Managerial Implications of Computerized Aircraft Design Synthesis

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Several aerospace industry management teams were surveyed in late 1972 to evaluate managerial aspects of computerized design programs. Areas investigated included program initiation, feasibility studies, computer systems, the programs, management operations, and evolution of program objectives. The advent of real time man-computer interaction has affected aerospace management by reducing design cycle time and expanding the range of design options. Most programs started at lower levels and initial objectives were to get a program working quickly. The programs were integrated by commonality of input and output and modular via disciplinary responsibility for each module. Use and development of the programs has increased crosstalk between the disciplines. Design information is now better organized and more thorough. Output more closely reflects capability and innovation has been enhanced. Program success correlates well with management involvement.

Introduction

COMPUTERIZED aerospace vehicle design synthesis procedures with varied levels of engineering discipline interface are being used by several aerospace organizations. These synthesis procedures evaluate the inter-relationships of structures propulsion, aerodynamics, guidance and control, auxiliary power, costs, etc., in the aerospace project. They expose significant relationships that will enhance organizational decision making and improve utilization of organization resources. The effectiveness and achievement of these goals is affected by and affects the management of the organization. Managerial implications of computerized aerospace vehicle design programs have been evaluated through a survey of several aerospace industry design teams. The companies contacted (and their program acronyms in parentheses) were: The Boeing Co. (CPDS), General Dynamics, Fort Worth Division (SYNAC), Grumman Aerospace Corp. (IDEAS), Lockheed California Co. (ASSET), McDonnell Douglas Corp. (CADE), North American Rockwell Corp., B-1 Division (CAP), and Vought Systems Division (ASAP). All of the programs indicated above have been operational for at least two years; a time considered sufficient to allow managerial trends and opinions to develop. The survey was conducted in the fall, 1972, via written and oral interviews of cognizant personnel from each company and a review of existent literature describing the programs.

Aerospace vehicle design synthesis capability is also being developed by NASA in its Integrated Program for Aerospace-Vehicle Design (IPAD) study.[1] The evaluation of the managerial aspects concerning IPAD emphasize data management, both external and internal to the computer, and computer program operations and interfaces. IPAD is presently in the development stage and has yet to experience many of the problems encountered in industry. It also operates free from the competitive business environment although it is under pressure to assure its continuous funding. Where possible, problems encountered in the IPAD program are discussed in the survey results.

A questionnaire was devised covering the following areas of interest. Program start, feasibility studies, computer systems, the synthesis programs, and effects of the synthesis model on management authority or delegation of decisions. No attempt has been made to characterize the management styles. It is hoped that the results of this survey will assist aerospace management and information systems developers to chart a more accurate course for ongoing and future synthesis program development.

Many articles have been written about management information systems (MIS) and management; however, it is believed that no prior survey of the effect of MIS upon aerospace industry management has been published.[2-8] A survey of aircraft configuration design optimization techniques is presented in Ref. 9 which also contains an excellent bibliography relative to the problems of computerized optimization and technical interface. The following surveys the problem from the management side.

Program Start

A summary of the managerial aspects of starting the aerospace vehicle design synthesis programs is presented in Tables 1 and 2. The starting dates roughly parallel the transition periods from first to second or second to third generation computers. In fact, North American Rockwell

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Index categories: Aircraft Configuration Design; Aerospace Management.

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Table 1 Managerial factors at synthesis program initiation

Company[a]	B	G	L	M	R	V
Initial justification (Priorities)						
Cost savings	3	3	2	3	3	2
Response time	2	1–2	1	1	1	1
Accuracy	1	1–2	3	2	2	3
Planning	4	4	4	4	4	4
Management[b] initiation						
Upper		x				x
Middle	x			x		x
Lower		x	x	x	x	
Management support[c]						
Upper	N	G–E	N	G	P	N
Middle	F	F–G	G	F	F	G
Lower	F	G	E	P–F	E	F

[a] B = The Boeing Co.; G = Grumman Aerospace Corp.; L = Lockheed California Co.; M = McDonnell Aircraft Co.; R = North American Rockwell Corp., Los Angeles Div.; V = Vought Systems Div., LTV.
[b] Upper—vice president and up; Middle—Department Head and up; Lower—below Department Head.
[c] N = neutral, P = poor, F = fair, G = good. E = excellent.

Table 2 Why have a synthesis program?

Boeing: There was a desire to capitalize on the large investment in existing computer programs within the company for the purpose of increasing the technical depth of preliminary design and automating the solution of systems problems.

Grumman: There was a lack of interdisciplinary communication which led to excessive program delays. In this case, the primary problem was delay in development of loads needed to design the vehicle structure.

Lockheed: Competition for a study contract and knowledge of similar preceding efforts by a competitor were the primary stimuli. Study requirements called for a broad parametric evaluation with a quick response time.

McDonnell: Developed to support FX project design studies for Air Force which required a broad parametric evaluation with minimum response time. Capability was needed to maintain competitive status.

North American: Need to perform many advanced studies when manpower was tied up on current programs. Availability of first high capacity (IBM 701) digital Computers.

Vought: Initial recommendation was made in 1967 at department manager level. Recognition of other contractor efforts by Vice President of Advanced System in 1969 spurred interest in synthesis program development.

indicated that increased second generation computer capabilities enhanced justification of their initial synthesis program efforts. Competition at the preliminary design level leading to proposal submittal is emphasized by the high ranking for the speed of response and accuracy requirements. Early definition of the design leads to improved definition of the proposal submittal. Speed of response also enhances analytical capability for broad parametric studies thus improving the companies' competitive postures for study contracts. Accuracy assumed a paramount position for Boeing because previous procedures had not produced decision level accuracy in the time available for preliminary design work. Accuracy held less importance than cost at Vought which reflected the impending cutbacks in the aerospace industry and confidence in then current analysis methods. At Lockheed California, cost was a factor in competing for the FX study contract. McDonnell placed response time first for the same FX study. Cost, which has been a dominant factor in the creation of business systems (i.e., accounting, inventory control, etc.), enjoys the next to lowest overall priority as an initial objective. Cost savings have generally been a fallout of synthesis program usage. The use of design synthesis programs as a planning tool is considered as a future objective only by Vought. Business MIS has already entered this phase of computerized analysis indicating an earlier inception of this phase than in the aerospace industry. This can be attributed to the complexity of engineering analysis procedures and the continuous evolution of design technology.

The NASA IPAD programs are meeting the technology evolution head on with their goal of more detailed and rapid design definition at an early stage in the preliminary design process. Most of the aerospace teams have aimed at automating current methods but like NASA are keeping their procedures open ended to allow the infusion of better or more detailed analysis methods. Approaches to this area will be covered in the discussions of the synthesis programs. The outcome of the approaches should prove interesting. R. L. Ackoff of the Wharton School of the University of Pennsylvania has stated that it is easier to introduce finer information into an integrated information system than it is to combine fine subsystems into one integrated system.[2]

Initiation of the aerospace vehicle design systhesis programs occurred primarily at the lower levels as shown in Table 1. At Vought and Grumman, top management support evolved subsequent to the lower levels. As described in Table 2, Grumman responded to a specific product design—the F-14, whereas Vought and Lockheed were influenced by competitive pressures. Only Grumman and McDonnell top management offered good support at program inception. At Grumman, the main reason for this is that immediate cost savings appeared attainable for the F-14 program through early structural definition. McDonnell needed parametric analysis techniques to perform the FX design studies within a "hard" time constraint. At Vought, over-all top management support was fair because it really didn't understand the details of the synthesis program. The Vice President of Advanced Systems was a prime mover. The poor top management support at North American Rockwell seemed to indicate an inverse relationship to interest in the final product. Excellent support at the working level as evidenced by the initiation level was maintained. The parochial interests of the lower level at Vought and the middle and lower levels at Grumman were felt to be threatened by the synthesis programs which accounts for their fair support rankings. In most cases, this attitude dissipated as lower and middle management realized that their authority wasn't threatened but enhanced through better interdisciplinary communications created by better visibility of results from all areas.

Table 3 Disciplines involved in feasibility study phase

Discipline	B	G	L	M	R	V
Project Leader	x	x	x	x	x	x
Aerodynamics	x	x	x	x	x	x
Propulsion	x		x	x		x
Weights	x	x	x	x		x
Computing	x	x	x	x	x	x
Design	x	x	x			x
Mechanical systems	x	x				
Acoustics	x					
Systems	x		x			
Cost			x			
Mathematics						x
Structures[a]	x	x				
Initial computer	CDC 6600	IBM 360/75	IBM 360 Model 50-75	IBM 360/75	701	IBM 360 Triplex
ICG Scope	CDC 243	IBM 2250	None	IBM 2250	None	On order

[a] Includes loads, vibration, and flutter analysis.

All management levels showing good to excellent support appeared to bear a direct relationship to management involvement in program development. As Ackoff pointed out, the participation of managers in the design of a system that is designed to serve them assures their ability to evaluate its performance by comparing its output with what was predicted.[2]

Feasibility Studies

Surprisingly, Boeing was the only company which had a "formal" feasibility study to initiate their synthesis program. The definition of a "formal" feasibility study hinges upon determining the feasibility of the program and recommending the approach at the end of the study. Each company, however, did set up a separate study group. Except for Boeing, the primary objective was to develop a working model within 4–6 months.

All groups were directed by lower level management, either a group engineer or a project engineer. Higher level management was involved in establishing program information/decision requirements only at Vought and Grumman in the person of the Manager of Operations Research and the Engineering Vice President, respectively. Table 3 shows the study group members. Program complexity showed almost a direct relationship to the number of technical disciplines involved. In North American Rockwell's case, the evolution of technical capabilities and computer equipment have led to more complex programs.

The study groups all decided to build up their design synthesis procedures using existing computer routines or modules. Each company chose to start from a predefined baseline design and perturb the design by variations from the baseline to achieve point design convergence. In all cases the design synthesis programs are now set up to operate on third generation computer systems. Vought was the only company to require their program to be usable at all development stages. McDonnell and Vought specified minimum training for use. While the Boeing study uncovered holes in the technical capabilities, the other companies had to rely upon need to uncover these deficient technologies. This is a strong factor in support of the feasibility study approach, if . . . one can afford it.

All of the companies emerged from the study phase with formalized design synthesis groups. Grumman went one step further and established a design synthesis group for each project which rules program integration; but, each discipline is still responsible for its own input. Lockheed has established continued development on an as needed basis. At McDonnell a multitechnology program group develops and maintains the programs with each technology responsible for the content and input of its modules. At Vought, the aerodynamics group was selected to integrate the program but each discipline retained responsibility for its module. Boeing set up a similar arrangement with aerodynamics in charge of the first level or sizing analyses and structures in charge of second level or detail analyses.

Computer Systems

Use and organization of the computer systems has evidenced management interest in the cost of computer operations. All of the companies obtain some or most of their computer services via lease or contract type arrangements to minimize computing costs. Boeing, Grumman, and McDonnell have set up affiliated computer service corporations which provide computer systems analysis, operations, and operations research services under contract. North American Rockwell handles the computer systems analysis and operations services internally via a computer services group under the Director of Management Systems with computer operations research as a separate group in research and engineering. At Lockheed, California, the above services are handled by a computer services located separate from the Rye Canyon facility where advanced design studies using the design synthesis program are performed. Vought leases computer operations services and performs systems analysis and operations research functions within the mathematics department.

The most significant differences appeared in the programming area. Boeing, Grumman, McDonnell, North American Rockwell, and Vought have all vested their engineering department with freedom to generate engineering analysis programs. This is needed to finish programming tasks within time constraints. Vought engineering, however, is restricted from using machine language but has no known handicaps due to the restriction. The Lockheed, California, advanced design engineering group is restricted to writing small programs for use on remote access terminals. Large programs are written by the computer services department.

Generally, a shift in emphasis of computer usage from business to scientific applications was indicated. In fact, Vought, Boeing, and Grumman have computers dedicated primarily for scientific use. North American Rockwell indicated an anomalous shift in the opposite direction. This may originate from their management systems group calling for increased use of computers in company management, particularly, for the large number of subcontractors involved in the B-1 and space shuttle programs.

All of the companies are using third generation computer systems with interactive graphics to some extent. However, not all are using interactive graphics in the basic design synthesis program management. The most popular computer is the CDC 6600 system being used by Vought,

Table 4 Disciplines involved in development and daily use of aircraft design synthesis programs

Disciplines	B	G	L	M	R	V
Aerodynamics	DⓊ[a]	D U	D U	D U	D U	DⓊ
Propulsion/Thermodynamics	D U	D U	D U	D U	D U	D U
Structures	DⓊ[a]	D U	D U			D U
Weights	D U	D U	D U	D U	D U	D U
Cost/Operations analysis	—	—	D U	D U	D U	D U
Design	D U	D U	D U	D U		D U
Computing	D	D	D	D	D	D
Mech. systems	—	D U	—	—	—	—
Flutter	—	D U	—	—	—	—
Project	D U	DⓊ	DⓊ	DⓊ	DⓊ	DⓊ

[a] Aerodynamics on level 1, Structures on level 2. D—Development; U—User Input; Ⓤ—Controlling user.

Boeing, McDonnell, and the NASA IPAD team. McDonnell uses the IBM 370, 2250 system for graphics, and the IBM 370 as the primary corporation computer; Grumman uses the IBM 370-165 and 370-67 time shared for their design synthesis; North American Rockwell uses the IBM 370; and Lockheed California uses the IBM 360-91. Over-all responsibility for computer operations is at the vice president or director level at all companies.

The System Itself

In the survey questionnaire the companies were asked whether they considered their systems to be integrated or modular. The consensus was that they included both characteristics. They were integrated by the establishment of commonality of the inputs and outputs for the respective computer procedures or operating modules (OM). They were modular in that each discipline maintains responsibility for its module's accuracy and up to date analysis capability. The principal differences between the programs are the level of aircraft configuration detail or generality exercised or sought and the degree of automation involved in the design synthesis process. To be rigorous, none of the programs except CPDS can really be called a synthesis program because they all require an input baseline design. Rigorously, a synthesis would emanate from a vehicle design requirement and have initial start up capability.

The survey reviewed the following areas relative to the design synthesis systems: structure of the system, the disciplines involved in development and day to day use, program usage, interdisciplinary communications, and continuing activity. The disciplines involved in development and day to day use are summarized in Table 4.

Boeing

The Computerized Preliminary Design System (CPDS) is apparently the most complete over-all design system in use.[10] It achieves a high degree of generality by use of precompilation which allows the program to be tailored to the job by automatically preprocessing the selected modules for design/analysis and the synthesis control logic. CPDS operates on two levels of detail with aerodynamics controlling the first level and structures controlling the second more detailed level. The program is used exclusively for preliminary design but is not considered to be a main stream information source. In its basic operating mode data input may be empirical, actual test data, or output from analytical procedures being compiled in tabular format. Program initiation and update or revision of the solution by editing input are performed as a necessity. Batch processing capability is available but not often used. Both printed and graphical output are produced at the user's option. Optimizing results in sizing (synthesis) and performance of a point design aircraft. Although CPDS capability was increased more than ten fold in size it is cheaper to operate today than when it started. User difficulty increases rapidly with complexity but an experienced engineer (a CPDS task force member) can perform difficult tasks. Activity on CPDS has been shifted from the system approach to selected development of stand alone modules retaining some iteration capability.

Grumman

The Integrated Design and Analysis System (IDEAS) is more of a managerial network for use of many computer programs than a design synthesis program.[11] Synthesis capability is vested in a rough conceptual sizing analysis used for pre-preliminary design and configuration element (e.g. boron overlay for a panel) optimization. IDEAS was developed to perform detailed analysis of all aircraft structural design loading conditions and internal structural component loads needed for the sizing and analysis of the primary structure of an entire aircraft. It has been automated somewhat by establishing data interface via computer tape. Initial use was for production design development only, however, streamlined versions have been developed for preliminary design use. The primary mode of program initiation is in batch processing but certain programs can be initiated from an interactive computer graphics (ICG) terminal or scope. There is no perceptible effect of program complexity or cost on program usage. Costs of operation have been reduced despite increased complexity by reorganization of the IDEAS management network and input/output interface as opposed to reprograming of the modules. Both printed and graphical outputs are provided. Optimization is performed via engineering analysis.

Activity is continuing at Grumman at approximately a seven man level. Future developments include integrating of all pertinent disciplines, more automated modeling and interface, developing the Woodward aerodynamic analysis program with graphics to allow interrogation of input and output, and increasing data storage capability. A desired development would be increased availability of interactive graphics terminals to improve accessibility of computerized methods.

Lockheed, California

Initial synthesis efforts led to an integrated program which was tailored to the specific problem at hand (FX study). However, this approach was very cumbersome to change for other problems and a modular approach evolved. Lockheed's Advanced Systems Synthesis and Evaluation Technique (ASSET) program is controlled by the synthesis and evaluation section within the design integration department.[12] However, all of the disciplines listed in Table 4 are responsible for their respective modules, for data inputs, for checkout and for verification of output. ASSET is used at both the pre-preliminary (concept selection) and the preliminary design stages of aircraft design development. Data input can be empirical in areas such as weights and configuration, and analytical for items such as friction drag, and weights, with update and revision capability facilitated by modular program design. Present computer operations are entirely batch mode with auto-plot and printed output. Optimization capability is limited to mission performance related items (e.g., cruise and loiter conditions, optimum sweep for variable geometry wings, etc.). Major discipline optimization is done externally by analysis of program output. Although ASSET has steadily increased in size and complexity, no real effort has been made to clean up the program or reduce program size due to budgetary squeeze. Increased size and complexity have not created cost problems because faster computers, central input/output control, use of initial checkout cases and other management control techniques have reduced costs. The complexity increase has been offset by continued involvement and improved cooperation between the functional groups involved in the synthesis process. Continued modification of the ASSET program is aimed at improving program flexibility. Special modifications are devised as required to support projects.

McDonnell

The initial Computer Aided Design Evaluation (CADE) was an integrated program developed for application on the FX study in order to generate sufficient parametric analyses for credible design decisions within a "hard" time constraint. Subsequent program development has led to a modular structure to provide a broad scope of applications, ease of modification, and functional visibility. Detailed analyses by each technology are performed using appropriate analytical or empirical methods to establish a baseline configuration. A description of the baseline airframe geometry, mass properties, and aerodynamic characteristics; baseline engine performance data; and flight performance requirements comprise the input. The program sizes the aircraft for specific mission and maneuver performance requirements. The program can adjust the aircraft geometry, aerodynamics, mass properties, and engine size for changes in design parameters and/or flight performance requirements. Printed output consists of the sized aircraft geometry, mass properties, aerodynamics, flight performance, and cost. Configuration refinement can be accomplished via engineering analyses of the printed output or direct optimization algorithms. Interactive computer graphics has been developed but the primary mode of program execution is the batch mode. Noninteractive graphics can provide a configuration drawing or plotted results of a parametric analysis. The scope of application for CADE has increased markedly without increasing the cost of usage. On-going efforts continue to reduce computer storage and execution time through the use of overlays, logic improvements, precision relaxation, and use of alternate computer systems. Experience has demonstrated the importance of effective communication through documentation and training. Since its initiation in 1968, CADE-type multitechnology programs have been used on 38 study efforts at McDonnell Aircraft Company.

CADE has the widest application of any of the programs reviewed.[13] Derivatives of the program are used in preliminary design for point design selection, for proposal point design refinement, and for generating periodic reports during production design development. A formal multitechnology program development staff has been established under the Director, Project Technical Engineering. This staff includes assigned aerodynamics and propulsion personnel and other disciplines as needed. Future developments include: alternative optimization procedures, generalized mission capability, and exploration of ICG capability.

North American Rockwell

Two programs are available with the simplified version used for concept development and the more detailed Configuration Analysis Program (CAP) used for configuration development. These programs are considered to be highly integrated to reduce computing time and cost. However, future synthesis programs, complementary to existing programs, will be modular with each discipline responsible for its module's status. Currently, the synthesis programs are used for prepreliminary design concept selection, preliminary design configuration development and refinement, and proposal submittal definition final sizing and tradeoff data. Although not used, production design development capability is present. Empirical and analytical data are mostly generated external to the program and input in a table look up format. There have been no problems adapting the program to special configurations. Batch processing is the primary computing mode and provides a complete printout of each case with graphical plotting available. Optimization is internal via a one dimensional search with constraints on all requirements. Multiple cases involving several control variables may be handled on a single run. Interactive computer graphics terminals may be used to initiate all options of the simplified synthesis version but the low speed input/output of the IBM-TSO (model 155) used discourages extensive use at present. Annual program updates minimize cost impacts of program size or complexity increases. Program complexity does impose requirements for essential interdisciplinary coordination and a designated central or single program engineer for each project. A staff including a project manager, a weights engineer and a programmer with some aerodynamics and operations analysis support has been set up for on-going program development. They are currently developing a modular type synthesis program with first operational capability expected in mid-1973.

Vought

The Aircraft Synthesis Analysis Program (ASAP) has been constructed by a modular building block approach.[14] The modular construction provides maximum user flexibility and visibility of each discipline's input/output. Each discipline maintains responsibility for its module's accuracy and up to date analysis capability. An integrated approach was considered, but discarded, because it restricts visibility and flexibility, is expensive to run, requires extensive user training, and effects narrow viewed program management organization. ASAP is presently used for preliminary design for aircraft sizing and parametric studies and for proposal submittal definition for final sizing and data presentation to reflect the highest level of design data and analysis available. It also is used to assess the effect of mission or design changes on production aircraft. Empirical drag and weight analyses are built into the program to facilitate early preliminary design studies. Detailed analytical work is presently done exterior to ASAP and input separately (e.g., friction and wave drag, structures/weights, control surface sizing, propulsion, etc.) in a table format. Specialized problems such as VTO aircraft engine sizing are aided by the modular construction. Presently, computer processing of the point design weight, cost and performance analyses are done in the batch mode. Output includes a summary printout of each module and cards with point design weights and performance for fuel balanced aircraft. The output cards are the input for the CDC 6600 with an interactive graphics scope which presents parametric plots of all performance, weight, and cost outputs to facilitate design optimization. The user has full visibility of the interactive effects of any set of performance, weight, or cost parameters. This capability

Table 5 Management acceptance of synthesis: initial/current levels

	B	G	L	M	R	V
Upper[a]	N/F	G/E	N/G	G/G	P/F	N/E
Middle[b]	F/P	F/E	G/E	F/G	F/G	G/E
Lower[c]	F/F	G/E	E/E	P/G	E/E	F/E

[a] Vice President and up.
[b] Department Head and up.
[c] Below Department Head.

is unique in the industry. Plots of any interaction can be initiated from ICG for final report type presentation via the Calcomp plotter. All printed output summaries have been set up for final report presentation. Although ASAP has increased considerably in size its usage has increased even more. ASAP has been used for 23 design studies since its inception in 1969. Costs have been kept low by continuing efforts to streamline running time and core size. A typical fuel balanced point with all performance, cost and weight is now achieved in only 15 sec of computer run time. Normally, nine points are used for parametric optimization.

On-going activity is handled by an ASAP task group including a project engineer, aerodynamics, structures/weights propulsion, and mathematics. Current efforts are directed at incorporating automatic optimization capability for pre-preliminary coarse sizing studies, and ICG program initiation capability. The CDC 6600 with scope permits these features to be installed. Initiation capability will not only include ASAP but also lifting surface, friction and wave drag, propulsion, and structures/weights analysis output within ASAP. It will move towards true synthesis capability.

NASA

The Integrated Programs for Aerospace Vehicle Design (IPAD) are intended to automate to the highest extent possible the preliminary and detailed design of advanced aircraft.[1] The IPAD studies are preceded by extensive efforts in aerodynamic design integration[15] and structural design integration.[16] IPAD is to be built on a modular basis with an open ended capability (i.e., additional modules can be added or present modules can be modified without upsetting the program structure). Responsibility for the modules is vested in their respective discipline areas. Optimization capability is presently planned to be intra- and inter-modular. The system will have capability for complete management of information flow between modules. Users will be provided with the ability to monitor the system via interactive computer graphics and to override it at any stage in the process. Although primary emphasis will be design, selected modules should have the capability for detailed final analysis of a fixed configuration.

The development of this highly sophisticated program will greatly aid the aerospace industry. Prominent problems already anticipated include: analysis of the large volume of data output; conflicts in computer time and detail, especially for repetitive analyses; design stage definition and detail requirements; orientation of analysis procedures to design problems; and loss of visibility via heavy dependence on the computer for data interface. All of these factors must be considered in addition to the desire for an open-ended, flexible design system.

Summary

The unanimous opinion has been that use and development of synthesis or parametric analysis programs have substantially aided interdisciplinary communications although the degree of synthesis varies among companies. Modular program construction with open ended capability for revision/update is either used or sought by all program developers. Executive programs are used in all procedures except Grumman's IDEAS to control the sequencing of modules in design analysis. At Grumman, sequencing of modules is generally handled manually or by submission of multiple job steps via the IBM job control language. As the programs grow there is a danger that the synthesis systems could become the managers rather than the managed. A problem with increased automation is a loss of visibility of the adequacy and accuracy of the inputs and this factor should remain paramount as the synthesis systems grow in size and complexity. We must not let computer systems outstrip our capability to use them.

Synthesis Effects on Management

Questions asked of management covered the effects of synthesis on the management decision and design authority levels. Will synthesis enhance innovation or harm it? Will synthesis change the present management structure and if so, how? Now that various managements have lived with synthesis what is its present acceptability?

The consensus of the contractors was virtually unanimous with regard to the effects of design synthesis or parametric analysis programs on management. Before, design information frequently was not as systematically organized, was not available early enough in the design process and was not broad or thorough enough in its coverage. In other words, output did not reflect total capability. Now, centralized output for configuration development can provide total system decision making capability at an elevated level of management. In most cases it also provides quicker response to "open" items from configuration development meetings. The level of decisions hasn't changed but the quality has improved considerably.

Generally, it is felt that use of synthesis or parametric analysis programs enhances innovation indirectly through reduced evaluation time for derivation of point designs. This saving in time and manpower, properly channeled, can be directed toward design innovation. Experience has shown that higher quality designs are evolving in essentially the same time cycle as before. To get the same quality design as before, Vought has shown roughly an order of magnitude compression in design cycle time and cost. All users, however, have tended to retain the cycle time and improve the design quality.

The design synthesis programs have tended to centralize design authority from the functional groups to configuration development management. This occurs because increased visibility of the design process is now available at higher levels, particularly with parametric type optimization procedures. There is now less reliance on judgment and more reliance on detailed design tradeoffs. Design synthesis has decentralized some of the less complex design decisions by giving the working engineers problem visibility across disciplinary lines. In other words, these decisions can be delegated to a decentralized organizational level.

No one expected use of synthesis programs to have any effect on over-all management structure. Vought indicated they felt there could be a thinning of middle management due to diffusion of functional design authority, however, Grumman felt that the need to maintain high technology capability to use the synthesis programs would negate thinning of the ranks. All of the companies are continuing development of computerized design programs. Grumman and McDonnell have formed project groups to operate their design procedure whereas the Lockheed, Vought, and North American Rockwell programs have not set up special staffing for individual projects.

In Table 5 the management support attitudes at current levels are depicted for comparison with results shown in Table 1. All but one company has demonstrated an improvement in management acceptance of synthesis or parametric analysis programs. The common denominator was that those showing improved management attitudes had started small and progressed in stages. Also, program results provided objective means of balancing technology inputs to the design process. These results confirm those reported by A. Hershman of Dun's Review.[5] She stated that "no manager wants to lose his influence and power to a computer." Thus, the battle lines are drawn, and the most likely result is an overflow of useless information. In toting up the MIS track record the most successful systems seem to be those that begin small and progress in stages."

Many writers still feel that there will be a reduction of middle management people. D. L. Caruth of North Texas State University states the consensus that "the systems concept and its hardware heart, the computer, will reduce, both in number and importance, middle management jobs."[6] This consensus is probably correct for business applications, but not so in high technology industry. Caruth also stated "the total systems concept will eliminate traditional decentralization and its associated problems. This will be possible because we will possess the technology to build information systems transcending the necessity for compartmentalized arrangements based on functional specializations." Possibly a new breed of engineer is around the corner; namely a design synthesis specialist. Nevertheless, he will need technological support of specialized functions to effect continued excellence in design synthesis. The survey shows that there is a tendency for primary configuration design decision making to recentralize itself in the hands of top management.

Several interviewees stated that the success of a design synthesis model is strongly dependent upon the cooperation and effective working relationship between the synthesis group and/between the technology groups rather than the program capabilities themselves. This factor is evident where management acceptance has improved or remained high. There is also a correlation of the degree of acceptance with visibility and relevance of results presented to management.

Comparison to Initial Objectives

Over-all, it is to management's benefit to support computerized design program development. In all cases the intangible objectives of increasing speed of response and accuracy were achieved. Program operating costs have held ground despite increases in size and complexity. At Vought, the initial philosophy of heading straight toward optimization as a goal was changed to a step by step approach with parametric optimization analysis. This highly visible technique probably was the key to continued funding and excellent acceptance at all levels. McDonnell decided that the original method used for design optimization lacked visibility and have stressed this aspect in ongoing work.

One discussion has pointed out that the problem of system justification relies on an ability to demonstrate its benefits.[4] In the past, when a computer program was installed for repetitive tasks, there were almost always demonstrable savings from clerical worker displacement. This is a tangible cost saving. But most of the benefits of a management information system are intangible. In charting a course of action, management men can understandably become confused about what their systems people are trying to do in the field of information technology. There definitely is a communications gap between the systems professionals and the management people responsible for determining where the company is going in management systems development. It appears that Lockheed, McDonnell, Vought, and Grumman have bridged this gap as evidenced by their present high level of top management support for their computerized design program developments.

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