single 7-inch reel of tape will contain the record of over four hours of proceedings.

Tape speed can be quickly changed to 7-1/2 IPS by the operator for playing back tapes recorded at this speed.

Automatic shutoff of the tape recorder occurs when the tape runs out. The indicator light on the remote control panel will go out at the same time, indicating that recording has stopped. The operator then changes the reel and starts the machine again.

A monitoring head will be provided on the tape recorder. By using it, the operator can tell exactly what is being recorded and can immediately make necessary adjustments for best recording results.

By setting up the tape recorder in advance for playback, a previously recorded program can be remotely started or stopped at will.

A single highly directional microphone will normally be used for the recording function. It will be mounted on the ceiling near the viewing screen and will, by virtue of its directional pick-up qualities, provide coverage for the entire conference room. In addition, a compressor amplifier will be used to provide a constant recording level over a wide range of sound levels with maximum intelligibility and with a minimum of attention from the operator. The ceiling mounted microphone also has the advantage that its presence is not as noticeable as, for example, a number of microphones located on the conference table, and this should eliminate "mike fright".

By means of the switching panel previously described, any of the other microphone channels can be selected and recorded if desired.

3B. 1d. 4 Communication System

In order to minimize the complexity of the communication system (see Figure 60) and still provide the required utility, the intercom and telephone functions will be combined in one integrated system. The system will be installed and maintained by the local telephone company.

The proposed system will incorporate a 12 button "Call Director" instrument at the receptionist's station (see Figure 61). For maximum system flexibility, a selective communication system (Type 6-A) with 10 station capability is specified to work with the "Call Director". In effect, this arrangement is similar to a PBX and will provide code dialing from any station.

If this flexibility is not deemed necessary, a simpler and more economical arrangement can be used quite satisfactorily. In this case, the system would use only the "Call Director". Pushbutton signalling would be used rather than code dialing.

A separate private "com line" between the Administrator's remote control station in the Conference room and the Projection room station would be used to provide instant contact with this station without going through the "Call Director". Either a standard wall instrument, a headset, or a speaker phone can be used by the projection room operator as desired. If a speaker phone is used the projectionist can transmit or receive without manipulating a switch.

Another "com line" would be provided between the Administrator's desk instrument and the receptionist. A signal light on the Administrator's instrument would be used to indicate an incoming call. While a chime or bell could be used for this purpose, the use of a light eliminates aural distraction.

A total of eleven telephone instruments (in addition to the "Call Director") will make up the telephone/intercom system and will be located as follows:

Administrator's Control Station - 1 standard desk instrument (with "com line" selectors and signal buttons)

Conference Table - 4 standard desk instruments (with 2 position line selector button)

Conference Room - 1 standard wall instrument with line selector button

Projection Room - 1 standard wall instrument and 1 speaker phone

Display Generation Room - 3 standard desk instruments with two-position line selector button

Dark Room - 1 standard wall instrument

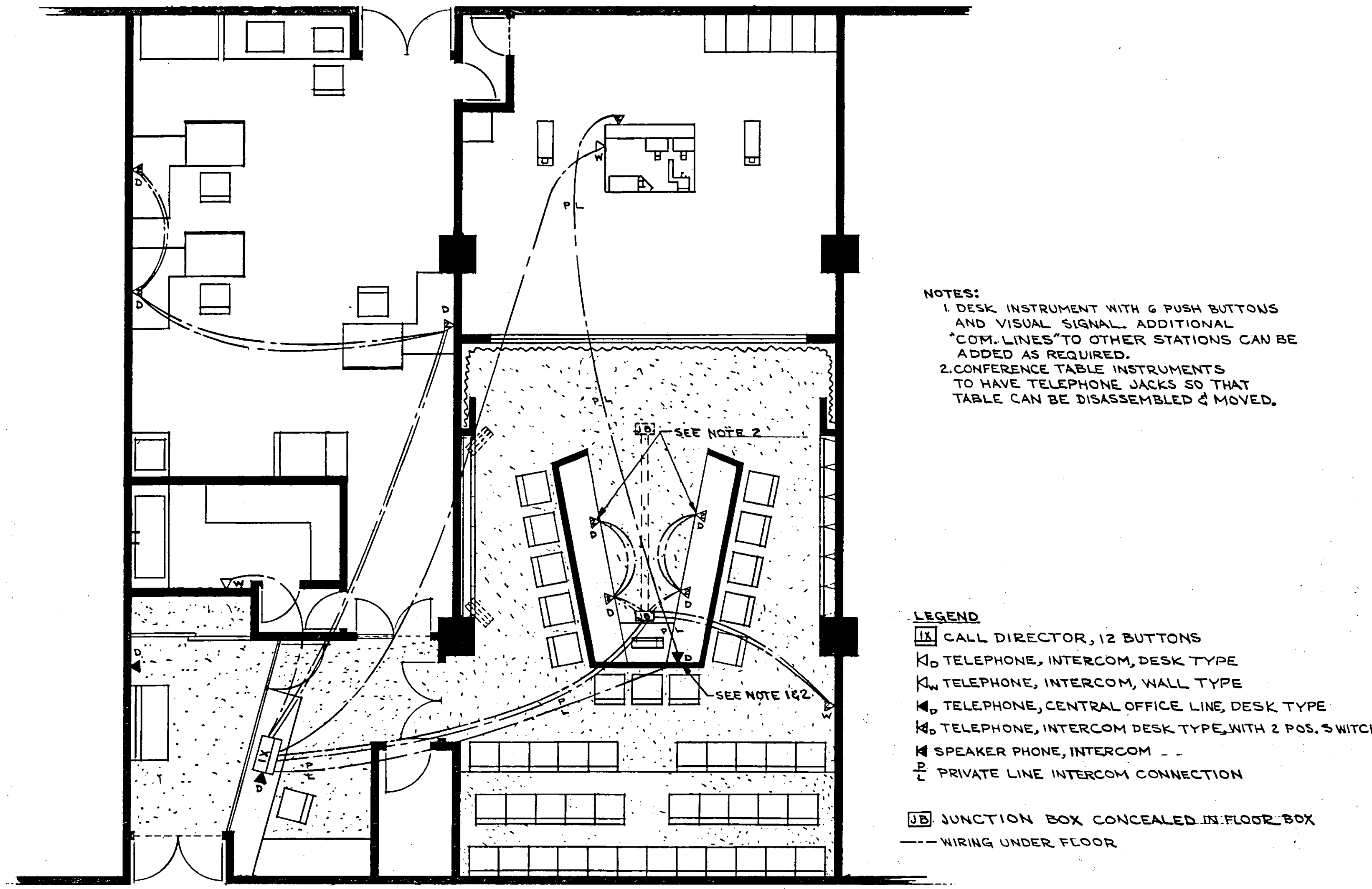


Figure 60. Intercom System

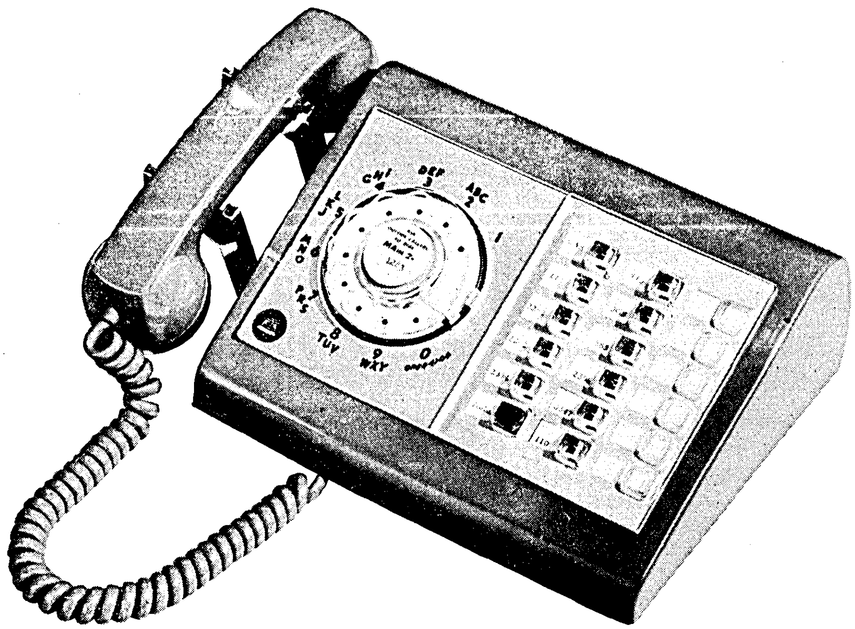


Figure 61. Telephone Master Control

Normally, the receptionist will take all incoming calls and direct them to the proper station. Outgoing calls will also be placed through the receptionist. A by-pass key will be provided on the "Call Director" so that outgoing calls can be made directly in the event that the receptionist is not present or is busy with other duties.

All incoming calls to the conference room area will be controlled by the Administrator. The receptionist will first contact the Administrator to advise of an incoming call. He will then direct the called person to pick up the instrument nearest him. The call will then be switched to this particular instrument by the receptionist. Each of the extension telephones located in the conference room will have a two-position line selector button so that two calls can be handled simultaneously.

Three central office lines will be terminated in the "Call Director", although a greater number can be used if desired. (A factor to be considered is that the greater the number of central office lines used, the more attention the receptionist will have to give to handling this function.)

A completely separate central office line will be terminated in a desk instrument located in the reception room, for use by visitors.

3B.1e VIDEO REQUIREMENTS

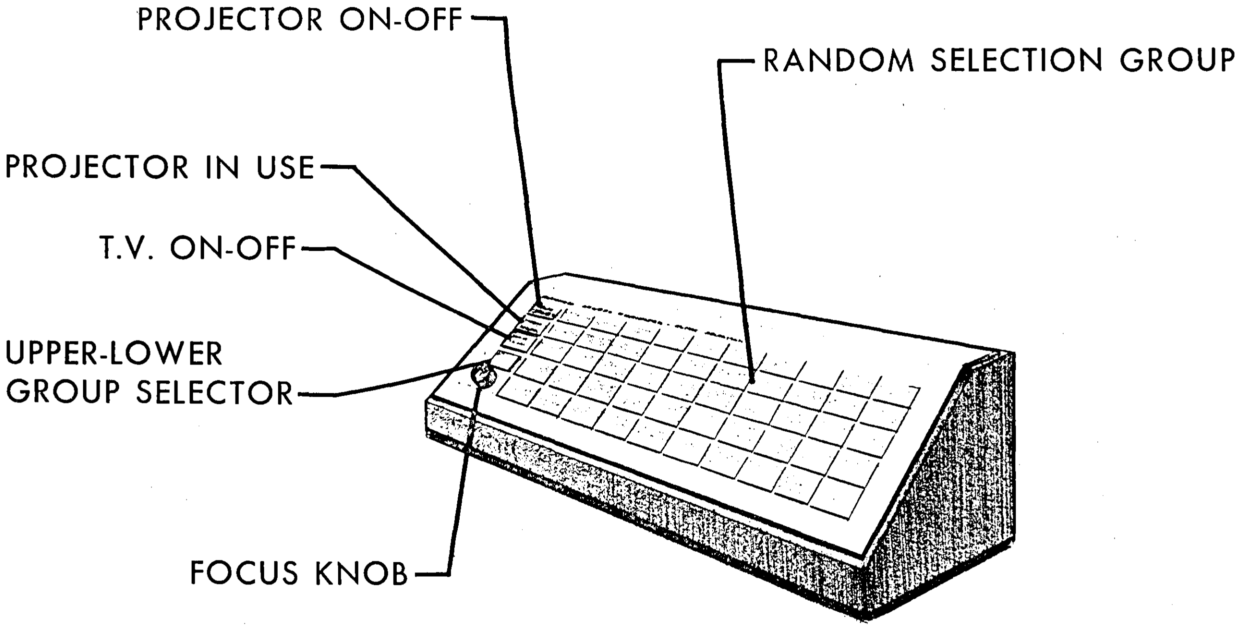
The Administrator's office will be provided with a control panel (see Figure 62), enabling him to select a slide from the random access projector and view this slide on a high resolution closed circuit television monitor. (See Appendix B.)

The slide selected will not be visible in the conference room. The light path of the projector will be folded optically and projected on a small screen in the projection room. This projected image will be picked up by a fixed mounting television camera (see Figure 55), and transmitted over coaxial cable to the monitor in the Administrator's office.

The administrator's control panel will be capable of over-riding the conference room control panel and locking it out until the Administrator's control panel is turned off.

Both the monitor and camera will be modified to eliminate warm-up time, thereby making the response of the video system more nearly equal to the projector and providing an almost instantaneous picture.

The monitor and camera together comprise a complete closed circuit video system. No other external circuitry is required. If, at some future date, it is desired to expand the capability of this system, it can be done without obsoleting any of the previously purchased equipment. The system, therefore, is sufficiently flexible to avoid unnecessary expense if expansion is found desirable.



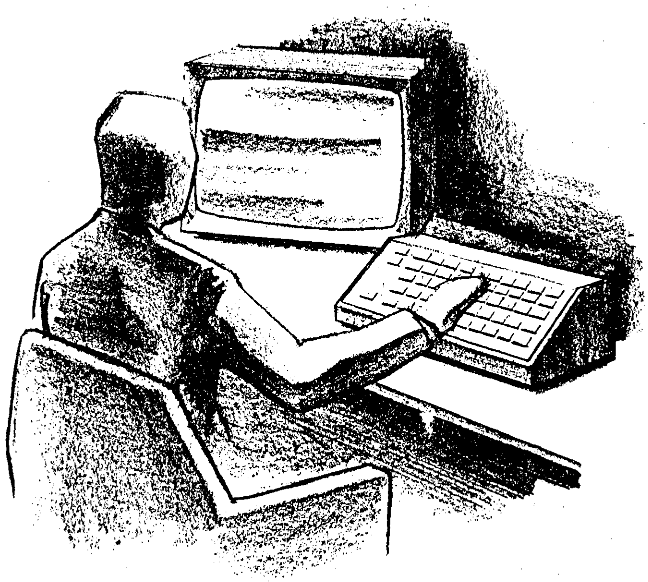


Figure 62. Administrator's Television Control Console

3B.2 Display System

Any type of display system contains three basic elements, which may be termed the Generator, the Processor, and the Projector. In most display systems, additional subsidiary elements are found, but these vary from system to system.

The three basic elements are generic, and apply to all forms of display systems. For example, take the case of a musical comedy. The Generator would be the composer who wrote the music to meet a set of specifications supplied by the producer. The Processor would be the printer who printed the musical score. The Projector would be composed of the orchestra, conductor, and singers who performed the music for the audience.

Continuing our example, which heretofore used human beings as the basic elements, it is equally valid to assume that the Generator might be a computer-controlled music-writing machine (such a machine has been demonstrated), the Processor could be another machine translating the Generator's output into a form acceptable to the Projector, and the Projector could be an all-electronic musical instrument (such as an electric organ). The elements are generic in nature, and apply equally to human or non-human portions of a complete system.

Figure 63 illustrates the various functional units which might constitute one display system, and the logical interconnection between these units.

3B.2a DESIGN CONSIDERATIONS

The design of any display system is based upon a number of fundamental parameters which must be satisfied in system operation. These parameters which must be satisfied in system operation. These parameters, for the NASA system, are sixfold:

- System flow time capability
- System operation cost
- System implementation cost
- Display product quality
- Color capability
- Simplicity of system operation

The system flow time is defined as the time interval required to generate, process, and project a given volume of display product. This interval is measured from the time at which raw data is fed into the Generator to the time at which the finished display product is ready for presentation. As defined above, it can be seen that the flow time is directly dependent upon the required product volume. In the design of the NASA display system, minimization of this time was stressed.

System operation cost is defined as the cost of materials consumed during system operation. For the NASA system, it was felt necessary

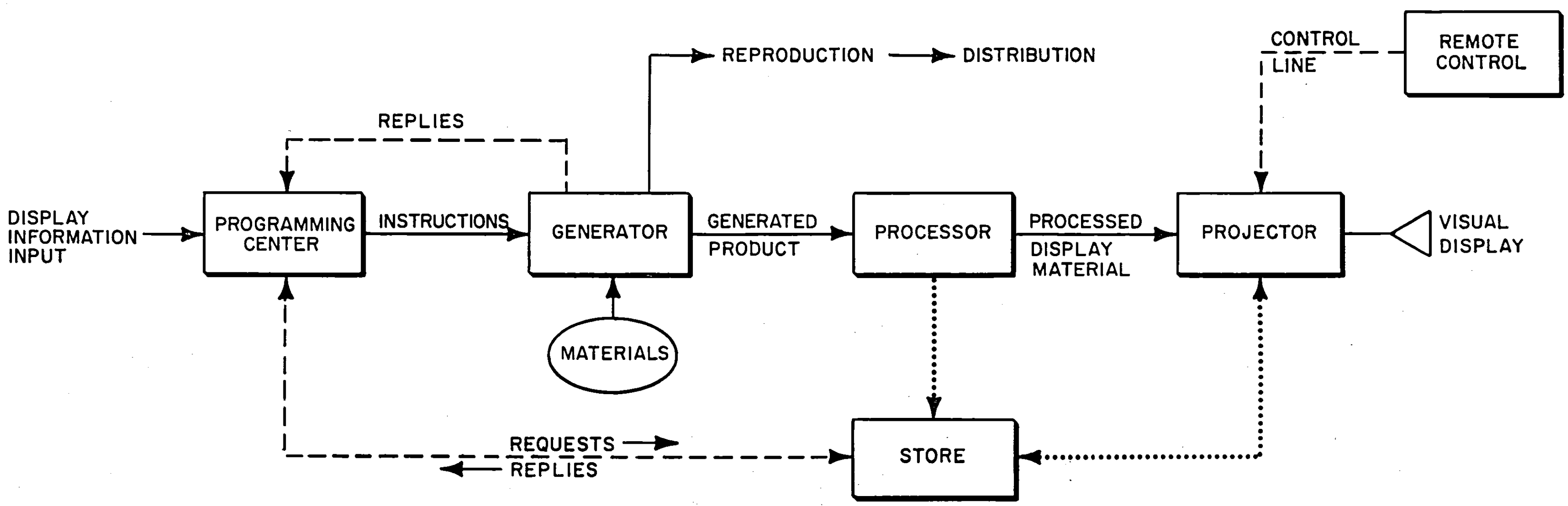


Figure 63. Typical Display System

to reduce this cost to a minimum consistent with high display product quality.

System implementation cost is defined as the cost of purchasing and installing the equipments necessary for system operation. Desirability of minimizing this cost was deemed essential for the NASA display system.

Display product quality is defined as a measure of accurate information transfer from machine to man. For example, information presented in the form of the display product must be clear, discernible, unambiguous, and must accurately correspond to the original data input to the system. Further, where colors are employed in the final display, they must be clear and distinguishable one from another. High product quality was one of the primary design objectives for the NASA display system.

Color capability is defined as the ability of the system to utilize colors other than black and white in the final presentation. In the design of the NASA display system it was felt desirable to incorporate the capability of either black and white or multi-colored displays.

Simplicity of system operation is defined as a measure of the ease of performing the operations required in the production of display products. In the design of the NASA display system it was considered essential to provide for operations that would not place excessive demands on the skill of human operators.

3B. 2b DESCRIPTION OF EQUIPMENT AND OPERATION

The system recommended for use by NASA was chosen after examination of all available types of display systems[15] and is characterized by:

Consistency with design parameters
Technical Validity
Relative independence upon operator skill
Capability of handling high volumes of display materials

The system's operation, in broad terms, is as follows.

Output of the Generator[16] is photographed onto black-and-white negative film. Three separate negatives are made from three separate Generator outputs, each containing information to be displayed in a single color.

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15. The full design procedure used, including reasons for elimination of other approaches, is described in Appendix D.

16. Operation of the Generator is variable; it is described more fully in paragraphs 3B. 2b. 1 and . 2.

The three negatives are contact-printed onto only one frame of color film. The color film is then developed through a rapid, non-reversal process, is dried, is mounted as a slide, and is projected onto the viewing screen by means of a conventional 35 mm slide projector.

In addition to this, a conventional offset-litho printing plate is made from the Generator output and is used to produce "hard copy" for reference uses.

As has been implied in this section of the report, little or no increase in personnel will be required to perform the tasks associated with operation of the display system. Aside from the talents already existent within the NASA organization, the only additional talent called into play concerns the photographic techniques involved in film processing. It is possible that one of the presently available personnel could be effectively utilized in this area following rudimentary procedural indoctrination. However, employment of a photographic technician who would already be familiar with photo processing techniques is strongly urged.

It should be further noted that establishment of the display system as a functioning entity will reduce the necessity for manually generated art work which is presently being employed as a display medium. The personnel, therefore, who are now engaged in the generation of this art work could be released to perform other tasks required by system operation such as photographing the hard copy output from the automatic typewriter, monitoring operation of the typewriter, and mounting and filing display slides.

The only other manpower aspects of system operation worthy of note here involve: (1) the programming and generation of the paper tape which carries instructions to the automatic typewriter; and, (2) the electrical maintenance required throughout the Control Center. These three tasks can readily be performed by such existing personnel as a clerk-analyst for the tape programming and generation functions and a projectionist for the electrical maintenance function.

This fully integrated and versatile display system may be used to generate and display either color or black and white film transparencies from a set of coded instructions. In block diagram form, the system is illustrated in Figure 64.

Since the recommended system actually consists of two co-operational phases—the creation of visual displays and the generation of hard copy—they will be treated separately for the sake of clarity in the detailed descriptions which follow.

3B. 2b. 1 Producing Visual Displays

The Programming Center provides both information and generation instructions to the Generator by means of a perforated paper tape. The Generator itself is an automatic typewriter which transforms this

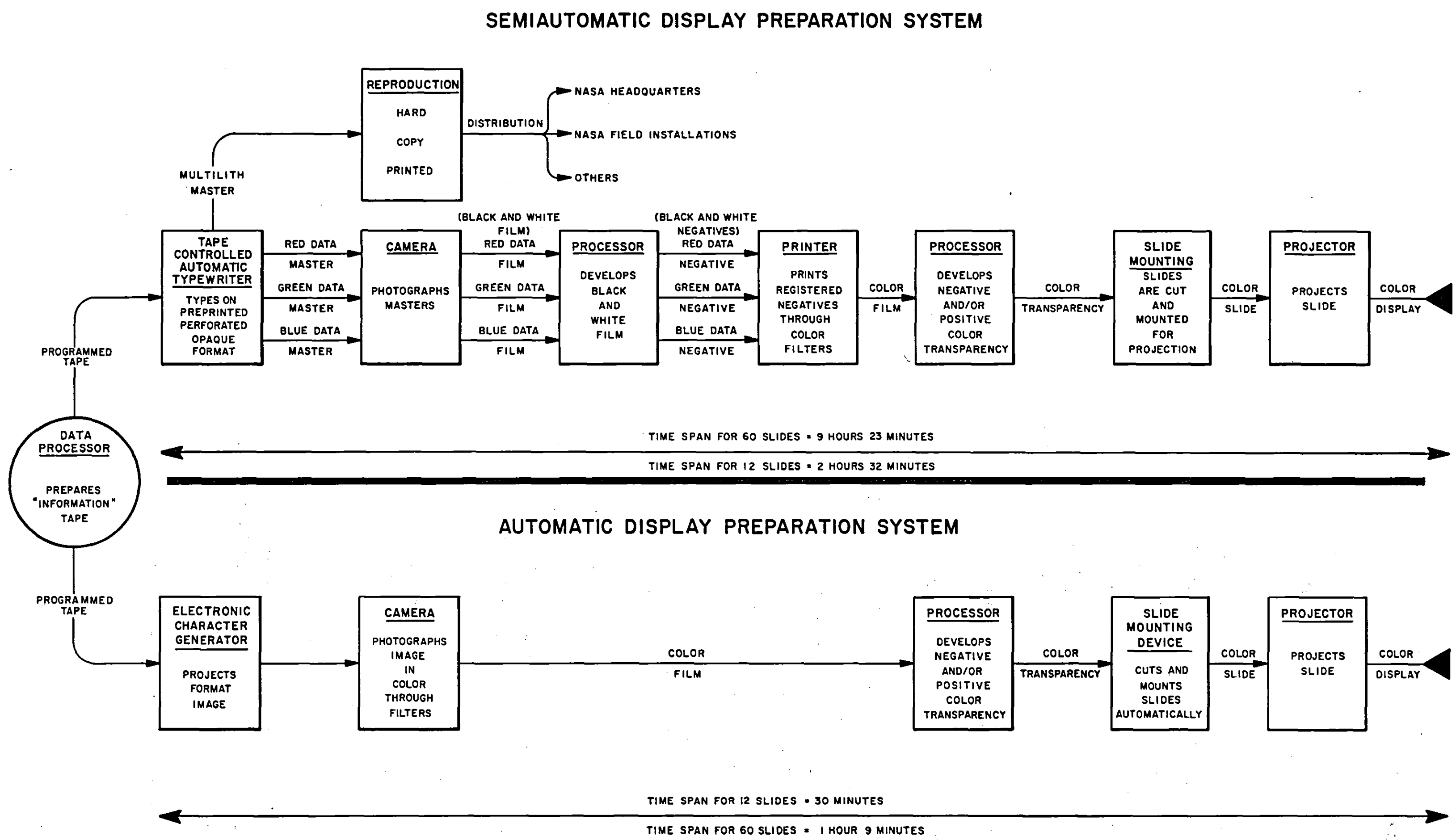

Figure 64. Recommended Display Systems

information into typewritten pages at the rate of about 100 words per minute. The material fed into the Generator is perforated accordion-pleated paper, supplied in a continuous form. The perforations permit the Generator to register accurately the output on the pages. In addition, every third sheet of paper contains pre-printed horizontal lines to aid the viewer in visually following horizontal lines of text on the display screen.

The typewriter then proceeds to generate three typewritten records for each desired display slide. Each of these three contains only that information which will later appear in a particular color on the viewing screen. Upon completion of generation, the hard copy records are photographed onto 35 mm black and white film in a microfilm copy camera equipped with a registration pin mechanism which assures that the typewritten text will be correctly positioned within the film frames. Since all the generated hard copy is of the same size, uniform copy illumination is achieved through the use of lamps which are pre-set positionally and which never require subsequent re-positioning. Further, the microfilm camera houses a film magazine having a 30-foot capacity. This provides a 240 frame capability per film load. The entire load need not be exposed at once, however, since the magazine may be removed from the camera at any time and any desired length of film may be removed from the magazine in a dark room.

The black and white exposed film obtained in the photographic step is then photo-processed in semi-automatic fashion in the darkroom. This is achieved through the use of a semi-automatic processing machine which requires manual loading but which then proceeds to transport the film through the required solutions automatically. Upon completion of the photo-processing step, the film is automatically dried.

The processed film strip is then manually transported to a step printing device which is loaded with unexposed bulk Ektachrome Color Film and which is also equipped with two registration mechanisms that engage the sprocket holes of both the color and black-and-white film. Further, the step-printer is designed in such a way as to permit the insertion of color filters between the light source and the black and white film. (A simplified diagram of such a step printer is shown in Figure 65.)

The operation of the step-printer is as follows:

1. Frame 1 of the black and white film advances to a position at which it is in contact with Frame 1 of the color film (see Figure 65).

2. One of the color filters moves into the optical path (red absorbing filter, for example) and the source light is turned on automatically for a timed exposure.

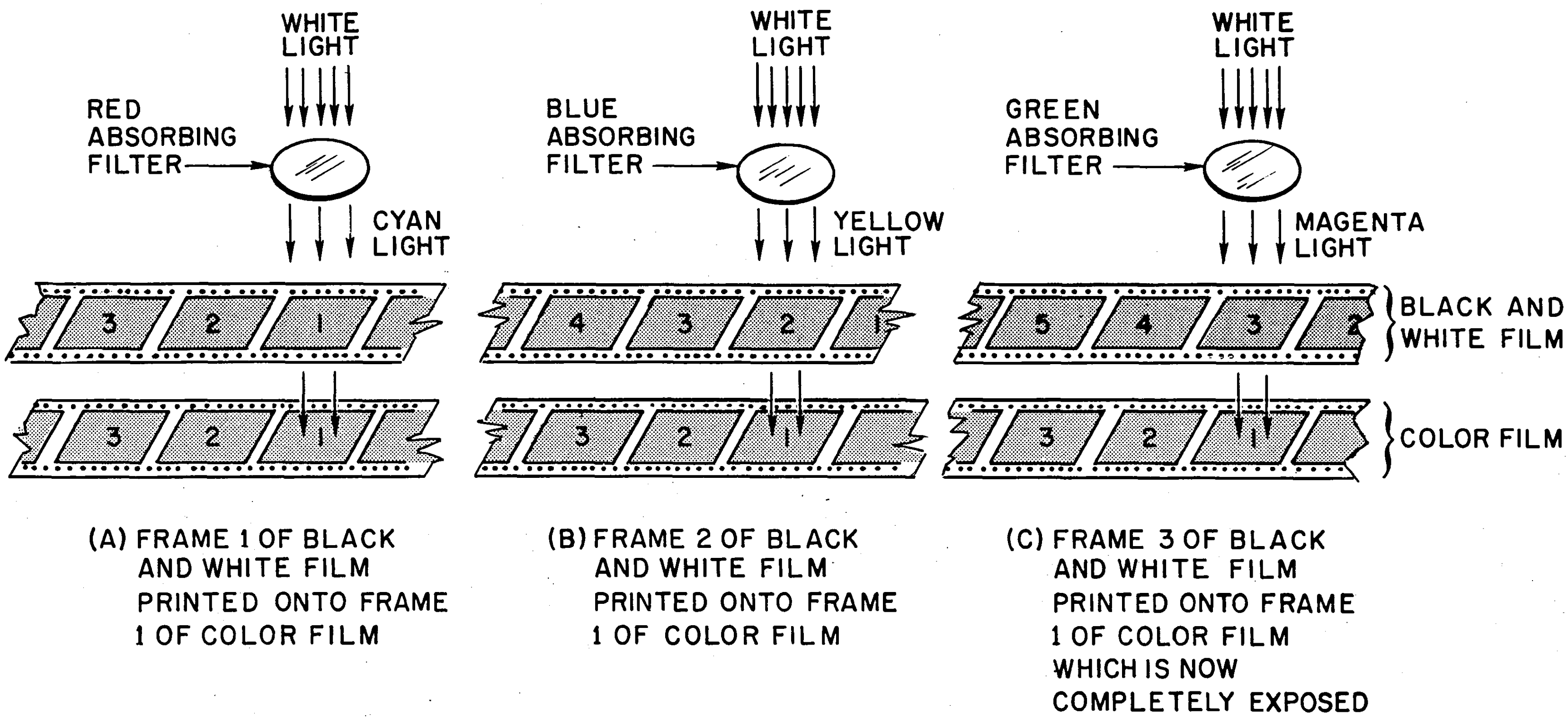

Figure 65. Step Printer, Functional Diagram

3. The source light is extinguished and the black and white film advances one frame while the color film remains stationary, such that Frame 2 of the black and white film is now in contact with Frame 1 of the color film.

4. The blue absorbing filter is inserted into the optical path and and light is again turned on for a timed exposure.

5. Once again the source light is extinguished and the black and white film advances another frame while the color film again remains stationary, such that Frame 3 of the black and white film is now in contact with Frame 1 of the color film.

6. The same procedure is then repeated, but with the green absorbing filter in the optical path.

7. The color film frame (Frame 1) is now completely exposed and the next film advance will cause both films to be set in motion for similar exposure of Frame 2 of the color film from Frames 4, 5, and 6 of the black and white film.

With the exposure of the color film carried to completion according to the preceding outline, it is manually removed from the step-printer and photo-processed in the same semi-automatic processor used for the black and white processing stage. Subsequent to processing, it is dried in the same dryer used before. Then, using a semi-automatic film cutter, the film is separated into individual frames and mounted in conventional slide mounts utilizing anti-Newton-ring glass which prevents the occurrence of annoying diffraction patterns in the projected color image. Finally, the mounted color positive film transparencies are inserted into the magazines of the optical projectors for viewing.

Note: The functions of the equipments involved can be reviewed in Figure 66.

3B. 2b. 2 Producing Hard Copy

A second perforated paper tape supplied by the Programming Center provides the automatic typewriter with instructions necessary for the generation of the reproducible hard copy. In this case, however, accordion-pleated multilith master paper is fed into the typewriter. The generating instructions are such that the typewriter now impresses onto each sheet of paper all the information that was previously distributed among the three hard copy records. As before, this printout is photographed onto black and white film in the microfilm copy camera after which the multilith masters are sent directly to Reproduction Services for reproduction and distribution. The exposed black and white film is processed as before and is contact printed directly onto a high contrast black and white positive film in the step-printer. In this case, however, the stepping capability of the printer is not utilized. Finally, the positive film is photo-processed, dried, cut, mounted,

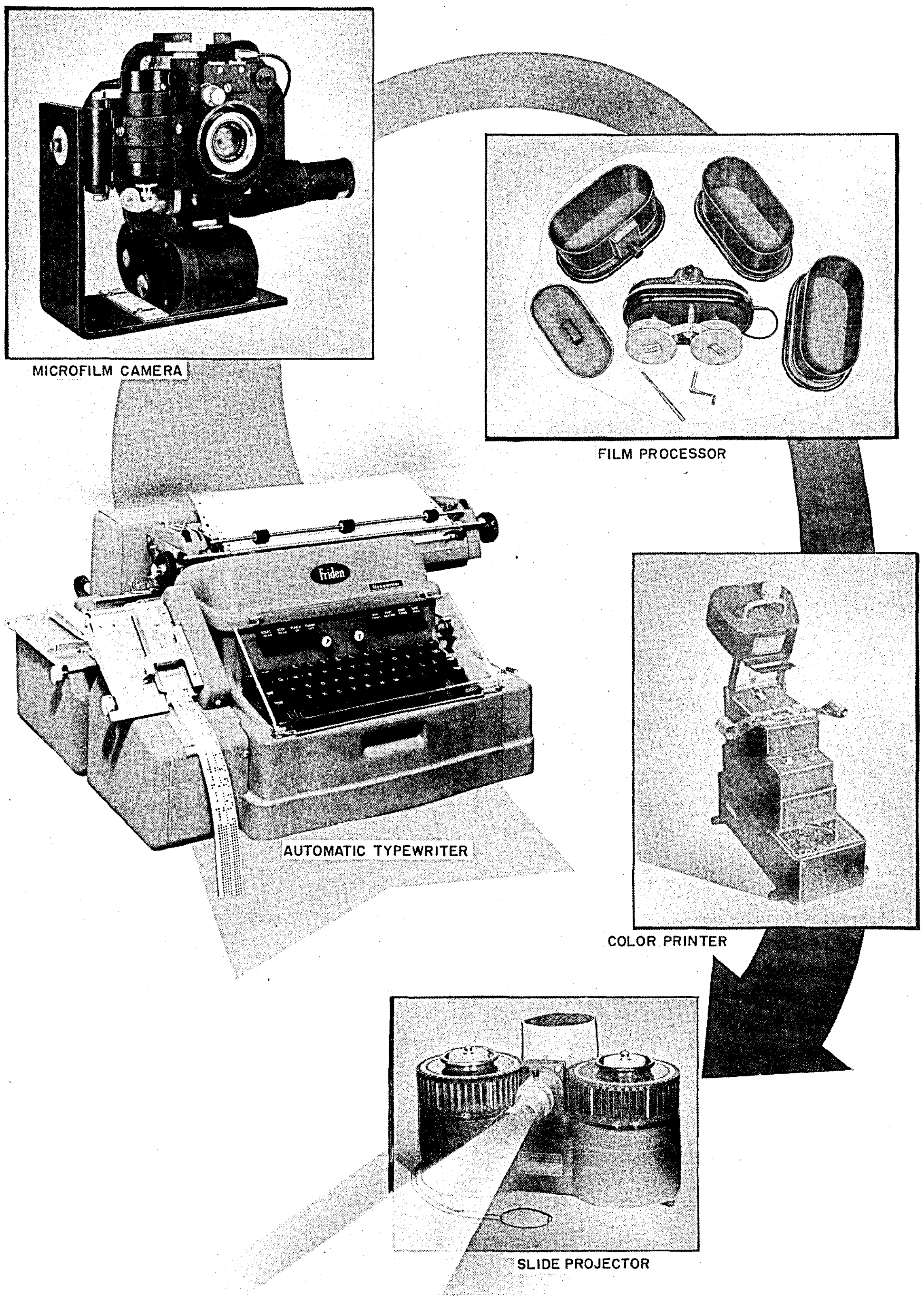

Figure 66. Equipment and the System

and inserted into the magazine of the fourth or random access projector. Thus installed, this black and white positive record will be available for viewing at any time without the need of a projectionist in the projection room as the random access projector will be completely controllable from the conference room.

3B. 2c ADDITIONAL SYSTEM CAPABILITY

1. Black and White Display Products

   As indicated in the preceding paragraph, black and white as well as color displays may be generated in the recommended system.

2. Display Products Generated from Miscellaneous Originals

   In addition to the routine system capabilities already outlined, the recommended system possesses the capability of generating displays from a wide variety of inputs. Any black and white or color hard copy of reasonable physical dimensions — including, for example, hand-generated color art work — may be used to produce black and white or color displays simply by employing normal system operating procedures.

3B. 2d AUTOMATED SYSTEM CONSIDERATIONS

The recommended display system, which is partially automated in nature, possesses sufficient speed and volume capability to accommodate the maximum quantity of display material that is likely to flow through NASA for the next couple of years. A significant future increase in this quantity, however, could be accommodated with small system revision. The principal bottleneck that might appear in the recommended system under the condition of high product volume would be the generation of the original hard copy by the electrically-driven typewriter and the manual black and white photographic operations which follow such generation. This foreseeable bottleneck may be removed in the manner suggested in the following paragraphs:

The same perforated paper tape that is used to program an automatic electric typewriter may also be used to program a character-generating cathode ray tube. Such a tube is capable of accepting instructions to produce an information display on the tube face. The information appearing on the tube would be in the same form as the information appearing on the automatically typewritten pages generated in the recommended system, but would be produced at a much higher rate of speed. With an operation such as this, an additional system modification is permitted. (Refer to Figure 64 for an illustration of the automatic modified system.) The entire black and white photography step could be deleted. With the three separate original (color) records appearing sequentially on the face of the cathode ray tube, it would be possible to photograph them sequentially, through appropriate color filters, directly onto the color film, thereby eliminating also the step-printing operation of the recommended system. A fourth record, combining all the information found in the other three records, could also be photographed onto color, or black and white film as desired.

In the case of this modified system, it is suggested that the manual photo-processing technique be retained. Until the volume of display material increases to approximately ten times the quantity now flowing through NASA, the purchase of a continuous film processing machine would hardly be justified.

It should be noted that, in the modified system, the hard copy original for reproduction may still be generated by the automatic typewriter in which case, however, the automatic typewriter will accept information codes which are on separate programmed paper tapes which contain generation instructions for the reproduction master record.[17]

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17. A detailed discussion of an advanced method is contained in Appendix B.

3C DECISION GAMING

3C.1 Detailed Description of NASA Decision Gaming System

The fundamental concepts underlying the Decision Game are shown pictorially in a simplified form in Figures 67 and 68. Two sets of displays enable the players to communicate with the computer. The first of these is a visual representation of the time phasing of all the important missions and goals of NASA. The information on this display is schematically represented in Figure 67 under the titles of "Launch Vehicle Program" and "Space Flight Program". The same display is shown on the upper left hand side of Figure 68 as the "Program Network Display". These displays are either cathode ray tubes or projections in screens, depending on the particular needs of the players of the Decision Game. Sufficient details will be shown so that all goals of importance to the players are displayed but the diagrams will not be so detailed as to confuse the players. As the Game starts, various questions will arise which will not be immediately answerable by the displayed material. To meet this condition, back-up displays will be stored which can be retrieved by the players as requested. By this technique, it will be possible for the players to go into any degree of detail in the time phasing of the missions and goals of NASA without making the presentation too cumbersome or confusing.

A part of the "Program Network Display" is the visual representation of the utilization and loading of the different NASA facilities associated with the Launch Vehicle and Space Flight programs. This display is shown by the third item from the top in Figure 67. All the previous comments made in connection with the visual representation of the Launch Vehicle and Space Flight programs apply for the Facilities Loading displays, too. Sufficient detail will be given so that the player can appraise the state and progress of various programs, and again sufficient back-up information will be available at request.

The second set of displays refer to dollars and economic costs such as manpower and others. In Figure 68, this is shown by the upper right hand corner. The dollar and manpower profiles as they unfold in time will be represented in sufficient detail so that all the important information for the players will be furnished. In addition, when it is required, the players will be furnished with hard copies of printed financial information.

The display capability so far described furnishes the players of the Game with such pertinent information as past history, status, and future projections of all the NASA programs. Particular emphasis is placed on the preparation of this information in such a form that the organizational structure of NASA is directly tied in to the information presented. For instance, information concerning each particular field installation will be readily available.

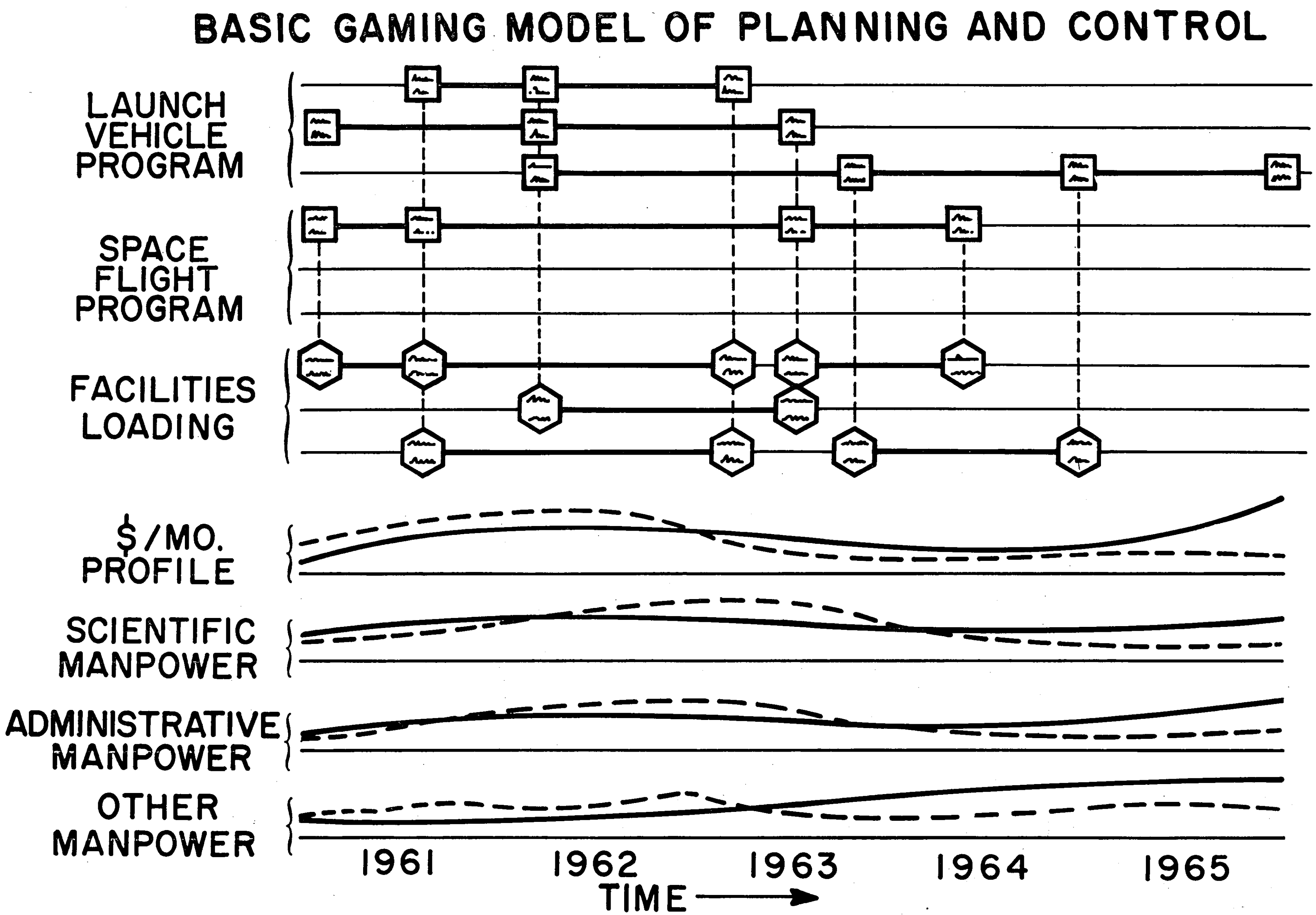


Figure 67. Basic Gaming Model

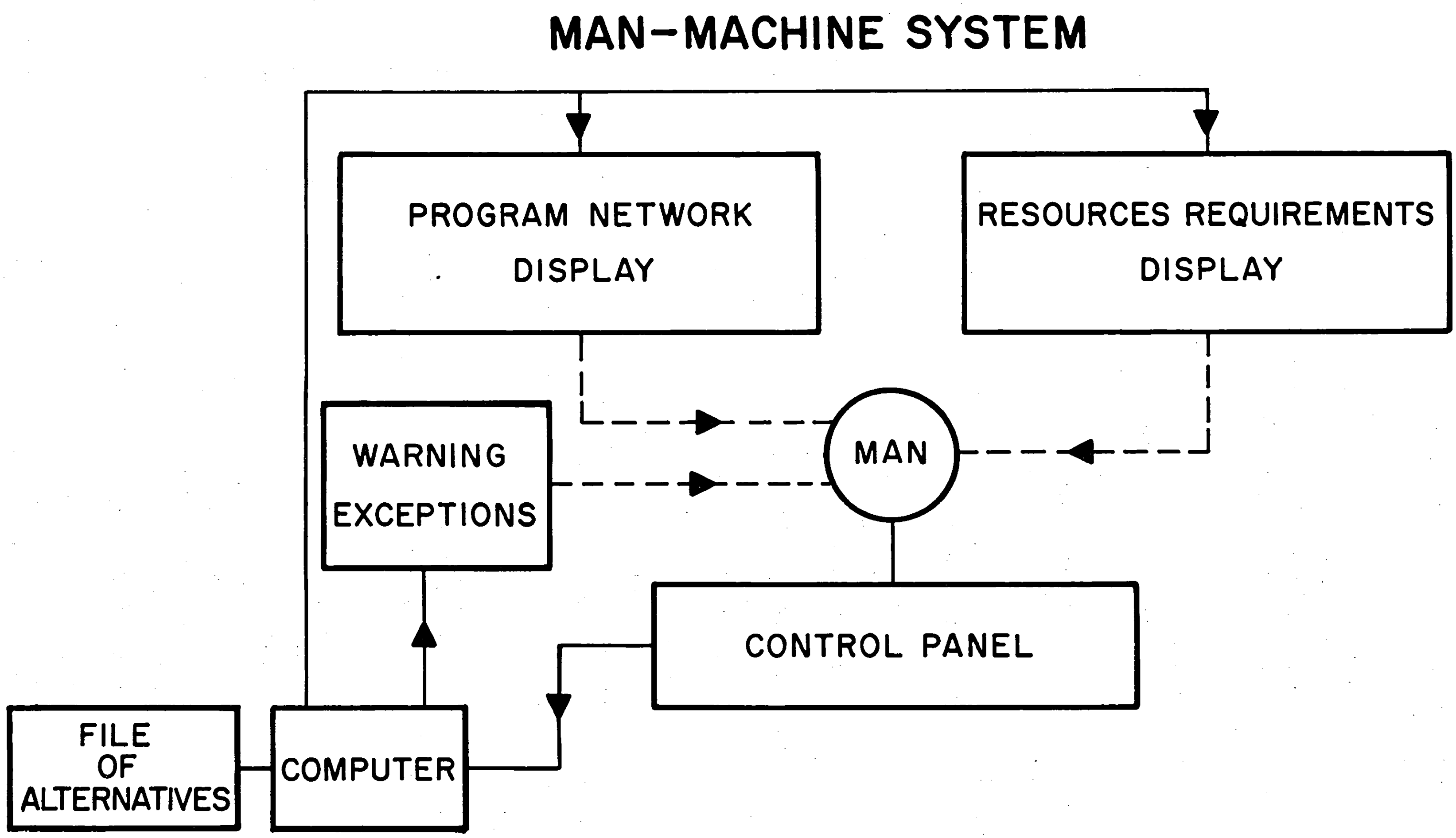


Figure 68. Man-Machine System

So far we have described the display systems and the type of information stored. We are now ready to proceed to the description of how the Decision Game is to be played. In order to be able to speak in more specific terms, we take the hypothetical problem of a new requirement that a particular mission is to be accomplished one year ahead of schedule. This new requirement requires the acceleration of a major program and a reorientation of the resources available to NASA.

When such a problem arises in NASA, various discussions will take place at different managerial levels. We do not propose that the Decision Game is to replace these conferences. However, after a preliminary consideration of the problem is completed, we visualize that the appropriate management group of NASA will gather in the control room and play the Decision Game. By a step-by-step procedure, they will evaluate, modify, and sharpen the preliminary ideas that have risen in connection with this problem of advancing the completion date of a major mission.

When the group meets the first time in the control room, the players will probably begin by calling out a number of different displays to update and verify their knowledge of the status of NASA programs. Such a review will consist of inspecting the principal displays associated with the problem and then calling various back-up information that throws more light on the problem and possible solutions to the problem. After such a preliminary discussion, a proposed first solution to the reprogramming problem will be suggested and the operator of the equipment will be advised that certain of the goals (as shown in upper part of Figure 67) are to be shifted in time. Those goals which are to be accelerated will be moved to the left, (they will have to be completed at an earlier time) and conversely, those goals which are to be delayed will have to be moved to the right.

As this information is furnished to the operator, he codes the information into the appropriate input form, and directs the computer to proceed and develop a new program compatible with the new requirements imposed.

At the command of the operator, the computer begins to carry out the routine associated with the particular reprogramming problem discussed. The computer consults the file of alternatives shown on the lower left-hand side in Figure 68, and on the basis of information stored there, computes the associated dollar requirements and manpower requirement. In addition, facilities requirements and loading are checked by the computer and computations are made to determine whether the desired acceleration is feasible at all.

As the computer proceeds through its program, it might find that the proposed acceleration is impossible or impractical. It might turn out that even putting all the projects required to accomplish the mission on a crash basis would not result in an acceptable completion date. It may be that facilities are not available, even if more shifts are employed. Under such conditions, the computer will indicate that the plan is not feasible and it will display and print out a warning signal, which shows in detail why the proposed solution to the reprogramming problem is not feasible.

At this point, a group discussion will follow to determine whether by a higher order of decision a solution could be found. For instance, the Administrator might decide that another facility can be built or made available, or that another contractor can be called in, or he might find some other way to solve the problem. Information available to the decision maker will not always be programmed into the computer and, consequently, feasibility indicated by the computer will always be considered only as tentative.

If indeed a need for such a new alternative way of proceeding with the program exists, this information will have to be put into quantitative form and fed into the machine. On the other hand, if the computer indicates general feasibility, then the players can immediately proceed to further evaluation of the proposed program.

When the program modification is feasible, the players will be primarily concerned with the resource requirements display and with the dollar and manpower profiles associated with the program. It is very likely that the first solution proposed will not be acceptable from the point of view of budgetary considerations. It is likely that the costs at certain phases of the program will be beyond possible funding, and perhaps at some other times there will be an indication of surplus funds. This, then, is the point where the players reconsider the time phasing of the mission and goals of NASA and propose an alternative. When the players agree on the next trial of the program phasing, the operator is advised of the proposed time phasing of the goals and this information is fed into the computer. At this point, the computer is directed to proceed with computations and to prepare a new NASA program. Again, the computer first explores feasibility and then proceeds to the detailed generation of the resource requirements.

It is seen that through a step-by-step process of deliberation, discussion and computer computations, the players will reach a better and better solution to the reprogramming problem. The computer programs will be prepared to enable the computer to generate the NASA program in the approximate time of one minute. This will allow the decision makers to make rapid changes and explore and evaluate dozens of different program proposals. As the Decision Game progresses, more and more satisfactory solutions to the reprogramming problem will be found. Towards the terminal phase of the gaming exercise, the players may desire highly accurate estimates of the various program details. If this is desired, it may be necessary to direct the computer to carry out more accurate

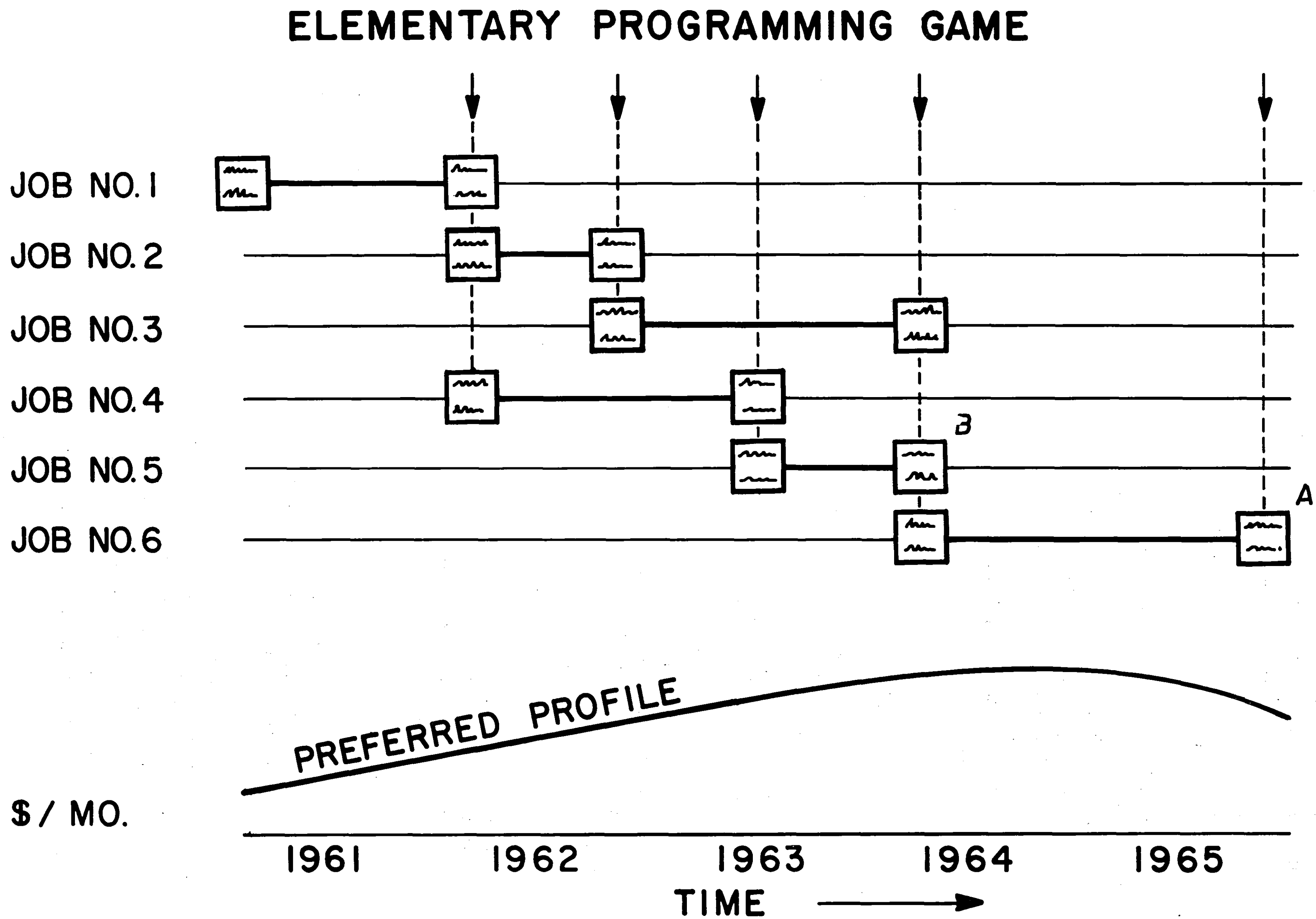


Figure 69. Elementary Programming Game

and more detailed programs, and it may then be necessary for the players to wait for a longer period of time to get the phasing of programs and the resource requirements. Finally, the computer will be directed to develop a detailed NASA program with the highest possible accuracy. Computation of such a program may require hours, and consultation with field installations.

So far, we have given only an outline of how the Game is to be played and described only those phenomena that will be observed by the players. In fact, as far as the players are concerned, this is the only type of information required. Now we will proceed to take a look inside the equipment and see how the various logical steps and computations are carried out.

3C. 2 Illustration of Reprogramming Computations

The basic principle in carrying out reprogramming operations is to provide the computer with data on possible alternatives and also with the myriads of details on how these alternatives can be combined into programs. The computer can be programmed to go through a large number of calculations in an efficient fashion, and therefore alternate programs can be generated by the computer in a matter of seconds. In order to illustrate the techniques, we will describe an extremely simple but still significant reprogramming problem.

Figure 69 is a chart showing six different jobs and the time phasing of the start and completion dates of each of these jobs. In this simplified programming Game, we are concerned only with the monthly dollar expenditures which are shown in the bottom of Figure 69. Suppose the player desires to accelerate by two months the accomplishment of Goal B, that is the terminal date of Job No. 5, and to accelerate by three months the final completion of the mission, that is of Goal A. The computer is to determine whether such an acceleration in the program is feasible, and what kind of dollar expenditures would be associated with this accelerated program.

As this information is coded and put into the machine, the machine examines all jobs to be performed to see which of these jobs will be immediately affected by the acceleration of Goals A and B. The computer will select Jobs 3, 5, and 6 and will evaluate the possibility of accelerating those three jobs. It will find that Jobs 3 and 5 are to be accelerated by two months and Job 6 by one month.

At this point, the computer seeks information on alternative ways of accomplishing Jobs 3, 5, and 6. As the computer consults the File of Alternatives, it finds for each job a time-cost relationship as shown in Figure 70. The horizontal axis shows alternative time spans allowed for the job, the vertical axis shows the total dollars that must be expended if the job is to be accomplished in

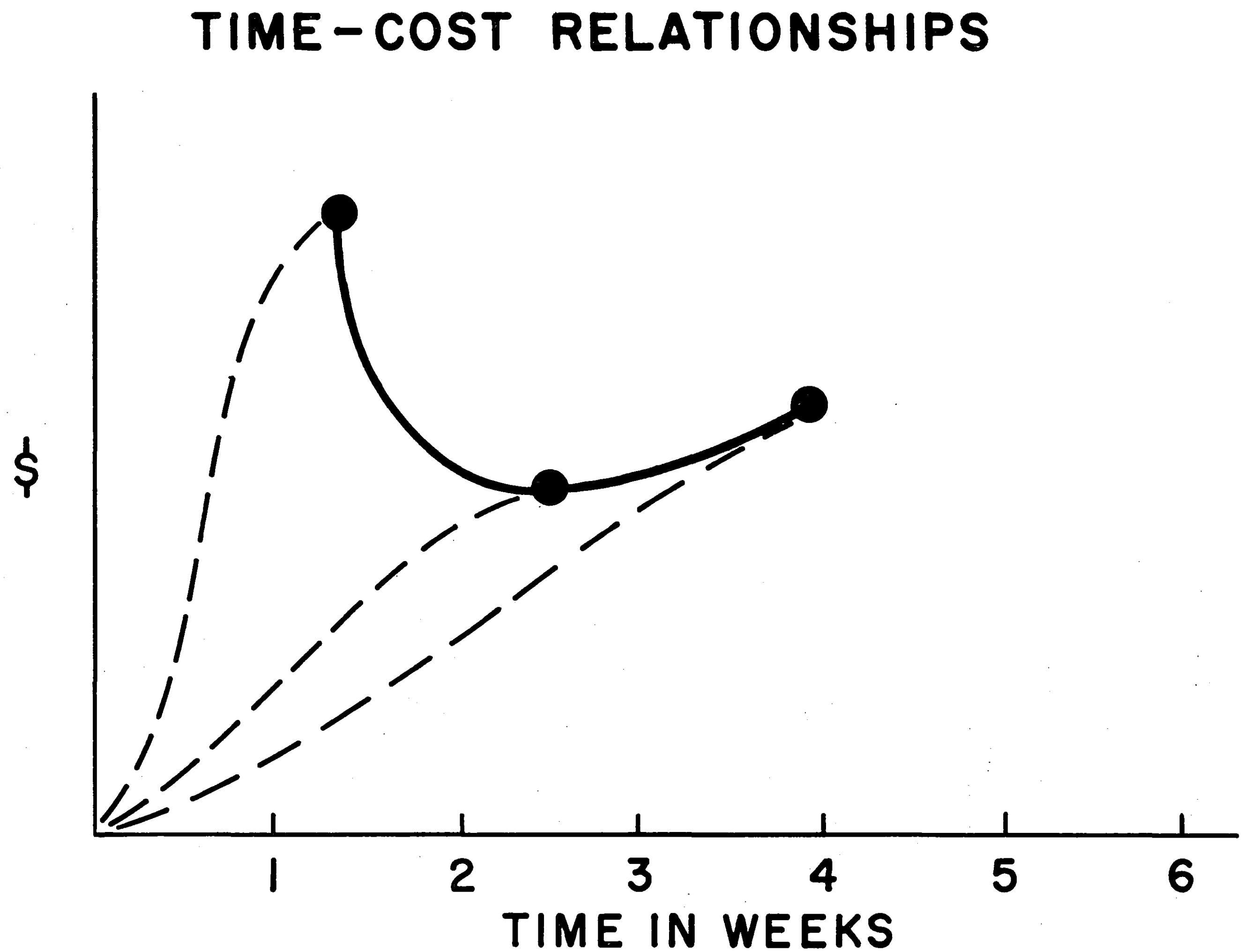


Figure 70. Time-Cost Relationships

the time specified. It is seen, for instance, that a crash program — doing the job in the shortest possible time — requires more total funds than a more orderly and efficient execution of the task. In the case of a stretch-out, due to overhead and some other supporting activities, the total cost of the job would also increase. The computer also finds how these dollars would be expended in time. (Dotted line in Figure 70.) The File of Alternatives has curves of this type for each of the jobs and therefore the computer can establish that the jobs can indeed be accelerated to the desired time span, but that a higher expenditure of funds will be required. Using this information, the computer can replace the old budgets for Jobs 3, 5, and 6 with the new budgets and determine a new dollar profile associated with the accelerated program. We see that when the computer is requested to reprogram, it first proceeds through these computational steps and then transmits the information to the display devices. The player can visually observe the required funding associated with the accelerated program.

We recognize that in a real problem we would deal with a much more complicated set of computations. Manpower profiles would have to be computed. Facilities loadings would have to be checked. Many other items of information on compatibility would have to be considered. In the case of prototype production, or in other tasks where quantities are involved, relationships dealing with "quantity made" would have to be included in the analysis. However, basically, these considerations would only complicate (admittedly by a great extent) the program that the computer would have to go through, but, conceptually, reality would not add significant new difficulties to the method of solution.

The time cost relationships as shown in Figure 70 form the basis of the File of Alternatives that a computer has to consult. As we already mentioned, there are types of problems where more complex mathematical models are required as building blocks for the File of Alternatives. However, for purposes of our discussion, we will concentrate on the concept of time cost relationships and we will show how such relationships can be generated. We will show how the basic input data is to be obtained and how these data can be built into the appropriate files for representing various alternatives that the programming task may require.

3C.3 Concept of Alternatives

Let us reiterate the type of information we seek. The player moves some of the gaming goals in time and certain jobs must be performed within the time limits indicated by the player. We need to find a way to determine the dollar requirements associated with the various alternatives.

Let us begin by considering a relatively simple task. Suppose that for this task there is a single manager in charge, and let us assume that this man has a good grasp of all the details involved in this particular task. He does his own planning with paper and pencil and by talking to his associates. We ask him, "How much would it cost to perform this

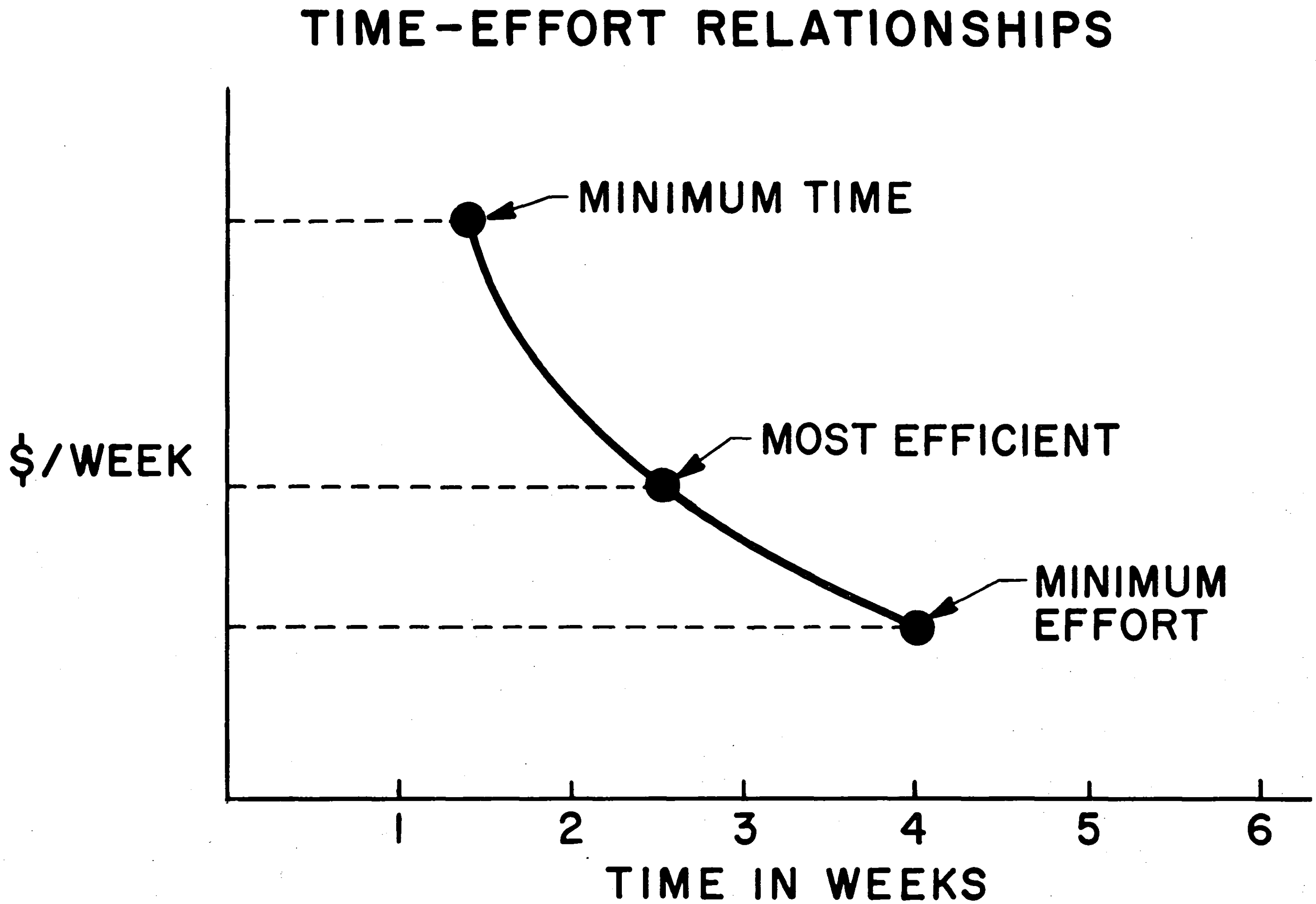


Figure 71. Time-Effort Relationships

job in an orderly fashion?" After studying the problem, he estimates manpower, material, overhead, and other requirements and prepares a report of the weekly effort required to complete the job. In Figure 71, we put this information into graphical form. In the horizontal axis, we show the associated effort, say dollars per week required to complete the job in the time specified. "Orderly" performance of the task is represented by the "most efficient" point in the chart. Then we ask the manager, "What would it involve to complete the job on a crash basis?" He would need more men, more resources; he would require a larger effort, but he could complete the job in a shorter time. We are discussing here a crash program which in our chart in Figure 71 is represented by the "minimum time" point. We can also ask him, "What is the minimum level of effort that he could do the job?" He needs two mechanical engineers, an electronic expert, a technician, a secretary and others. This establishes his minimum effort level and gives a lower point in Figure 71. Now we connect the three points with a curve and obtain a time effort relationship as we assume that he could operate at intermediate points on this curve. With the aid of the curves shown in Figure 71, we can now return to the time-cost relationship shown in Figure 70 by multiplying the rate of effort and the time required for the job.

We see, then, that we have a technique to get time-cost relationships, at least for relatively simple jobs. However, if we want to extend this technique to more complex tasks, we run into difficulty. It is difficult or impossible to find people who have all the details of a complex job. Consequently, in order to make cost estimates, the manager must work with his subordinates and he must put the various items of information together to get his estimate. This combination of input data into meaningful programs is a tedious and complex job and is precisely the kind of task that computers can execute with great efficiency. Therefore, we propose that time-cost curves for complex jobs should be prepared by computers. In order to make this possible, it is necessary to formulate the problem in a mathematical form. With the aid of mathematical models and sub-optimization technique, it will be possible to construct time-cost relationships.

3C.4 Sub-Optimization Considerations

Let us take a simple combination of two jobs to be performed in sequence. Various ultimate time spans can be allowed for Job No. 1, and also for Job No. 2. This implies a number of combinations of ways that the two jobs can be performed. In Figure 72, we show the problem in a graphic way. Suppose tentatively we select a certain duration for Job No. 1, and we determine the total dollars required to do the job from the time-cost relationship. In Figure 72, this time-cost combination is represented by point A. Now by starting at point A, we can assign different time spans to Job No. 2. A possible representation for Job No. 2 is point B. It is seen that we can combine the two time-cost curves in many different ways. In Figure 73, the various possible time-cost curves for Job No. 2 are shown by dotted lines. Now we need a policy to select, out of these many possibilities, the desirable ones.

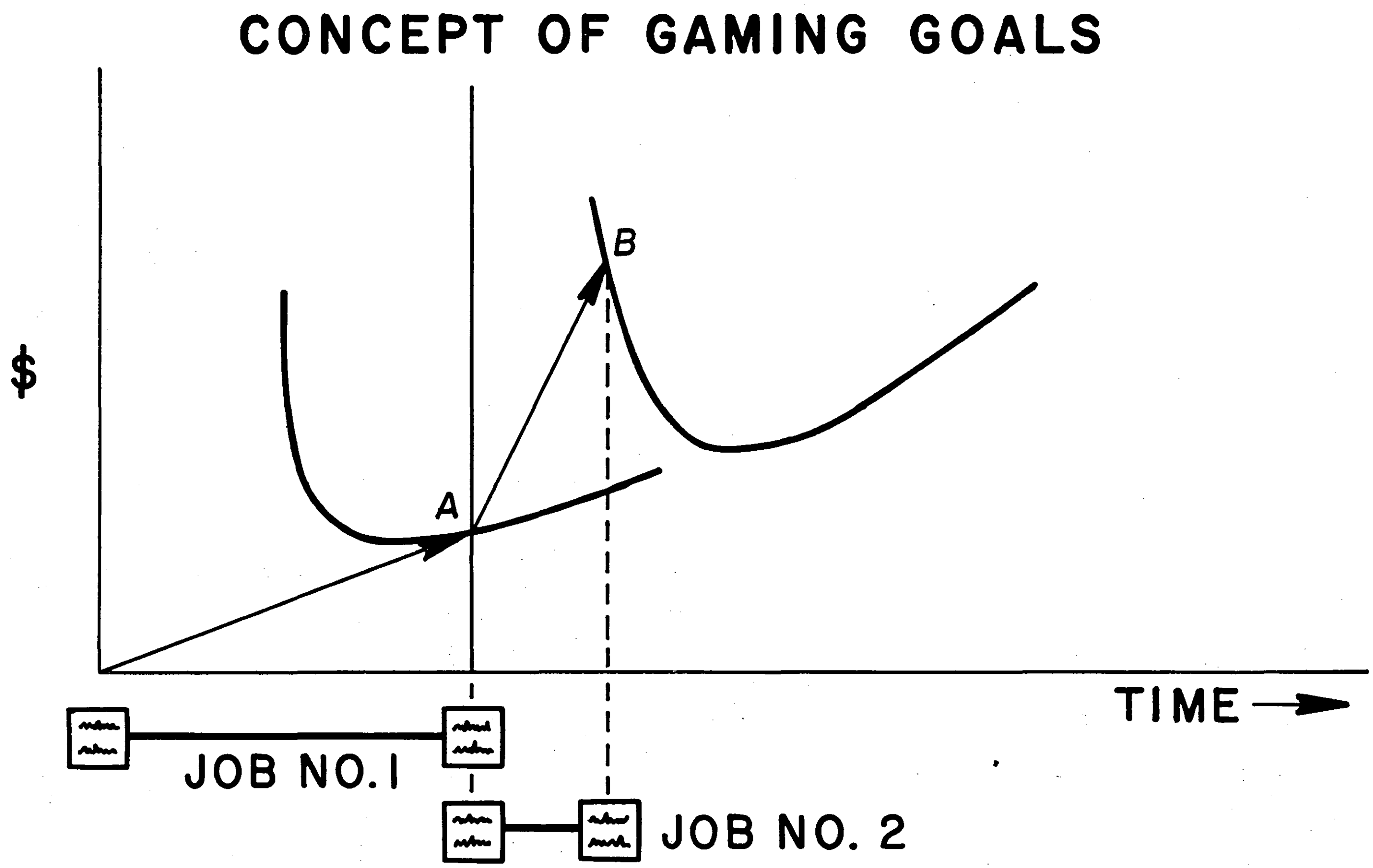


Figure 72. Concept of Gaming Goals

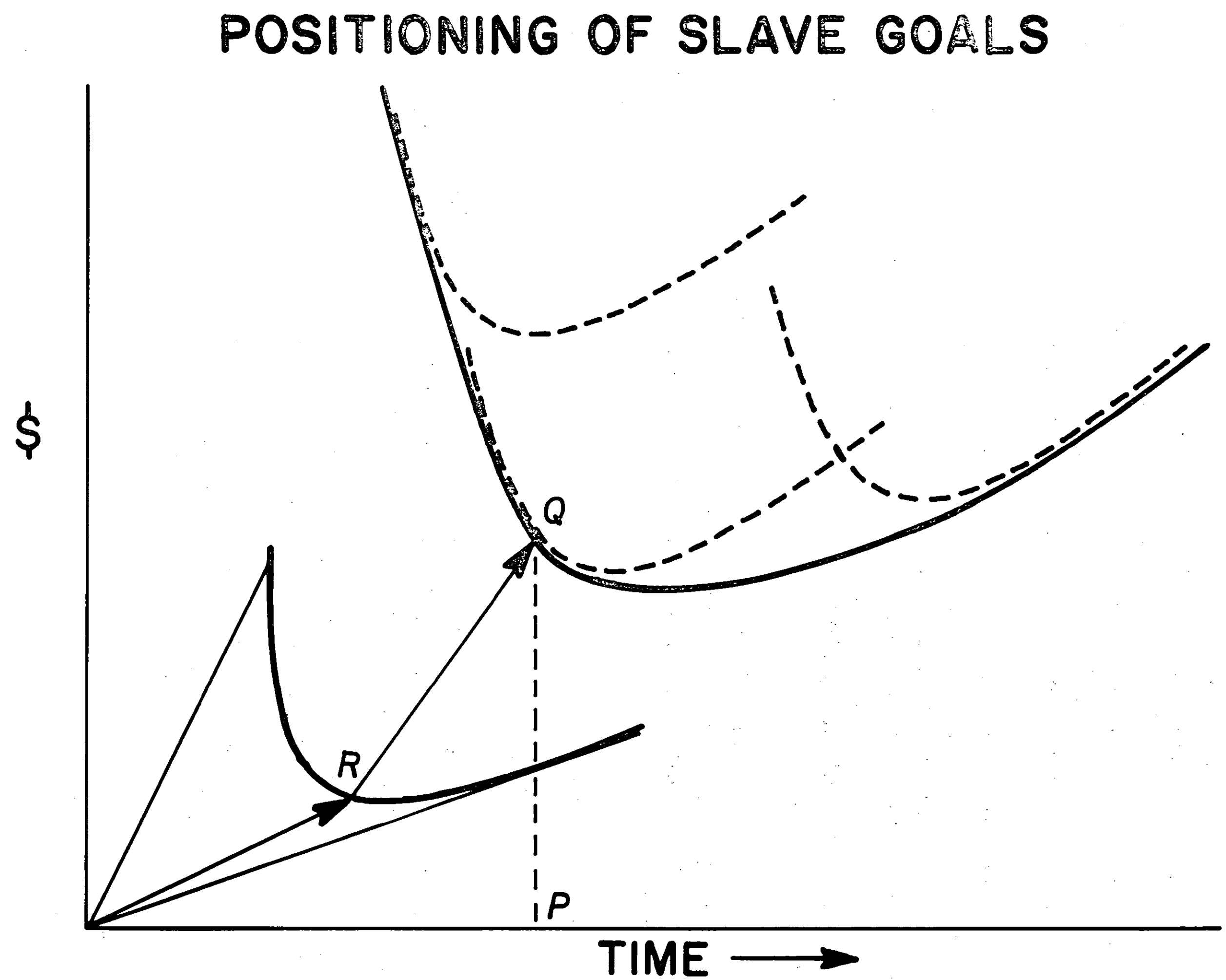


Figure 73. Positioning of Slave Goals

Suppose we agree that we want to complete the two jobs within a given time span, but we want to do this with the least amount of money. Here we recognize that when the combined span for the two jobs is specified, there are many ways to do the two jobs, and out of these many possibilities there is one that represents the lowest cost. In Figure 73, these low cost combinations are represented by the envelope of the dotted curves. We say then that this envelope corresponds to our policy of minimum cost, and this envelope is the combined time-cost relationship for the two jobs to be performed. For instance, if we wish to complete the two jobs at point P in Figure 73, we draw the vertical line from point P until we reach the envelope at point Q. This gives the combined cost of the two jobs. Working backwards from point Q, we can get point R which represents the time and cost requirements of Job No. 1.

The policy we used here is to perform the two jobs with the lowest possible cost. If there is another policy such as say a constant manpower requirement or the utilization of a facility, etc., these policies would have to be programmed into the computer. The important point, however, is that even if complicated policies are formulated due to the high-speed capability of computers, consequences of these policies can be deduced efficiently.

Actually, the computer would not construct the envelope of the curves, but would solve the appropriate mathematical relationships. It is easy to show that the two jobs are to be combined in such a fashion that the following equation holds:

$$\frac{dC_1}{dT_1} = \frac{dC_2}{dT_2} . \qquad (1)$$

Here on the left-hand side we have the derivatives of the time-cost relationship for the first task, and similarly on the right-hand side, we have the derivative relationship for the second task.

The computer would compute these derivatives, select the appropriate combinations of the tasks and generate the new time-cost relationships.

In Figure 74, we show now a somewhat more complicated problem when there is a whole sequence of jobs to be performed. Here again it can be shown that the following equation must hold:

$$\frac{dC_i}{dT_i} = \lambda . \qquad (2)$$

The meaning of these equations is that the derivatives of (that is the slopes to) the time-cost curve must be equated. This procedure can be observed in Figure 74 by considering the three upper curves and realizing that the three tangents shown are all parallel. Another representation of the same set of equations is shown by the lower set of curves. These are the derivatives (or slopes) of the time-cost curves. The corresponding points on the time-cost curves are selected by taking points on the same vertical level.

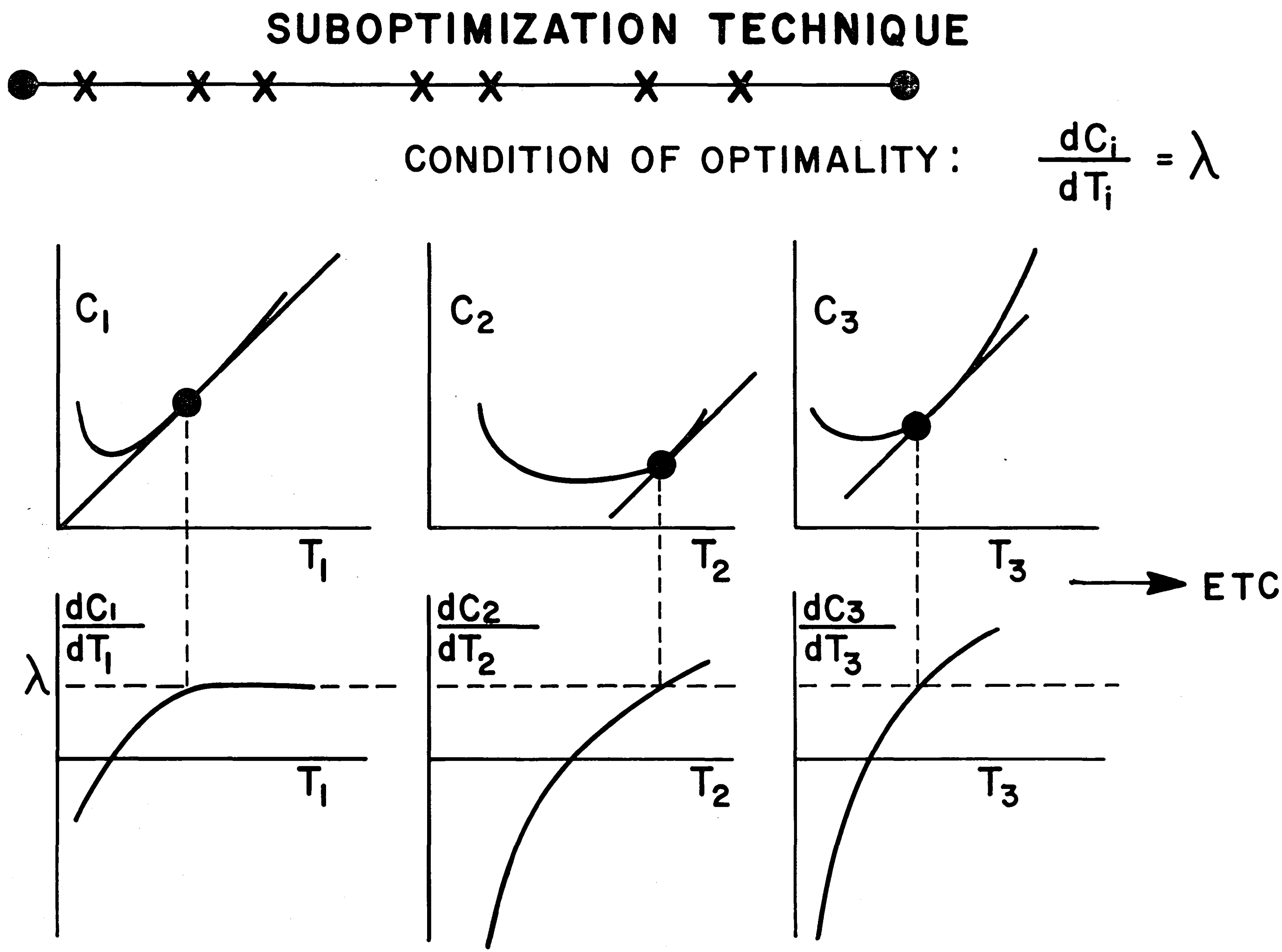


Figure 74. Suboptimization Technique

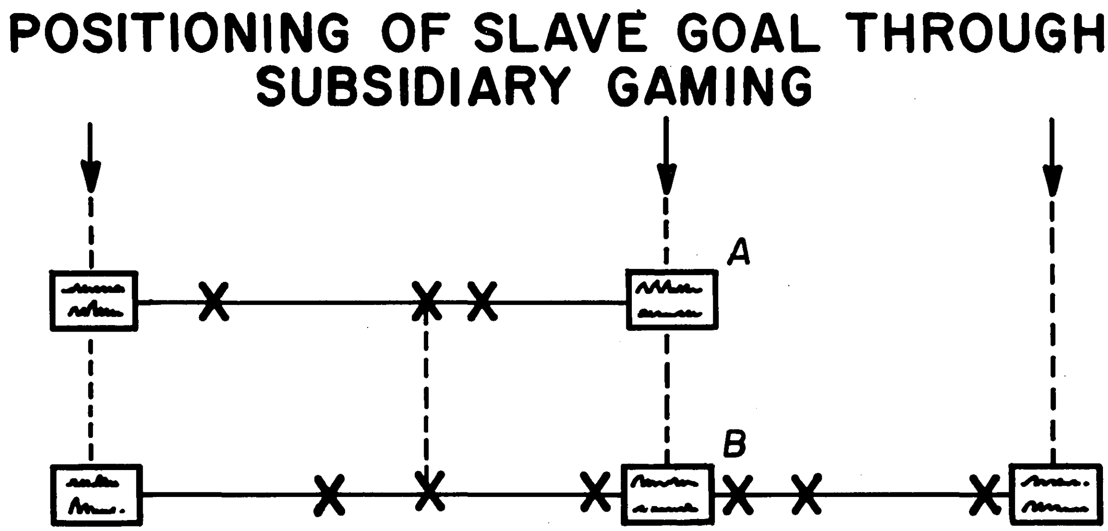


Figure 75. Subsidiary Gaming

Again, this is the type of computation that a computer can carry out very efficiently.

Another way to describe the technique used here is to state that whereas many goals are to be manipulated during the course of a Game, some of these goals are not sufficiently important to be manipulated by the players. Therefore, some "slave" goals are automatically manipulated by the computer. We can say that placing of the slave goals proceeds according to some sub-optimization technique. For instance, in the discussion so far, we sub-optimized by using least-cost job combinations. As stated before, some other principle might be involved in positioning of the slave goals and then other corresponding sub-optimization principles must be developed. It is also possible that in some complex situations, one would have to be satisfied by accepting a relatively "good" solution instead of trying to find a sub-optimum.

In Figure 75, we show a somewhat more complicated problem. Those goals marked with crosses can be made slave goals by the technique so far described. However, goals A and B are interconnected as they have to be completed at the same time, and therefore this interconnection must appear somehow in the computational procedure. What we have to do is to take the time-cost relationship for the first and second jobs up to A and B and add the cost of these two jobs together and thereby construct a single time-cost relationship. We have to go through the same procedure for the jobs to be performed after A and B, and again form a single time-cost relationship there. When we have these two time-cost relationships, we have reduced our programming problem to the problem of having two jobs performed in sequence. Here we can use the technique previously developed.

In a way we could say that first, we have a technique of turning into slave goals those goals which are in series, and then we turn goals which are in parallel into slave goals. By use of this principle step-by-step, we can construct the necessary time-cost relationships for complex programs.

In summary, we can say that we get basic data on relatively simple jobs from managers of simple projects. Then we formulate the rules of combining these simple jobs into complex jobs, and through some method of selecting the most appropriate combination, we construct combined time-cost relationships.

Let us, however, recognize that when we deal with really complex structures, it might not be possible to put into logical or mathematical form the rules of combining tasks, and the policies that would determine the most desirable combination. If this be the case, it will be necessary to resort to auxiliary gaming technique to establish the File of Alternatives.

The problem shown in Figure 75 would be solved now by a group of executives moving goals A and B and by examining the consequences of these moves. Here we will have to perform the same type of gaming as we have previously described. In Figure 76, we show in a schematic

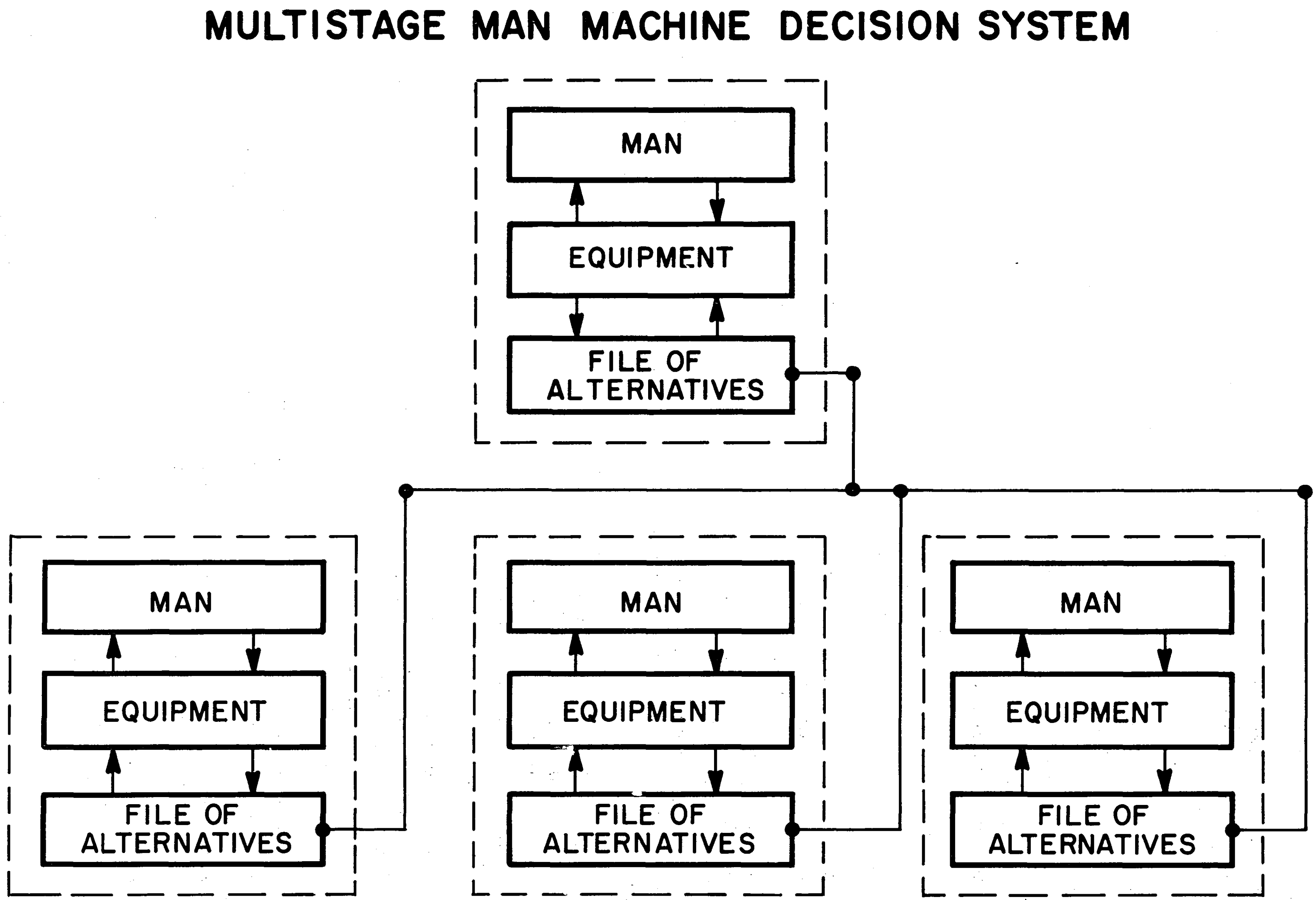


Figure 76. Multistage Gaming System

form, the multi-stage man-machine gaming system that we envision here. On the top we show the game that we have already described and which is to be played at NASA headquarters. On the lower level, we show the subsidiary games which would be performed perhaps at field activities. The purpose of the field activity games would be to develop Files of Alternatives which would be tied in automatically to the File of Alternatives at NASA headquarters.

Perhaps the most significant aspect of this multi-stage gaming technique is that various levels of NASA management could participate in a most effective fashion in the reprogramming effort of NASA. As problems develop at lower levels of management, these problems are reviewed by field facility management and the implications of changes in program phasing are incorporated into the plans of the field facility. Even more significant is that not only are single plans developed, but alternative possibilities of tackling jobs are considered. When field facilities management agrees on the various alternatives, these are placed in the File of Alternatives and transmitted to NASA headquarters. This way, NASA headquarters is apprised of the most recent and significant changes in the time phasing of programs and is provided with a capability of using the best information in preparing overall plans for NASA.

3C.5 Confidence Factors in Programming and Scheduling

We have so far attempted to divide the planning task between equipment and man in a systematic way. We recognize that a great many logical and mathematical tasks must be performed in order to generate program plans, and that many of these tasks can be performed better by computers than men. We believe that the capability of computers surpasses human judgment in one more area and we propose that the NASA management Gaming System should take advantage of this capability.

We refer here to estimating the uncertainty of dates of completion of various tasks. It has been found that human judgment is fairly good in estimating upper and lower limits of when a job will be completed, provided the task to be performed is relatively simple, and provided the man who makes this judgment is completely familiar with the job to be performed. However, when people combine the various component estimates of complex jobs, we find that it is difficult to get reliable answers.

We show in Figure 77 the problem in a highly simplified form. Suppose there are three tasks to be performed in sequence and for each, there is an uncertainty of the completion date. These uncertainties are shown in the diagram by the shaded areas, lower estimates being the optimistic ones while the higher ones are the more pessimistic estimates. In the lower part of the diagram we add the times required for the three jobs together and also add the uncertainties (three shaded areas) into a single one. What is now the measured uncertainty in completing the three jobs?

The total variability is of course shown by the sum of the shaded areas. However, it is unlikely that all three jobs will be completed at the earliest possible completion date, or conversely, that all three jobs will take the

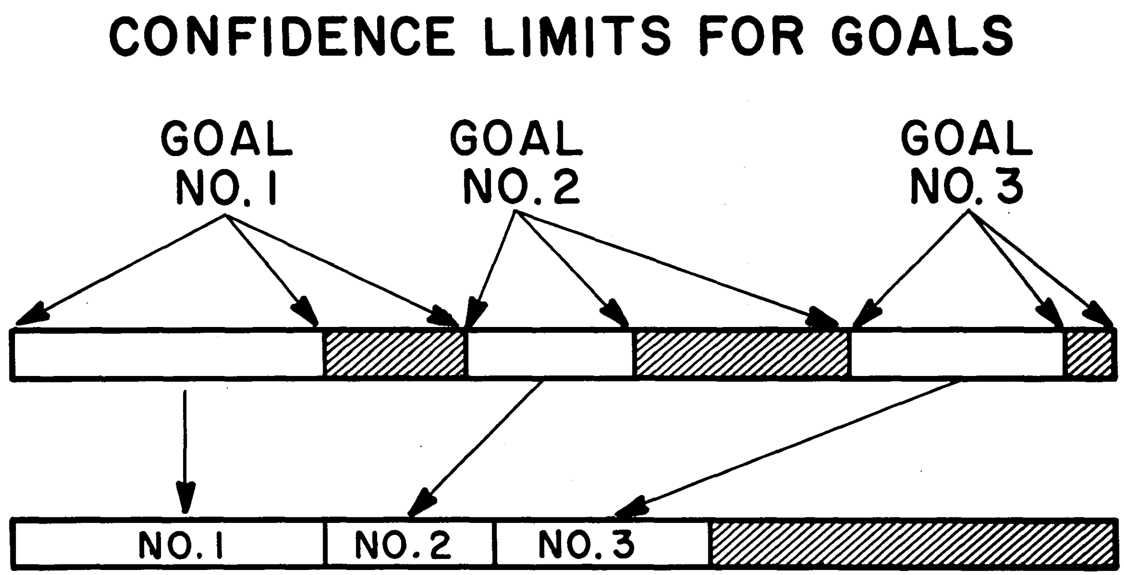


Figure 77. Confidence Limits

longest time estimates. Therefore, we can say that whereas the total variability is shown by the combined shaded area, the area still contains some unlikely completion dates.

If we think in terms of a more complicated program, our problem becomes more acute. When there are hundreds of jobs to be performed, it is impossible for the unaided human brain to form a composite picture of the probabilities involved.

However, this is a sort of a problem that statisticians have already studied. In Figure 78, we show the simple example when we want to cascade the uncertainties in the three different jobs. If we estimate probability distributions of completion dates for each task and associated standard deviations, then at least under certain simplified conditions, we can use the following equation for determining the standard deviation of the composite probability distribution:

$$\sigma^2 = \sigma_1^2 + \sigma_2^2 + \sigma_3^3 . \tag{3}$$

In this equation on the right-hand side are the squares of the individual standard deviations, while on the left-hand side is the square of the composite standard deviation.

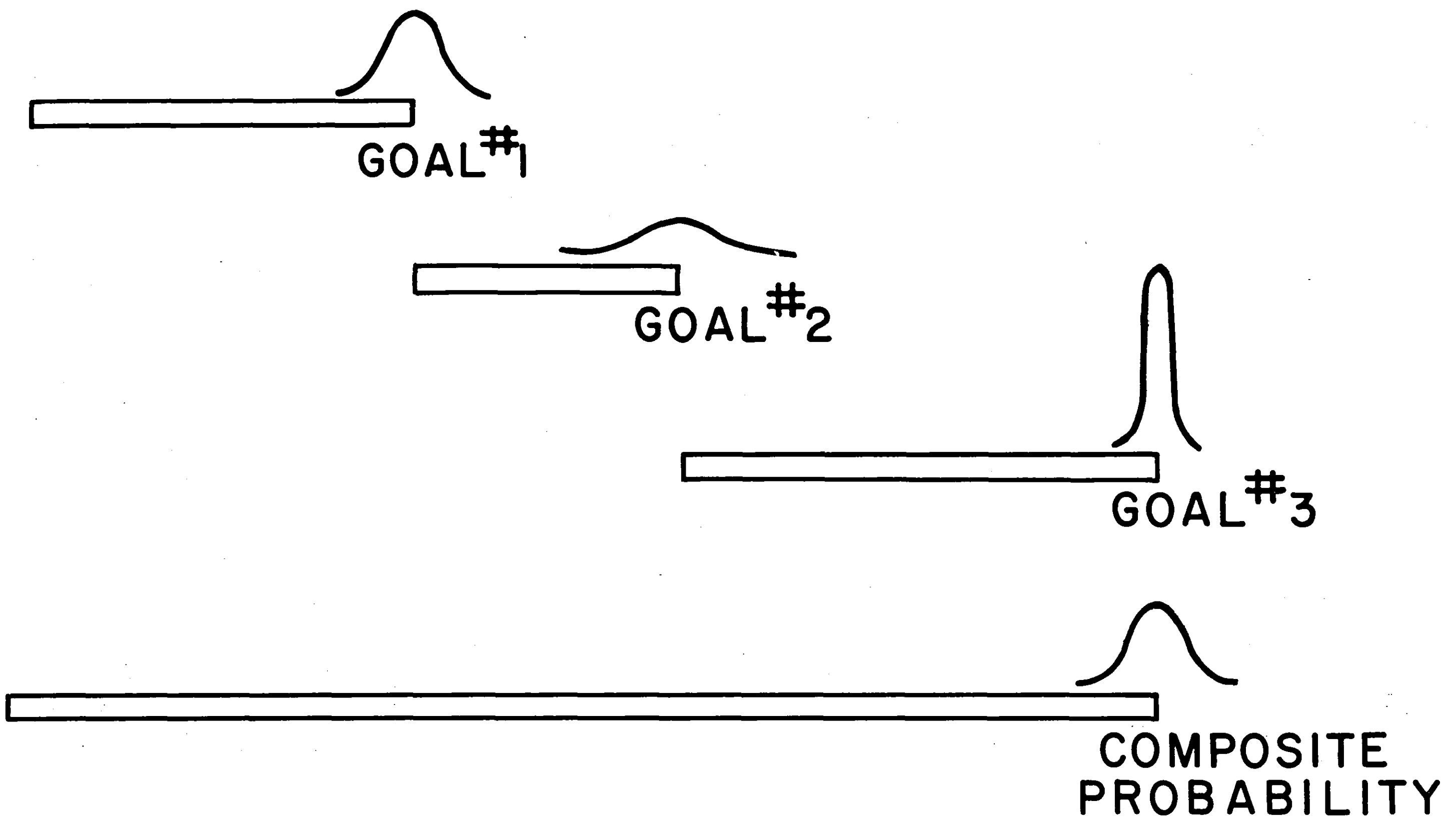
So far, we have talked only about a very simple situation. However, during the last year some mathematical studies have been made, devoted to the problem of how to combine these probability distributions for complex programs. It is believed that when these techniques are combined with machine computations, one can obtain quickly more reliable estimates of completion dates than is possible today by unaided human judgment.

In fact, even if the input data is not very reliable, if appropriate techniques are used to put the data together, fairly good estimates of composite completion dates can be obtained.

3C.6 Improved NASA Management Capabilities

The decision gaming described in this report is aimed to increase the capability of NASA executives in programming and reprogramming the NASA effort. It is recognized that this type of effort requires a great deal of human judgment and we do not propose to eliminate human judgment. On the contrary, the system we propose is tailored to the need of executives so they can use their judgment more effectively and efficiently. We accomplish this increased capability by eliminating all the routine steps that must be examined in order to prepare program plans and delegating these tasks to a high-speed electronic computer. The Decision Gaming System described capitalizes on human capability and matches it with the ability of computers to perform repetitive tasks at a great speed. The Decision Gaming System is made possible by an integration of man-machine capabilities that currently exist only separately.

CASCADING PROBABILITIES



$$\sigma^2 = \sigma_1^2 + \sigma_2^2 + \sigma_3^2$$

Figure 78. Cascading Probabilities

More specifically, the distribution of tasks between man and machine is effected in the following fashion:

Tasks for Man

- He manipulates the phasing of goals.
- He selects acceptable alternatives in the case of multi-stage gaming.
- He chooses the most suitable solution.

Some other tasks remain for people to do: the computer has to be programmed; policies have to be articulated and put into logical steps; the Game itself must be designed.

Tasks for Machine

- The computer checks feasibility, both in time and as far as facilities are concerned.
- Indicates when the program is infeasible.
- Indicates probabilities and confidence limits.
- Sub-optimizes through scientific and mathematical programming techniques.
- Computes dollar and manpower profiles.
- Prepares and presents displays.

The Decision Gaming System described here will result in increased NASA capabilities, at least in the following ways:

- Determination of money, manpower, facilities loading and other requirements, in order to accelerate a program, to establish a new program, or to cancel a program.
- To program and re-program NASA activities so that resources and facilities are used to the best advantage.
- To indicate program slippages so that early corrective action can be taken.
- In order to follow, control and monitor contractors participating in NASA activities.
- In the task of preparing executive and legislative reports for the U. S. Government.

SECTION IV

PROPOSED PLAN AND PROGRAM FOR DEVELOPMENT AND INSTALLATION OF THE NASA IOC-MAPCS

4A. CONTROL CENTER

Section 3B of this report presented a detailed description of the proposed site requirements and a method for the production and subsequent display of pertinent management information. These paragraphs describe the method by which these actions would be accomplished.

4A. 1 Facilities

4A. 1a CONSTRUCTION AND DESIGN COORDINATION

If acceptable to the NASA, Ramo-Wooldridge would provide the engineering direction and coordination that would be required to actuate the facility (See Figures 79 and 80), by the expected date of occupancy of FOB No. 6. Acting with NASA representatives, they would:

> Provide the necessary industrial design and human factors talents to insure subcontractor performance as required to meet the facility design specifications.
>
> Secure and direct a group of specialists in the illumination field who would design and install the type of collimated light required in the Conference Room.
>
> Working with acoustic specialists, R-W personnel would monitor the Control Center construction to guarantee installation of proper acoustical controls. At the same time they would study the security problem which arises from sound transmission and then design and/or install devices which would insure acoustical integrity throughout the center.
>
> Industrial design and human factors engineers, working with NASA representatives, would coordinate the efforts of plaster and painting subcontractors to guarantee wall treatments that matched the environmental requirements of the center, and monitor the procurement and installation of the furnishings (e.g., chairs and drapes).
>
> Engineers and draftsmen would design (in construction detail) the special cabinetry required, the projector racks, the conference and light box tables, control panels, the housing for the control consoles, the lectern, the reception room partitioning, desk and file cabinets and the blackboard enclosures. They would also coordinate and police the efforts of R-W cabinet makers and machinists who would produce the conference table, cabinetry, files, desk, light box table, display light boxes, blackboard enclosures, electronic consoles, lectern, projector racks and control panels.

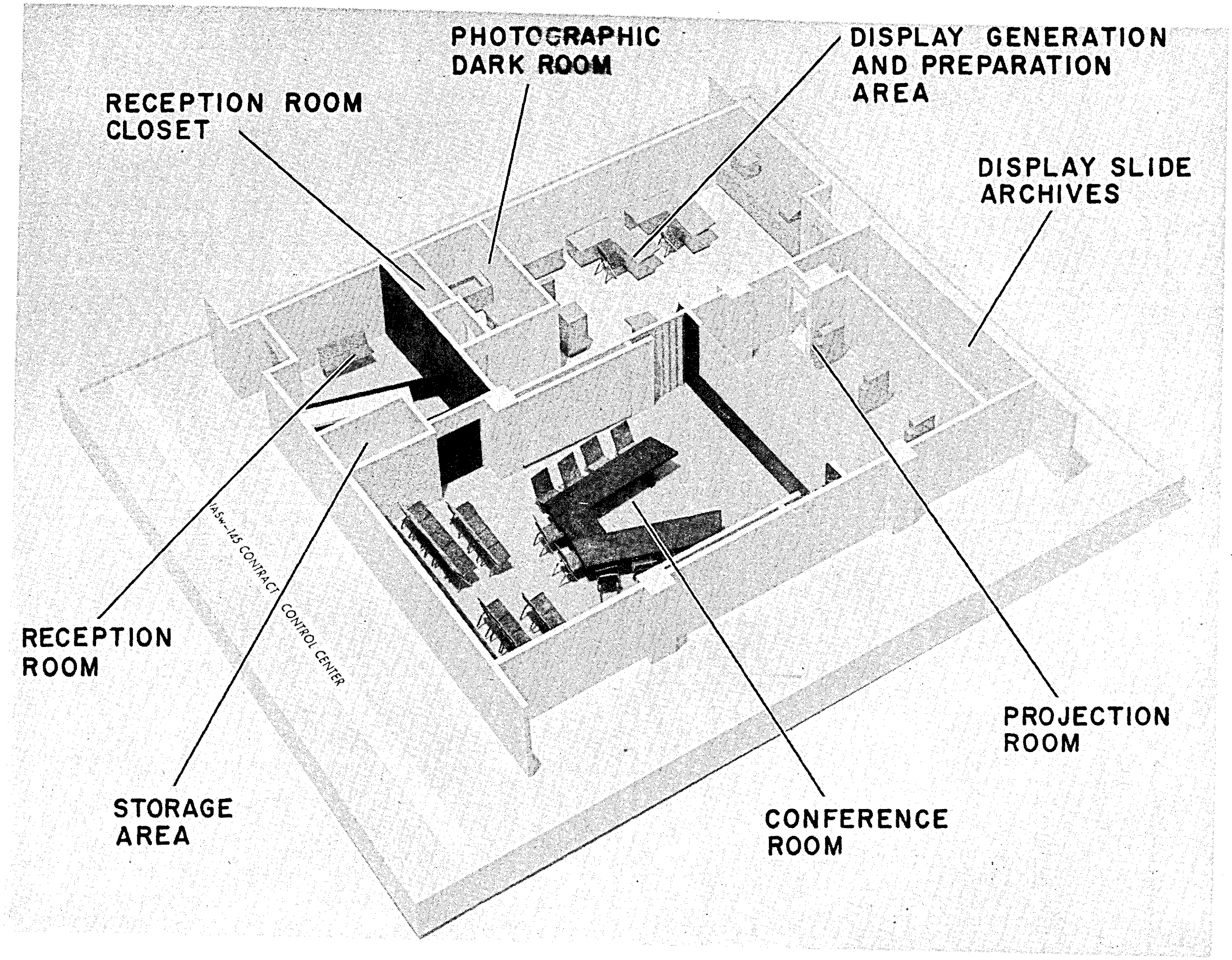


Figure 79. Control Center, Right Aerial View

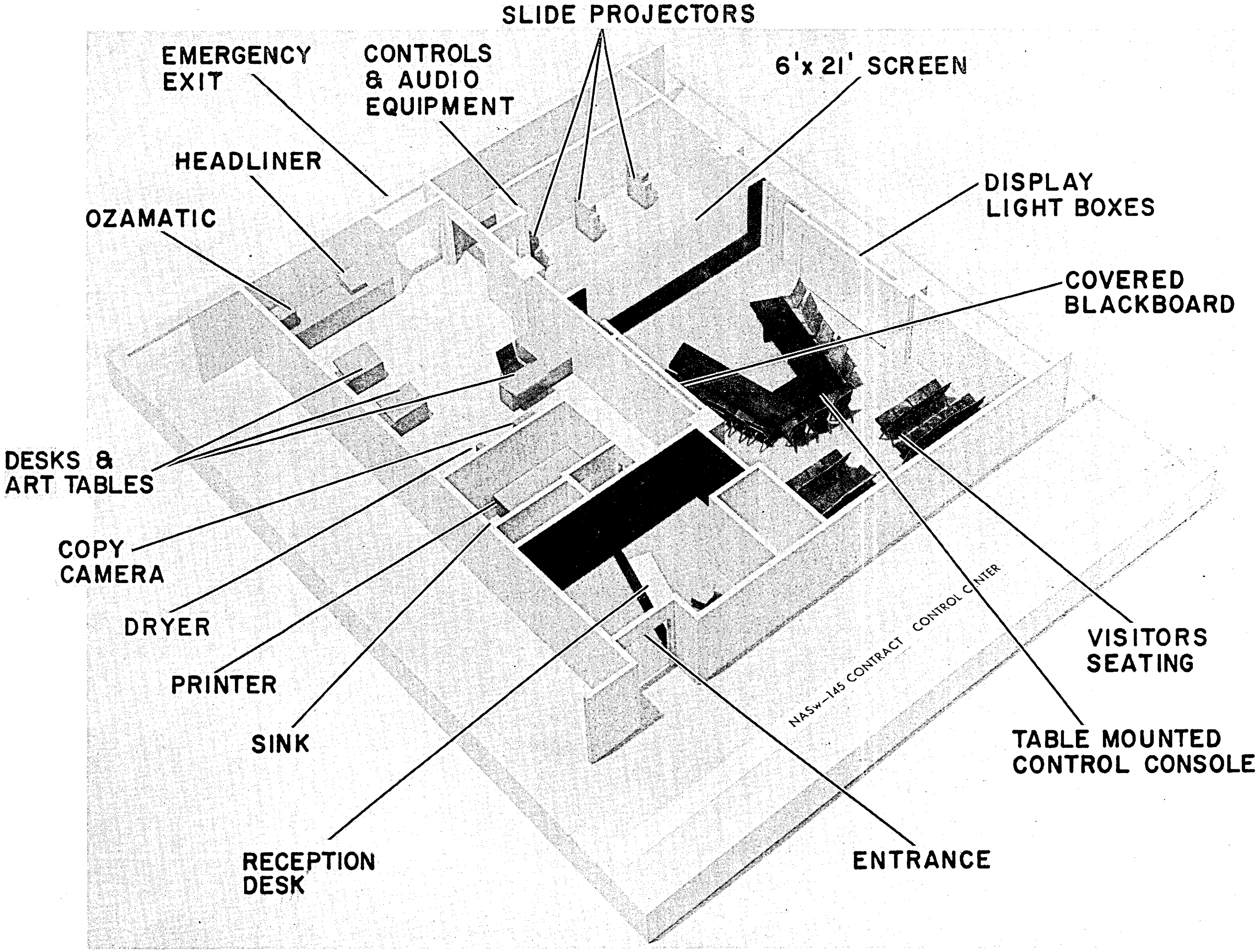


Figure 80. Control Center, Left Aerial View

Photographic engineers, working in conjunction with NASA personnel and subcontractors, would provide counsel and technical guidance in the construction of the facilities which affect the photographic processes. They would make certain that: the light traps were constructed correctly; the darkroom storage and production facilities were designed, constructed and installed properly; and, the lighting and electrical installations met the specifications.

Electrical engineers and technicians would provide technical guidance to the chosen subcontractor to produce the required power facilities. Also they would modify, design, fabricate and install the electrical equipments to be used in the Center. A detailed listing of these items is given in Paragraph 4A. 6.

4A. 2 Display System Implementation and Equipment Installation

The proposed system implementation would primarily utilize (or require modification of) equipment that NASA presently owns, or "off-the-shelf" equipment. Certain other equipments would require design and construction.[18] In this regard, R-W personnel would:

Procure all equipment to be included in the system
Perform the design required to accomplish the modification
By themselves, or in concert with others chosen by NASA, perform the required reconstruction or revision

4A. 3 Personnel Indoctrination

Inherent in any implementation plan is the consideration of the personnel who will be the eventual users of the system and the equipment. With this in mind, it is proposed that Ramo-Wooldridge human factors and technical engineers train NASA personnel in the proper utilization of the equipment and the implementation of the system. This would include: the development and application of an "on the job" training program; the attendance of R-W technicians and engineers at NASA for an agreed upon period to guide NASA personnel in the use of the equipment; periodic checks and visits, if requested, to improve performance capabilities; and, a continuing study of the system effectiveness by R-W representatives.

4A. 4 Manuals, Procedures and Reports

During the initial implementation stage and at the times that new personnel are added to the NASA staff, operating efficiency will depend to a great extent on the written guides available to personnel. Consequently it is proposed that system procedure manuals, equipment repairs manuals, parts lists, and wiring diagrams be produced and made available at the time that the system is installed.

---

18. Equipments affected are listed in Paragraph 4A. 6.
Appendix B describes the function of the equipments.

Finally, during the course of the contract effort every step would be taken to keep NASA management informed of progress and development by the submission of written and verbal reports. These reports would be transmitted monthly or otherwise, as required, with the understanding that additional special reports would be prepared and submitted as requested.

4A. 5 Advanced Studies

Since it is apparent that NASA will not be a static organization and that the scope of its effort will alter considerably within the next two years, it is safe to assume that the volume of managerial inputs and subsequent reporting may grow beyond the capabilities of a semi-automatic system. Also, during this period, continued developments within the state-of-the-art may provide a display system which would make it advisable to proceed to a more automated system earlier than previously imagined. Consequently, it is suggested that, during the period of the proposed R-W effort, it would be advisable to keep abreast of these developments. If such a decision should evolve, Ramo-Wooldridge engineers would initiate an effort to study the problem and advise the NASA representatives of the circumstances which create a situation justifying a more automated system. Also as a part of its efforts, if required, R-W, systems and technical personnel could present to the NASA their recommendations regarding the feasibility of increased automation, the timing involved, the costs which would accrue and a detailed design and plan for its implementation.

4A. 6 Equipments

4A. 6a OFF THE SHELF EQUIPMENT REQUIRED FOR CENTER

Location	Item	To be procured and installed	Presently owned
Reception Area	Typewriter	x (either/or)	x
	Transcriber	x	
	10 Key PBX and separate telephone	x	
	Lounging Chair	x (either/or)	x
	Gate Control Switch	x	
Conference Room Storage	Stacking Chairs	x (either/or)	x
Conference Room	40 Db Doors	x	
	Drapes and Motor	x	
	Conference Chairs	x (either/or)	x
	Stacking Chairs	x (either/or)	x
	Microphone Jacks	x and	x
	Speakers		x

Location	Item	To be procured and installed	Presently owned
Conference Room (Cont'd)	Screen	x	
	Blackboards		x
	Hexcel Ceiling Materials	x	
	Reflective Ceiling Tiles	x	
	Switches and Plugs	x	
	Prompting Box	x	
	Carpeting	x	
	Microphones	x and	x
Projection Room	35 mm Serial Selection Slide Projector	x	
	35 mm Random Access Slide Projector	x	
	Sound on Film Motion Picture Projector		x
	Tape Recorder	x	
	Tape and film storage cabinets	x	
	Cuing and Signal Lights	x (either/or)	x
	Slide Storage Racks	x	
	Carpeting	x	
	Acoustical Tiles	x	
	Outlet Boxes	x	
	TV Camera	x	
Display Generation Area	Ozamatic Machine		x
	Headliner		x
	Artist's Desks		x
	Storage Cabinets		x
	Light Box		x
	Light Box Table	x	
	Copy Camera	x	
	Film Driers	x	
	Automatic Typewriter	x	
Dark Room	Kreonite Sink	x	
	Film Printer	x	
	Film Processor	x	
Adminis-trator's Office	Television Monitor	x	

4A. 6b EQUIPMENT TO BE MODIFIED OR FABRICATED

Location	Item	To be fabricated	To be modified
Reception Room	Desk and File Storage	x	
	Gate and Restraining Wall	x	
Conference Room	Conference Table	x	
	Control Console	x	
	Drape Controls		x
	Lectern	x	
	Drapery Holders	x	
	Light Boxes	x	
	Lights		x
	Blackboard Covers	x	
	Loudspeaker baffles	x	
Projection Room	Three 35mm Serial Selector Slide Projectors		x
	One Random Access 35mm Selection Projector		x
	16mm Motion Picture Projector		x
	Projector Racks	x	
	Control Box	x	
	Control Center		x
	Tape Recorder		x
	Conference Room Controls	x	
	Viewing Port	x	
	Television Camera	x	
Display Generation Area	Light Box Table	x	
Dark Room	Cabinets	x	

4B. INFORMATION SYSTEM

4B.1 Design Over-all Information Flow System to Working Detail

Implementation of the IOC-MAPCS information system will involve these steps, in order (but steps overlap in sequence):

Final specification of information system detail, including forms design.

Selection of information processing equipments and receipt of display generation equipment format requirements.

Programming for data processing equipment.

Develop files for initial project applications.

Begin development of training aids.

Installation and checkout of initial project applications.

Establish training courses for system operators and users.

This section sets forth in detail the nature and sequence of these tasks.

4B. 1a. DEVELOP SPECIFICATIONS FOR MACHINE-READABLE DATA CODES

A first step in developing the working detail for the IOC-MAPCS information system will be to settle final specifications for the coding system upon which the information system is to be based. The coding system described in an earlier section of this report is based upon several assumptions, which must be either substantiated or disqualified in the implementation phase. These assumptions are that:

1. NASA efforts can be organized and controlled in the project-oriented manner described in the section relating to the coding system.

2. Tasks can be planned in sequences of stages, steps and paths, as described earlier.

3. A sequence of 93 stages and steps will be adequate for any path in the system.

4. A total of 100 paths will be adequate for any task in the system.

5. Any project in the system will have no more than 23 sections.

6. Any section in the system will have no more than 99 tasks.

7. Any program in the system will have no more than 99 projects.

8. The system will not be required to control more than 23 programs.

Any change in assumptions 2 through 8 will require a change in the coding system. Such changes will only increase the number of characters required in the code representation, and will not affect the basic coding system structure.

In developing final specifications for the project network code structure, it is recommended that a sample of actual tasks be charted and coded in order to test assumptions 2, 3, and 4. The largest NASA project should be carefully examined to test assumptions 5 and 6. Assumptions 1, 7, and 8 rest on matters of NASA policy and should be reviewed with the Associate Administrator and Program Directors before acceptance.

The coding system proposed for use with project networks is a completely feasible system for use with a data processing system. It is of some importance, however, that this statement be fully qualified by carrying out analyses of programming and file maintenance problems involving use of the coding system prior to final acceptance.

A coding system must be developed for the Facilities Inventory recommended in a preceding section. The code used must have the ability to specify a given facility uniquely, to reflect such information as shift of usage, and to be readily manipulated by automatic data processing equipment. It is desirable that the code reflect such information as facility type, geographic location, organizational control, and degree of freedom of access. Development of the Facilities Inventory code will proceed logically from a study of available facilities to determine the desirability of including each within the Inventory. Facilities to be studied are:

Major computing equipments
Launch pad complexes
Special Laboratories
Test stands and test beds
Wind tunnels
Major production facilities

Final specifications for preparation of both project network charts and facilities utilization charts must be prepared. The initial study, herein reported on suggests the format for the former type of chart, but not for the latter. The format for the facilities utilization chart should differ significantly from that employed for the project network, both to minimize possible confusion and to allow display of such items as percent of capacity utilized, percent available, number of shifts of use during a given period, etc.

Procedures for updating and distribution of network charts must also be determined. Some suggestions in this area are made in Section 3A.

Final specifications for the synonym capability of the information system should be drawn at the same time the code system is finalized. As initial projects are placed under the IOC-MAPCS, the synonym cross-reference tables will be incorporated in the information system. Procedures for use of these tables will be established at the same time.

4B. 1b DEVELOP IOC-MAPCS CAPACITY INDEX

The development of an accurate IOC-MAPCS capacity index will depend upon many basic parameters to determine its basic capability, and how, where, and when this capability will be applied to the overall NASA program to insure optimum management control. Among the numerous parameters which affect the capacity index, probably the most important are:

Data Volume
Processing Times
Frequency of Reports
Anticipated Organizational and Program Growth

It is, therefore, to this end that further intensive and exhaustive studies should be made to firmly evaluate and predict the capacity index. To accomplish this purpose, the following appraisal and analysis procedure is proposed for each of the four major parameters listed above.

4B. 1b. 1 Data Volume

Probably the most critical of all the four parameters is the first, because it is linked in almost direct proportion to the capacity index valuation. That is to say, a doubling or trebling in the NASA data volume will immediately be reflected in a corresponding doubling or trebling of the capacity index. It is because of this critical direct ratio relationship, that perhaps the greatest attention must be focused on this particular parameter.

The basic approach to the data volume problem should consist of two major considerations; 1) a complete analysis, projection, and synthesis of all the existing and planned PMP's and milestones currently in use or under consideration for the Program Management Plan being utilized at present by NASA, and 2) having established a firm base on which to work, to then analyze each PMP and milestone very carefully and in minute detail to establish the equivalent network pattern of stages, steps, links and goals for each milestone or unique grouping of milestones.

Once an accurate count of all existing and projected programs, PMP's and milestones has been established, the second step of translating this into a meaningful network system of tasks, paths, stages, steps, and goals will be necessary. In the preliminary study, we have analyzed the types of milestones shown on the present PMP's and have also analyzed the types of tasks, stages, and steps which we would include in our network system and have applied various factors to arrive at numbers of projected stages, projected steps and projected goals. The over-all effect of this type of application resulted in a ratio of from three or four to one, up to as high as eight or nine to one, between current milestones and these projected stages and steps, while the overall average appears to be approximately four or five to one. While we feel that this ratio is basically a very sound one, the actual network system may result in a much higher relationship. It is for this reason that in the final study sample test conversions must be attempted on some of the projects already in existence to get a possibly better approximation of the numbers involved. These sample conversions will also yield an approximation of record size, by showing the average length of variable fields.

4B. 1b. 2 Processing Times

Once the data volumes have been established, our next task is to analyze the second parameter, processing times. However, if we first look at the list of four parameters shown we see that actually processing time is a dependent parameter, being a function of all three other parameters which are independent. In other words, the amount of processing time depends on the data volumes, it depends on the frequency of the reports, and lastly it depends on the anticipated organizational and program growth at NASA.

Because of the multiple dependency of this parameter upon these other three parameters (and possibly many others), as well as the rated speed and capacity of the respective available computers in the NASA inventory, it is extremely difficult to express processing time as an absolute number of minutes and hours.

The best approach to solving the estimate of processing times will be to program small sample portions of the over-all program and then to run them on the computer. Once the processing time from this small sample is determined, it will be a relatively simple matter to project this into a total for the entire program. However, our investigation, to date, of the types and varieties of logic involved in maintaining the network system of control, together with the detail required at the various levels, has led us to conjecture that the total processing time at each specific field center should not exceed three to four hours per week, and that the most probable time will be expected to run in the neighborhood of two to two and one-half hours per week.

4B. 1b. 3 Frequency of Reports

The third of our four parameters to determine the capacity index does not have a direct relationship on the amount of time required or the capacity needed, within a given reporting period, but rather relates directly to the total over-all cumulative time. In other words, a report cycle of two weeks as opposed to four weeks or a month does not appreciably reduce the amount of computer time required for one computer updating. However, since there would be twice as many two-week reporting periods as four-week reporting periods, the total required computer time for a given time interval would actually result in requirement of a double amount of computer time.

For this reason, we would strongly recommend a plan to investigate completely the possibility of a variable length reporting period, from program to program, and project to project. Since it is normal at the beginning of most projects and programs for technical and financial progress to be relatively slow, we feel that a bi-weekly or monthly reporting is unnecessary and that a reporting cycle of two to four months in length would be sufficient during the initial reporting periods. Therefore, to investigate the possibility of a variable length reporting cycle, a study will be initiated which will include the following considerations:

> Rate of data flow, from the contractor to the field center, within the field center, from the field center to headquarters, and within headquarters.
>
> Response requirements of the various levels of NASA management in all three directions, upward, downward and laterally between same levels of management.
>
> Types of programs and projects which could be included under a variable reporting cycle, since some will probably be fixed length reporting periods.

Rate of growth of the NASA programs and projects, which would affect the capacity of any variable length reporting cycle.

Cost of variable length vs. fixed length reporting cycles.

4B. 1b. 4 Anticipated Organizational and Program Growth

The last of our four parameters is probably the one which will be subject to the largest degree of error, since it depends on so many factors, namely; 1. success or failure of current programs or projects, 2. budget allocation and fiscal policy of the government, 3. expansion or contraction of the scope of various projects. 4. status of the international situation at any time, with a reduction of effort toward defense. 5. reprogramming of effort, due to achievements by foreign power. These are but a few of the types of factors for which little or no estimates can be made. Therefore this parameter will require extensive study in each of the areas listed above to enable a proper development and evaluation for the IOC-MAPCS capacity index. To a degree, also, the determination of this parameter is a policy decision to be made at the highest NASA and governmental levels.

4B. 1c ESTABLISH ALL NECESSARY FILE CATEGORIES

The basic files recommended in this report are (1) the project file and (2) the facilities network file. Certain recommendations have also been made with respect to file formats, level of detail to be carried in field center and headquarters files, and the physical characteristics of these files. The implementation phase requires careful study of these recommendations and the development of firm policies and procedures relating to the establishment and maintenance of files.

The policy for establishing raw data files must answer these questions:

Under what circumstances should a separate project file be established? It is the recommendation of this study that a project file should be established upon approval of a development plan.

What level of detail should be carried in field center and headquarters project files?

Who shall be responsible for setting down and enforcing procedures to insure the completeness and accuracy of original file information?

What restrictions shall apply to the format and content of project files?

Under what conditions shall facilities inventory files be established?

What shall be the policy with respect to format and content of facilities inventory files at field centers and headquarters?

What hard copy backup shall be required for project and facilities inventory files (punched card or printed matter)?

What are the organizational responsibilities relating to file establishment?

Policies for maintaining and updating files must follow a similar pattern, and in addition must specify:

Need for verification procedures to insure the legitimacy and accuracy of file change data.

Limits on periodicity of file maintenance operations.

Means by which file changes are communicated to appropriate parts of the system.

Means by which authority to initiate file changes is established.

Organizational responsibilities for file maintenance operations.

The over-all policies regarding files must also be extended to cover the question of "authority to look"; that is, the priorities and authority for retrieval of data from established files. In most circumstances the "authority to look" will reside with the project manager and higher levels of management, and in any event the project manager should be held responsible for all reports requested by his project organization. The purpose of this recommendation is two-fold: (1) to maintain a reasonable degree of control over use of information contained in the file, and (2) to guard against a potential danger of lower levels of management proliferating unnecessary special reports from file data. The policy must also cover the establishment of procedures for handling and maintaining classified information in the project files, and for handling and distribution of system reports containing classified information.

Early in the implementation, as suggested previously, the data processing equipments and communications links required for the reservoir concept must be determined. As soon as this has been done, the physical requirements should be carefully restudied to provide firm estimates of needs for manpower, equipment, and supplies, for each reservoir location. The organizational pattern for the reservoirs should also be determined at this time, with responsibilities for reservoir establishment and management being assigned at as early a date as possible.

4B.1d DESIGN OVER-ALL SYSTEM FORMATS

One of the first and most important objectives necessary to implement the system will be the study and design of necessary formats to make the system operable. The first requirement will be to establish the types of input necessary to achieve the desired results. Since approximately 80 percent of the annual NASA budget is expended with outside contractors, the first determination must be made as to whether NASA management desires the system to control all the activities of the in-house effort expended on projects. The assumption in this discussion is that control will be established on all phases of the project including both in-house effort and out-of-house activity. Two basic types of input will be necessary in the proposed system: information regarding technical progress or scheduling, and information regarding financial status of the contract. An investigationmust be made to determine the feasibility of using IBM cards to introduce input data into the system. When a format is decided upon it will become necessary to obtain Bureau of the Budget approval in order to require contractors to submit such reports. A decision will also be required to determine the method of making the submission of these forms a contractual requirement. Simplicity should be stressed in designing input formats, assuming that information coming from a contractor should be more valid if it is kept at a minimum. Discussions should be held with project managers and people in financial management to determine the possibility of gathering input data in addition to the basic requirements, such as knowledge of second or third tier sub-contractors activities, or possibly additional cost information.

In addition to contractor reporting requirements, it will be necessary to establish reporting criteria for field centers working directly on projects. This will mean the initiation of certain changes in systems and procedures at the field center level, particularly in the area of accounting for project costs. Presumably this will be accomplished by coordination with the systems and procedures group working in the Financial Management offices at Headquarters and the field centers affected.

Once the decision has been made regarding types of input made to the system, it will be necessary to determine the kind of reporting outputs necessary for immediate control purposes and for historical documentation for future use. A study will be made at various levels of management to determine their needs in order for them to exercise adequate control over their projects. Assuming that management at lower levels will desire more detailed reports than at higher levels, an investigation will be made to ascertain exact requirements in order to fit output reports to the demand.

Reasonable boundaries of tolerances must be established in terms of schedules and expenditures which, if exceeded, will result in an early warning "flag" to managment that a project is in trouble. Through discussions with various levels of management, it can also be determined what types of special reports will be needed to help them fulfill their responsibilities.

4B.1e SPECIFICATION OF ALL SYSTEM EQUIPMENTS

Once the entire concept of the IOC-MAPCS is fully understood and accepted, the next problem comes in the specification of just which types of equipments are to be utilized. Since so much excellent equipment and hardware exists for performing the job, rather than specify any particular set, we feel it is far superior to keep the exact specifications entirely flexible so that the over-all final equipment inventory will represent a composite of the best features from many excellent computers and pieces of auxiliary equipment. The best method of selection will be to investigate some of the most widely known in each of the several equipment areas under consideration and then to select the one which is best suited for the particular job it is intended to perform in the NASA system. Some of the major areas under consideration for study are:

The data processing and computer elements.
The data storage elements.
The communications links, and input/output devices.
The display generators.
The hard copy output devices.

4B.13.1 Data Processing and Computer Elements

The first of the categories shown above is, of course, the largest and by far the most important since it is the nucleus of the entire system. In this category would be included the whole line of standard auxiliary data processing equipment (such as keypunch and key-verifying machines, card sorters, collators, interpreters, reproducers, printers, etc.), which goes to make up the normal electronic accounting machine system. This equipment would normally be required whether a fully automatic or only a semi-automatic system were to be installed, since even under a semi-automatic non-computer system punched cards would be the media for carrying data.

As for the other half of the first category, the computer elements, it is only necessary to say that the current complement of large scale computers contained in the NASA inventory is far more than adequate in capability to handle the NASA management and control problems.

The problem, if any arises, will not be one of capabilities, but rather of capacities. In order to see if capacity is a problem, we propose to investigate the machine schedules to determine:

which computer shifts (if any) have available computer time.

if rescheduling or combining of certain programs, now operating, is feasible.

how critical are management's requirements concerning date and time of report receipt.

if time is not available on existing equipment, to investigate the possibility of leasing equipment, either from other governmental installations, from private industry, or from a service bureau.

if NASA program management programs can be phased into the operation of the computers as other scientific programs may be phasing out.

if varying amounts of technical and financial reports with their peaks and valleys of workloads will cause undue hardship on current computer operations.

Once these points have been thoroughly investigated it will then be necessary to fit all the pieces into one homogenous pattern of computer operation and to coordinate this function between the three sub-reservoirs, the central reservoir, and NASA headquarters.

4B.13.2 Data Storage Elements

Since a tremendous amount of historical data as well as current and future data will be required for the NASA Initial Operational Capability—Management and Program Control System, important consideration must be given to just which types and numbers of data storage elements will be used.

In general, data storage components for automated systems usually fall into five classifications:

Punched Cards
Magnetic Tapes
Magnetic Disc Files
Magnetic Drums
Electromagnetic Core Storage

Of these five, punch cards are universally known and therefore will be bypassed in our discussion, other than to say that whatever system is developed, the punched cards utilized should be IBM compatible to fit all of the data processing equipments already existing in the NASA inventory. Also, punched cards give unlimited amount of data storage, but have the slowest access time of any of the five groups listed.

Magnetic tapes constitute the next level of data storage. As for capacity, tapes are unlimited in the sense that one can put as many consecutive tapes into a system as he desires. However, where one standard IBM 2400-foot tape must remain in the system at all times, it has a capacity of about six million characters per reel and an average access time of two hundred seconds per record sought. Both tape capacity and access time can be greatly improved by using the Burroughs Tape File System consisting of a series of shorter tapes. Here the total capacity is approximately fifty million characters with an average access time of fifteen seconds.

Magnetic Disc Files represent the middle range both from a speed and a capacity standpoint. They are usually referred to as "random access storage", thus the name RAMAC given them by IBM. The IBM RAMAC has a capacity of ten million characters per unit and an average access of one half second per record. Other disc file systems are the RCA disc file with a capacity of two and one half million characters and an average access time of 2.2 seconds, the Bryant disc file with a capacity of twenty-five million characters and an access time of only 0.07 second per record, and the LFE single disc file with a small capacity of only 150 thousand characters, but an extremely fast access of only 0.007 second per record. Thus, it can be seen that disc files offer a wide range of capacities,. all with relatively-fast-to-extremely-fast average access times.

The fourth classification, magnetic drums, offers low character capacity at a relatively low cost and a most favorable speed factor. Two of this type of data storage devices are the Bryant drum having a capacity of only ten thousand characters but a highly favorable access time of only 0.017 second per record, and the LFE drum file system with a much larger capacity of two and one-half million characters and a reasonable average access time of 0.15 second per record.

The last classification, electromagnetic core storage, gives by far the greatest amount of character storage at intermediate speeds, but it is also the most expensive. Looking at just two companies dealing in this product, we find Aeronutronics, with a storage system capacity of ninety million characters at an average access speed of one-half second per record sought, and Telex, with two slightly different systems: the lower-cost system has a capacity of twenty-five million characters with an average access time of 0.15 second and the higher-cost system has a capacity of eighty-five million characters with an average access time of 0.12 second.

From the discussion above we see that data storage capacity (excepting punch cards and multi-reel magnetic tape) ranges all the way from 150 thousand characters up to ninety million characters, and average access times range from 0.007 second to 200 seconds per record sought. On this basis, it appears that practically any capacity and speed desired can be obtained from the data storage units.

In order to best evaluate which type of data storage units would be best suited to the NASA management system, it will be necessary to investigate these factors:

data volumes, both from a total over-all volume standpoint and by rate of data flow.

frequency of the reporting cycle and possibilities of dual requirements.

accesibility of the data in the data storage units, both from a pure availability viewpoint and by time required to extract a specified record.

capacity of each data storage unit, either singly or if possible in parallel with multiple units.

costs, both in total and on a per-record basis.

4B. 1e. 3 Communication Links and Inputs/Output Devices

We have already enumerated an extensive listing of the various types of communication links and input/output devices available on the market today, together with a brief explanation of the capabilities of each. The only problem which remains is to select the proper set or sets of equipment suitable to handle the NASA management control system. However, before any selection can be determined, the following elements (and possibly more) must be given due consideration:

The types and volumes of inputs and outputs required for the NASA management system, especially the outputs which may take any of several forms — tabulated listings, magnetic tapes to be converted to punched cards or to report forms, film slides or other hard copy, TV pictures, etc.

The compatibility of any proposed input/output device with existing equipments already in the NASA inventory, or if incompatible the cost and time involved in modification to effect compatibility.

Capacities of the selected devices to handle the workload both in total and in the kind required for NASA, and at such a rate as not to impede the system capabilities of the other equipment.

Ability to expand or contract in a modular fashion consistent with increases or decreases in the over-all NASA problem.

Reliability of this equipment to function properly, and availability of immediate servicing.

The equipment must be of sufficient flexibility to handle not only current NASA requirements, but also must have the capability of adapting to new situations as the definition of scope within the problem changes.

The cost of this equipment, whether purchased outright or leased, both for the total application on which used and on a per-record basis.

4B. 1e. 4 Display Generators

A complete and detailed explanation of the display generation equipment, whether semi-automated or fully automatic, and all the related steps involved in the complete cycle (input development, photographic processing, etc.), has already been outlined in Section III of this report. However, before deciding just which equipments will be finally selected, it will be necessary to investigate the various types of display generator equipment and to evaluate them in the light of these considerations:

Which types of displays will be required (i. e., straight large-screen projection, closed-circuit TV pictures, displays before large groups in auditoriums, before small groups in conference rooms, etc.)?

Will direct communication with the computers by NASA management be required? Will it be necessary that a corresponding display be flashed on a screen, cathode ray tube, or some other display device?

If immediate display is desired, must the requestor be present at the computer site, or may he initiate the request from some remote location? If so, just how remote, and how fast a response is required?

Which physical characteristics must the display have (i. e., what are the maximum dimensions required; how large must the character representation be; will color be necessary, and if so, how many and which colors must they be; to what distances must the display be visible; to which private offices must the image be projected, etc.)?

What speed of transmission will be required, between computer and display, between the requestor and display, between the central reservoir and subreservoirs, or will direct display capabilities between reservoirs be a requirement?

What obsolescence, if any, must be considered in selecting the specific types of display generation equipment required by NASA?

What special structural, electrical and location restraints are already in effect or will later affect specific equipments?

Can inputs from external sources be introduced directly into the computer system to give rise to some type of display, or if not, what type of conversion routine will be required to change it into an acceptable form, cards, paper tape, magnetic tape, etc.?

How permanent must the display image be? Will hard copies of it be required?

How rapidly must the display be capable of changing or altering its configuration? How many unique and distinct displays can be processed within a given unit of time?

Will the computer have the capability to give answers, based on information shown on the displays, and if so, how extensive will this information be?

4B.13.5 Hard Copy Output Devices

Details of the various types of hard copy devices are also contained in Section 3B, dealing with Control Center facilities. However, the types of considerations necessary in investigating hard copy output devices differ from those needed in evaluating display generators, since a somewhat different output product is obtained. Some of the main items which must be studied for these devices are:

> Exactly which types of hard copy outputs are required (cards, tabulated listings, special forms, full page size photographs, etc.)?
>
> Having determined which type is needed, how many copies will be required? If only a small number, will carbon copies be adequate or must multilith or ditto masters be created?
>
> If output is taken from a printer, will straight tab paper suffice or will special preprinted continuous forms be required?
>
> Must the printer be connected directly to the computer on an on-line basis, or can a tape-to-printer off-line operation be used?
>
> How many different hard copy devices will be connected to one system at one reservoir? Must a remote reservoir have the capability of sending commands to other reservoirs and then receiving the results on its own hard copy devices?
>
> How fast must the printers or typewriter be able to print? What are the maximum and minimum size requirements of the hard copy used on each?
>
> If a printer or typewriter is used on-line, must it be used for all normal outputs or may it be reserved to accept only danger flags or exception reports?

4B.1f PROGRAMMING

If the NASA Management and Program Control System is to be fully automated, the computer programming and analysis will be one of the most vital links in the entire system chain, since computer time is closely proportional to the proficiency utilized in writing the programs. Whatever system and standard of programming is developed, it must be built on a sound base representing the combined efforts of all NASA field centers coordinated with direction from headquarters. The over-all effort should consist of two main functions:

> Generation of appropriate programs covering all of the information processing requirements of the IOC-MAPCS.
>
> Generation of standardized specifications for all programs.

4B.1f.1 Generation of Appropriate Programs for the IOC-MAPCS

The first function will consist of all the coordination, problem definition, charting, coding, systems analysis, etc., which go into the makeup of the programming package.

One of the most important steps will be the selection of a coordinated programming group, representing the best programming personnel from the various 7090 installations at each of the field centers. One among these should be chosen to represent NASA Headquarters. He should be actually transferred to NASAHeadquarters, to have direct and close contact with top management desires and requirements. He would also head this programming group and coordinate all systems study and programming effort, and would act as a focal point for the interchange of ideas between various members.

Working together, the group should then define the over-all scope of the programming effort, and should give specific systems study and analysis assignments to each member.

Each member should then obtain problem definition, including input availability, output requirements, schedules, etc., for his specific problem or problems.

The group then should reconvene and, based upon the findings of each member, outline the entire programming effort, which should include:

- Enumeration of all programs.
- Selection of a common programming language to be used for all programs, such as COBOL, SURGE, 9PAC, etc.
- Selection of initial sample programs to be used in determining over-all programming effort and computer running time.
- Development of an order of precedence of programs, placing the most critical ones first and so on down to the least important.
- Development of a Programming Schedule, for block diagramming, coding, checkout, parallel running, and final installation for each program.

All system study and programming efforts by the programming group should be coordinated with the findings of the final design group so that the programs derived represented solutions to requirements of NASA. To assist in this coordination effort, Ramo-Wooldridge would act as program consultants, assisting in problem definition, flow charting, block diagramming, etc., working together with the design group and programming group.

4B.1f.2 Generation of Standardized Specifications for all Programs

The second function is closely akin to the first, and will actually be performed at the same time. However, here we refer more to the discipline of standardization of all NASA management and control systems.

The method employed in carrying out this discipline will be similar to that defined under the previous section, with the programming and design groups being held responsible for its execution, augmented by assistance from the various NASA project and program groups requesting programming service. Actual delineation of the standardized specifications, systems, and procedures will probably be executed by other than the programming group.

Listed below are the various elements which must be given consideration for this particular area:

> Standardization of Report, so that the same formats are being used at all field centers and at headquarters.
>
> Standardization of Terminology, so that elements defined in a program written at one field center have the identical meaning if used in a program from another field center. Development of a library of frequently used subroutines, for logical processes occurring over and over in several programs.
>
> Institution of a programming bulletin system, so that special techniques developed by one programmer or programming group may rapidly become common knowledge to all groups.
>
> Standardization of request formats, so that all prospective customers for programming may more clearly define their problems in computer-oriented expressions. This includes writing of a standard procedure manual which will define all methods, systems, and procedures to be followed in making a request for computer service.

Once these various standards have been set up and a strong programming team has been selected, NASA can then have full confidence in the completion of a strong Management and Program Control System.

4B. 2 Installation and Checkout

Broadly speaking, implementation of the IOC-MAPCS may be considered as analogous to development and production of a piece of hardware. That is, the same series of phases must be followed: design (preliminary and final), fabrication, test, final adjustment, and delivery. The equivalent steps in implementing the IOC-MAPCS are:

> Preliminary design (represented by preceding sections of this report.)
>
> Final design (the procedures recommended in this section).
>
> Initial installation.
>
> Checkout.
>
> Revisions and full scale operation.

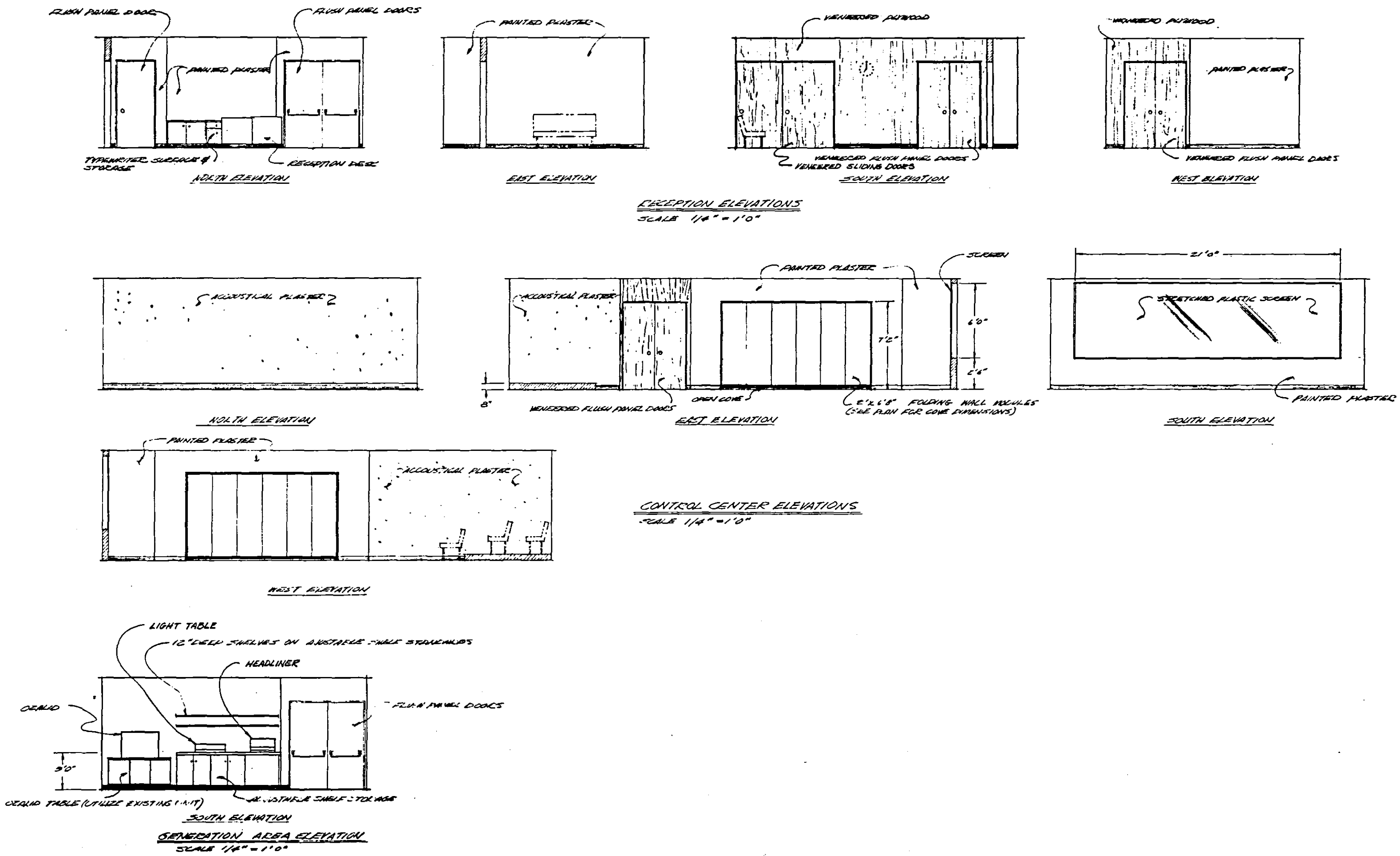


Figure 36. Architectural Elevations

all necessary procedures will almost certainly doom the system to failure. The instructions should include:

An explanation and justification of the use of the system.
An operational description of the coding structure and reporting system.
An explanation of the network chart structure.
Detailed reporting procedures, with sample forms.
An explanation of the reporting discipline.

In addition to this basic document, provision should also be made in the detailed instructions for transmittal of particularized information to each contractor. This information should include the set of reporting forms, the network chart for the particular task, the particular reporting cycle established for the task, and the organizational responsibilities associated with the task.

The initial version of the contractor information package, together with complete specifications for use, should come from the installation team. The team, and later the responsible Headquarters operational directors of the system, must also take steps to insure that the package is properly used, and should control all revisions.

4B. 2c ESTABLISH THE TYPES AND NUMBERS OF MANPOWER REQUIRED THROUGHOUT THE ORGANIZATION FOR INITIAL IMPLEMENTATION

A firm estimate of the types and numbers of manpower required to make the IOC-MAPCS function throughout the organization should be developed at the earliest possible date in order to accomplish necessary adjustments to budgets and manpower allocations. Estimates will be derived during the final design phase, but it then will become the responsibility of the installation team, the Advisory Committee, and NASA top management to finalize these estimates and initiate action toward acquiring the necessary manpower.

4B. 2d PROVIDE FOR INITIAL TRAINING OF PROGRAMMERS FOR ALL INSTALLATIONS

If the same data processing equipment is used for all data reservoirs in the IOC-MAPCS, programming can be done centrally by the IOC-MAPCS installation team. Even if this is done, however, it will be essential to have at each data reservoir programmers who are familiar with the system and with the programs written for it who will be able to:

Supervise file construction and data preparation.
Troubleshoot program bugs.
Perform any necessary program maintenance operations.
Assist in program improvement and development.
Maintain communications with installation team programmers.

The number of such programmers at each installation may not be stated at this time. The preliminary study indicates that at least two and probably three or four programmers from each installation should be trained in using and maintaining the system, but in all likelihood the actual work required will consume less than full time for one person after the system is installed and checked out. The purpose of training more than one person is to provide backup in case of termination, transfer, or unavailability.

4B. 2e PROVIDE DIRECTION AND ASSISTANCE IN ESTABLISHING ALL MACHINE FILES AND PROGRAMS

In addition to training programmers for each installation the IOC-MAPCS installation team should take a direct hand in the establishment of machine files and programs at each reservoir location, both as a training device and to help insure satisfactory installation. Detailed procedures covering these activities should be written and then tested by the installation team during actual operations to insure completeness and clarity. Detailed documentation of all computer programs should also be prepared by the installation team and reviewed with programmers who will be involved in system maintenance.

The importance of adequate system and program documentation cannot be overstressed. Too frequently in the history of computing and data processing have brilliant programs proved useless in the long run because the documentation of their construction and use failed to cover essential points. This is particularly true in cases where, as with the IOC-MAPCS, several installations will be using the same set of computer programs over a long period of time.

4B. 2f PROVIDE DIRECTION FOR ESTABLISHING AND CHECKING OUT ALL COMMUNICATION LINKS

All forms of communications employed by the IOC-MAPCS information system should be pre-tested by the installation team. This statement applies not only to electrical and electronic devices employed, but to mail communications as well. The installation team should sample mail transmittal times from various parts of the country to the field centers at which reservoirs will be established, and should also sample the condition in which pre-punched cards (if these are used in the system) are received. Internal mail systems should be similarly sampled, if data on their operation is not available.

The installation team will also be responsible for preparation of detailed procedures covering use of other forms of communications (e.g., TWX, data links, etc) and for training or indoctrination of communications personnel.

4B. 2g EMPLOY COMPUTER SIMULATION TECHNIQUES TO PROVE OUT DESIGN FEATURES PRIOR TO MAKING MAJOR EXPENDITURE COMMITMENTS

The installation team shares with the design team the responsibility for proving the operational feasibility of all system design features. In those cases where the design team has undertaken studies to provide this proof, the installation team retains the option of accepting the study results or devising and conducting its own testing procedures. The final responsibility for any procedure rests with the installation team. It is strongly suggested that where necessary and feasible the installation team employ computer simulation techniques to prove out design features. Such techniques have been demonstrated, in missile and rocket work in particular, to be both accurate and economical.

4B. 3 Specify and Provide for System Audit and Review

It will be a function of the systems group, or whoever is chosen to implement and monitor the control system, to continually evaluate the system for at least the first year to insure its reliability. Since this system incorporates a new concept from the existing PMP system in effect at NASA it will take considerable time to re-educate the users and to establish complete acceptance by all levels of management. A team should be created whose job it would be to de-bug the system as problems arise and to make corrections and improvements on a continuing basis.

After the system has been installed for one year, and again after the second year, NASA should closely examine the possibility of making advanced modifications to take advantage of state-of-the-art techniques which will have been developed during this time.

4B. 4 Develop a Management Training Course

In order to provide for full understanding and exploitation of the NASA Management and Program Control System, the installation team should undertake to develop and organize a management training course for both in-house and contractor personnel. Development of this program will involve the creation of appropriate literature, organization of a curriculum, instructor training, and establishment of realistic schedules. The course need not be long in duration; probably one or two full days and certainly less than a week should be adequate. If organized on this basis, it may well be that the "course" could be a traveling school, bringing the instructors to the "students" at the various field centers and at important contractor installations. This approach could represent significant savings in cost and time.

This training course should be repeated periodically at each installation, and the materials and presentation techniques employed should be subjected to continuous review. Properly exploited, the training course based on the IOC-MAPCS could develop into a vigorous and profitable broad management training program for the entire NASA organization.

4C. PLAN FOR DEVELOPMENT AND INSTALLATION OF NASA DECISION GAMING SYSTEM

4C. 1 Time-Phased Approach

One way to develop and implement the Decision Gaming System would be to prepare a detailed comprehensive plan and then to proceed implementing this plan. If the NASA program were not dynamic and rapidly changing, and if time and money were not a primary consideration, such an approach might be best. However, considering limitations on funds and manpower and the rapidly changing character and magnitude of the NASA programs, the time-phased approach is believed to be more suitable and more economical.

The proposed plan consists of three different phases. Here we will develop in detail only the first phase, since the program is so phased that each phase of the program generates detailed planning for the next.

4C. 1a PHASE 1 - DEMONSTRATION GAME

The most important and urgent task to be accomplished is to clarify the gaming concept, to spell out in more detail how the gaming is to be performed, and to reach agreement by the people who will play the game, to assure that this Game will indeed satisfy their needs. For this reason, the first objective is the design and testing of a preliminary Demonstration Game which will include (from the point of view of concepts) all the important aspects of the NASA Decision Game, but will be simplified to the point that it can be played at NASA headquarters within a time period of six months.

4C. 1b PHASE 2 - OPERATIONAL DECISION GAMING SYSTEM FOR A MAJOR NASA PROGRAM

The Demonstration Game will give adequate information, both from the conceptual and the practical point of view, so that it will be possible to design and implement an operational gaming system. However, again in order to be more efficient, we propose to develop the Decision Gaming System for a Major NASA program such as the Saturn program, before designing the comprehensive gaming technique for all of NASA. This phasing of the program will allow the gaming system to be developed to a completely practical and operational level, but still will avoid the risks of trying to design a comprehensive Game for all of NASA with data insufficient to cover all eventualities. This second phase of the program will be started prior to the completion of the first phase, since during the course of the first phase some aspects of the second phase will become apparent. By telescoping the various phases of the program, it will be possible to save both time and money. Depending on the effort expended, the second phase of the program should be completed not later than one year after the completion of the first phase.

4C. 1c PHASE 3 - DEVELOPMENT AND INSTALLATION OF THE NASA DECISION GAME

The first two phases of the program will give adequate information for the third phase of the program, the development of the comprehensive gaming system for NASA. Phase 3 of the program will be carried out primarily by NASA personnel. We visualize that the Decision Gaming technique described in this report will become an integral part of NASA operation and consequently the system will never stay static but will be adapted to the changing needs of NASA. This requirement makes it mandatory that NASA personnel should be able to modify, up-date, and improve the Decision Gaming System without using outside assistance. A detailed program to assure NASA of this In-house capability will have to be prepared and carried out during the second phase of the program so that NASA personnel will be prepared to carry out this third phase of the program.

4C. 2 Steps in Developing and Installing the Decision Gaming System

We can visualize at least twelve steps in carrying out the development and installation of a Decision Gaming System. Each of the three phases of our program will include these twelve steps though the effort expended and the requirements in each of these steps will be different depending on whether we are developing the Demonstration Game, the Major NASA Program Game, or the NASA Game.

4C. 2a. STEP 1 - CONCEPTUAL FRAMEWORK OF THE GAMING SYSTEM

During the first phase, development of the Demonstration Game, emphasis will be on simplicity and on the requirement of meeting the short time scale of Phase 1. Details that might be of great importance from the practical point of view will be omitted for the Demonstration Game. In fact, the primary objective here will be to have a Game that has some bearing on reality and which does not lead to obviously erroneously answers. However, no emphasis will be put on accuracy or realism.

In the case of the second and third phase, it will be of the greatest importance that the preliminary formulation of the problem includes all necessary facets of the problem, in a realistic fashion.

4C. 2b STEP 2 - CHECKING OUT CONCEPTS

In the case of the Demonstation Game, it will be necessary to check the concepts with headquarters personnel. As the Demonstration Game will be primarily from the point of view of headquarters it will not be necessary to get agreement on all levels of management. However, even in the case of the Demonstration Game it will be necessary to have some discussions, at least with representatives of the field laboratories.

In the case of the operational Games of the second and third phase, it will be necessary to check out the concepts with various levels of management and to assure that all concepts developed are correct and acceptable to NASA management.

4C. 2c STEP 3 - DEVELOPMENT OF MATHEMATICAL MODELS

In the case of the Demonstration Game the mathematical models will be simple, so that computations can be carried out rapidly and with a minimum of programming.

On the other hand, for Phase 2 and 3 we expect a certain level of sophistication in the mathematical models. Whereas in the Demonstration Game we will ignore confidence limits and probabilities, in the final Game we will have to consider these more complex aspects of the problem. In fact, one would hope that as years go by NASA will develop a mathematical theory of how to operate a large Federal program of the NASA type.

4C. 2d STEP 4 - FLOW CHART

After the mathematical model is completed, it will be necessary to develop a complete information flow chart for the Decision Gaming System. This will not be much of a job for the Demonstration Game, but for the second and third phase will involve a considerable level of effort. It is to be recognized that there will be a great deal of manual input to the system, and also much manual data processing. For this reason, the flow charting of realistic Games will necessitate a detailed study of the manual information system involved and the flow charting of the complete system.

4C. 2e STEP 5- SELECTION OF EQUIPMENT

For the Demonstration Game, this will not be much of a problem. Equipment available at NASA will be used, as will manual input and output systems. Displays will be prepared manually as there will not be time to wait for special equipment.

For the operational Games of Phase 2 and 3, the proper selection of equipment will be of great importance. If the equipment is not properly matched with the needs of the executives playing the Gaming System, the whole program may become ineffectual. In this stage of the program it might become apparent that certain new types of equipment are required for the NASA Game, or more likely that some existing equipment is to be modified.

4C. 2f STEP 6 - COMPUTER PROGRAMMING

The Demonstration Game will be simple and the programming effort will be relatively small. Even for Phase 2 and 3 we do not visualize any particular difficulty. However, an important aspect of the programming effort will be inclusion of the realization that as time goes on the Gaming System will have to be up-dated and modified. For this reason, the programming system must be such that updating and modification can be carried out at the lowest possible cost. As we have already said, we do not visualize any of these Gaming Systems as static, therefore the computer program must be such that it will not be necessary to reprogram the whole system each time an up-dating occurs.

4C. 2g STEP 7 - SHAKEDOWN OF PROGRAMMING AND FLOW CHARTING

Before we present the Game for actual play by executives, it must be verified to ensure that everything is in order. This means that some preliminary gaming will have to be done by the designers of the Game. It is of great importance that a Game is not presented to executives in such a form that technical difficulties arise. Such a situation may lead to a general lack of confidence in the whole concept, without the realization that only minor matters have to be straightened out.

4C. 2h STEP 8 - PLAYING THE GAME

In the case of the Demonstration Model, this should be primarily done to determine the requirements of executives. For Phase 2 and 3 the playing will furnish the final test to determine that everything is in order and meets requirements.

4C. 2i STEP 9 - EVALUATION OF GAMING TECHNIQUE

As playing of the Game proceeds, an evaluation function must be carried out so that necessary changes in the Gaming technique can be made. Many unforeseen conditions always arise in the course of such Decision Games. These can be realized and analyzed during the playing of the Game.

4C. 2j STEP 10 - ESTABLISHMENT OF FINAL GAME

After playing each of the Games, by evaluating the system, it will be possible to specify the desired modifications and proceed to the design of the final Decision Game. During this step the Gaming System will be developed in all its details and will be documented so that it can become a part of NASA operations.

4C. 2k STEP 11 - MANUAL INFORMATION PROCESSING SYSTEM

As we have said before, not all aspects of the Gaming technique can be mechanized. The primary consideration here is cost and time. Only those phases of the Gaming System which can be performed better by computers and displays are to be assigned to equipment.

4C. 21 STEP 12 - IMPLEMENTATION

In the case of the Demonstration Game this step will of course be omitted. In the case of Phase 2 and 3, this step will involve a great deal of practical and competent systems and procedures work.

An important aspect of the implementation phase of the program will be the elimination of difficult mathematical and computational concepts so that the system can become an integral part of the daily operations of NASA.

We believe that the operational concepts of the Decision Gaming System, after they are completely developed, will be sufficiently simple to be described by conventional types of manuals. We expect that it will take much patience to translate the more complex aspects of the Gaming technique into simple terms, but we believe that this can be done, and must be done, in order to make the Decision Gaming System an everyday tool of NASA management.

4C. 3 Establishment of Inhouse Capability for NASA Management for Use in the Decision Gaming System

The Decision Gaming System described in this report represents a new management and planning control tool. It is well known that new management concepts—even if basically sound—can fail if there is a lack of appreciation on the part of the organization which is supposed to use the new tool. The assimilation of new management tools into large organizations presents a particularly difficult problem, and unless special measures are taken unnecessary delays may occur. It may even happen that the concept is refused.

One way to assure that appreciation and assimilation of the new management tool occurs is by careful education and training of personnel involved. It is possible to conduct courses, seminars, and workshops to aid in the transmission of new concepts. However, it has been common experience that reliance on such special educational tools often fails to bring about the desired results. We believe that the only way to prepare the NASA organization for the acceptance and operation of this new management tool is through active participation on the part of NASA personnel in the preparation, design and installation of the NASA Decision Gaming System.

For this reason the time-phased approach is designed in such a manner that there will be an increasing participation on the part of NASA, and in fact the third and final phase of the program should be carried out by NASA personnel.

Our proposed approach, then, to the development of inhouse capability is to begin with informal workshops to bring more and more people aboard on the work to be performed, to rely more and more on NASA personnel, and to phase outside assistance out of the program.

During the execution of such a complex program it might be necessary, as already mentioned, to have special educational and training courses. When a genuine need for such assistance arises, we believe that special educational and training methods should be made available to NASA personnel. For instance, in the case of mathematical model building and programming techniques, and also in the use of new and complex computing machines and equipment, more formal educational and training methods may be employed. We do not foresee any particular difficulty for NASA in obtaining this kind of assistance.

APPENDIX A
HISTORICAL REVIEW OF RAMO-WOOLDRIDGE STUDY PROGRAM

1. GENERAL

The Air Force Ballistic Missile Division attributes the rapid and efficient development of their Intercontinental Ballistic Missile capability to their use of a management control system employed as a dynamic decision making tool. Likewise, the Special Projects Office of the Navy Department attributes its accomplishment of producing the Polaris Weapon System with an approximately two-year saving of time from original plans to the use of a management control system which they refer to as the PERT (Program Evaluation Research Technique) system. Ramo-Wooldridge recognized that the National Aeronautics and Space Administration would be confronted with similar problems in carrying out their extensive space exploration program. It was reasonable to assume that this relatively new type of application should be of significant interest and value in the management and control of the numerous and extensive NASA programs and projects.

The need for this type of management tool for NASA was recognized by the Associate Administrator, Mr. Richard Horner, in an early discussion with Ramo-Wooldridge (July 8, 1959). This initial discussion was followed by a number of meetings with his designated assistant, Mr. Robert King, in which the general philosophy and concepts of management control systems were discussed with respect to the NASA operation. After a number of subsequent additional exchanges of information, during which time Ramo-Wooldridge submitted tentative program plans for the study and development of a management system tailored to NASA needs, a work statement was finally established, and a contract formalized in February 1960.

As a further step to employ new management techniques, NASA established an Office of Program Management under Mr. Robert King. In addition to administering the Ramo-Wooldridge contract, this office set about developing and implementing an interim management and program control system referred to as the Program Management Planning (PMP) System. It was intended to have this interim system operating during the Ramo-Wooldridge study program, and until an advanced or improved system could be developed and installed. The basic interim system design was a direct copy, even to the use of identical forms, from the Navy PERT System. However, the NASA application used only parts of the Navy PERT System, and did not attempt to apply in extent or in detail the full implication of the PERT System. NASA did not want to design a system but rather adopt parts of a working system which could be adapted to their individual needs. The original NACA organization, which formed the basic unit for NASA, did not have any project management system. Reporting at that time was on research projects and was largely in a documentary and historical form. The mission of the previous NACA organization did not require the extent of management control implied by the mission of the new NASA organization.

The initial contracted effort provided for funding coverage of approximately two men. This appeared to be a sufficient level of effort to study the general problem and to arrive at recommendations for a system concept and for an estimated level of effort necessary for design and implementation. Approximately three months after the start of this program, NASA was confronted with a decision concerning the establishment of a control center in their new quarters in the Federal Office Building No. 6 currently under construction. Occupation of these new quarters was planned for the middle of 1961. In order to provide proper space and facilities for a management system control center, certain decisions regarding the Management System design had to be determined within the following few months. Accordingly, it was necessary to expand the scope of the Ramo-Wooldridge contract to provide the additional study effort to support earlier development of a control center design. Since the control center is integrally related to the supporting management information system, it was also necessary to expand the system study so that the control center design recommendations would be compatible with the proposed advanced management system.

The expanded scope of effort provided for approximately a four man level of effort to develop a design concept for the control center, and a two man level of effort increase in the systems analysis. Approval was granted to Ramo-Wooldridge on or about the beginning of July 1960. The Ramo-Wooldridge program was increased in staff rapidly and effectively, as was evidenced by a rapid increase in program activity and progress.

During the whole span of the study program, the Ramo-Wooldridge project personnel received excellent cooperation and support from all NASA personnel involved in administering, guiding, advising, and otherwise contributing to the over-all effort. The general acceptance of the need and usefulness of an Advanced Management and Program Control System by all NASA personnel should be indicative that the future implementation of such a system will be both successful and rewarding.

2. INDOCTRINATION PERIOD TO STUDY NASA MANAGEMENT PROBLEM

Much information related to the mission and objectives of NASA was obtained during the early part of the study program through numerous discussions and exchanges with the NASA Office of Program Management. Further understanding was obtained from documents such as the NASA Ten-Year Plan and various Congressional Records. Congressional Records on the subjects "Review of Space Programs" and

"NASA Authorization" offered extensive testimony related to the over-all program and expenditures expected of the NASA operation. To summarize, numerous documents were reviewed and discussions carried out as a necessary first step in obtaining a comprehensive understanding of both the character and purpose of the NASA organization.

3. ANALYSIS OF NASA ORGANIZATIONAL STRUCTURE

A study of the NASA organizational structure was somewhat hampered by the fact that, during the early period of this study program, the organization was in a formative stage. However the major functions of the organization, having already been established, were sufficiently indicative and representative of the intended NASA operation.

The NASA organization was initially studied by analyzing the function of all management positions starting with the Administrator, the Associate Administrator, and the Directors, and then proceeding down through the organization. The various lines of authority and functional responsibility was traced into the field center organizations. As mentioned above, some of the organizational relationships were not yet clearly defined, and accordingly posed problems. Particular divisions of responsibility, as reflected in the organizational format, were considered unique and required a greater degree of careful analysis than might be otherwise sufficient. The initial analysis indicated a greater degree of urgency in the development and implementation of a management control system primarily based on the fact that the rapid growth of NASA had not permitted the institution of certain policies, reporting formats and requirements, and other control measures which would be normally expected.

At about the time the Ramo-Wooldridge study program was begun, the Marshall Space Flight Center was being annexed to the NASA organization. The regulations and policies governing its function as a NASA field center operation had not yet been clearly defined. Since the Marshall operation represents a major activity, it was necessary and important to properly evaluate the implication of its annexation in the over-all NASA management problem.

It is generally agreed that a management and program control system must be designed to be responsive to the particular needs of an organization. Accordingly, it was relevantly important that Ramo-Wooldridge prepare a detailed list of questions which would explore personal requirements and expressions of the various top managers of the NASA organization. Since the requirements expressed by the various personnel consulted proved to be non-uniform, it was necessary to establish "common denominators" with which an integrated system could be developed and still be responsive to the needs of the key management personnel. Interviews were arranged and carried out with the Office of the Administrator, the Office of the Associate Administrator, the Directors of the Office of Launch Vehicle Programs, Office of Space

Flight Programs, Office of Advanced Research Programs, Office of Business Administration, and the Office of Technical Information and Educational Programs. Discussions were also carried out with various Assistant Directors under each of the above offices. The prepared list of questions attempted to determine each individual method of operation, and what it required of or contributed to over-all management and program control. These questions were planned to determine how each individual evaluated his position with respect to other management personnel located both vertically and laterally in the organization. Among many other important details, these interviews also attempted to determine reporting requirements with respect to format, volume, timing, and frequency.

4. ANALYSIS OF THE NASA MISSIONS, PROGRAMS, AND PROJECTS WITH REFERENCE TO IMMEDIATE AND LONG RANGE OBJECTIVES

A detailed analysis was performed on most of the major NASA programs and projects to determine how responsibilities were being assigned and carried out within the organization. The interfaces of administrative and program assignment reporting were charted to create an over-all picture of the effective chain of command, and of the effective information flow lines. This analysis proved extremely beneficial in getting to the "heart" of the NASA operations. This analysis also served as one of the more important steps in our understanding of the type of machine-readable data code system which could be applied to facilitate comprehensive, rapid machine generation of reports to all pertinent parts of the organization for all projects. The difficulties which could arise through the use of different methods or modes of operation at the various field centers also became more apparent. These factors were naturally considered in the subsequent establishment of the design criteria for an advanced management system. The review of the long range objectives of these projects helped to determine the growth factors which any management control system would have to face before a final design were determined.

5. EVALUATION OF OTHER MANAGEMENT CONTROL SYSTEMS SUCH AS THE PERT AND BMD SYSTEMS FOR POSSIBLE APPLICATION TO NASA

Both the Air Force BMD and the Navy PERT management control systems were studied in detail to determine what concepts or techniques could be adopted and incorporated as part of the NASA Advanced Management and Program Control System. It was hoped that time and effort could be saved by taking parts of these management systems which were apparently or possibly applicable to the NASA organization. The Air Force BMD system primarily represented a formal discipline for collecting and reporting program status and progress information in a manual type of operation. The review of the BMD system served primarily to reveal certain philosophical attitudes and approaches to implementation of a management system.

A much greater contribution was made by our study of the Navy PERT system, since it incorporated a greater degree of automation or machine application. As was generally conceded, the PERT system presented a most complex and detailed approach to planning and reporting with sole emphasis on "technical progress versus time". Cost evaluation or cost collection information was not made part of the PERT reporting system and consequently represented a significant reason for its inapplicability. Various reporting formats and methods of manual display, although interesting and informative, did not prove to be desirable in or consistent with an advanced system concept. One of the basic assumptions established at the beginning of the Ramo-Wooldridge study was that displays employed in control centers for briefings of top management should be automated to whatever extent practical and feasible.

It should be emphasized that although the above two management control systems could offer little in direct application of specific system designs or equipments, the review of the considerations and problems which both the Navy and Air Force underwent in the development of these concepts were tremendously beneficial in formulation of our thinking and developments. This review offered us a quick means of running through numerous possible considerations which were previously weighed and evaluated.

The R-W review of the Navy PERT system offered another side benefit. Various personnel assigned to the NASA Office of Program Analysis and Control (changed from the earlier designation of Office of Program Management) under Mr. Robert King had been previously associated with the Navy Department Special Projects Office in the development and application of the PERT system. Consequently, our discussions with these personnel were greatly facilitated through mutual understanding of the fundamental considerations in the development and application of a management control system to a dynamic operation.

6. PROVIDE TECHNICAL ASSISTANCE TO NASA WITH REGARD TO THEIR CURRENT PROGRAM MANAGEMENT PLANNING (PMP) SYSTEM

During the course of this study program, the NASA Office of Program Analysis and Control, under Mr. King, installed an interim management control system referred to as the PMP System. The intent here was to provide some formal means of charting and reviewing the various program milestones so that management attention could be focussed on program slippages and delays, and on the problems created thereby. The methods employed in planning and charting program milestones were borrowed from those methods created by the Navy's PERT system. As part of this study program, Ramo-Wooldridge agreed to review the PMP system with the responsible NASA staff in an attempt to assist in improving the usefulness of this tool. It was also intended that this assistance would extend to over-all management control system implementation analysis and planning.

The technical assistance offered was not extensive since it became apparent at an early time that the PMP system could not be altered to perform a more comprehensive service without a major effort. Principal requirement for alteration of the PMP system centered around the collection and reporting of program cost data closely associated and compatible with technical progress. Accordingly, it did not seem fruitful to spend much of the limited appropriated effort on a management system which was only intended as an interim measure.

It is important to note that the effort spent on the PMP system did serve in determining what types of information are most useful to NASA management, and specifically which appear to be most helpful in program review meetings. The institution of the PMP system was invaluable in determining the psychological reactions and attitudes of various organizational elements toward the implementation of controls where control had never been previously exercised. It also proved to be a "conditioning" exercise to develop eventual acceptance, by various personnel and groups, of management controls.

The implementation of the PMP reporting system appeared to be extremely beneficial to NASA from the beginning. Schedule improvements were obtainable through the practice of presenting the responsible officers with needed vital information. The PMP system also served to establish what was necessary for reporting cycles for one type of program as opposed to other types of programs. For research and development projects, where a definite area of uncertainty would always exist with regard to accomplishment of given milestones in the project, the PMP system of reporting bi-weekly appeared to be sufficient and adequate. However, where other purely development type projects were involved, the report cycle appeared to be adequate on a monthly basis. Regardless of the specific case, it was obvious that the PMP system could serve to grade all types of activities and programs currently in the NASA plan with regard to required and necessary frequency of reporting.

The PMP charts created for the Mercury program, the Tiros programs, the Atlas-Agena program and others also served as invaluable information to the Ramo-Wooldridge study group in obtaining a comprehensive understanding of the breakdown of these large programs. In later activities involving the development of advanced management and program control system criteria, the appreciation of the complexities of these large systems were most helpful in the rapid formulation of design criteria which might otherwise have been omitted.

7. PROGRAM OF VISITATIONS AND CONFERENCES WITH NASA FIELD CENTERS

In conjunction with a schedule of interviews with various NASA Headquarters management personnel, a program of interviews with the various field flight centers was planned and carried out. Visits were made to the (contractor) Jet Propulsion Laboratory, Langley Research

Center, Goddard Space Flight Center, and to the George C. Marshall Space Flight Center. Conferences with the field centers concerned their working relationship to NASA Headquarters in addition to their internal operations. Problems of reporting on both the technical progress and the financial progress of their respective programs were explored in detail. Methods of cost collection and general fiscal policy for each field center were reviewed. This was particularly necessary since each field center operates its own independent financial activity, and reports only broad financial information to the Division of Financial Management at NASA Headquarters. It is the responsibility of the Financial Manager at the field centers to submit to Headquarters the Financial Operating Plan, a schedule which outlines the anticipated utilization of funds for NASA programs within fiscal year budgetary limitations. The breakdown of these appropriations by project and by type of expense must be prepared so that they can be properly compiled and collated with similar information from other centers.

The methods employed by each center for planning, programming, and scheduling for over-all activities have been reviewed with regard to applicability to an advanced management system. It was also necessary to determine the types of data processing equipments currently available at the various flight centers. The review of how these equipments are currently being used and what their potential availability could be as part of an over-all integrated management information system was explored. It is important to note, at this point, that the current inventory of data processing equipments in the NASA organization offers a strong possibility at this time for serving an Advanced Management and Program Control System without any additions of large capital equipments.

Visitations to the various field centers also proved useful in coordinating and disseminating information regarding the Ramo-Wooldridge study. Considerable interest was expressed by all centers in their being able to participate at an early time in the formulation of policies and principles regarding their part or activity in the proposed Advanced Management System.

8. DEVELOP DESIGN CRITERIA

During the latter half of this study, the Ramo-Wooldridge team devoted intensive effort to the development of design criteria. Project study notes were reviewed in detail. It was during this period that the Ramo-Wooldridge project management system began to emerge. It was determined that more specific attention needed to be given to the requirements of project managers for control information. As an initial contribution to the establishment of a project management concept three basic charts were developed: (1) a composite detail organization chart of the entire NASA organization; (2) a mission/project chart showing again in great detail the interrelationships between all NASA missions and projects currently under or projected for the PMP system, and (3) a flow chart of the PMP system. These charts proved extremely helpful in pointing up design criteria.

The NASA contract structure for research and development programs also came under intensive scrutiny at this time. Details of NASA contracts in effect for the fiscal years 1959 and 1960 were recorded on punched cards and analyzed at the Ramo-Wooldridge data processing facility. This study revealed a basic pattern in the NASA contract structure which proved of great importance in giving direction to the development of design criteria. The detailed analysis made possible through the use of punched card equipment also provided valuable facts for the information system designers.

With this detailed information concerning the NASA contract structure, it was possible to conduct a further correlative analysis of the PMP system which contributed even more to the development of the system design criteria. In particular, the nature and use of PMP milestones suggested the Task and Goal Concept for the Initial Operational Capability, Management and Program Control System (IOC-MAPCS). Following, it was necessary to work out details of the nature and content of the reporting system, the criteria for an information processing system, and to evaluate the over-all effectiveness of the Task and Goal Concept. For these purposes, a hypothetical NASA project was established, Project MIM, in which many of the design criteria were tested and refined. Project MIM, set up as a mission to impact an instrumented space craft on the surface of Mars, attempted to incorporate all major features of a typical NASA mission. MIM illustrates the marriage of space craft and vehicle programs, and in its organization, reflects the coordination and control problems that NASA project managers must face. Project MIM has proved to be a valuable tool for illustrating testing, and otherwise justifying the design criteria of the IOC-MAPCS.

The visits to JPL, Marshall, Goddard and Langley Field Centers, previously described, resulted in further analysis of the design criteria with respect to their effectiveness and appropriateness. Informal discussions of these concepts and criteria with NASA Headquarters personnel pointed the way to further improvement.

9. STRUCTURING THE INFORMATION SYSTEM

Structuring the information system for the IOC-MAPCS proceeded in parallel with the development of design criteria. At each step in the system design, careful consideration was given to the potential effect of proposed criteria on a physical information system. As the Task and Goal Concept emerged, the basis for an information coding system emerged with it. This led to the development of the concept of the integrated file structures and to the reservoir concept for information storage and processing. Project MIM was again employed as a "simulation vehicle" for testing the concepts used in the information system structure. Punched card machine facilities at Ramo-Wooldridge were used to simulate the proposed information system. A complete project file was established for the MIM Project and many different types of reports were actually produced on punched card equipment using the basic principles established for the information system. The simulation extended to the introduction of real-time reports from contractors and the preparation of financial status and schedule status reports designed for project management use. Many of the results of that simulation are included in this report.

Visits were also made to Lockheed Missile Systems Division and Aerojet General Corporation, two large NASA contractors, for the two-fold purpose of assessing the PERT system and for studying the feasibility of the contractor reporting structure proposed for the IOC-MAPCS.

Study of the NASA Field operations revealed the availability of sufficient electronic data processing capability and capacity within the over-all NASA organization to carry out the proposed system without requiring any additional large capital equipments. From this point, further attention was devoted to applying a reasonable degree of automation to the information system. This included the use of pre-punched cards for contractor reports, and direct communications between field center and Headquarters' data reservoirs. The system, as it is currently designed, was predicated on the use of these features.

The effectiveness of the information system has also been studied with respect to the decision gaming capability of the NASA IOC-MAPCS, and with respect to the display generation requirements associated with the Control Center.

10. CONTROL CENTER AND DISPLAY SYSTEM STUDY

The initial Control Center study involved the generation of numerous drafts of suggested control center facility configurations which reflected design changes resulting from coordinated effort between NASA and R-W personnel. In accordance with contract requirements, the R-W project concentrated on this effort to deliver, 30 days after the beginning of the program, a report titled "NASA Program Control Center Early Facility Description and Architectural Layout". This report summarized preliminary facility design study in order to arrive at an early estimate of the required general area or floor space. The report included:

An early facility description
Human factors considerations
Environmental requirements
Preliminary layouts and perspective drawings

An intensive schedule of design effort and coordination followed immediately. During the ensuing period, five meetings were held with NASA representatives at the R-W plant and at NASA Headquarters in Washington, D. C. In the course of these meetings, investigations regarding operational requirements, equipments, and facilities were conducted. Various drawings were delivered to NASA to formally document this progress.

Also during this period, supplementary plans beyond the scope of the study were transmitted to NASA for evaluation.

Other concurrent inputs to NASA provided an abstract Scale Model of the Control Center facility, samples of suggested materials, and photos of various other mock-up models.

In addition to design activities, R-W provided technical support to NASA personnel in their meetings with the architect for FOB No. 6, with the General Service Administration, and with Security representatives. Items of business accomplished during these sessions were: solution of the security problems, definition of construction problems, resolution of space allocations, discussion of lighting techniques, and refinements of other facility requirements.

Facility studies conducted at R-W included human factors studies of space allocation through the use of a full scale mock-up, and studies of lighting and sound proofing techniques.

An intensive study of various display techniques and their applicability to the problem at hand followed the final definition of NASA's requirements. The study included:

> Methods for automatically preparing format original copy for subsequent conversion to display slides.
>
> Techniques for the generation of white on black, black on white, and color slides.
>
> Evaluations of various methods to develop color slides from color originals, color slides from black and white originals, and color addition in the projection step.
>
> Practical solutions to the projection problems which prevailed.
>
> Considerations of optimum image projection on the screen.

Throughout these studies, full consideration was given to environmental and operational limitations and/or capabilities for each of the systems and their respective equipments.

During the month of October, a presentation to the NASA representatives to explain the study effort and proposed system which had been selected was given. The presentation covered recommendations for:

> Selection of the proper display slide generation technique
> Proper projection capabilities
> Advanced data generation and display systems

In summary, during the contract period, the display system study effort developed: a Control Center which is unique and operationally efficient within the construction and space restrictions that prevail, and a display system recommendation which is applicable to the problems at hand and sufficiently flexible to permit future expansion and automation.

APPENDIX B

CONTROL CENTER INTERIOR DESIGN

1. CONFERENCE ROOM FURNISHINGS AND EQUIPMENT

a) Conference Table Console

The conference table control panel (see Figure 50) is divided into three distinct sections. The center and largest section provides the controls for the random access projector. These consist of "OFF" and "ON" illuminated pushbuttons, an "UPPER-LOWER" split indicator illuminated pushbutton, and a spring-loaded rotary switch "FOCUS" control. All of these are located in a row on the extreme left hand side of the center section. The major portion of this section is taken up with fifty split indicator illuminated "SLIDE SELECTOR" pushbuttons arranged in a 5 x 10 matrix.

The right-hand section contains the controls required for manual and semi-automatic pre-programmed operation of the three serial projectors.

Located in the upper left area of the right-hand section are large illuminated "OFF" and "ON" pushbuttons for providing these functions for all three projectors simultaneously. In addition, six slightly smaller pushbuttons across the top provide these functions for each projector individually. Directly under these are six pushbuttons for "FORWARD" and "REVERSE" control of each of the three projectors individually. At the bottom center is an "INDEX PROGRAM" illuminated pushbutton for use in sequencing all the projectors in the semi-automatic pre-programmed mode. To the right of this is a "RESET" pushbutton for returning to a program after deviation.

The left hand section provides four split indicator illuminated pushbuttons providing a master "ON/OFF", tape recorder "ON/OFF", public address amplifier "ON/OFF", movie projector "ON/OFF" and a cuing signal pushbutton.

b) Lectern Control Panel*

The lectern, which will be vertically adjustable, will contain a set of controls which are partial duplicates of those found on the control console, a "prompting box" for use with verbal presentations, a microphone connection, a light, a cuing signal, and a recess for a speaker's papers. It is shown in Figure 51.

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* It is recommended that this unit be designed and fabricated, since "off-the-shelf" units are too complex, and controls within the lectern should match those in the console to eliminate, whenever possible, human error.

The control panel contains, in effect, the right and left hand sections of the conference table console and provides manual and semi-automatic pre-programmed operation of the three serial projectors. Thus, the speaker will be able to command an effective visual display without distractions from a complicated control panel.

c) The Conference Table

A "V" shaped conference table (see Figure 52) will be constructed in three parts, each of which can be dismantled for removal from the room. The apex portion of the table will provide a recess for the installation of the control console and will be designed in such a way that the console can be folded into the table, locked in place, and provide a smooth continuous table surface in the area in which the console was previously raised. The apex portion of the table will also house telephone jacks for the extension telephones which will be placed along the conference table sides.

Surface units of the conference table will be built in a sandwich pattern which will provide covered shelving for tablets, pencils, ashtrays, and other items required for briefing sessions, yet when a presentation is not in process, the surface will be free and clear of impediments.

d) The Easel

Portable easels will be available for presentations in which "flip charts" are used. Normally, however, these will be stored in the Control Center storage closet.

e) Chairs

Comfortable and practical chairs will be utilized in the room. The recommended chairs are shown in Figure 39.

2. THE PROJECTION ROOM

a) Serial Projectors and Controls

1) General

Three Serial Projectors, modified to meet the control requirements, will provide a simultaneous display of three slides. Each projector will use one-third of the available screen area. Two distinct modes of operation will be available:

Mode 1 — Individual remote operation
Mode 2 — Semi-automatic pre-programming.

2) Mode 1. Individual Remote Operation

Each of the three projectors will be provided with a set of controls to provide full operating capability independent of the other two projectors. Each projector's controls will consist of "ON/OFF" and "FORWARD/REVERSE" illuminated pushbuttons. Two additional pushbuttons, "ON" and "OFF", will accomplish these functions for the entire battery of three projectors. They will also control the screen curtains and the first bank of house lights and projection room lights. These remote controls will be duplicated on the conference table control console and the speaker's lectern.

3) Mode 2. Semi-automatic pre-programming

This mode of operation provides controls to operate all three projectors as a unit in a planned program, as in a formal report presentation.

Prior to the presentation, a Serial Programmer Unit (located in the projection room) will be set up in a sequence of steps designed to correlate visual information to the speaker's oral presentation. This unit is designed to be simple to program, flexible to operate, and if desired, a visual indication is available for monitoring the program sequence by a person stationed in the projection room. The Serial Programmer Unit will permit the speaker to sequence one, two, or all three projectors at one time by means of only one pushbutton, the Index Program button.

In addition, the speaker may deviate from his program by reversing any or all of the projectors. When any of the projectors deviate from the pre-set program, the illuminated "RESET" pushbutton will light. A Program Memory Unit will remember where the speaker was when he deviated from his planned program. At this time, the illuminated "RESET" pushbutton will go out indicating synchronization of the projectors with the planned program.

At any time in the sequence, the motion picture projector can be programmed for an automatic-on operation. Facilities will also be available to provide tape recording playback from any commercial tape recorder at any desired step in the program.

It has been estimated that the time required for entering a planned program into the Serial Programmer Unit that utilizes the three Serial Projectors, motion picture projector and a playback tape recorder will be approximately 10 minutes. The majority of this time will be used for the motion picture projector and tape recorder setup.

4) The Recommended Serial Projectors

The projectors in each instance will be the Spindler and Sauppe, Dual Selectroslide, Model SLD-1200. It is designed for heavy duty projection of 96 slides in two interchangeable magazines. Remote control operation of both forward and reverse sequences is provided. The projector will accept lamps up to 1200 watts. A large volume of air provides cooling to both sides of the slide and a permanently lubricated 87 C.F.M., four-inch Venturi fan directs the air through special cooling channels. Also, the Model SLD-1200 is equipped with three plug-in heat absorbing filters in addition to the necessary air cooling channels.

b) <u>The Random Access Projector and Its Controls</u>

1) General

The Random Access Projector will replace the 30" x 40" status charts presently used for briefings. The controls will be designed so as to provide access to any one slide with a multiple digit address by means of a single pushbutton operated remotely from the conference table console or from a control console located in the Administrator's office.

2) Remote Slide Selection

The Slide Selection and UPPER/LOWER pushbuttons in the control console (see Figure 50) are the split indicator type. Only one-half of the pushbutton will be illuminated at a time. Each half of the display indicator on the Slide Selection pushbuttons will name the slide in that position.

The UPPER/LOWER pushbutton selects and partially illuminates half (upper or lower) of each Slide Selection pushbutton. The addressable slide names will then be partially illuminated.

The utilization of this UPPER/LOWER pushbutton doubles the slide selection capability. At the present time, it is proposed to have 50 Slide Selection pushbuttons, giving a total slide selection capacity of 100 slides.

Depression of the Random Projector "ON" pushbutton will place this projector in an operable-standby mode, and illuminate the pre-selected halves (upper or lower) of the Slide Selection pushbuttons. Upon selection of the desired slide, the screen curtains will open, the slide selection mechanism will be activated, and the projector lamp will go on when the slide is in the film gate. The portion of the Slide Selection pushbutton associated with the selected slide will now be fully illuminated, thus depicting clearly the projector state at all times.

Subsequent slide selection commands may now be entered, and the displayed slide will be removed and the new slide placed in projection position.

At the conclusion of the Random Projection program, depressing the "OFF" pushbutton or Serial Projector "ON" will initiate a time delay during which the slide on display will be returned to its magazine, and the projection lamp and projector will be turned off.

3) The Recommended Projector

For the Random Access Projector, we recommend the new Spindler and Sauppe, Random Access Projector which, optically, is similar to the SLD-1200. The random access model has a 98 slide capacity at present with a maximum selection time of 10 seconds, minimum of one second in a two digit system. With a 1200 watt lamp, the light output is approximately 3200° Kelvin.

c) <u>The Motion Picture Projector and Its Controls</u>

1) General

The Motion Picture Projector will be operated in three different modes: Mode 1 — Locally, from the projection room; Mode 2 — Remotely, from the control console at the conference table; Mode 3— Automatically, pre-programmed as part of a sequential program.

2) Mode 1

In the first mode, the projector will be operated in the normal manner by a projectionist from the projection room.

3) Mode 2

Controls will be provided at the conference table for manually operating the projector. This will consist of "ON" and "OFF" illuminated pushbuttons. Depressing the "ON/OFF" button will open the screen curtains, turn down the first bank of house lights and start the projector. The end of the showing automatically initiates an "OFF".

4) Mode 3

In the third mode, the Motion Picture Projector will be a part of a larger presentation, using the serial projectors. Prior to the start of the presentation, a program will be set up on the serial programmer unit in the projection room. (See section on Serial Projectors.) The Motion Picture Projector can be programmed to operate at any time in the sequence. The program is presented by means of the Index Program switch on the control console or the lectern. When the proper step in the program is reached, the serial projectors will revert to a standby condition, and the Motion Picture Projector will start automatically. At the conclusion of the film, projection will be stopped by indexing to the next program step.

5) The Recommended Projector

For motion picture projection, presently available equipment will be quite adequate. A Bell and Howell, Model 614 CB, 16 mm Civilian JAN projector has only optical sound track capability and conceivably a need for magnetic sound track capability might present itself in the future.

d) Other Projectors

Provision has been made to utilize existing projectors (e.g., the vue-graph) and others which visitors may carry into the complex. Portable racks which can be locked in place will be designed or procured to house these units.

e) Display Slide Storage and Indexing

The recommended cabinet is the Brumberger Slide Cabinet No. 1093. The glass mounted slides will be stored in all steel six-drawer cabinets. Each drawer holds 150 individually partitioned 2" x 2" glass mounted slides, arranged in six rows of 25 each.

An index to the slide cabinets will be kept in a rotary type card file designed for quick reference to display information. The cards will show the location of the slides containing the required display. They are slotted so that they can be quickly detached for typed notations and then slipped back into place. A control knob twirls the index cards, bringing the subject card into view rapidly.

f) The Projection Room Monitoring Control Panel

All the controls will terminate in a cabinet located in the projection room. (See Figure 54.) This cabinet will house the necessary power supplies and switching circuitry to accomplish the control functions. In addition, some special control panels will be provided.

1) Programmer Unit

The programmer unit will have facilities for setting up a program of 50 sequential steps using the three serial projections, tape recorder and movie projector. Three rows of 50 switches will provide for addressing the serial projectors. A row of 50 lights will act as a visual monitor, indicating what step in the program is being presented. A set of rotary selector switches will determine at what steps the movie projector and tape recorder playback will occur.

2) Mode Selector Panel

The mode selector will consist of a series of switches with three positions: ON-OFF-AUTOMATIC. The OFF position will keep the equipment de-energized. the ON position will energize the equipment and permit it to be locally operated only from the projection room. In the AUTOMATIC position, the units will be operated from the various remote stations.

3) Supplementary Controls

A cueing signal on the remote units will provide a visual and aural signal in the projection room. Manual controls will be provided for operation of the screen curtains, projection room lights, and the first bank of conference room lights.

g) The Television Camera

The camera will be permanently mounted in a fixed position in the projection room. Power requirements will be 45 watts at 115 volts, 60 cycles.

The camera will have a vidicon pick-up tube and a transistorized video amplifier capable of a high resolution of 600 lines horizontally. Variations in light level of 200:1 will be automatically compensated for by the camera. The camera lens will have a focal length of one inch.

3. DISPLAY GENERATION ROOM

a) The Format Original Generator (Automatic Typewriter)

1) General

The present information flow rate of NASA indicates the need for a semi-automatic generator; i.e., a punched card or punched tape operated printer to produce the type of display that lends itself to automation without gross conversion.

The primary function of the generator will be to produce hard copy print-out of information to be used in photographic display. It will assimilate color separated coded information and automatically produce symbol and alpha-numeric print-out information onto sheets of one copy per color. This generator can be either a modified commercial punched tape or punched card driven typewriter as recommended for the interim system, or become an inherent part of the data processing equipment for the fully automated system.

2) Generator Specifications

The following specifications are applicable to either the interim or automated system.

OUTPUT

Rate: Interim System - 10 Characters per second (minimum).
Automated System - 50 Characters per second (minimum).
Recording Accuracy: 0.1% in repetitive placement of clearly defined symbols on permanent copy.
Symbols: Modified to provide the required symbols.

Symbol Capacity: 57 Independently addressable symbols.
Machine Indexing: Normal copy and type indexing.
Half space indexing for both copy and type.
Copy: Permanent black symbols on an opaque white background.

INPUT

Rate: Interim System - 10 Characters per second minimum.
Automated System - 150 Characters per second minimum.
Reader: Interim System - Either a punched tape or punched card reader.
Automated System - A high-speed punched tape reader.
Manual: Capable of keyboard input with keys modified to clearly depict symbols and machine copy and type indexing.
Code Capacity: Minimum of 64 useable, including symbols and machine indexing command codes.
Coding: Minimum of six information and one parity bits per character line.

3) The Recommended Generator

For the interim system, a Friden Flexowriter Model SFD with selected type face, tape reader and tape punch, and modified with a register pin platen and two-part bin to accommodate accordion folded, perforated paper will be used. The ribbon should be of the polyester film base type that completely eliminates the problem of breakage associated with carbon paper ribbons. The Columbia M-50 is a "Static Free" solvent coated film base ribbon of this type and produces the nearest approach to actual printing. It is smear-proof, and designed specifically for photo-copy work. The sharp images can be reduced without fear of distortion or loss of original clarity.

b) The Microfilm Recording Camera

The Karl Heitz, "Robot Recorder 36" is an electro-automatic recording camera for 260 exposures (24 x 36 mm) on 30 ft. of standard 35 mm black and white film. The installation will include the Robot Recorder 36 camera, with rewind knob and sequence release, 45 mm f/2.8 Schneider Xenar lens or equivalent. A universal camera mount with a quick release lever facilitates unloading and reloading of the film without the need for constant re-setting. The unit is remotely controlled via pushbutton. Power required for the camera control unit is 24V DC supplied via transformer (included) from 110V AC.

The entire camera unit mounts on a Solar-matic Reproduction Stand, equipped with Durst incandescent Rilu copying lights. This is a heavy duty stand with a baseboard large enough to accept the registration pins used to hold the hard copy records in place. The sliding head of the stand has a counter-balance spring to compensate for the weight of the camera unit. The copy lights are mounted on the reproduction stand baseboard and once adjusted for the most efficient illumination, and set, need not be re-set. The four reflectors accept No. 1 photoflood lamps or other similar size, depending upon the amount of light required.

The black and white film to be used in the camera will be 35 mm, perforated, 30 ft. rolls. The film emulsion will be either Eastman High Contrast Positive Film (a positive emulsion suitable for making negative or positive slides of excellent definition and sharpness when clear whites and dead blacks are required) or Kodak Microfile, a comparatively fast, fine grain, panchromatic film of high contrast and high resolution designed for microfilming.

4. THE DARK ROOM

a) Photographic Film Processor

The Microfilm Processing Tanks develop microfilm and 35 mm film rolls by traveling the film back and forth on reels automatically during the processing cycle. The reversal of the rotation of the reels is governed by five feet of leader and five feet of trailer. The tanks and reels are made of corrosion-resistant plastic and only one gallon of each solution is required. The unit operates on 110 volts, 60 cycle AC and is capable of handling up to 200 ft. of 35 mm film.

b) Film Dryer

A Microfilm Film Dryer dries the roll of black and white 35 mm film record in approximately 10 minutes. The film contracts naturally while it dries, a requisite for the registration capability of the system. The stainless steel drying cage has a capacity of 50 feet of 35 mm film and is rotated by a 110 volt AC motor.

c) Color Printer

A modified Karl Heitz "Colorcontact", 35 mm contact printing unit, prints the 35 mm black and white film records onto color or black and white film. The negative carrier will take film rolls up to 90 ft. in length, the dustproof and light-tight magazine will hold 30 ft. of color or black and white raw stock. A 60-watt lamp with opaque screen, diaphragm and index knob (f/1-64) guarantees constant actinism eliminating the necessity for a rheostat. Provision has been made for color filters to be placed in the light path providing the necessary color for the ultimate slide. Registration pins will have to be added so that the color film will coincide or register with the various colored film records. A built-in contact allows the coupling of the exposure knob to any automatic timer.

Color processing and drying will be accomplished in the same equipment as used for the black and white step. Additional tanks will be required for the color solutions but because of the nature of this semi-automatic processor, it is capable of various processing techniques. The same dryer is used for both color and black and white film, the color requiring more drying time because of the complex nature of the film.

d) Film Cutter

Lutes Model "IT" is a semi-automatic film cutter for rapid transparency cutting. Once the film is inserted on the track it is automatically advanced eight perforations (one frame) for standard 2" x 2" slides without the risk of fingers touching the film. The film tracks are fully illuminated to give the operator a clear view of the film as it is being cut. As the film is cut, it drops into a bin underneath, stacked, and is ready for mounting.

e) Slide Mounts

Leitz "Pro" Color Slide Binders are recommended. The mounting step is a hand operation carried out on the light table in conjunction with the cutting of the film. Cut frames of film are inserted between thin, anti-Newton-ring optical glass and quickly and securely sealed in the metal binder.

5. THE TELEVISION MONITOR

The monitor will require 175 watts at 115 volts, 60 cycle and be equipped with a 14 inch picture tube. In addition to the normal monitor controls, there will be provided a remote focusing control for the television camera.

6. EQUIPMENT LIST

a) Display Generation and Production

Item	Manufacturer and Model	Price
Flexowriter	Friden Model SFD	$
Camera	Heitz, "Robot Recorder 36"	900.00
Lights	Durst, R12U Copying Lights	100.00
Reproduction Stand	Burke and James, Solar-Matic No. 3707-S(W)	70.00
Film Processor	Microfilm Co. of Calif. Model FEM 8/90	235.00
Film Dryer	Micro Record, Model DR-10	75.00
Color Printer	Heitz, Color Contact	* 150.00
Film Cutter	Lutes, Model "IT" No. 7902-S	60.00
Slide Storage	Brumberger, Model No. 1093 Cabinet	30.00
Sink	Kreonite, Model 3065	460.00

* To be negotiated.

b) Projection

Item	Manufacturer and Model	Price
Four Projectors	Three Spindler and Saupe Model SLD-1200	$ 820.00 ea.
	One Spindler and Saupe Random Access Projector	1,600.00 approx.
Screen	Screen, Stewart-Trans-Lux, Lux Chrome 50 (Gain Factor of 2 to 2.5)	*

c) Public Address System

Sound Amplifier	One, RCA, Type SA-34C, MI-38103	**
Loudspeakers	Two, 8", RCA, Type SL-8A, MI-12480	**
Line Matching Transformers	Two, RCA	**
Microphone	Miniature, RCA, Type BK-6B, MI-11017	**
Microphone	Varacoustic, RCA, Type SK-5D, MI-12034	**
Microphone	Cardioid Dynamic, Univ. Mod. 502S	86.00
Input Transformer	Three, RCA, MI-12398 or 12399	45.00
Baffles	Two, Special Design (for loud-speakers) 2-1/2 cu. ft.	100.00
Decorative Grilles	Two (for loudspeakers)	20.00
Audio Switching Panel	Altec Mod. 1555A	50.00
Volume Indicator Meter Panel	ATT	**
Monitor Speaker Panel	ATT	**
Miscellaneous	Cables, connectors, small parts, etc.	50.00
		$ 351.00

* To be negotiated
** These items are available at NASA.

d) Recording Equipment

Item	Manufacturer and Model	Price
Tape Recorder	Remote Controlled, Ampex PR-10	890.00
Compression Amplifier	Altec Mod. 438A	199.00
Microphone	Electrovoice "Sound Spot", Mod. 644	65.00
Microphone	Electrovoice, All Directional, Mod. 654	59.00
Eraser	Bulk Tape, Robins Mod. ME-99	25.00
Demagnetizer	Tape Head, Robins, Mod. HD-6	7.50
Recording Tape	Ten, 7" reels, 2400 ft., "Scotch" Type 200	62.00
Tape Splicer and Tape Head Cleaner Kit	Robins Mod. TS4A-SLX	10.00
Miscellaneous	Cables, connectors, small parts, etc.	50.00
		$1,367.50

e) Communication Equipment

Call Director	12-Button, Bell Telephone Co.	*	50.00
Communication System	Selective, Type 6-A, BTC	*	165.00
Central Office Telephone Lines	BTC, Three	*	30.00
Telephone Jack Installations	BTC, Five	*	37.50
Telephone Instruments Installation	BTC, Fourteen	*	140.00
Headset	Boomtype, Telex		42.00
"Speaker Phone" Installation	BTC	*	4.00
Visual Signal for Remote Control Panel	BTC		10.00
Cue Signal	(For Projection Room)		50.00
			$ 528.50

f) Television

TV Camera	Dage Automatic Model 70 BR	1,645.00
TV Monitor	Dage Video Monitor Model 602-C	475.00 **
Camera Lens	To be determined	100.00 appr.
Miscellaneous	Cables and Controls, to be determined	
Video Amplifier***	Dage Line Driver, Model 275-LD	250.00

* These costs are for installation only. Monthly charges are in addition and would be approximately $65.00 per month. Figures are based on Los Angeles area charges and may be quite different in the area where the installation is made.

**Custom installation is slightly higher.

***Required for expansion only.

g) Format Generation Supplies

Chemicals	B and W Process	Color Process	Still Photo B&W
Developer	D72		D72
Fixer	Kodak Rapid Liquid Fixer	Kodak Rapid Liquid Fixer Kodak C-22 Processing Kits Kodak Photo Flo	Kodak Rapid Liquid Fixer Kodak Photo Flo Kodak Ektachrome Processing Kits, E-2
Film	34mm, Eastman High Contrast Positive 5362, Neg. Perf.	35mm Kodak Ektachrome, Type F EF 404, or 35mm Ektacolor Slide Film	
Slide Mounts		Leitz Pro. Color Slide Binders w/anti Newton Ring Glass	
Flexowriter Ribbon	Columbia M-50		
Flexowriter Paper	Hammermill Bond 1 Sulfide, 20 LBS, Perforated and Preprinted (Moore Business Forms, Inc.)		

h) Electrical

Conference Table Control Console	$ 5,993.00
Lectern Control Console	8,832.00
Administrator's Control Console	4,271.00
Control Cabinet	31,331.00
Cable Kit	5,828.00

7. ADVANCED SYSTEM AND EQUIPMENTS

a) General

Since the automation described in Section III. B. represents a sizeable investment and considerable changes in information flow techniques, a description of a typical information input system has been prepared for consideration. Figure 81 exhibits a typical display system flow. However, since, as is mentioned earlier, the generation portion of the automation being considered is an item of great importance, a description of the requirements is presented below.

b) Automated Display Generator

The display generator in the fully automated system would become an integral part of the data processing equipment (see Figure 82). It would, without constant attention of an operator, produce displays under computer control. The responsibility of decisions in display format, data allocation, interpretation, and computations will be put to the computer. The computer will assimilate the information received from the Field Station, make calculations, add the necessary control commands needed to operate the automatic generator and store information routine for slides. When either asked by the internal program or by the operator, the computer will feed the requested slide information from its buffer to punched tape for use in the Display Generator. This tape can feed directly to the Display Generator's tape reader/puncher for on-line type slide generation or be stored for future use. It should also be pointed out that a remotely located computer could, by use of wire transmission, produce the tape at control center for on-line or off-line use.

An automatic display generator unit can be divided into seven sub-assemblies according to their functions in the system.

1) Tape Punch
2) Tape Reader
3) Control Programmer
4) Symbol Generator
5) Film Processor
6) Film Chip Handling Equipment
7) Monitor and Control Panel

c) Tape Punch Sub-Assembly

The computer fed and operated tape punch provides control and symbolic information on tape for operation of the Display Generator System. This information is punched in the paper tape in characters (lines) of six information punches (bits), a parity punch and a

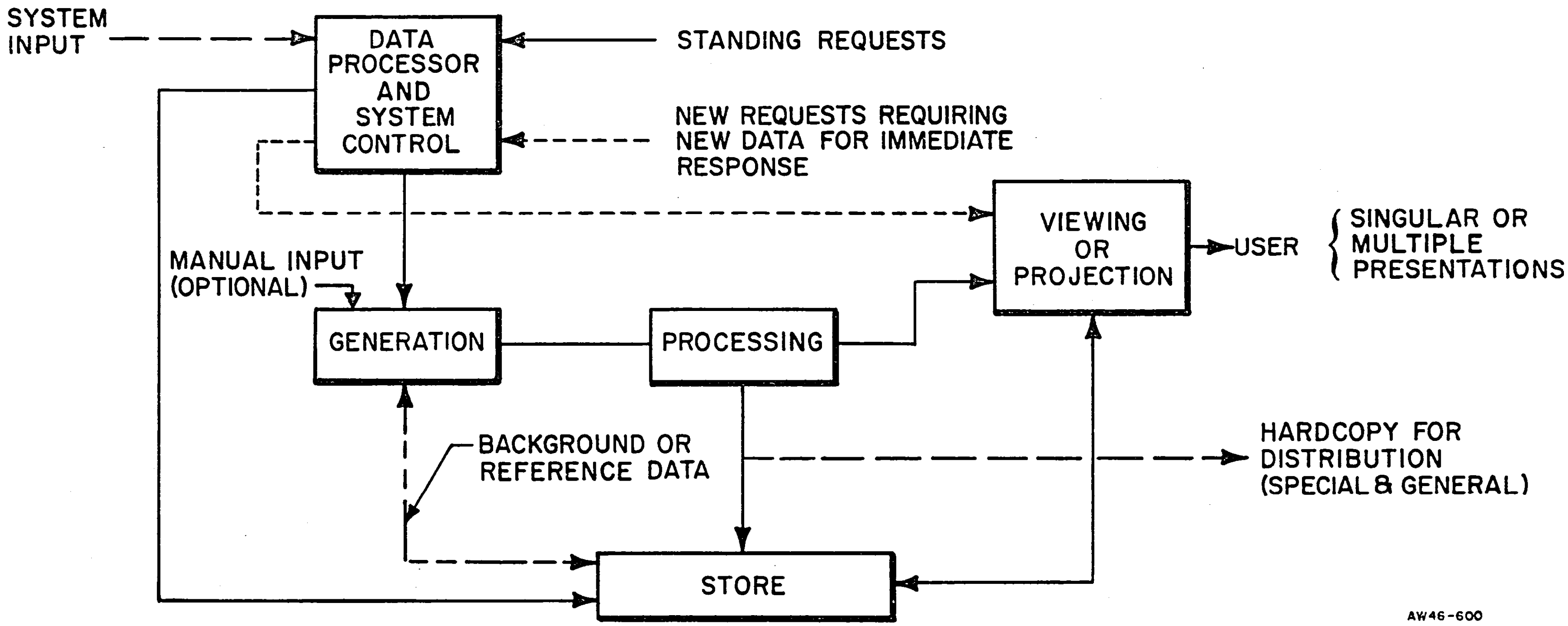

Figure 81. Typical Display System Flow

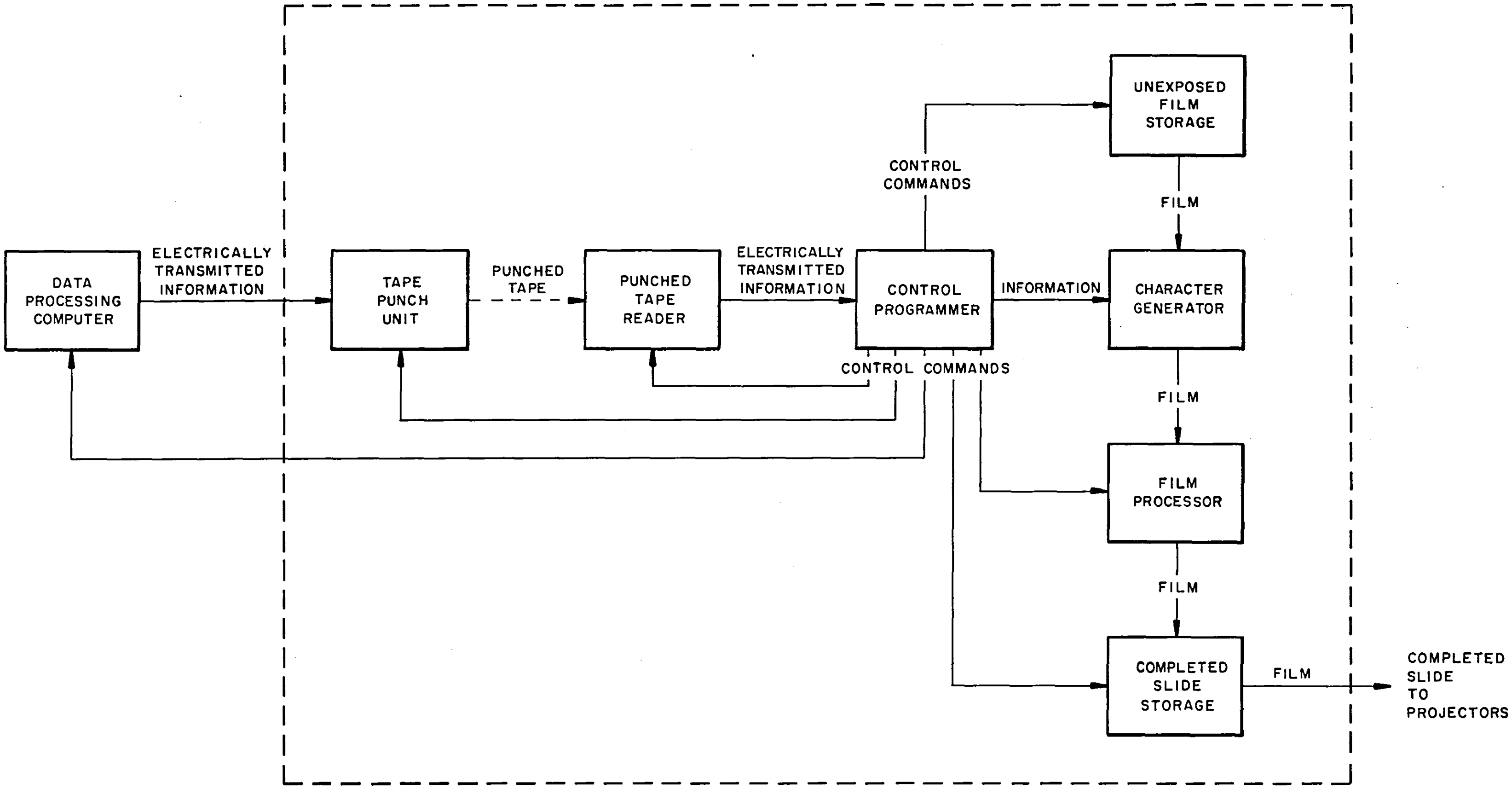

Figure 82. Automated Display Generator

synchronizing punch. The tape punch should be capable of producing this information at rates exceeding 150 characters (lines) per second in order to maintain the information flow needed for the tape reader during on-line operations. When operated in the on-line mode, the tape is a continuous strip being read during punching with a slack loop between the puncher and reader to provide a temporary storage. The tape punch will then be controlled by the computer with the electronic control programmer in the display generator indicating a readiness for the next character of information. The electronic inlocking and tape loop for interim storage will provide an even and efficient information flow.

Tape generation during off-line operational modes will allow the computer to operate the tape punch at extremely high rates. This capability allows for a back log of slide information on tape for the display generator during high input information densities. The prepared tapes can then be stored for use in specific presentations at a future time. This tape generation and storage will decrease the computer operational time since tapes of a by-product classification can be generated during computer runs that are aimed at receiving specific information.

The utilization of a separate tape punch and tape read system that employs a standardized coding technique allows for the tapes to be punched manually. This capability of manual tape punching provides on-location updating and special slide generation. A typical tape punch typewriter would be the "Flexowriter".

d) Tape Reader Sub-Assembly

The tape reader converts the punched tape information to electronic pulses for control and information inputs to the control programmer. This reader must be capable of automatic start/read/stop or continuous reading operations as directed by the control programmer. The minimum rates expected of this reader should average 150 characters (lines) per second and be capable of rates up to 300 characters per second, a typical off-the-shelf tape reader would be the Potter 903A Reader and Amplifier Unit.

e) Control Programmer Sub-Assembly

The electronic control programmer is the internal decision-making device of, and provides the following services to, the Display Generator.

1) Interprets the punched tape information,
2) Allows for a flexible programming technique,
3) Converts this information to directive commands for the sub-assemblies of the Display Generator,
4) Monitors the execution of these commands,
5) Monitors the Display Generator System for malfunctions,
6) Commands the tape reader to start, read and stop as dictated by the information consumption rates of the Display Generator.

f) Input Operations - Control Programmer

The control programmer sub-assembly receives each character (line) of punched tape information in an eight wire parallel type configuration. Each wire electrically reflects the presence of a punch in the tape in its allocated track at the read-time for each character or line of punched information. Tape tracks L 1 through L 6 are allocated to binary coded information and track L 7 is to be used for parity checking.

g) Programming

The binary coded tracks L 1 through L 6 are interpreted by the control programmer as representing various types of control codes or data codes according to the programming technique. This type of code interpretation is based sequence. The code following a reset code is identified as a control code. These control codes instruct the control programmer as to how to react to each following data code until the next reset control code is received. This technique of programming increases the efficiency of data flow and increases the number of different control and data instructions to the Display Generator.

h) Reset Control Code

This code indicates the beginning and end of an operational sequence and identifies the next code as a control code.

i) Control Codes 1 through 9

These are command or instruction type codes. Upon receipt of a control code, the Control Programmer will select and command the various sub-assemblies to react to the data codes to follow. The control codes for identifying data codes might be as follows:

Control Code 1 - start of new slide generation
2 - data code for color selection to follow
3 - data codes for X and Y location of symbols to follow
4 - data codes for selection of symbols, alpha-numeric information to follow
5 - data codes for X and Y points of line drawing to follow
6 - end of present slide generation and new slide generation to follow
7 - end of present slide generation and no new slide generation to follow.

j) Data Codes

The same binary number can represent different data codes since each is identified by the preceding control code and the pre-assignment according to binary number value. These 63 binary numbers provide the Control Programmer with symbol, alpha-numeric, and X and Y locations for symbols.

k) System Monitoring

The Control Programmers provide interlocking and monitoring of all the Display Generator sub-assemblies. The internal control center offered by the Control Programmer provides the system with a malfunction alarm system. Upon receipt of a malfunction, the tape reader stops, and the type of malfunction occurring is presented on a Control Panel.

l) Tape Reader Control

The various consumption rates of each sub-assembly necessitates controlled operation of the tape reader. Since the Control Programmer sub-assembly communicates with the various sub-assemblies of the Display Generator, it will also maintain operational control of the tape reader. A control multivibrator circuit in the Control Programmer is capable of commanding the tape reader to start, read one or more characters of tape, and stop on any character now being read.

m) Symbol Generator Sub-Assembly

The Symbol Generator provides exposure of symbols, alpha-numerics, and lines onto unexposed film chips. This must be capable of placing the pre-determined symbols in any desired position in a relatively short time. There are two techniques that are considered to be acceptable and efficient means of symbol generation. These are symbol generation using the Cathode Ray Tube Character Matrix and the slower servo-driven Template Matrix. Both of these approaches are state-of-the-art techniques and a working model of each has either been developed at Ramo-Wooldridge or is under construction at the present time.

Each technique possesses its own attributes according to the application.

n) Cathode Ray Tube Character Matrix

Generation by use of the Cathode Ray Tube is by far the fastest and most expensive approach. It finds its application most suited for high speed display generation.

The Cathode Ray Tube Character Matrix utilizes an internal character matrix for forming the characters on the phosphor screen. The electron gun, when electrically commanded, emits a beam of electrons which are accelerated and shaped by anode number 1. This beam is then deflected by the first set of electrostatic plates to select the desired character shaped hole in the matrix. The second set of electrostatic plates re-orients the electron beam in skew and direction in order that the beam will pass through the character shaped hole and then later strike the phosphor screen properly orientated. The electromagnetic coils near the screen of the tube provide positioning of the selected character as well as providing final acceleration of the beam.

This technique requires a pre-determined set of characters or symbols with expansion hindered by a limited number, 64, and the costly reproduction of the tube.

o) Servo-Driven Template Matrix

The servo-driven template matrix utilizes a stationary light beam that is shuttered through movable stencil templates. The desired character shaped hole is indexed into the light beam, the light is then gated on, and positioned on the film chip by X and Y mirrors. The electro-mechanical technique of character or symbol generation offers the reliability of a typewriter at exceptionally high rates.

p) Comparison

The advantages and disadvantages of both Generators are summarized as follows:

Input Rates: Both generators will operate in on-line and off-line modes with a computer. The CRT generator can accept faster rates from the computer.

Output Rates: Both generators are capable of generating the normal slide in less than one minute. Although the CRT generator can select, position and expose faster, its output rate is deterred by the wet processing of the high speed film required by CRT exposure.

Film Type Required: The CRT Generator requires high speed film while the servo-driven Template Matrix Generator utilizes both high and low speed film and both wet and dry processing film.

Image Quality: The characters or symbols generated by the Template Matrix far surpasses the quality derived from the CRT Generator.

Reliability: The servo-driven Template Matrix Generator offers the more reliable system.

Cost: The servo-driven Template Matrix Generator is slightly less costly.

q) Processor Sub-Assembly and Film Handling Sub-Assembly

The film processing station in the automated Display Generator is capable of automatic rapid processing times on the order of one minute for wet processing and a few seconds for dry processing. The dry processing type film that is adaptable to rapid processing has exposure times and spectral responses that dictate the use of the servo-driven Template Matrix Generator. After being exposed to high intensity ultra-violet, this dry processing type film can be developed by heat en route to the internal storage for completed slides.

All film and slide transportation internal to the Display Generator is a rapid automatic system.

Storage of unexposed and exposed film is provided in magazine capacities of 60 slides for each.

r) Generation and Projection

This automated but more expensive approach to the problem of display format creation would be through the use of the Ramo-Wooldridge developed character generator operating in conjunction with Colorvision, Inc., optics.

This technique utilizes color-separation image areas on a single piece of black and white or dry-processing type film which is then projected through reversed beam-splitting optics, producing a single additive color image on the screen. The symbol color is determined by the area in which the symbol appears on the film. The mechanical servo-driven Template Matrix symbol generator selects and positions the symbols within each image area depending upon the displayed color desired.

8. RECOMMENDED INTERIOR COLOR AND FURNISHING SCHEDULE

a) Conference Room

Walls:
    Plaster - Kemtone #215 - Driftwood White
    Wood (Flush Panel) - Oiled Walnut
Doors (Flush Panel) - Oiled Walnut
Drapery - Herman Miller #144 Capra
Carpet - unspecified
Furnishings:
    Conference Table - Oiled Walnut
    Conference Chairs - Herman Miller PAC-1
      Upholstery - Herman Miller Rainbow #279
    Auditorium Chairs - Herman Miller DSS-1
      Upholstery - Herman Miller Rainbow #279
Sliding Wall Panels - Micarta #90M14 Sand

b) Reception Room

Walls:
    Plaster - Kemtone #215 Driftwood White
    Wood (Flush Panel) - Oiled Walnut
Doors (Flush Panel) - Oiled Walnut
Carpet - unspecified
Furnishings:
    Reception Desk - Oiled Walnut (Desk top - micarta #90M14 Sand)
    Receptionists Chair - Herman Miller PSCC-1
      Upholstery - Herman Miller Rainbow #283
    Sofa - Herman Miller 5691A on 5671 Base
      Upholstery - Herman Miller Rainbow #278

c) Projection Room

Walls - Kemtone #226 Cork
Carpet - unspecified
Doors - Paint Kemtone #215 Driftwood White

d) Display Generation Room

Walls - Kemtone #215 Driftwood White
Doors:
From Reception Room - Paint Kemtone #226 Cork
Other - Paint Kemtone #215 Driftwood White
Floor Tile - unspecified

e) Dark Room

Walls - Kemtone #215 Driftwood White
Doors - Paint Kemtone #215 Driftwood White
Floor Tile - unspecified

APPENDIX D
DISPLAY SYSTEM DESIGN PROCEDURES

1. PARAMETERS

As described in paragraph 3B. 2 of this report, the NASA display system parameters were defined at the beginning of this study. These parameters and NASA requirements are:

Time necessary for generation of any display—minimum.
Operating costs—minimum consistent with quality.
Cost of implementation—minimum.
Product display quality—maximum.
Color capability—included.
Independence of human-operator skill—included.

With system parameters and final requirements established, the next question to be answered was, "What specific avenue of approach best fills the needs of NASA?" Conventional techniques, such as that illustrated in Figure 83, were not ruled out.

As an initial approach, possible display product types were categorized into three distinct classes:

Black and White hard copy output from Generator leading to black and white display product.

Color hard copy output from Generator leading to color display product (Direct color).

Black and White hard copy output from Generator leading to color display product (Synthetic color).

Although the above description of the classes is self explanatory, it should be noted here that the term Generator may refer either to man or machine and that a black and white display product implies a visual display consisting of white symbolic (or alphanumeric) information on a dark background (negative image) or dark symbolic information on a white or clear background (positive image). Similarly, a color display product implies a visual display consisting of color symbolic information on a dark background (negative color image) or colored symbolic information on a white or clear background (positive color image).

2. SYSTEM AVENUES

For each of the three classes of product types introduced in the preceding paragraph, a family of system avenues was established. The term avenue, as used here, denotes a complete sequence of steps or operations that are required to produce a particular display product from a given Generator output. For example, if the Generator output

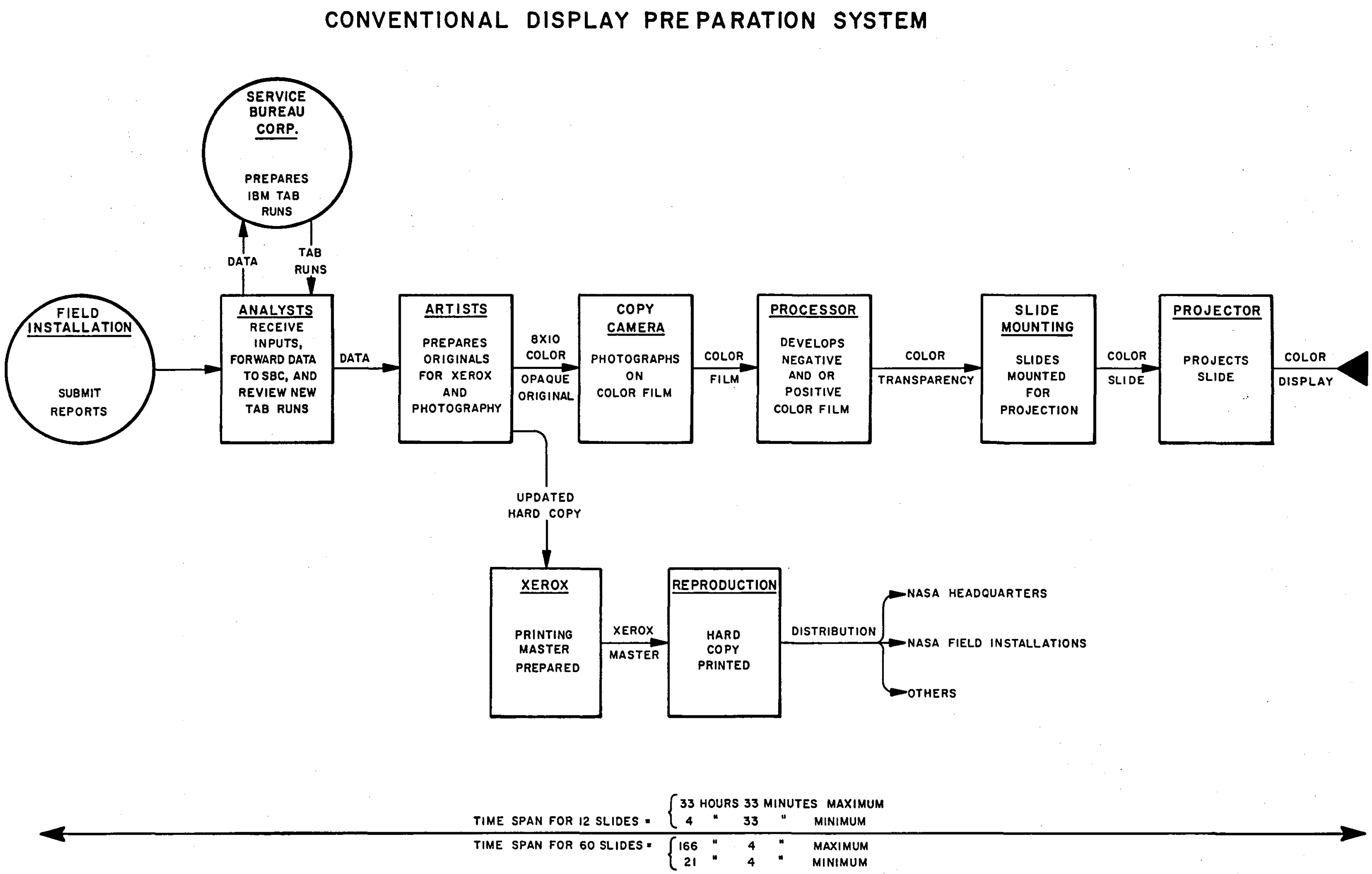

Figure 83. Conventional Display System

is an 8' x 10" typewritten sheet of paper and the desired product is a visual black and white presentation consisting of clear symbolic information on a dark surround, then one possible avenue might appear as follows:

B and W Opaque Copy (8 x 10)	Photo - reduce to 35 mm and Process (negative)	Mount	Project negative 35 mm slide

Figures 84, 85, and 86 illustrate the complete sets of avenues which were considered for the NASA display system operation. The first task following establishment of these many avenues was to determine which avenues were totally consistent with the system design parameters discussed in paragraph 3B. 2b.

3. GROSS AVENUE ELIMINATION

Instead of expending the large amount of time that would be necessary to carry out a detailed evaluation of each of the individual system avenues illustrated in Figures 84, 85, and 86, certain groupings of avenues involving particular characteristics were treated in a gross fashion. Such treatment resulted in the summary elimination of several of these groups from further consideration.

a. Dimensions of Generator Output

The first group of avenues treated were those involving Generator outputs having physical dimensions considerably greater or less than 8" x 10". Experience in the field of display generation devices has shown that automatic or semi-automatic generation equipment for the production of display items having large physical size is not commercially available. Further, the cost of producing such equipment is excessive. Hence, since the desirability of designing a display system amenable to some degree of automation is unquestionable and since automation should be provided at a reasonable cost, all avenues involving physically large Generator outputs were dropped from consideration.

Further investigation indicated that Generator outputs considerably smaller than the 8" x 10" dimensions were also unsuited to the proposed display system. Here, however, the elimination was made on the grounds of product quality rather than on those of cost. Semi-automatic or automatic readout or print out devices chosen for system implementation must be capable of sufficient resolution to produce about thirty-six lines of copy on the display product. Such resolution can be achieved easily with available equipment only if the generated output is of reasonable size.

On the basis of the above considerations, a nominal size of 8" x 10" was retained, and all system avenues that were based upon the utilization of Generator products differing significantly from this size were eliminated.

SYSTEM PATHS FOR BLACK AND WHITE DISPLAY PRODUCT FROM BLACK AND WHITE ORIGINAL

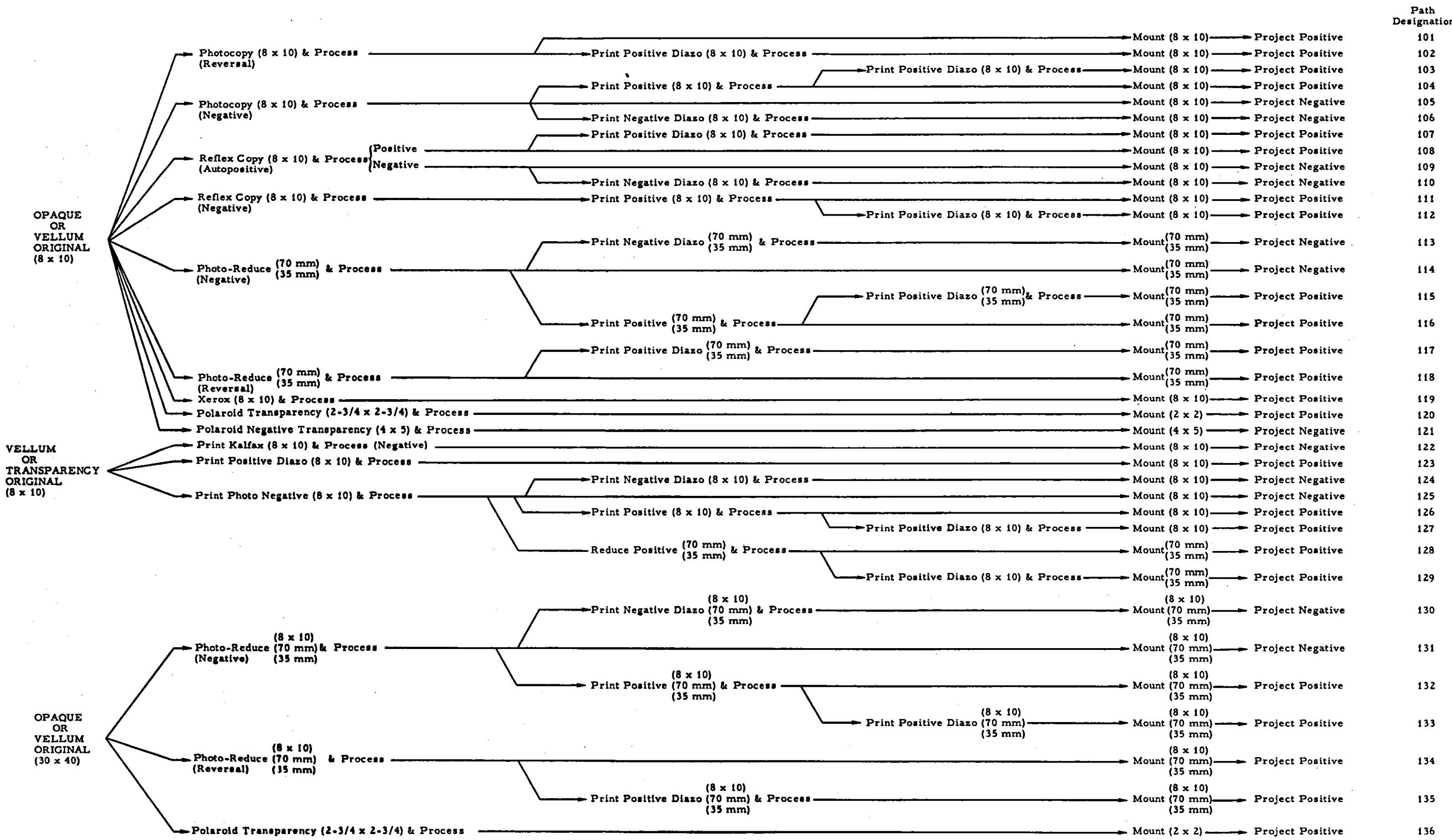

Figure 84. Black and White System Avenues

SYSTEM PATHS FOR COLOR DISPLAY PRODUCT FROM COLOR ORIGINAL (DIRECT COLOR)

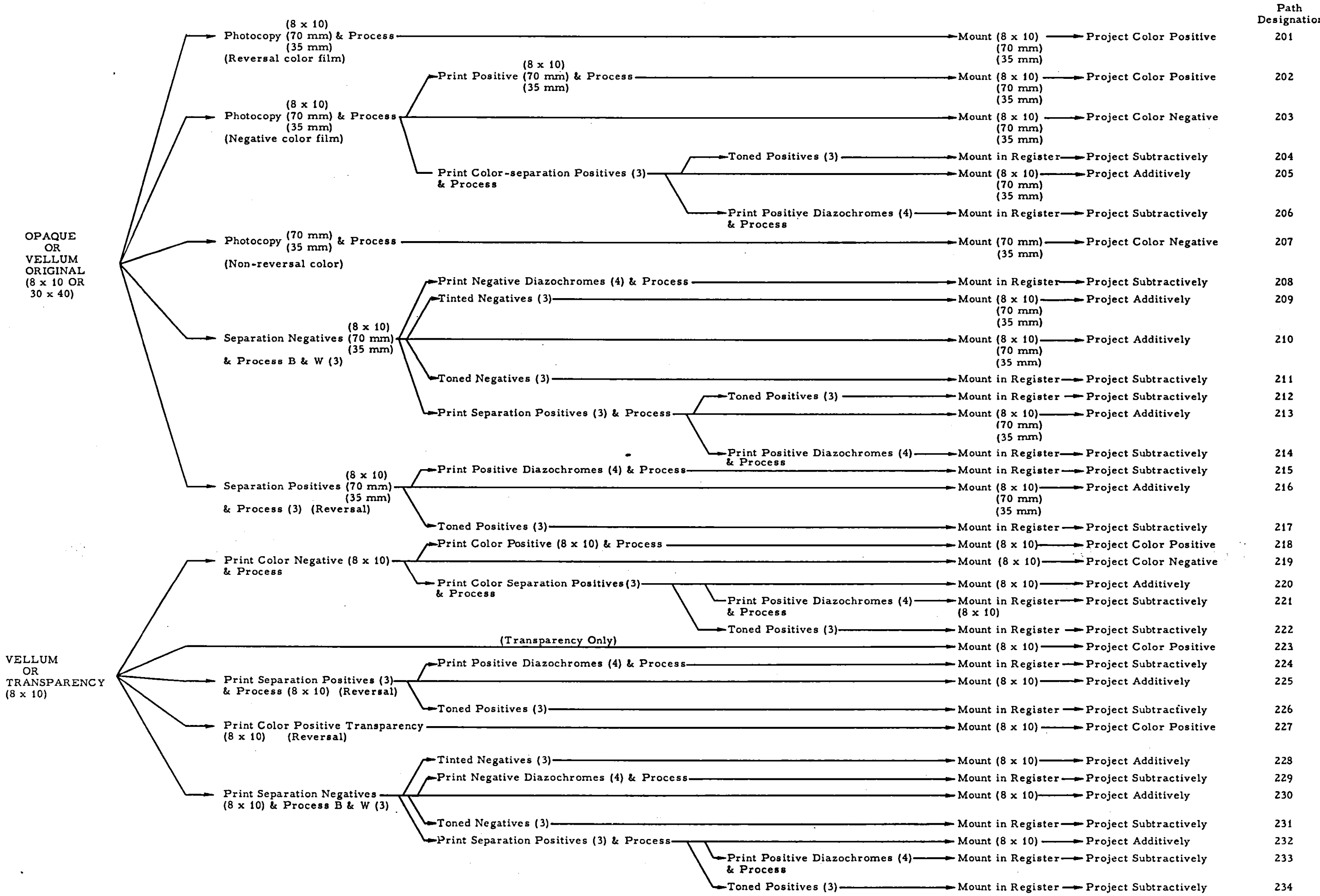

Figure 85. Direct Color System Avenues

SYSTEM PATHS FOR COLOR DISPLAY PRODUCT FROM BLACK AND WHITE ORIGINAL (SYNTHETIC COLOR)

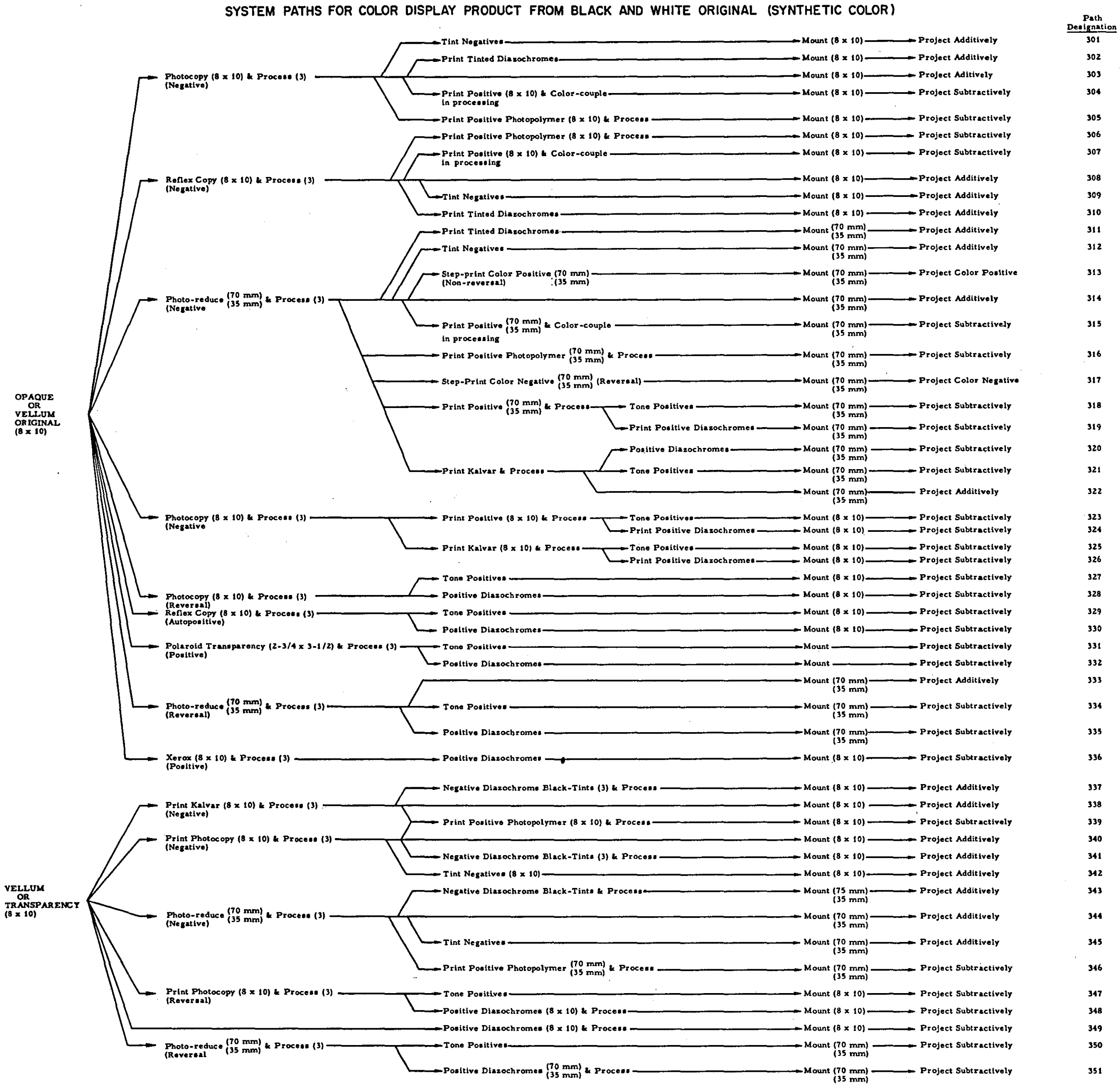

Figure 86. Synthetic Color System Avenues

b. Dimensions of Display Product

The second group of avenues treated in gross fashion were those involving display products having dimensions varying from the dimensions of a standard 35 mm double frame (24 mm x 36 mm).

In the case of products having dimensions smaller than those of the 35 mm double frame, decision revolved chiefly around required screen brightness and permissible projection distance — two criteria which are basically inter-related. Since the layout of the control center establishes a limit on the dimensions of the projection room, it also, therefore, established a limit upon the projection distance or the linear distance from the lens of the display projector to the viewing screen. Further, since the projection distance possesses a fixed relationship to the required optical magnification and since the brightness of the image projected upon the viewing screen falls off as the square of the magnification, it is desirable to set an upper limit on the magnification. The projection of a mounted 35 mm slide onto a viewing screen having a vertical dimension of 6-feet represents a magnification of 80 which may be regarded as an upper allowable limit. Since a smaller slide requires even greater magnification to fill the viewing screen, utilization of a display product having dimensions less than 24 mm x 36 mm will have adverse effects on the viewing quality of the displayed image.

In the case of display products having dimensions significantly larger than those of the 35 mm double frame, decision revolved about the availability of equipment capable of storing, processing and projecting large formats. In handling formats dimensionally larger than 70 mm size, the problem is extremely severe due to the unavailability of equipment that is capable of such handling and also of being automated. While it is true, for example, that there are projectors available for large formats, they are strictly manual in their operation. Further, the use of 70 mm display product was considered acceptable until investigation indicated the excessive cost of equipment for handling this size.

The net result of the above considerations was the elimination of all system avenues which were based upon the generation of display products different in size from 35 mm. It should also be noted here that since 35 mm is a standard used in the motion picture industry and, to an even larger extent, in the field of amateur photography, a wide variety of equipment is readily available at relatively low cost for handling this size.

c. Black and White Class of Display Products

The third group of avenues treated in gross fashion were those involving black and white display products arising from black and white Generator output. Since none of the avenues in this class is amenable to color utilization, and since any avenue in the synthetic color class may be used to produce black and white as well as color display products, this entire class of system avenues was eliminated from further consideration.

d. Direct Color Class of Display Products

Although it was deemed desirable to provide color displays on the viewing screen, investigation indicated that no reasonably priced device was commercially available which possessed the capability of programmed readout or printout in color. Any of the avenues in this class, then, could only be employed in the NASA display system if the Generator output were in the form of manually prepared colored art work. For this reason, this entire class of display product types was dropped from consideration. As will be noted later in this report, artist-generated material may be utilized, if desired, in the recommended system.

e. Utilization of Diazochrome Materials

Although diazochrome materials are in some cases useful in the production of color displays, they cannot be used easily or economically when exposed to the restrictions delineated in the above paragraphs. In order to produce a color display, for example, several sheets of diazochrome, each carrying a separate color, would have to be register-mounted in a sandwich type arrangement and projected in a conventional projector or would have to be individually mounted and projected by three projectors or by one projector fitted with special optics. In the second case, the cost of necessary equipment is extremely high, and in the first case, the technical problems are immense.

Discussions with representatives of diazochrome manufacturing firms have indicated that perforated diazochrome material is not available in 35 mm size except by special order for which the cost would be prohibitive. Unperforated diazochrome material, however, would dictate the use of laborious manual registration techniques which would, at best, be only reasonably accurate. The problem of registration is further complicated by the tendency of diazochrome material to stretch while being conveyed through conventional processing machines. For these reasons, all system avenues relying upon the use of diazochrome materials were discarded.

f. Utilization of Translucent or Transparent Generator Outputs

Translucent (vellum) or transparent (acetate, plastic, etc.) Generator outputs were initially considered because of the fact that information can be transferred onto photographic film from either of these through a contact printing operation rather than through a photographic operation. It is apparent, however, that such contact printing not only dictates the use of expensive 8" x 10" sheet film, but also necessitates the use of a subsequent photo-reduction step to product a display product of desirable dimensions. For these reasons, all system avenues relying upon the use of translucent or transparent Generator outputs were discarded.

4. REFINED AVENUE ELIMINATION

Upon elimination from further consideration of the system paths discussed in the preceding paragraphs, twelve avenues still remained. Each of these was carefully scrutinized from the standpoint of technical feasibility, and as a result, the following six avenues were discarded for the reasons stated:

a. Avenue 312 was not retained because of the handling difficulty in separating and collating the negative film frames after the tinting process.

b. Avenue 315 was eliminated because of the fact that color-coupling film developers are expensive and not readily available.

c. Avenue 316 was discarded since the photo-polymer materials required for use are still in the research and development stage and are quite expensive.

d. Avenue 318 was not retained since an identical display product can be achieved more easily and in shorter time by means of the procedure of Avenue 334.

e. Avenue 321 was discarded summarily when it became evident that Kalfax material cannot be toned as can ordinary film positives.

f. Avenue 331 was eliminated for the reason that Polaroid material is too unpredictable for high density information loading.

5. DESCRIPTION OF REMAINING AVENUES

With the elimination of these system avenues, it was found that six avenues remained for further consideration and that all of these were members of the Synthetic Color class. They are illustrated in Figure 87. For each of these avenues, the original copy (or Generator output) is identical and consists of three separate "copies" - each containing the symbolic information that will appear in a particular color on the display product. The word "copy" as used here may refer to a type-written sheet of paper, an image on the face of a cathode ray tube, or some other device which conveys information visually.

In Avenue 333, the three "copies" are individually photographed onto separate frames of black and white reversal film. Each of the frames is then photo-processed in reversal fashion and the resultant positive film frames are mounted individually (or together if all three frames appear side by side on the same piece of film). Finally, they are projected onto the viewing screen, through appropriate color filters, by means of three separate projectors (or one specially constructed

SYSTEM PATHS REMAINING AFTER ELIMINATION

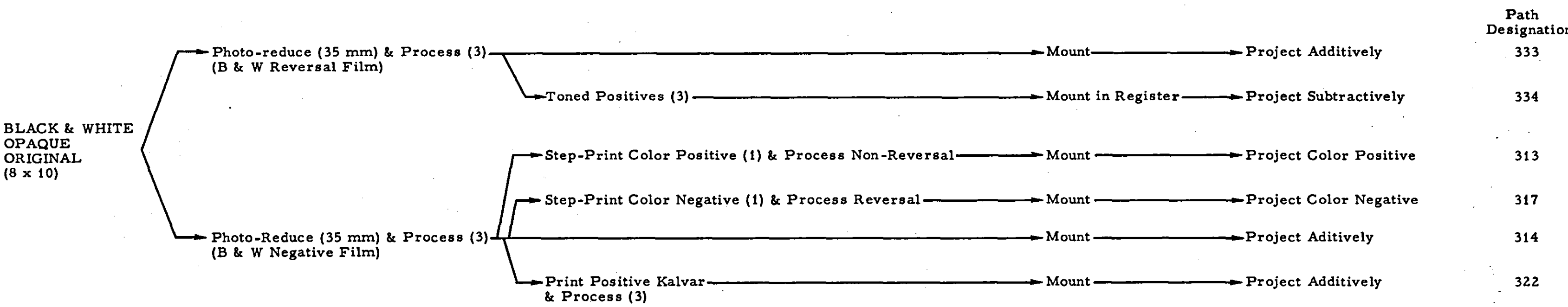

Figure 87. Remaining Avenues

projector in the case of the three frames positioned in one mount). The three separate colored images are added at the viewing screen to produce a three color display.

In Avenue 334, the photography is carried out in the same fashion as in Avenue 333. The photo-processing, however, contains one additional step in which a toner is applied to the film positive, thereby imparting color to it. Finally, the three toned frames are mounted in accurate registration and projected subtractively upon the viewing screen. Such subtractive projection is illustrated in Figure 88.

In Avenue 313, the black and white photography is again performed in the same manner as in the two preceding avenues, but in this case, a negative (or non-reversal) film is employed and the photo-process is non-reversal. All of the three negative frames thus produced are contact printed only only one frame of color film. (This technique will be discussed in greater detail in subsequent paragraphs.) Finally, the color film undergoes rapid non-reversal photo-processing from which it emerges as a single positive film transparency. This transparency is mounted in ordinary fashion and projected onto the viewing screen by means of a conventional 35 mm slide projector.

In Avenue 317, the entire procedure is the same as in Avenue 313, with the exception that the color film is rapidly photo-processed in a reversal fashion thereby generating a negative color image instead of a positive one at the screen.

In Avenue 314, the procedure is identical to that in Avenue 333, except that the non-reversal photo-process provides a negative color image at the screen instead of a positive one. Here again, additive projection is employed.

In Avenue 322, the black and white photography and photo-processing is performed in the same fashion as in Avenue 333. In this case, however, the three negative frames thus produced are contact printed onto Kalfax material which is rapidly processed in hot water or in a hot air blast. The positive Kalfax frames are finally treated in exactly the same way as were the resultant positive film frames of Avenue 333, and additive projection is again employed.

6. SYSTEM TIME AND PRODUCTION COST ANALYSIS FOR REMAINING AVENUES

For each of the six technically sound avenues discussed above, an estimate was made of the time required to perform all the relevant operations and the cost of materials consumed in the various processes. The curves depicted in Figures 89 and and 90 are based on these estimates.

Figure 89 represents a plot of system flow time versus volume of display product. It should be observed that the system flow time does not include the time required for the Generator to produce its output.

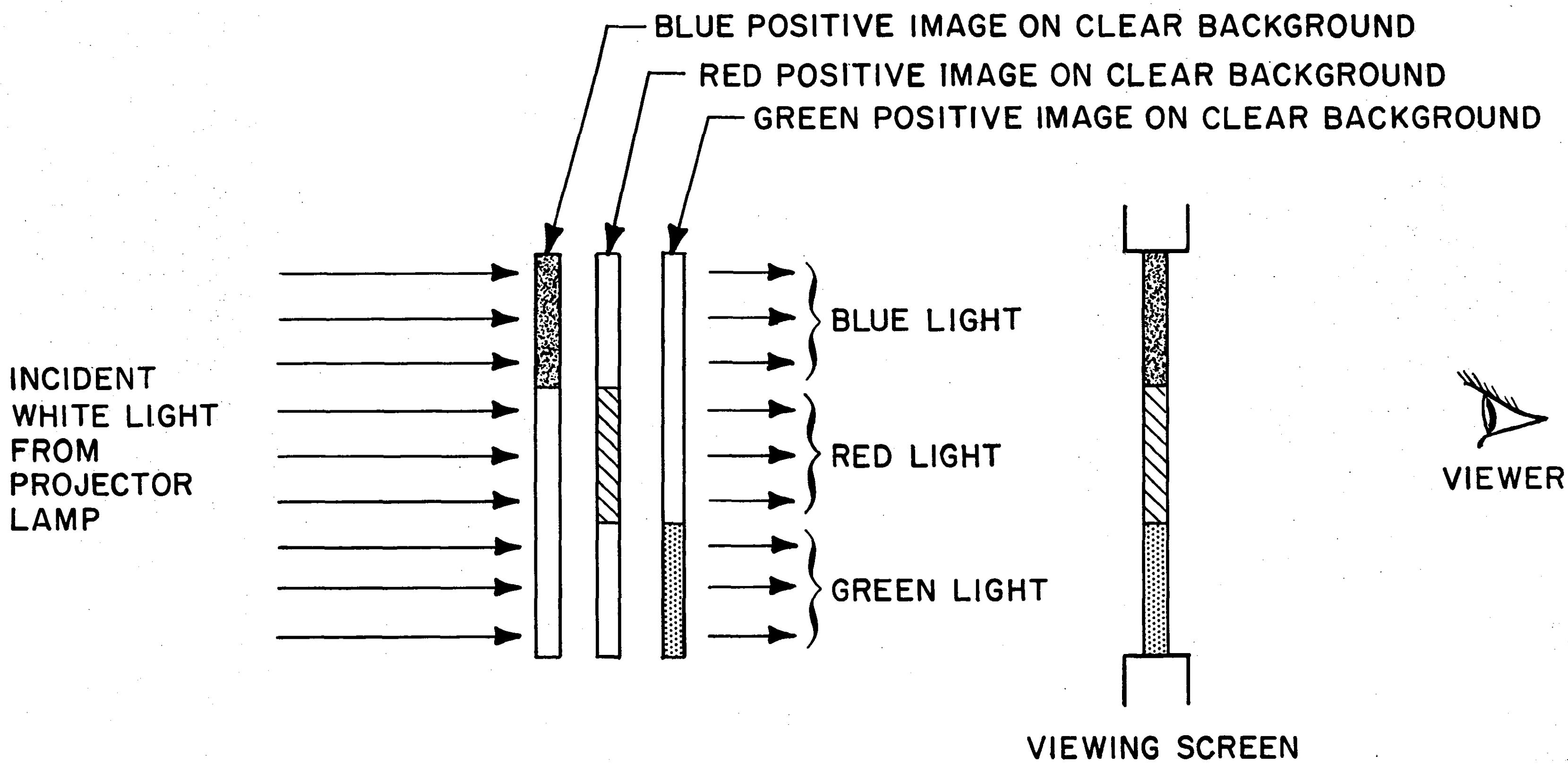

Figure 88. Subtractive Color Projection

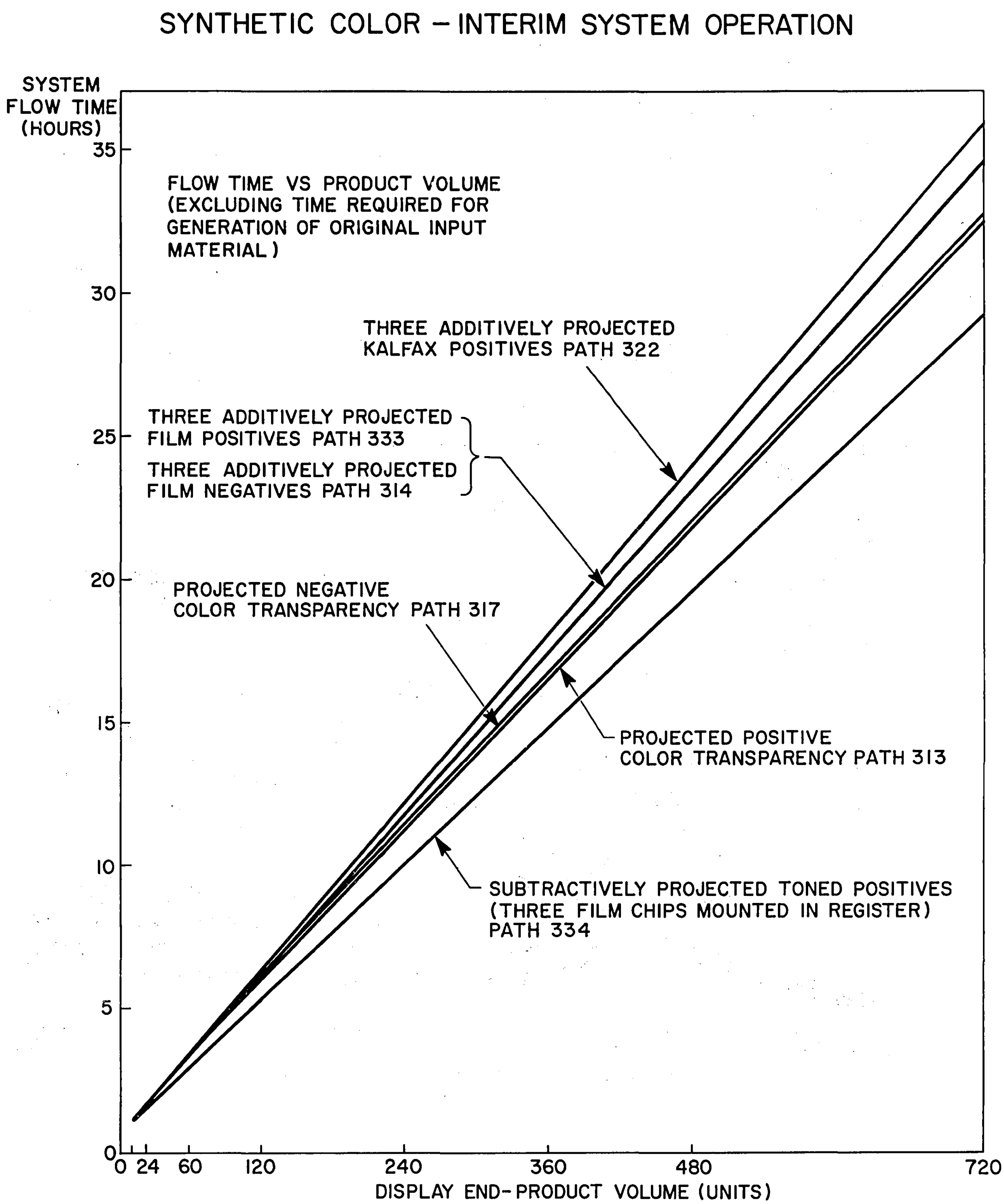

Figure 89. System Flow vs. Production

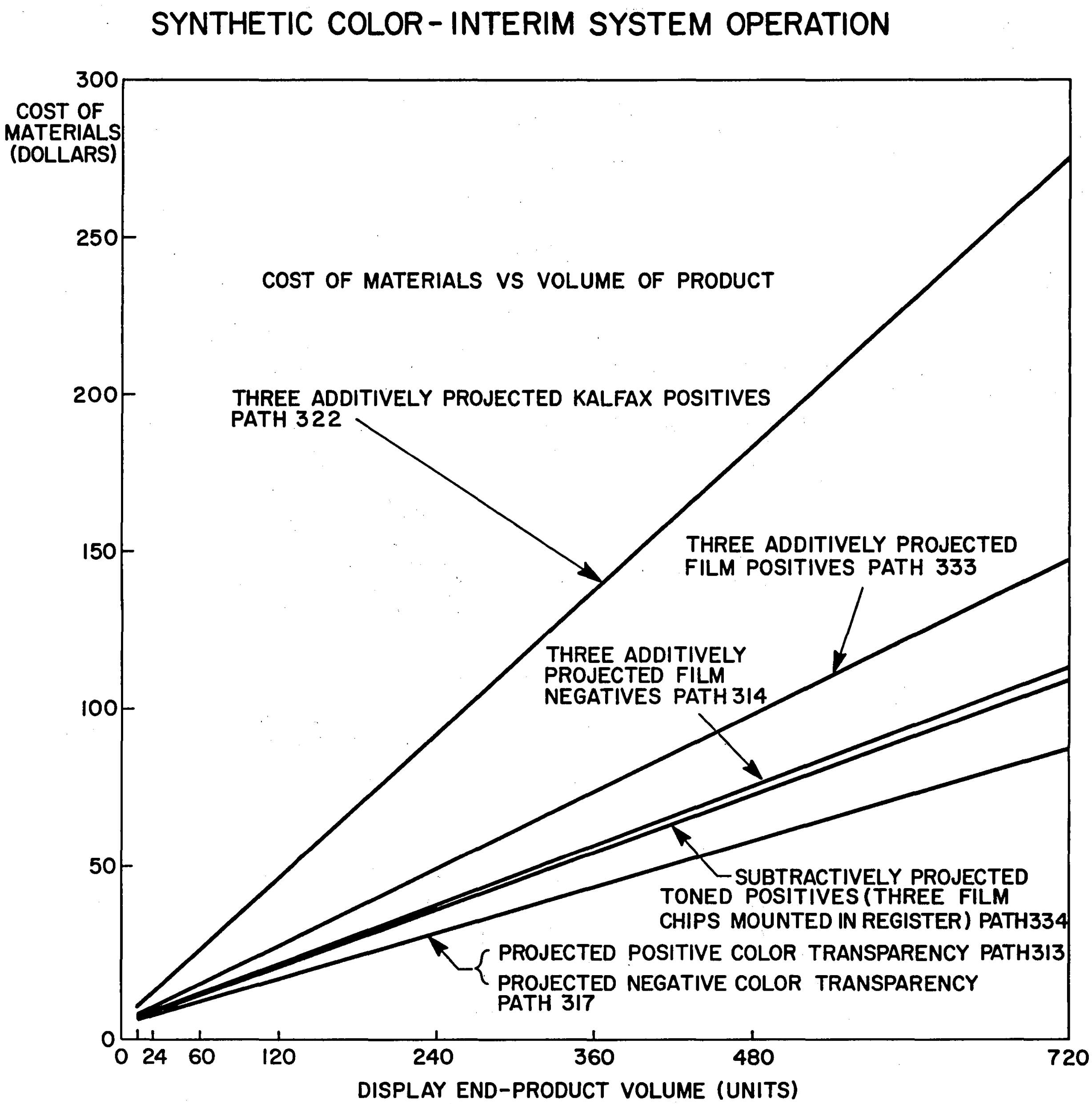

Figure 90. Cost vs. Production

Since this time is identical for all avenues, the relative position of the curves would be preserved upon its addition although the slope or steepness of any given curve would not be preserved. In any case, however, the generation time represents only a small fraction of the total system flow time. As can be seen from these curves, avenue 334 requires the least time while avenues 313 and 317 require next to the least time and are almost identical. More will be said later in this paragraph concerning technical considerations which must be weighed prior to accepting or rejecting any of these avenues.

Figure 90 represents a plot of cost of consumed materials versus volume of display product but does not include the cost of operators' time. As can be seen from the curves, the cost of consumed materials for avenues 313 and 317 is identical and is less than that for any of the other avenues. Here again, however, certain technical considerations must be weighed.

The technical aspects that must still be considered fall into two distinct categories. First, there is the matter of color film processing. Second, there is the problem of additive or subtractive projection.

In four of the six avenues, three are dependent upon additive projection and one is dependent upon subtractive projection. As noted previously in this section of the report, additive projection implies prohibitively expensive equipment. In the case of specialized projectors or projectors fitted with special optics designed to add the three projected images at the screen, the cost is on the order of $25,000 per projector. While this type of projection equipment does indeed find application, it is hardly advisable for incorporation into the NASA display system.

Subtractive projection technique, on the other hand, involves a problem which is of a technical rather than a financial nature. That problem is one of registration. In order that the color image on the viewing screen be an accurate representation of the system information input, it is necessary that the three product toned positives lie in correct spatial relationship to one another in the slide mount. Unfortunately, this cannot be done with accuracy unless the mounting operation is performed manually since there are no mechanical devices available to accomplish this. Such manual registration mounting is both time-consuming and tedious, and the registration achieved at the screen is strongly influenced by the diligence and perseverance of the individual performing the mounting function.

In the two remaining avenues, a photographic processing step for color film is required. Ordinarily this is a rather complicated and time-consuming operation because of the general desire to reproduce on film all the delicate gradations in color that are found in a given scene —including skin tones which are most difficult to capture on film. For the NASA display system, however, the color reproduction requirements are far less severe. Here it is necessary only to produce a color equivalent of black and white line copy in which there is no overlapping of color or gradations of tone. In this case, much of the complexity of the color processing is removed. Further simplification is obtained if the color film is processed in non-reversal fashion; that is, if a color positive image on the viewing screen is deemed desirable. Here, then, the final criterion for path selection is encountered. Since a positive color image is more easily readable than is a negative color image, and since generation of a positive color image implies the use of non-reversal photo-processing as opposed to the more complicated reversal photo-processing demanded by a negative color image, avenue 313 is recommended for use in the NASA display system. In addition, a rapid non-reversal color photo-processing technique developed at Ramo-Wooldridge is available for incorporation into the system. This technique will significantly diminish the required color processing time.

7. DISPLAY SLIDE, FORMAT AND SCREEN IMAGES

In any visual presentation it is both desirable and necessary that displayed information be presented in a clear and orderly fashion and the employment of well designed display formats (with appropriate symbols) is the first requisite of an efficient transfer system. With this consideration in mind, several tests to ascertain symbol size and density (in relation to the projected image) were conducted at R-W. These tests developed the facts that are presented below.

a) In a given screen size of six feet by seven feet (1/3 of the total planned screen size) the maximum size of the displayed character should be 1.25 inches high; however, with appropriately chosen symbols this can be reduced to one inch in height with an appropriate aspect ratio for the width.

b) Of the many type sizes projected, displayed, and studied, three prove most acceptable to format generation. These were Venus Medium Extended, Futura Medium Extended and Friden's Commercial type face.

c) Symbols to be displayed (e.g., triangles, squares, etc.) must match the face ratios of the type face being used.

Generally speaking, then, the determination of the proper symbol size for display presentation starts from the perceptual threshold for the stimulus under consideration. For visual stimuli of normal contrast the threshold is usually taken to be equivalent to a visual angle of 1' of arc. The threshold is then multiplied by a "field factor" which is intended to weight the threshold to account for conditions in the working environment which cause an increase in its value. These conditions range from a decrease in contrast ratio at the display screen from that of the laboratory setting in which the threshold was originally measured to a lessening of the visual acuity requirements for the observers. The choice of a field factor is an arbitrary one based on the quality of the display and the environment in which it will be viewed.

In the R-W study of the NASA format requirements certain other factors were also considered. These included:

a) A study of image size in relation to the maximum viewing distance (36 feet).

b) The use of color as a viewing aid.

c) Studies of appropriate color products (e. g., diazo color foils, photographic color film, etc.)

d) Considerations to insure flexibility in the format generating scheme (i. e., guarantee the fact that tabular data, Gantt charts, curves and other types of display products could be prepared efficiently and inexpensively).

All of these criteria can be met in the proposed system; however, the details of lens size and proper lighting should be re-examined in the environment in which the system will be used.

In summary, suffice it to say that the formats detailed in other parts of this report can be generated with little difficulty.

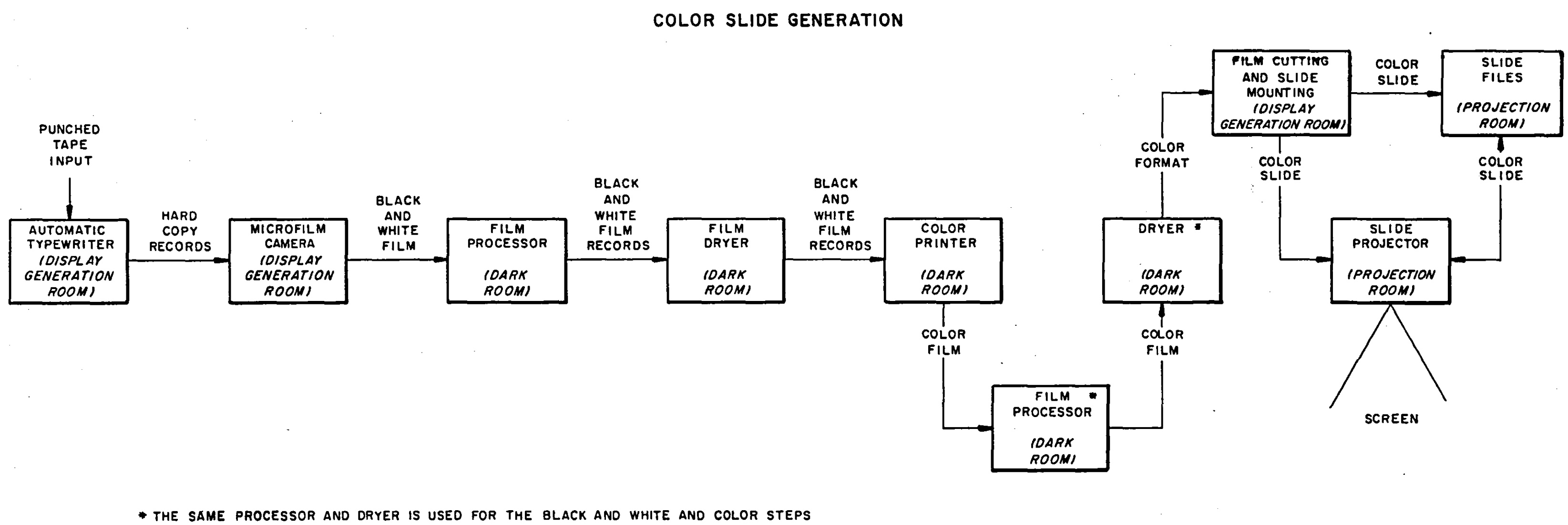

Figure 91. Implementation of Recommended System