INSTRUMENTATION SYSTEMS ENGINEERING MANAGEMENT

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Summary Examples of practical, effective, tools for the management of systems engineering have been presented. The usage of those tools is further examined. Management, as used here, pertains to the technical management of the systems engineering Job. The techniques described are structured around a medium/large data transmission/ acquisition/processing system. The principles can be applied to other systems also. Fundamental to the discussion is the use of models, criteria, and selected data for evaluation which results in decisions and program direction for systems optimization.

Introduction For this paper the “program” will be considered to consist of the following phases: conceptual, preliminary design, production design, qualification testing, and usage. The conceptual design phase includes the trade studies required to demonstrate feasibility and documenting the functional requirements and design constraints to which the equipment will be designed. The preliminary design phase includes the selection of the design approach to be used, confirmation of the requirements and constraints, and demonstration that the design can be expected to be a workable, producible design. The production design phase culminates in the release of drawings to the production factory, i.e., it evolves the preliminary design into the production design and uses an engineering model appropriately “similar” to the production design to develop engineering test data which demonstrates the adequacy of the end item/system under the environments/ usage to which it will be subjected. The qualification and usage phase are self-explanatory.

The model used in the example was a simulation model which can be programmed for manipulations on a computer. Such a model or some other mathematical model of a system (or circuit or environment) is typical of the models used for engineering purposes. There are other types of models which may also be used effectively during a systems engineering or design/development program. There are mechanical models, dynamic models, thermal models, etc. Models may be used for analyses/test purposes or may be used as performance models. The latter is used as the model to which the performance is compared as a basis for evaluation. The model specification is used to describe a model in terms of measurable performance parameters. It is necessary to have a model or a set of criteria with which we can compare the system, to determine the degree of success of the operation. A schedule is one example of a “model” to which the actual accomplishments of milestones may be compared as a relative measure of merit.

The model will generally be in a state of change - with refinements and corrections being applied during the evolving development/test/ usage phases of the system. True, some models may befirm or optimized rapidly to the point of becoming a rule or standard against which performance may be measured. But generally as data are obtained, by analyses or test, the detection of biases, offsets, inconsistencies, etc. , will be identified and the model corrected accordingly. In other cases, the model may change abruptly and drastically when situations change or anomalies appear. For example, the mission plan (model) for Apollo XIII was changed drastically to fit the circumstances of the time. The new emergency model was then further corrected and altered such that it could be followed to its ultimate satisfactory conclusion.

A model of a communications system provides the obvious and commonly used means for determining where the resources should be applied to obtain minimum acceptable performance in terms of SIN requirements. The model plus a knowledge of obtainable parameter values in the various equipments, cost of available hardware, risk and schedule of new design/development efforts, etc. will permit trade studies to be initiated, evaluated, and decisions formulated and implemented. Similarly, error models developed for data acquisition/ processing systems provide a tool for determining the large error contributors, thus permitting the maximum effort to be expended in reducing same. Or, conversely, the two previous examples preclude expending effort on minor items which could not resolve the problems alone in any event.

The important point is that regardless of the nature or form of the model, it is necessary to maintain success criteria by which the program may be evaluated based on all the pertinent data available. The evaluation will result in decisions tempered by the managerial and technical skills of the manager or management team using the other available inputs to provide program direction. The output of such a systematic approach should permit the continual optimization of the systems engineering task. Figure I is a schematic representation of the approach.

Essential to the use of a model is the acquisition, storage, application, and correct interpretation of the pertinent data. The dilemma with which the project engineer or program manager is confronted is depicted in Figure 2. The problem is to select the meaningful and pertinent data and properly apply same to direct the program to a satisfactory conclusion. Even during the conceptual phase when it might be suspected that little data have been generated, the importance of data management should not be overlooked. In fact, this may be the most critical time for effective data usage, since this phase has a large leverage on the- course of events which will follow. The proper usage of the source data should assist in establishing technical feasibility and prioritization of resources to accomplish the task. A computer augmented system can provide historical data on the repeatability of the critical parameters, test method inadequacies, production problems, and hardware weaknesses or troublesome areas.

As the development cycle progresses, breadboard and engineering test data may be evaluated against the results expected from source data and analyses. These data should be treated separately, since they are generally acquired under unique conditions and not necessarily acquired from the configuration of the final design.

Upon production of the baseline configuration, units will be placed in test. These test data may be used as examples of the performance of the equipment during subjection to environments. Equipment tendencies may be identified which will form a basis for future decisions on special tests, flight readiness, etc. Production and test of flight hardware will establish the data baseline for the program. Experience has shown that samples of one to five units will identify test equipment/test method differences. Ten (10) to twenty (20) units will identify equipment characteristics and permit the establishment of repeatability limits and provide a baseline for observing trends which may be predicting equipment failure. At this time the computerized system will begin routinely rejecting or identifying for further test/evaluation equipment which is faulty but would otherwise go undetected into a flight mission if examined on a go/no-go basis at each individual test site. Such faulty equipment would quite likely fail upon subjection to the flight environments with undesirable-to-catastrophic results depending upon the nature and criticality of the failure and its effect upon the mission.

Perhaps less dramatic, is the application of the program to detecting recycles of equipment because of failures/out-of-tolerances. The program can identify the failure rates and modes at the various test sites such that an investigation of the causes and cures can be conducted. Further, it can identify problem parameters or critical design areas or test methods for investigation and resolution. It also permits standardization of data from test site to test site since any biases or differences inherent in the test sites can be normalized or accounted for. Cost or other sensitive data may be included in a normalized or relative sense which does not allow it to be utilized by inappropriate persons. Schedules and flow times actually experienced during the usage phase may be documented for use in predicting schedule/flow times of various equipments/systems. These data provide information on ordering lead times, scheduling of design changes or modifications, shelf-life posture, long-pole items or activities, etc. Changes in equipment/test parameters may also be time correlated permitting further research into the cause for the change, such as test equipment repair or calibration, procedure changes, operator changes, equipment changes, supplier changes, etc.

The evolution and usage of a program such as ISMAP is essential for the efficient development and performance analysis of the communications system. ISMAP may be considered a model in itself, a portion of a more complex model, and an analysis tool. The model applications provide the systems designer with a method for defining the expected system performance during the mission under both nominal and abnormal conditions. The ISMAP permits a systematic evaluation of the ground station support posture. It provides quantitative assessments of the margins/risks during the various phases of a flight profile within the limits of the uncertainties. Those uncertainties may be treated as random or systematic errors to permit realistic judgment based on mission requirements and acceptable risks. The capability of such a program to predict signal levels has been demonstrated by comparison of the predicted levels to the actuals taken from flight data.

It should be recognized here that the examples presented here are not foolproof and all inclusive - rather, they are tools which may be used to improve the efficiency of the systems management process. The concepts presented were developed because of recognition of a need or of a deficiency in the existing (at that time) procedures. They were implemented to provide a more systematic and quantitative method for utilizing the myriad of data available in various forms and locations. In combination they represent a systematic approach to system development management. They do not (and were never intended) to replace the need for technical skill, experience, and judgment by the project engineer/systems designer, but rather to allow the decisions to be made based on all the pertinent data available. The situation is depicted in Figure 3 and this solution in Figure 4. Technical expertise and decisions based on insufficient or misleading or misconstrued data cannot be expected to optimize the direction which will be given to the program. Further, when adequate data are available for backup, arbitrary and argumentive decisions or initiative decisions are avoided or minimized. The data may also indicate what additional data/tests are required to preclude premature decisions.

The effectiveness and applicability of the techniques presented must necessarily be determined by the cognizant managers of any given project. The concept of systematizing data for the optimization of decision making and technical direction is valid for projects of any magnitude and complexity.

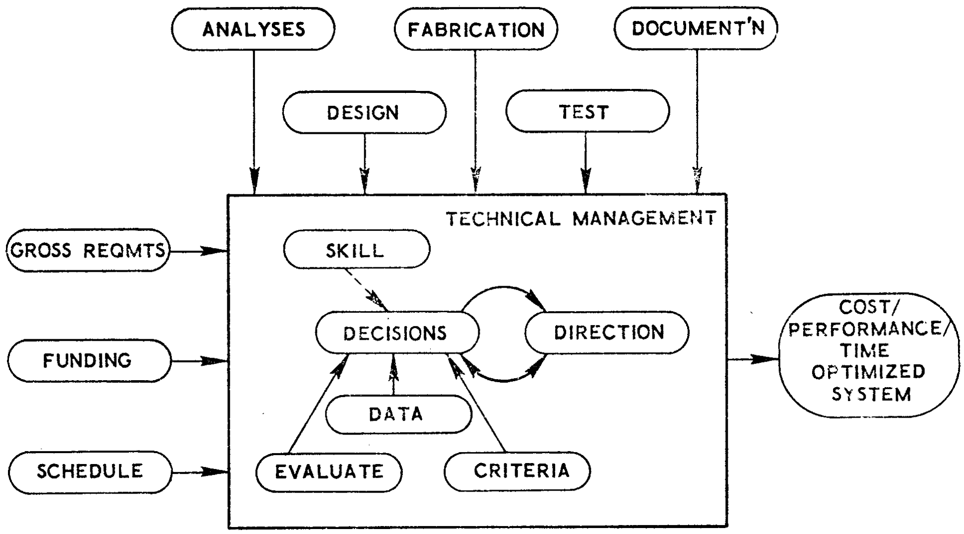

FIGURE 1

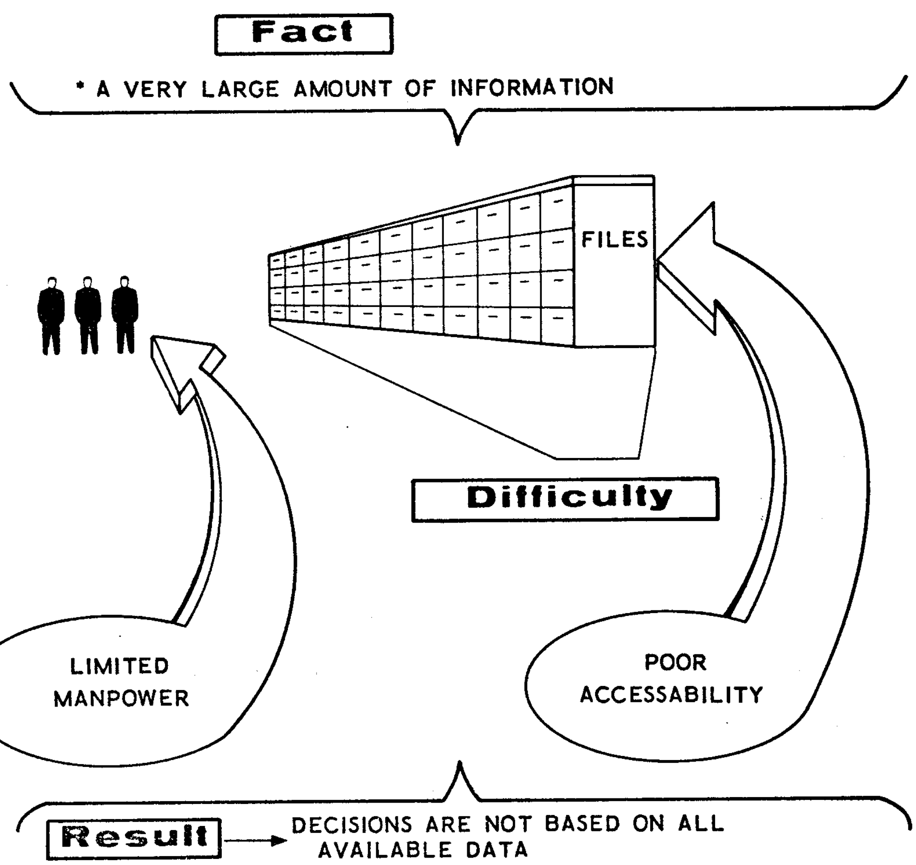

FIGURE 2

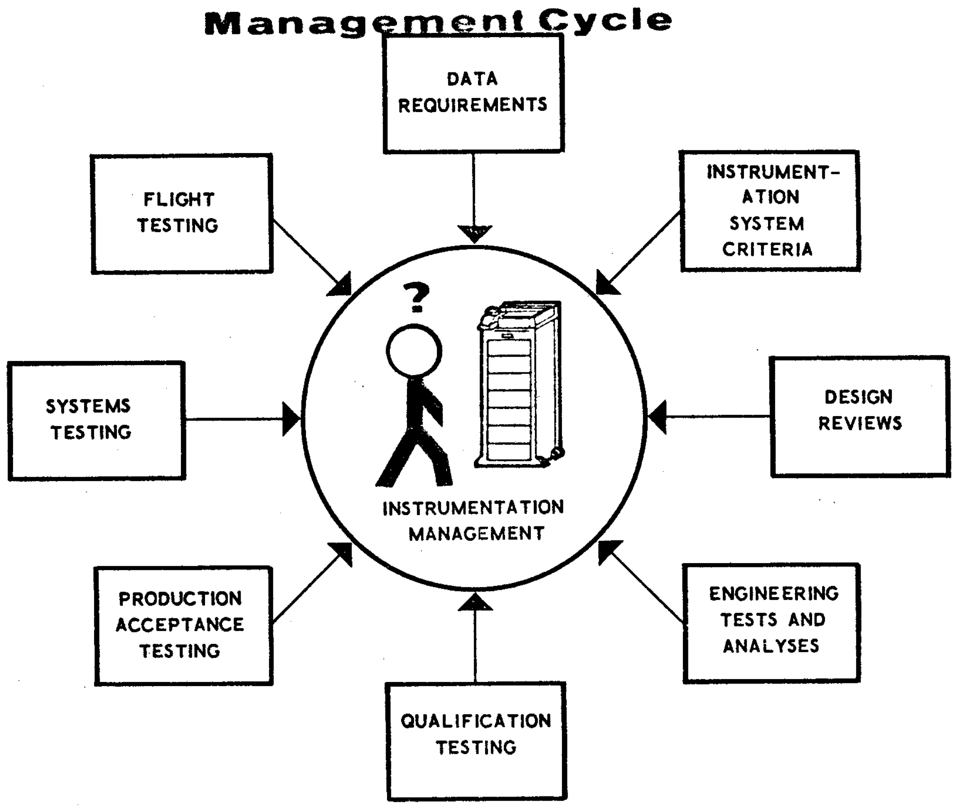

FIGURE 3

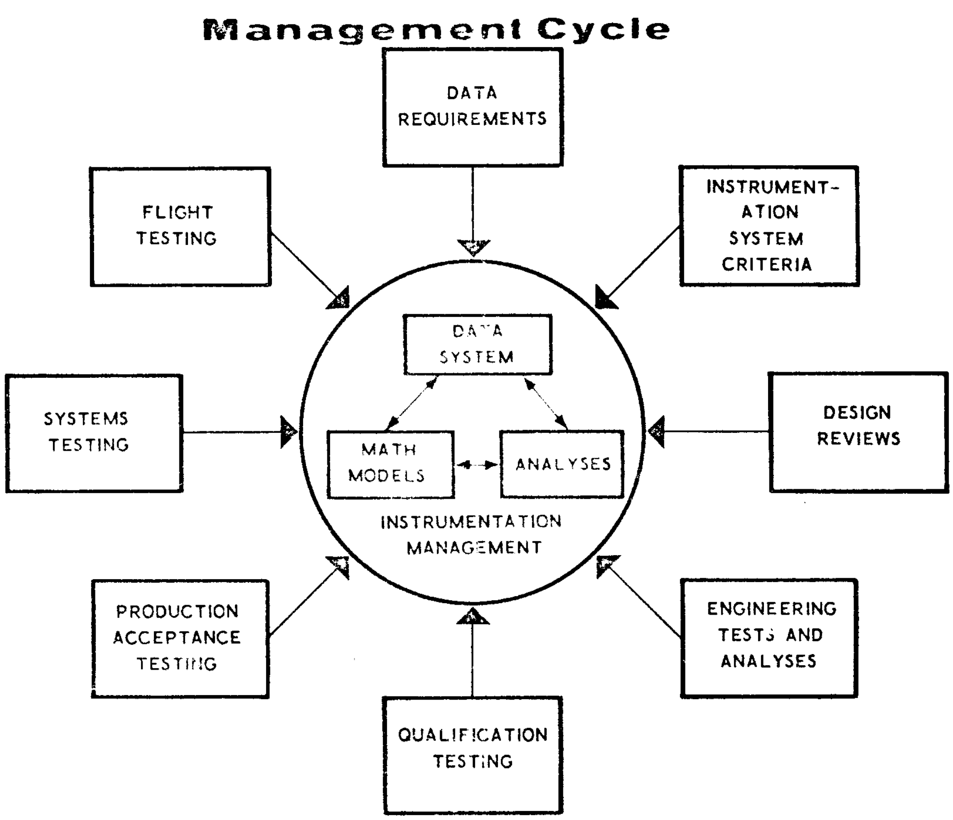

FIGURE 4