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Systems Approach to integrating Cost and Technical Data

Howard M. Carlisle

The increasingly technical nature of many industries poses a problem in merging technical and cost data for meaningful management decisions. This article describes IMPACT, a program merging the milepost chart and the forecast budget into a common plan in which each element is considered —

SYSTEMS APPROACH TO INTEGRATING COST AND TECHNICAL DATA

by Howard M. Carlisle
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NEARLY every phase of industry has been characterized by a growth in complexity since World War II. This complexity has been brought about to a large degree by the scientific advances of the aerospace era.

This has resulted in a business environment far more technical — and dynamic, too — than has faced the manager in the past. Such an environment has created unique problems for management. The problems are not necessarily new in type, but they are new in terms of size and scope. Technical skills and knowledge have tended to advance and develop more rapidly than managerial skills and knowledge. This leaves the frequently referred to "management gap" in many industries such as aerospace.

Because of the scientific composition of these aerospace programs, one of the major problems encountered has been how to gain sufficient understanding of the nature and operation of massive engineering projects, the understanding necessary to control them. The technical composition of these programs is such that it is difficult to obtain widespread understanding by the responsible management team of the basic project problems or operations.

This complexity becomes apparent when one attempts to mesh the technical, schedule, and cost aspects of any one program. The Apollo Program to place man on the moon is a good example. This program, administered by the National Aeronautics and Space Administration, will cost over twenty billion dollars and involves several thousand separate industrial firms, providing over 500,000 separate

parts. In smaller industrial operations where communication is less difficult, making sound management decisions with full consideration to the technical, schedule, and cost features of any problem situation is not a major problem. In all organizations there is a natural division of interests and talents between technical and administrative groups (or individuals) because of the different nature of their inclination, education, and training. Perception and communication often become complicated because of this factor alone. When such communication is further complicated in highly scientific projects covering a development and production timetable of as much as five to seven years — or even longer, as in the case of major weapons systems—it results in one of the major blocks to effective management. In the development of these weapons systems in the past decade, this has been a major hindrance to effective management.

Problem of integration

This situation creates special problems for the accountant and all staff-type groups. The accountant cannot submit a cost statement to operating supervisors and assume that it will be automatically meaningful to them. Unless this cost statement is integrated in some manner with the program's technical status or production status, it does not serve as a useful management tool. Decision making at all management levels must take into consideration cost and technical factors if ineffective decision making is to be avoided.

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Various attempts have been made to overcome this management problem. One of the more common practices has been to include a column on the cost statement which indicates for each project or activity the per cent of physical completion as of the appropriate reporting date. In a limited way this approach is useful, but, again, it does not contain sufficient technical progress data to meet the needs of program personnel.

Input-output charts have also been developed attempting to integrate the technical and cost status of major programs.[1] On these charts, the input line represents the costs or dollars applied to the program over a specific time period, and the output line represents accomplishments or production units completed over the same time base. Comparisons can be made between the cost and technical progress trend lines, but these charts are limited in terms of both the quantity and variety of information that can be shown.

PERT (Program Evaluation and Review Technique) has been developed as a valuable planning and control tool. The cost dimension has been coupled with this to form PERT/Cost, which is an attempt to integrate the basic planning and cost data. PERT has proven to be very useful on certain types of programs, especially those requiring detailed planning of new activities. However, because of its detailed nature, it leaves unresolved the problem of presenting meaningful overall reporting to management.

Several quite unusual applications of concepts aimed at combining the pertinent technical and cost information for a program were developed recently in conjunction with a management reporting system known as IMPACT, Integrated Management Program Analysis and Control Technique.[2] This technique was developed by a group of consultants as part of a management system established for a major aerospace firm.[3] This system integrates the two basic management tools utilized on aerospace programs. The first of these is the milepost (or milestone) chart, which indicates by date on a time-phased schedule the key mileposts or significant technical accomplishments or goals of the program plan. The milepost chart is updated periodically to indicate the status of mileposts which are in the process of completion and mileposts completed. Target technical goals versus actual accomplishment are compared in all instances. The milepost chart is an application of the Gantt chart[4] technique to aerospace programs.

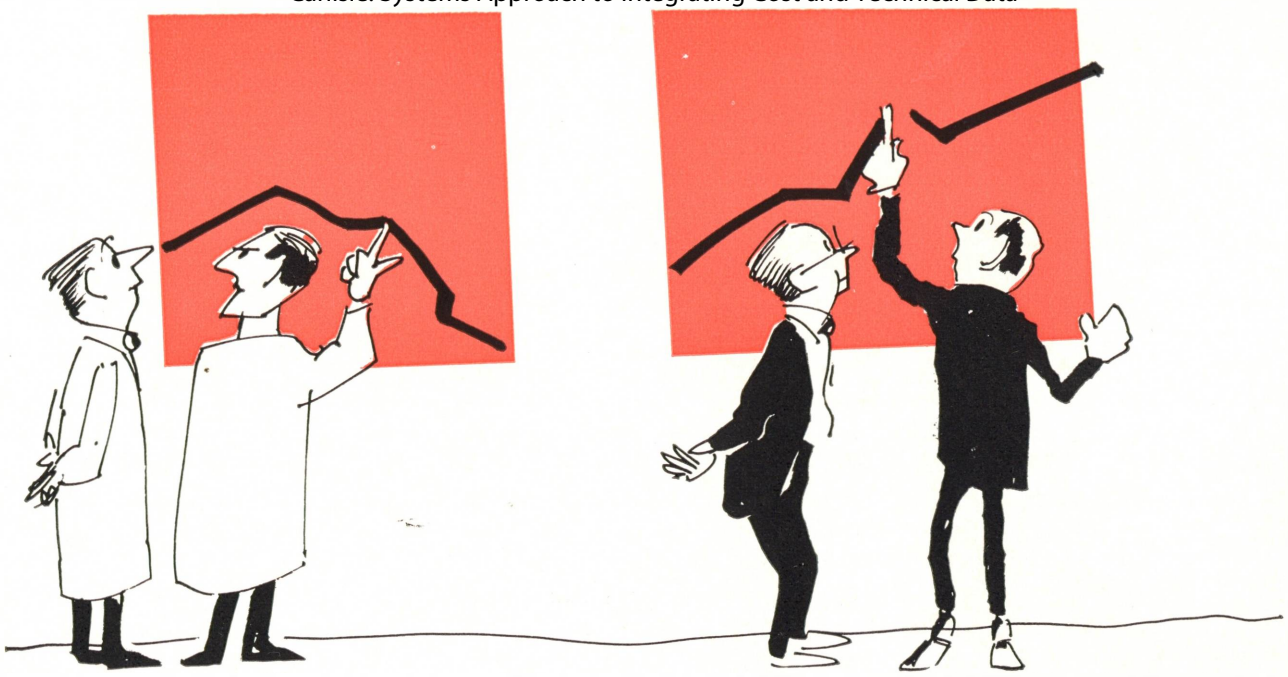
The second basic management tool of advanced technology programs is the forecast budget. This type of budget has been useful in research and development projects and in government contracting, where frequently a fixed dollar amount is to be expended within a specified time period, either on an annual basis or based on the period of performance of the contract. The forecast budget typically involves a system by which funds are allocated or cost ceilings are established either by work project (task) or by cost element. In addition, manpower is frequently allocated by project on a man-year basis. The manpower figures and cost estimates are provided by time periods, usually months of the fiscal year. A frequent source of problems, especially on larger programs, is that when technical planning

[1] For an explanation of these concepts see the author's article "Aerospace Industries and the Budget Function," *California Management Review*, Spring, 1964, pp. 17-27.

[2] This technique should not be confused with the IMPACT system developed by International Business Machines Corporation for inventory management. There is no relationship between the two systems.

[3] Developed by Aerospace Management Consultants in 1964.

[4] Henry L. Gantt, the originator of the Gantt chart technique, died November 23, 1919. One of the better explanations of this technique is found in Wallace Clark's book, *The Gantt Chart*, The Ronald Press Company, New York, 1923.



A problem which frequently occurs, especially on larger programs, is that technical personnel make up the program plan, from which budget personnel develop the forecast budget. The difficulty is that each group frequently makes different program assumptions, without considering the implications of its decisions.

personnel make up the program plan and milepost charts, from which budget personnel develop the forecast budget, each group often makes different program assumptions and does not give adequate consideration to the implications its decisions have for other areas of activity. Decisions are frequently heavily oriented in one direction with the result that other functions or areas of management suffer and performance is frequently substandard.

IMPACT concepts require the fusing of the technical plan and the financial plan on one common time-phased chart, thus helping to ensure that the plans are interrelated and consistent. Also, it provides an extremely simple yet useful technique for analyzing programs. Exhibit 1 on page 37 contains an IMPACT chart which synthesizes a typical program plan with a forecast of costs by project. It will be noted that each of the separate program phases is identified against a time base. The key mileposts are also included. The lower half of the chart reflects the cost forecast by program, which is time-phased in a similar manner.

Exhibit 2 on page 37 is an IMPACT chart which contains a forecast of manpower requirements by skill categories. These charts are completely flexible as this same manpower information can be shown by program, plant, or in any other manner management desires. The advantage of integrating this information on one chart is that it makes it relatively easy to analyze the manpower and cost data to determine whether they are consistent in terms of build-up, phase-out, or any other time increment.

The basic rule underlying the concepts is that cost data, program plans, schedules, or other similar information will never be understood by management unless they are jointly presented in a common chart similar to Exhibits 1 and 2. The reasons for this have been enumerated. Management cannot make a sound decision unless it is sure that all of the technical and cost aspects of the program are given consideration. Key management decisions are not solely technical or financial; they are both. Consideration must be given in management decision making to alternatives affecting performance, schedules, and costs. The decision making process typically involves trade-offs based on these variables. If there is any potential change in cost or in the technical program, management should be informed at the time the decision is to be made of the implications these changes have for budgets, schedules, and technical progress.

Use in control

The IMPACT approach is also useful for control purposes. Once the program plan and budget are established, as in Exhibit 1, performance can be measured against this technical and cost plan as actual experience is incurred. Exhibit 3 on page 41 reflects this. Exhibit 3 represents a status report on a hypothetical rocket motor program showing the actual accomplishment versus the plan outlined in Exhibit 1. Two differences be-

Milestone Legend
1. Com. Prel. Des.
2. Test FIM Motor
3. Award S.D. Con.
4. App. Sys. Des.
5. Initial F.T.
6. Final PFQT Test
7. Award Site Dev. Con.
8. Final Qual. Test
9. Award Prod. Con.

IMPACT PROGRAM AND COST SCHEDULE

By Project & Task

WS NO. XXX NO. 1 REV. NO. 0

CONTRACT NO. XXXXX Large Solid Motor DATED 2-2-65 PREPARED BY

DESCRIPTION	Program Number	1965 1	2	3	4	1966 1	2	3	4	1967 1	2	3	4	1966	1967	TOTAL MOTORS
System Definition	1	⟶		*												3
Feasibility Dem.	2		1 1	1 ⟶												36
System Development	3				1	2 2 1 ⟶										6
Design	1			⟶			1 1 2	2 1 1 ⟶								8
PERT	2					⟶			1 1 ⟶	1 ⟶						3
Continuing Dev.	3							⟶	(1	1 1 2	22 ⟶					9
Qualification																10
Flight Test						(1	1 1		1	1	1	2 2 ⟶				150
Production	4												⟶	50	100	189
Key Program Milestones			▽	▽	▽	▽	▽	▽	▽		▽	▽				

DESCRIPTION	Program Number	1	2	3	4	1	2	3	4	1	2	3	4	1966	1967	TOTAL
System Definition	1	$35.000														$35.000
Feasibility Dem.	2	10.000	$20.000	$15.000	$5.000											50.000
System Development	3															
Design	1		5.000	10.000	20.000	$20.000	$5.000									60.000
PERT	2			5.000	5.000	20.000	35.000	$25.000								90.000
Continuing Dev.	3							15.000	$20.000	$10.000						45.000
Qualification	4								30.000	30.000	$20.000					80.000
Flight Test	5					10.000	10.000	10.000	10.000	10.000	20.000	$15.000	$5.000			90.000
Production	4											15.000	35.000	$250.000	$200.000	500.000
TOTAL In Millions		$45.000	$25.000	$30.000	$30.000	$50.000	$50.000	$50.000	$60.000	$50.000	$40.000	$30.000	$40.000	$250.000	$200.000	$950.000

*These figures represent rocket motors produced for or utilized on each program or project as indicated.

EXHIBIT 1

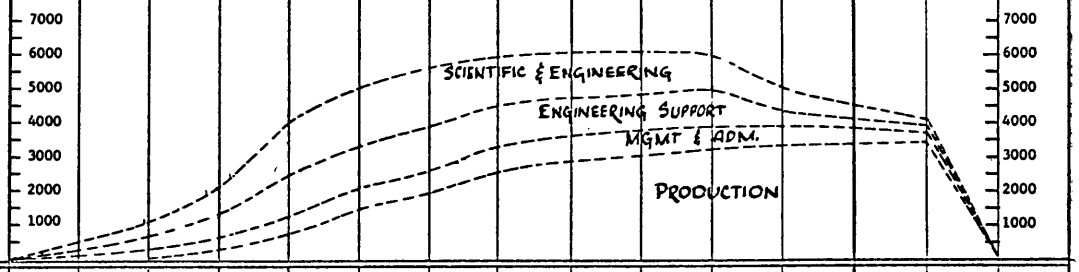
EXHIBIT 2

IMPACT PROGRAM AND COST SCHEDULE

Manpower By Skill Categories

WS NO. XXX NO. 1 REV. NO. 0

CONTRACT NO. XXXXXX Large Solid Motor DATED 2-2-64 PREPARED BY AMC



DESCRIPTION	Program Number	1963 1	2	3	4	1964 1	2	3	4	1	2	3	4	1966	1967	TOTAL
Scientific & Engineering		250	500	775	1575	1600	1625	1500	1400	1375	1200	650	400	150	100	
Engineering Support		175	350	675	1325	1350	1400	1275	1050	1025	1000	500	300	100	50	
Management & Administration		75	150	300	500	600	650	700	700	700	700	700	600	500	350	
Production				250	600	1450	1825	2525	2850	2900	3100	3150	3200	3250	3000	
TOTAL		500	1000	2000	4000	5000	5500	6000	6000	6000	6000	5000	4500	4000	3500	

The system, to meet management's needs, must contain information on the primary management aspects of any program. Emphasis is placed on the need for the system to integrate and correlate technical planning, scheduling, and performance with financial planning, scheduling, and performance.

tween the exhibits should be noted. For reporting purposes, Exhibit 3 is on a monthly rather than quarterly basis, and it covers only the system development project rather than all of the four projects included in Exhibit 1. Exhibit 3's value as a control document is readily evident. In reflecting the status of the project as of the end of February, 1966, the circled numbers under the design subproject in the January and February columns, on the top half of the report, represent the actual dates the rocket motors in the subproject were completed. It will be noted that for all four motors this effort was completed approximately ten days later than the original plan. This gives a good indication of the technical progress under the program as of this date.

The budget status is reflected on the same basis. The top row of cost figures opposite the system development project represents the planned budget. The "P" in the January column indicates that these are planned figures. The "A" just below the "P" in the January column identifies the actual costs for January and February. The figures below the system development project totals are a breakdown of these totals into the various subprojects.

It will be noted that the project overran $4,900 in January and underran $4,500 in February. By adding this budget information on the lower half of the chart, the cost status of the project and the technical status are shown simultaneously. In this particular example, as both technical and cost performance are reasonably close to the plan on a cumulative basis, there is no cause for alarm. However, if the costs were overrunning significantly and the technical program were behind schedule, it would be adequate warning to the program manager that his project was in trouble. It should be noted that Exhibit 3 is only a basic summary report. Supplementary budget and technical reports in much greater detail are needed to more closely identify the individual variances.

Systems requirements

It is not possible in a brief article to explore fully all potential applications of these concepts. However, appreciation of their scope and usefulness can be obtained by reviewing the implications the concepts have for management control and reporting systems. Any management system which successfully meets the needs of rapidly changing industrial programs must contain the following features:

The eight essentials

1. The system must be management oriented. It must contain the key items of management concern in decision making, and it must be consistent with the manner in which management plans, monitors, directs, and controls programs. With effective communication presenting the problem that it does on aerospace-type programs, the prime aim must be to develop an integrated control and reporting system for management.

2. Closely related to the above is the requirement that the system must contain information on the primary management aspects of any program. Emphasis is placed on the need for the system to integrate and correlate technical planning, scheduling, and performance with financial planning, scheduling, and performance

3. A third requirement is that the data should be graphically portrayed in a manner to highlight relationships and enhance quantitative analysis. With the mass of information management must digest on programs of this sort, it is mandatory that data be effectively, schematically portrayed for ease of understanding and to provide quick visibility regarding interrelationships.

4. The system should be as simple as possible and yet contain the key items of management concern.

One of the problems created by PERT is that specialists must be trained to operate the system. Current industry practices should be emphasized. Accordingly, under the IMPACT system, industrial accounting is utilized, the milepost approach to planning is incorporated, and no intricate concepts are included which require extensive training for those working with the system. Actually, PERT can be effectively utilized as the basic planning tool in the system, but it would be integrated for management reporting purposes with the IMPACT technique.

5. Stress is also placed on flexibility. The dynamic nature of aerospace programing has resulted in frequent changes. Unless a system is flexible enough to accommodate these changes, such a preponderance of available time is required to update and revise obsolete information that the system never does reflect the current situation. Standardized formats should be utilized so that management can become familiar with the manner in which the information is portrayed. Once management obtains a working familiarity with the information in these formats, it can easily comprehend the cost and technical interrelationships.

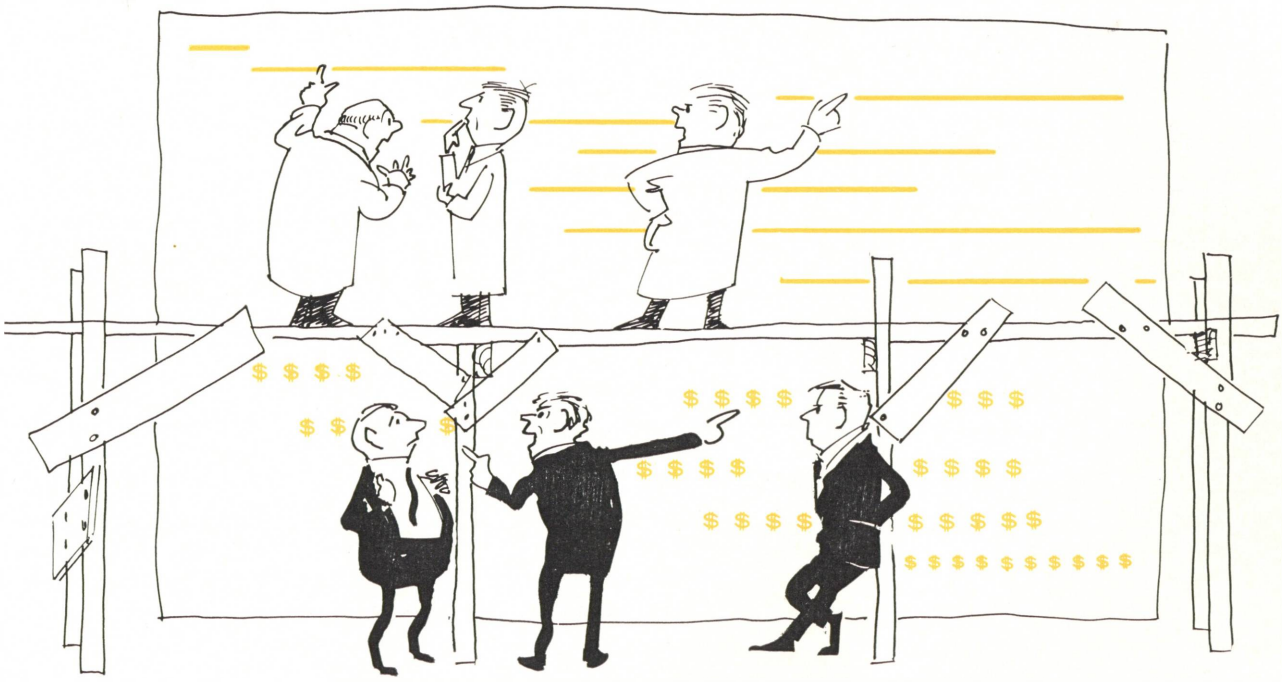
6. The concepts are to be applied uniformly at all levels of the organization or program. This will increase the ease with which the information is either analyzed or accumulated for reporting at the higher management levels. For example, when lower-level organizational elements submit budget estimates on a program, they must do so in an IMPACT format so that their technical assumptions and goals are also shown. The rule is always to be followed that all organizational elements, regardless of the level within the company, must submit all basic planning or cost data in IMPACT form so that this information can be reviewed and considered simultaneously. Supervisors at all levels find these techniques extremely useful in carrying out many of their planning and control responsibilities.

7. The basic system should be established to cover the life cycle of any program or project. On this basis it will be a valuable planning tool as the charts integrating the cost and technical information are developed with the first program plan. Cost and technical changes in the basic charts are consecutively numbered, which is a significant aid in tracking the history of a project. As IMPACT's primary value is in research and development programs, it would not be utilized in depth on other phases of a program, such as during production, except for basic summary management reporting.

8. Finally, the system must provide a meaningful measure of cost and technical performance for the project as a whole, for individual segments of the project, or for individual groups participating in the project in accordance with Exhibit 3.

Utilizing IMPACT concepts

One or two examples will serve to indicate how a system of this sort is utilized in practice. One of the most striking examples of its application is in proposal preparation for bidding on government programs. The usual manner in



IMPACT concepts require the fusing of the technical plan and the financial plan on one common, time-phased chart, thus helping to ensure that the plans are interrelated and consistent.

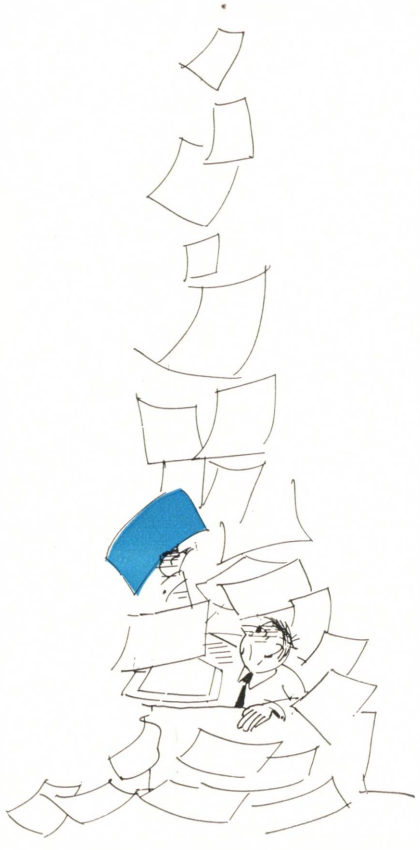
which parallels the organizational structure of the Department of Defense or any other government agency is to provide separate technical, management, and cost volumes. This separation increases the lack of understanding which already exists between technical and administrative personnel. With the exception of the project officer, who is typically well versed in the technical and cost aspect of his program, individuals with a scientific background review the technical proposal, and specialists in price analysis review the cost proposal, with no guarantee that they are reviewing information which is consistent and properly interrelated. The problem of analyzing the cost volume is extremely difficult for the price analyst, who generally has very little technical training.

On a scientific program, all cost estimates are based on technical assumptions, and when these estimates are separated from the appropriate assumptions, they become meaningless and misleading. The advantages of the IMPACT approach are threefold: It requires that all proposal data be tied together through common formats; it forces the company presenting the proposal to integrate technical and cost planning; and it makes it easier for the price analyst and all others working with the proposal to comprehend the interrelationship among the cost, technical, and scheduling variables. The splitting of the proposal, resulting in its complete segregation into technical and cost sections, has supposedly been for the convenience of technical and cost specialists, but in actuality it has been to their detriment. It is also entirely contrary to the manner in which management must make its decisions and should view problems of this nature.

Another good example of the value of these concepts relates to the problem of management reporting. In this era of rapid data accumulation through the utilization of electronic data processing, we have tended to overload management with a wide variety of frequently useless reports. Generally, more reports cross the manager's desk than he can possibly hope to review or absorb. In many instances these reports come from separate organizational units and cover different program aspects or management problems, and there is no assurance that the information is consistent or properly interrelated. When these concepts are used, it is possible to submit one report to management which covers the cost and technical features of any program. Also, adoption of formats similar to Exhibits 1 and 2 gives assurance that management will not receive any technical report or recommendation which has been developed apart from the appropriate cost considerations. At the same time, it ensures that cost reports which are submitted contain sufficient information regarding the technical status of the program to make the reports meaningful and understandable to the manager.

There are many other possible examples in addition to these two illustrations of the usefulness of the IMPACT concepts. In any management activity where program planning or cost information is presented, these concepts have definite application. They are beneficial in a commercial activity where consumer products are being developed and produced as well as in aerospace-type programs. The concepts have also been found to be extremely useful in the construction industry. The principle holds true under all operational situations that cost information is most easily understood and most effectively presented when it is shown simultaneously with the physical data regarding production status, effort expended, or work accomplished as a result of the costs incurred.

An operations manager must be able to see behind cost figures and interpret them in a familiar frame of reference. The dollars alone tend to be meaningless in strictly operational situations as the manager works directly with



Since the advent of EDP, management has become overloaded with a wide variety of frequently useless reports. With the IMPACT concept, it is possible to submit one report to management which covers the cost and technical features of any program.

IMPACT PROGRAM AND COST SCHEDULE

WS NO. XXX — By Project & Task — NO. 1 — REV. NO. 0

CONTRACT NO. XXXXXX — 1966 — DATED 2/2/65 — PREPARED BY

Large Solid Motor

DESCRIPTION	Program number	Prior yr. Actual	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	Total 1964	TOTAL
System Development	3															Motors 18
Design	1		2 (2)	2 (2)	1											5
PFRT	2						1	1	2	1	1					6
Continuing Develop.	3											1	1			2
Qualification	4													1		1
Flight Test	5						1		1	1			1			4

System Development	3	$45.000	P $12.300 A 17.200	$20.800 15.300	$16.900	$17.800	$16.800	$15.400	$16.300	$19.300	$14.400	$14.300	$23.300	$22.400	$210.000	$255.000
Design	1	35.000	P 8.000 A 6.700	8.000 7.400	4.000	3.500	1.500								25.000	60.000
PFRT	2	10.000	P 1.000 A 2.500	9.500 7.800	9.500	11.000	12.000	12.000	12.000	9.000	4.000				80.000	90.000
Continuing Develop.	3		P A						1.000	7.000	7.000	8.000	8.000	4.000	35.000	35.000
Qualification	4		P A									3.000	12.000	15.000	30.000	30.000
Flight Test	5		P 3.300 A 8.000	3.300 .100	3.400	3.300	3.300	3.400	3.300	3.300	3.400	3.300	3.300	3.400	40.000	40.000
TOTAL		$45.000	P 12.300 A 17.200	$20.800 15.300	$16.900	$17.800	$16.800	$15.400	$16.300	$19.300	$14.400	$14.300	$23.300	$22.400	$210.000	$255.000

In Dollars (Millions)

EXHIBIT 3

manpower, materials, and other resources in accomplishing his assigned responsibilities. Cost figures, when presented separately, will only disguise this basic information.

It should be noted that when the IMPACT system is utilized alone, it does present some limitations. One of the original weaknesses of the Gantt chart approach which led to the development of PERT was that milepost charts do not, as a built-in feature, show dependent relationships. Thus, if the initiation of a project or activity is dependent upon the completion of some other project or activity, it is not necessarily evident from the milepost chart. The PERT network approach eliminated this deficiency. This same basic weakness carries over into the IMPACT system as it is based on Gantt charting. Also, IMPACT does not take advantage of the "management by exception" approach as well as PERT does. PERT does this by highlighting the pacing activities in a program through the critical path technique. IMPACT does reveal how far a program or activity is ahead of or behind schedule, but it does not do this in terms of comparing a particular series of events and activities with all other events and activities within a specific program. It is for this reason that it is recommended that PERT be utilized in conjunction with the IMPACT system when appropriate.

Conclusion

Since World War II this country's aerospace programs have presented the greatest management challenge which exists today. Management of these projects is necessarily complex as a result of the massive engineering activities which they encompass. Because of this complexity, special problems in communication have arisen, resulting in a requirement for innovation in management systems. IMPACT is one attempt at providing a management reporting system which integrates the key aspects of management concern regarding advanced technology programs. It involves a simple integration of the concepts behind milepost reporting, utilizing the Gantt chart approach and the concepts of the forecast budget. It offers the following four primary advantages:

1. It integrates and effectively correlates technical program planning, scheduling, and performance with financial planning, scheduling, and performance.
2. It requires that all program changes be accompanied by financial and budgetary updating since these changes must be submitted in the IMPACT formats.
3. It provides data in a form for effective and meaningful review because it schematically portrays the program and cost aspects of any situation.
4. It is oriented to meet the needs of management.

The concepts are indicative of a trend in management reporting. The emphasis on departing from the traditional practice of segregating technical and cost information and replacing this with the concept of integrating such data in accordance with the needs of management is a useful concept which should be and will be incorporated in management systems of the future.