An Integrated Analytical System

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Summary

The purpose of the Integrated Analytical System is to assist in the accomplishment of many functions which are now performed manually at the Air Force Eastern Test Range. This paper will describe the Range Operations Model (ROM) which is designed to assist the Range in test scheduling and the documentation of range support required by test programs.

The design of the ROM has as its main objective the integration of the various interlocking and mutually supporting factors that constitute the range planning and operating system. A major key to the effective operation of this system is the use of the computer to assist in the accomplishment of many of these functions. The computer will enable range personnel to better carry out their specific functions by performing faster, more accurate and more complete analyses. This role of the computer will be achieved by properly integrating the total analytical system into the range environment, so that the computer becomes a part of the man-machine system.

The Range now performs many difficult and complex functions. These functions include the analysis of user documents which detail the user needs for a particular program, the preparation of Range documentation to support various programs and tests, the preparation of a six month test schedule, a weekly test schedule, and even hourly changes to the daily schedule. In each of these functions, many different problems must be defined and solutions formulated. Range personnel are continually making decisions using their technical knowledge, judgment, intuition, experience, creativity and imagination. They must evaluate alternate range support solutions, resolve scheduling conflicts and make judgments consistent with the constraints of the specific problem. In all these functions, the ROM will have a great pay-off. The computer will be capable of storing and processing large amounts of data, and proposing alternate solutions to specific range support problems.

By providing rapid access to necessary information, performing thorough analysis, and making decisions that can be defined explicitly enough for a computer, the model is able to present an in-depth picture of the Range situation. The human judgment factor can then act on the basis of complete and accurate information.

When all modules are in use, the Range Operations Model will be an effective tool to decrease Range response time substantially by automatically handling the tedious detail and time consuming analysis.

Range Operations Model

I. Need for ROM

The Range has changed its character in response to the changing needs of the Range users. Originally, the Range supported aerodynamic missiles of limited range and data accuracy needs. Now the Range supports ballistic missile and space vehicle launches requiring very accurate data. For the past few years, the Range has been tracking satellites launched from other locations. This work is increasing at a rapid pace. As manned missions and satellite tracking become more important, the Range scheduling and documentation response time must be reduced.

Although the launch rate at the AFETR has decreased considerably in the past five years, individual tests have become much more complex. A multistage booster with a sophisticated space payload represents a very large expenditure of funds; consequently, the testing to ensure success is more exacting. The cost factor precludes reliance on repeated launches to ensure success.

Another factor that increases the test complexity is the world-wide nature of space launches. Other ranges and tracking networks are required in addition to the AFETR stations. Again, the problem of interfaces with these other organizations to ensure adequate support requires network simulations so that each group understands and can accomplish its portion of the overall tracking mission. Overall control of the tracking network may rest with the AFETR as in the Titan III program, or control may be under NASA with the AFETR acting in a subordinate role. In either case, the AFETR has to carry out network simulations to ensure a successful tracking mission. Both planning and operations must consider the changing role of the AFETR support under global support requirements.

II. Model Description

The ROM is composed of several interlocking but functionally independent modules, and will be capable of performing any or all modular tasks for one program or for many. The following is a brief description of these modules.

The Requirement Preprocessor. The Requirement Preprocessor maintains and updates the file of program requirements imposed by all range users (see Fig. 1). Data is entered either by manual extraction from documentation to punched cards, or by mechanized documentation when it becomes available.
The requirement data is accepted in a card format developed for convenience in manual extraction, or in a tape format supplied by the range user. The data is then sorted by program and ordered by functional requirement into a master requirement file suitable for efficient automatic processing.

The master requirement file is kept current by deleting, adding and changing requirements and programs as necessary. When requirements documents are mechanized, it will be possible to obtain an automatic comparison of a revised document against its predecessor with an identification and enumeration of the changed items.

The Program Support Analyzer. The Program Support Analyzer (see Fig. 2) will analyze all known requirements of a single program at one time. Any number of programs may be processed sequentially during a single module exercise. The product for each program is a detailed statement of one or more Range support solutions, and the degree to which the requirements are satisfied. The goal is to determine the optimum means for accomplishing the task and also to hold alternate means for substitution if needed to resolve scheduling conflicts. The input to this module is the program requirement from the master requirement file. Last-minute changes can be incorporated into the process directly without the necessity of rerunning the Requirements Preprocessor. The changes may be permanent ones that will be incorporated into the file at the next periodic update, or only be temporary for emergencies or hypothetical cases that will not necessarily affect the permanent solution file.

Each requirement is analyzed as an entity but in context with related requirements, program parameters, and Range constraints. Several proposed partial solutions, for example, metric instruments, may be entered into the model for evaluation against the corresponding requirements. However, all available range resources will be considered to permit a comprehensive analysis of both proposed and potential capabilities.

None of the satisfactory solutions is discarded. If documentation is being produced, the solution that is best by some prescribed standards will be annotated. Statistics on back-up solutions can be presented optionally. When formal documentation is not requested, the statistics on all solutions considered (including failures) will be output.

The solutions are filed by program, with the various items coded for easy reference by subsequent modules. The code word indicates (a) application of the item to each generated document (b) related items for each document (c) primary or backup solution (d) related test type (e) test number connection when applicable.

If there are any inputs missing or any requirements that cannot be met, the module will note the inadequacy. Where sufficient information is not available, the affected sections of the module will be skipped. The output will then state what is missing and what was left out. Where a requirement cannot be met, the output will include the solution that comes closest to satisfying the requirements.
As range support solutions to each requirement or group of requirements are formulated, the demands placed on other range resources by these solutions are determined. These demands become indirect requirements and are tabulated so as to be automatically considered in their proper contexts.

Effects of each successive partial solution are entered into the over-all solution as they are developed. The model is so arranged that a minimum of solutions will affect those preceding them. By the time the analysis reaches a particular section, all the generated requirements will be compiled along with the user requirements.

As the requirements are added to and revised, they are entered into this module. Affected subgroups are re-analyzed, and the solutions are filed according to the permanence of the change. Deficiencies are output in detail. If the requirements are in the form of a mechanized document, a listing of the changes will be output.

This module establishes a file of range solutions to all program requirements, and keeps it updated to reflect the latest requirements modifications, the various special requirements connected with individual tests, and changes in range capabilities and internal support loadings. Summaries are to be printed for all acceptable solutions.

Optional output abilities incorporated into this module permit using the module for operational planning, preliminary study and negotiation purposes. Detailed intermediate answers can be delivered upon demand to enable a Range representative to bargain with the user about excessive or marginal requirements and alternate solutions. The effects on current programs of changes in Range configuration and capabilities, or of temporary downtime on various instruments and facilities, can also be determined precisely by using this module with optional output.

A file option may be used in conjunction with the output option. The results of an analysis may be entered into the program solution file if the probability is high that the results under study will be of continuing interest. Otherwise, the output is printed for reference only.

The Program Support Analyzer will be developed by major functional phases in the order: trajectory, telemetry, communications, and then other phases after completion of the basic three.

Additional details on the trajectory and telemetry phases are contained in the following paragraphs.

**Trajectory.** The trajectory measurement analysis program is designed to accept the requirements for trajectory measurement from the range users, and analyze the capability of the range resources to meet these needs. These requirements will have been previously sorted by user, by type of requirement, and by start time of the requirement.

The first step in the analysis is to examine the several requirements and if necessary, convert to a common set of units, for example, feet for linear measurement and mils for angular measurement. Next, the trajectory tape is set for the first time point of the requirement start time.

Each metric instrument at each station is then analyzed to see if it applies at this time. The analyses include tests for beacon-transponder compatibility with the instrument, tests of signal-to-noise performance, and look-angle analysis.

After all the metric instruments at all the stations have been checked for valid application against the trajectory point at the time, the specific requirements for trajectory measurement accuracy are analyzed. Each requirement at this time is compared to the capability of the range instrumentation systems applicable. This is done either from a pre-computed Geometric Dilution of Precision (Gdop) tape or from normalized values of instrument capabilities for the different types of measurements. Thus, for each requirement, a statement can be made at the trajectory point on instrument coverage and accuracy, and on whether the requirement is met by each system.

The time control is then incremented, and the analysis proceeds with the next trajectory point until all the requirement times have been analyzed. The summary outputs of coverage are then used to generate support instrumentation requirements (such as communications and data handling) for later analysis.

**Telemetry.** Telemetry signals are broadcast from the missile and received on the ground over RF links. One missile or spacecraft may broadcast on many such links. Each of these links has one or more subcarriers that carry streams of data, and each subcarrier may in turn have additional data streams through signal encoding. As range users place requirements on the basis of individual data streams, the system must be able to handle requirements at this level. Therefore, one type of coding has been developed for the different signal modulation types and another coding developed for the different telemetry requirements.

Several different aspects of telemetry must be analyzed in the selection of instrumentation. From the ground antenna through the receiver, the link characteristics of frequency, power, modulation, and so forth, are of prime consideration. The particular requirement and the signal encoding are of little importance. Conversely, when instrumentation is selected downstream from the receiver, link characteristics are no longer important and selection depends on the type of signal and the requirement.
Therefore, the antenna-through-receiver portion of the solution for one requirement on a particular link is the same for all other requirements on that link if the times of the requirements are the same. This characteristic has been taken into account in the logic flow charting.

Some instrumentation, such as antennas, do not require that the number of inputs or outputs be counted. Other instrumentation, such as pen recorders, have multiple, but limited, inputs and outputs. Therefore, the inputs and outputs must be counted to know when one unit is saturated and another is needed. Still another type of instrumentation, such as cathode ray tubes, can handle only one input and can only be used once at any one time. All of these situations are provided for in the logic flow.

Support Documentation Generator. The complexity and number of requirements for support levied on the AFETR and its partners in the global range system dictate a need for a standardized, rapid, and effective system of documentation. Considerable progress has been made in expanding and standardizing the present documentation system, and it is to this system that the primary reference will be made in this paper. The jointly issued Manned Space Flight Support Requirements Documentation Manual (October 17, 1966) represents, however, one other specific effort towards standardization with the goals of:

a) Establishing effective communications between requesting and support agencies.

b) Providing an effective interface with the many support agencies involved.

c) Eliminating inconsistencies inherent in the use of several different documentation systems.

This approach also takes the initial steps of organizing page and data format so that eventual mechanization and automation of the documentation will be facilitated.

In the discussion of documentation, various references are made to documentation, standardization, mechanization, and automation. The following definitions clarify the usage of these terms.

Documentation is a formal presentation of program and test requirements, as well as the specific support planned or directed to satisfy the program and test requirements.

Standardization is the establishment of conformity in similar or mutually supporting documents.

Mechanization is the transcription of data from program and range documentation into a format and physical status (cards, tapes, disk or other EDP medium) suitable for (a) utilization of the computer for editing and correction, and (b) for output for reproduction or for electronic transmission.

Automation is the processing, by computer based Range Operations Model, of a program and test support requirements versus range capabilities. It represents the optimum coordination of man and computer rather than a completely automatic computer system.

One product is the development of ordered solutions, with subsidiary detail instructions, and supporting analysis, for incorporation in computer formulated documentation. This documentation can be output with a minimum of lead time and of man-computer interface except for the provision of sound basic data and for decision and evaluation at vital points in the process. Included also is post-action reporting and analysis, as well as the formulation of documentation for electronic transmission down range or to other ranges and agencies.

Mechanized Documentation. Logistics of keeping a requirements document up to date in many copies requires a monumental effort. The long time required to get a specific test requirement submitted, certified, printed, and disseminated is prohibitive for impending tests. Because of the delays involved in formal documentation, originators of test requirements sometimes wait until just before the test is scheduled to launch before sending in their test requirement by teletype message. This practice places a heavy burden on the range to work out its support directives just prior to the time the range support is needed. In addition, the range has found it difficult to prepare timely support documents not only from the aspect of lead times, but also from the lack of standardized presentation of requirements by the user.

Mechanization of the documentation process offers many benefits, although it does not solve basic problems such as the long lead time required for the certification of requirements and agreement on specific range support. It does (a) encourage discipline in standardizing and recording of document entries (b) save valuable time in document formulation, editing, correction, and publication (c) permit efficient electronic transmission of the document or excerpts (d) permit post-mission analysis that is effective to the degree with which test action is recorded and data available for electronic data processing.

The maximum advantage comes when automation is combined with mechanization.
The addition of automation permits a rapid range response to validated requirements with ordered alternate responses for bargaining or backup. The system can then respond on an item by item basis with a support plan and annotate this response with subsidiary support resources and amplifying information. Satellite routines can also provide cost and manning estimates in near real time. The same basic data, expanded with additional time-developed detail and analysis, can then serve as the basis for production of support directives in answer to all identified test items for specific tests. Basic data is continuously updated and new documentation can be produced on request to reflect these changes. The range then has, in effect, a "live" documentation system rather than a system of dated, printed and bound but outdated documents.

With the inclusion of all programs being supported by the range, scheduling and rescheduling becomes possible on a near-time basis. Automation includes the capability to analyze user requirements, range support and completed test actions, along with all of the subsidiary or "iceberg" factors (cost, manning, overtime, utilization statistics, and so forth). Document files can be utilized to analyze, in required detail, the range capability to meet each documented requirement as well as to present the resulting information in required report formats. Documentation created can be (a) output on multilith mats for printing or (b) printed in limited number directly by the computer system printer or (c) disseminated electronically to designated recipients, or finally (d) selectively presented to interested users by means of cathode display or remote devices. Automation would of necessity leave many key decisions to be made by responsible range personnel. Automation would, however, significantly assist in the clear presentation of the data and alternate solutions to the personnel involved, relieve personnel of much tedious analysis, and provide a means of rapidly and effectively implementing decisions made. In addition, the effect of these decisions on other aspects of range operations can be evaluated. Time savings at all levels of operations would be significant.

Document Preparation. The Support Documentation Generator (Fig. 3) will, in summary, draw on the information in the range solution file to prepare support plans, support directives, range schedules, and other documents. Originally, the formats will duplicate, if practical, those in use today. Input, in addition to the solution file, consists of format modifications, nonstandard comments, and other pertinent items not generated by analyses of Range responses. Large blocks of nonanalytic material will best be handled outside of the model as standard operating procedures, or inserted literally as completed sections or entries.

FIG. 3 SUPPORT DOCUMENTATION GENERATOR

The module extracts information pertinent to the requested document from the file by item coding. This material is arranged in the specified format, modified by change orders, and combined with non-analytical material. Only the preferred solution is used for format documentation. Alternate solutions can be assigned preference at documentation time.

Previously generated documentation is changed by declaration to this module or by a requirement change and re-analysis through the Program Support Analyzer. Changed pages or completely revised copies can be presented in a variety of displays.

For support plans and support directives it is anticipated that automation and evolution will cause changes toward a single, up-to-the-minute document. In this consolidated single document, the level of detail required for the support plan will be expanded, as detail becomes available, until the level required by the support directive is obtained. Thus, instead of one dated document for the support plan and one for the support directive there will be a continuously updated and expanding document that will contain the best detail available on any current date.

Scheduling. The purpose of the Weekly Scheduling Module (WSM) of the ROM is to provide Range Scheduling with a near-real-time capability to identify scheduling conflicts. A scheduling conflict is an attempt to use a range resource which is not available or which is needed for other users. The resource may be unavailable because of its prior or duplicate commitment to another test, because of
scheduled downtime for maintenance, limited shift manning reasons, or because of a breakdown of equipment.

An ability to identify such conflicts allows them to be resolved ahead of time, avoids costly delays and, in some cases, prevents potentially dangerous situations.

With the WSM, Range Scheduling personnel can input test schedule data to a computer where it is processed by a conflict-identification subroutine. Any conflicts thus identified are reported back to Range Scheduling for resolution. Test action data (run, scrub, delete) is also an input by Range Scheduling. The input is added to the computer-stored test schedule data for historical purposes and report generation. Additionally, the computer will provide printouts of the test schedule for either a particular day or an entire week. Scheduling of tests and/or downtime may be simulated to find their best possible place in the schedule.

Interim Scheduler. This ROM module will be an expansion of the concept of the present operational program. Specifically, it includes:

a) A permanent input support directive data bank.

b) More detailed identification of scheduling factors and range resources.

c) A more flexible conflict identification routine.

d) Historical (and statistical summary) reports to meet specific needs, such as equipment usage, overtime conflicts and conflict resolutions, etc.

In summary (see Fig. 4) when an item is entered on the test schedule, a support directive number and a test time (Zulu time) are given. The computer program references the appropriate support directive on a disk-stored file and extracts the information pertaining to resource utilization. It also converts the test oriented times in the support directive to Zulu time. All tests for a given day are thus processed and the program then checks each resource for scheduling conflicts. Each resource is also checked against the stored downtime and range status file for conflicts. Any conflicts identified are printed out at Range Scheduling for resolution. The weekly test schedule is retained in the computer on disk storage for printout or updating as required. Test action information may be added to the schedule on an item-by-item or daily basis. Because of the more complicated processing and computer storage requirements of the interim scheduler, only two weeks' schedules are retained in active memory. These are the current week and the week following.

Follow-On-Scheduler. The follow-on or expanded scheduler is actually an open-ended project to add to the interim scheduler those refinements which will make it a more complete scheduling tool. One of the more immediate improvements will be to add more range resources to the list of those considered in conflict identification. Another will be to expand the analyses of what actually constitutes a conflict on a resource-by-resource basis. Orbiting vehicle and satellite ephemeral data will be incorporated in the program for selecting the best tests to schedule. Warm-up and calibrate time data will be refined so that individual resources and individual circumstances can be considered.

The follow-on program can also be expanded to include conflict resolution by searching for alternate resources and/or alternate schedule times for tests of lower priority. As other modules of the ROM are developed, the need to maintain manually some special scheduling data files such as the support directive files will be eliminated since they will be generated by other portions of the system.

Advance Scheduler. The Advance Scheduler (see Fig. 5) organizes the activities of all user programs on file into an advanced time sequence relationship. A six-month range forecast is prepared in this manner. Ship scheduling, aircraft scheduling and other activities requiring long lead times are analyzed in relation to the established support dates.
This module can project a schedule as far into the future as information exists. However, the period requested will usually be six months to a few years. The term of analysis is specified at the time of use.

Gross program conflicts, major problems caused by tight launch windows, time constraints in positioning support ships and aircraft, major repair downtimes, and other incipient scheduling problems are anticipated to allow adjustment. Minor test scheduling is not included except where pertinent in the first few weeks.

Direct output of a schedule and implementation of schedule changes can be accomplished by augmenting this module and providing appropriate hardware.

Report Generator and Reports. Questions regarding range utilization are frequently of concern to commanders, managers, operations and other personnel. How many tests of what type were completed over some given time frame? How many tests were scrubbed and for what reason? How much range time was charged to which user and what range equipment was required? How much personnel overtime was required in a given time and was it reimbursable? What tests were not supported and for what reason?

Such questions are of continual interest and for a variety of reasons. Accounting, improvement of performance, planning, evaluation and over-all management are examples of fields of interest. Consideration of these questions and others will be incorporated into the ROM Report Generator (see Fig. 6).

This report generator module will utilize the ROM coordinated data accountability concept as a basis for the preparation of range reports. In addition, historical or statistical studies from the test results, schedule action and other data stored in ROM data bank will be available.

Such a report generation concept is a logical part of the ROM, with computers providing rapid response to various types of inquiries.

III. Operational Methodology

General Summary. It is structurally possible for a set of requirements to be processed completely through the Range Operations Model at one time; however, it is not anticipated that this will occur often. Instead, only those modules that give the products desired at the time of the run will be used. (See Fig. 7). Programs can be run through the Program Support Analyzer and Documentation Generator individually or in series of any length. The scheduling modules, of course, treat all tests in their time periods. Any assortment of modules and programs can be used in a single computer run. Computer availability and operational constraints will dictate the length of the program series.

When Range support is first requested for a test program, the request usually is far enough in advance that all requirements are not definitely known. Therefore, the first entry of the program into the model will be through the Requirement Preprocessor to the Support Analyzer. The complete output will be requested, and incomplete results will not be filed.
The results of this run will be a detailed basic analyses of the Range capability to meet those requirements levied at this point. A list of support deficiencies and a list of missing requirement types and information will also be generated.

With this output, the Range can request further specific information from the user program, negotiate on various requirements and consider special actions to provide requested support. This process may be repeated several times at intervals of days to several months, depending on how rapidly the user solidifies his requirements and specifications.

When sufficient stability is achieved, the alternate solutions will be filed and subsequent changes reflected into that file. From this time on, a document based on the current support status may be output.

As the action time approaches, specific test requirements will be fed into the Analyzer, modifying the program file either permanently or just for that test. When the time arrives to publish one of the support directives associated with the program, the document is produced by the Documentation Generator.

If there are more changes at this time, the Support Analyzer is run in conjunction. Subsequent modifications are put through both modules to generate support directive revisions.

Periodically, the Advance Scheduler will be run, using all the programs predicted to be active in the desired time span. As program real dates and launch windows are established, they will be put into the model time reference and used in the scheduling.

Similarly, the Weekly Scheduler operates on all tests in its time range. A given program will appear first in the Advance Scheduler and progress step-by-step into the Weekly Scheduler as its dates get nearer and its details become known.

A typical run through the model may include one or more programs through the Program Support Analyzer only; or include several modified programs through the Program Support Analyzer and the Documentation Generator for support plans. Several programs will have additional test requirements processed into support directives. The Weekly Scheduler will then create next week's schedule. Rescheduling will most probably be done in single entries using computer interrupts.

Operation of the Interim Scheduler. Basically, the operation of both the interim and follow-on schedulers is similar. On each Wednesday, when the test schedule for the following week is prepared, test schedule requests in their various forms are translated by scheduling personnel to loading forms. These forms are 80 column card creation sheets for the various tables. The forms are sent to a card punch and translated into data cards. A control card is punched which requests a conflict identification analysis by the computer. All cards are then input to the computer by means of the scheduler's remote console. The computer program calls up the various stored data as needed to operate the program and identify any conflicts. The weekly test schedule data is stored for future reference. A printout of any conflicts identified is sent from the computer to the remote console at Range Scheduling. If there are any conflicts, they are resolved by the Scheduler; and new data cards are punched to reflect the changes. The new data cards, with a control card, are input to the computer again for another conflict identification analysis. This process is repeated until the schedule is free of all conflicts. Range Scheduling then punches a control card requesting a schedule printout and inputs this card to the computer. The program uses the weekly schedule data stored earlier to prepare the printout. The schedule can be printed out at other remotes, such as at Operations Control, as well as at Range Scheduling. Additionally, the schedule data can be output directly to teletype machines for downrange distribution. Output at Range Scheduling can be in multiple copies or a multilith mat for reproduction.

Changes to the weekly schedule are handled in a manner similar to that above. The big difference is that the bulk of the schedule is already in storage and only a few data cards need be entered for each change. Thus, response time will be considerably shorter for schedule changes than for the weekly initial input. When a schedule change affects only one day, a printout can be requested for only that day.
Test action data is added to the weekly schedule by means of preparing the proper loading forms and then punching cards from these forms. These data cards and the appropriate control card are input to the computer where the test action data is added to the weekly schedule data. Printouts of the day's schedule with the test action data can be provided as above for the regular schedule.

Each day, computer operations personnel will have the computer check on the completeness of test action reports for the second previous day. For instance, on Wednesday, the previous Monday test schedule will be checked to assure that each test has had some test action reported. If some test action reports are missing, the computer program lists these out at Range Scheduling. Range Scheduling then provides the missing reports. Once the day under consideration has a complete record, the computer provides a printout of the schedule for that day for filing. The computer also copies that day's schedule with its test action reports on tape for a permanent historical record. That day's record also remains in active computer storage for recall and printout until the next Wednesday when a new week's test schedule is read in, erasing the old week's schedule.

Any of the data tables or files stored in the computer can be updated and/or printed out as desired. Remote consoles at various locations can be used to input and print out the data.

IV. Computer System Operations

General. The operation of the ROM can be visualized by reference to Fig. 7. Since the ROM includes many program modules and the data to operate these modules in an interlocking and mutually supporting system, the first requirement is to designate to the system exactly what is required for one "RUN" or specified series of operations. This is done by means of a control entry that presents information to the Applications Program/Data Control Module (Ring 1) as to:

a) Module or module sequence desired (Ring 2). Example: Interim Scheduler followed by Report Generator.

b) Specified limiting parameters. Example: Operate Interim Scheduler for 7 days starting with November 7, 1966, and for Metric and Telemetry only.

c) Administrative data. Example: Date and time of run and requesting office.

The Applications Module with its guidance from the control entry via the Line Control Program can then call in the specified program module(s) from Ring 2 into the Operating Module (Ring 3). Similarly, the data to operate the selected module is made available from the Data Bank (Ring 4) and the system is ready to run.

The simple outline given above masks the complicated organization and interlocking of the Line Control Program, the Applications Routine, the Program Module, the Data Bank, and the man-machine action that may be required to actually arrive at "Ready to Run" status. To give a more detailed appraisal of the operation of the ROM, an outline follows which uses for an example the operation of the Interim Scheduler.

Interim Scheduler Computer Systems Operation. Implementing the Interim Scheduler, a system which identifies conflicts in range scheduling with requirements of immediate response and remote processing, requires new solutions to data processing problems. Problems that require extensive evaluation must be solved and the optimum method must be found. The solution to these problems must be predicated upon their being applicable to the maximum degree to other modules as they are implemented, recognizing that the Interim Scheduler is the lead module for ROM development. Of primary importance is the provision for such techniques as:

a) Organizing for "system" call-up of one program (the Interim Scheduler) and its data out of many programs and a large data system.

b) Elimination of sorting data files prior to computer analysis.

c) Efficient storage and retrieval of related data records.

d) Inter-relationship of data files.

e) Obtaining an acceptable processing cycle.

A processing cycle measured in seconds cannot afford traditional sorting techniques. Data organization and integration must be devised which reduce or eliminate the necessity for sorting and in other ways provide efficient retrieval. The design of the over-all system is a determining factor in the response time to a request for conflict analysis. The ROM planned data organization and file maintenance procedures are designed to place special emphasis on turnaround time by providing these techniques. Many factors will influence the total time; however, normal requests can be processed in seconds.

The design philosophy of the range scheduling system module of the ROM was to segment the problem and isolate these new data processing demands and package these functions into a service module. This module is referred to as the Applications Program/Data Control Module and provides a variety of services and facilities to the specialized application routines.
Normal data processing functions such as file maintenance, report preparation, loading and unloading data sets remain as separate processing routines used in conjunction with the control module.

V. Data Organization

Need for a Data Management System. The current need is for a Data Management System that encompasses (a) adequate identification (b) efficient and accessible storage (c) timely survey and update (d) responsive retrieval and reporting capability (e) and reasonable suitability for direct access. For the ROM, this system must include provision for storing programs as well as data. This provision is necessary so that the system can, under control of the Applications Program/Data Control Module, call from the same data bank both the operating program (ROM module) and the data required by the called program. This means that the two - the program and the data -- must be designed to the same operating specifications. Otherwise, a time consuming retrieval system must be utilized.

System Design. The design of a Data Management System is compounded by the fact that there is no single user. The needs of all -- Commanders and managers, engineers, analysts and programmers, administrators and clerks -- must be satisfied. In turn, these myriad users are split by many organization lines. For some of these users a list oriented system is adequate. In such a system the identification of data items is determined by reference to a dictionary which translates format and table locations into identification. For others (such as ROM), a "Data directed" system is often needed. Here the data entry, through suitable coding, permits data manipulation and identification without excessive reference to a dictionary.

These users provide two basic points of view, in addition to those of command or company. The technical point of view (which in most instances is that of engineer, analyst and programmer) is basically an internal point of view, concerned with detail, detail correlation, the computer, computer word allocation, programming, and analysis. On the other hand, the administrator is more likely to have an external point of view. This user thinks about data, but generally with its broad synthesis or interpretation to support his problems, tasks, and operations. It is important to remember these distinctive points of view because we often fall into the trap of exchanging comments without realizing that they mean entirely different things to different people. ROM must respond to both points of view.

Data Files. The way in which the Data files are structured has important effects upon all functions of the system. There is a danger, in Data Management Systems, of basing the system design upon preconceptions of the contents of the Data files and the required file-processing operations. The difficulties that arise when these preconceptions are wrong (or only temporarily valid) have been experienced by many. There have been several approaches to introducing versatility in system operations to adapt to the problems of file structure; they all involve close coordination, a high degree of cooperation, and a flexible and responsive file structure concept.

In the development of file structures a sharp distinction must be made between the structures in the Data relevant to the user, and the organization and manipulation of the Data in the computer. The languages used to communicate with the computer should not be limited to terms associated with the Data processing organization within the computer system. These languages should permit the flexible expression of Data in terms that the user would naturally and relevantly look for in the Data. This does not imply that the language should be English with all of its redundancy and shades of meanings, nor a highly sophisticated language. It does mean that a compromise must be reached that permits memory association for the non-programmer user, adequate precision for computer interpretation in its input routine, and some consideration for economy of Data storage.

VI. Operational Savings and Improvements

General. The broad subject of operational savings and improvements is one which must be discussed in generalities. This is particularly true in comparing the ROM with the present Range System. Such diverse but pertinent factors as (a) change in response time (b) increase or decrease in cost (c) change in manpower requirements (d) improved product reliability (e) improved growth potential must be considered. In addition, these factors must be viewed as they apply to the whole spectrum of range responsibilities from planning documents, through operations and real time control, to post-test and statistical analysis.

Often, in analyzing seemingly heterogeneous factors, some common denominator (usually money) can be found to simplify the analysis. In the present case this does not work, since it is impossible to answer such questions as: How much money is realized by saving three days in test directive preparation? How much is it worth to be assured of a conflict-free test schedule? Is a day saved in support plan preparation worth as much as 10 minutes saved in processing a Test Schedule Change?
Lack of such a common denominator requires that the individual factors be considered separately or that some subjective analysis be attempted. Detailed coverage of operational savings and improvements visualized for the ROM in specific areas are contained in the appropriate sections of this paper. A subjective analysis of the overall ROM is given below.

**Analysis.** There are four main functions with which range management must be concerned and to which the ROM can be applied. These are production, analysis, theoretical configurations, and task management.

**Production** refers to the preparation of a product in response to some requirement levied on the Range. The product might be a support plan, a support directive, test schedule, or post-test analysis. Production refers to both the initial preparation and the subsequent revisions.

**Analysis** is the process that determines which range resources can do the job, selects which ones will do the job, and evaluates how well the job was done.

**Theoretical configurations** allow the simulation of theoretical or proposed changes in order to assess the consequences without actually making any physical changes to the system. This type of simulation is especially useful in planning AFETR activities.

**Task management** refers to the overall responsibility of management to get the job done in the most efficient manner. It requires that information be made available to management; it requires decisions to be made; and it requires control to be exercised to implement those decisions.

With the present Range System, the available resources of men, money and, the most important, time -- are allocated largely to production. The remaining functions of analysis, theoretical configurations, and task management must be accomplished with leftover resources. (See Fig. 8). The trend towards more complicated Range programs, resulting in more complicated requirements and increased production time, only make the picture look worse. However, the use of the ROM will allow reallocation of the available resources to bring the four functions into proper balance.

Within each category, such as the use of operational planning to analyze resource usage, or the production of a document, consideration was given to many possible changes. These changes were in response time, cost, manpower requirements, product reliability, and growth potential. Some of the considerations were favorable to the ROM; the ROM was rated better than the present system; and, in other cases, considerations were unfavorable to the ROM.

The overall evaluations indicate that the ROM is an improvement over the present system for all the listed phases of range responsibilities. In some instances, these improvements are paid for by, and come about in spite of, increases in cost and manpower. However, the trend towards more complex Range operations has been taken into account in the evaluations. The question in the near future may not be, "Will the ROM do the job better?", but rather, "Can the job be done at all without the ROM?"

![Fig. 8 Available Resources](attachment:fig_8.png)