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Estimating as a Management Tool

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ESTIMATING AS A MANAGEMENT TOOL

Estimating in the fullest sense involves far more than cost analysis. Rather, it should be a comprehensive planning process, a model of company organization, operations, goals under the conditions imposed by the program being considered.

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EVERYONE grumbles about the estimating profession—its practitioners most of all! The estimator says management ignores estimates and quotes jobs at give-away prices. Management seems to remember only when it bought the estimate for a major program which promptly went down in flames. Somebody is always unhappy. And to make matters worse, everyone thinks of himself as an expert in estimating who can do better than those responsible.

The situation is often explained with the old bromide that estimating is art, not science. This is indeed true of much estimating—from estimating the cost to make or machine a casting to that for assembling a large missile or developing its design and prototype. But that answer begs the issue. For what is it that makes estimating so bothersome?

At the very outset, certain elements of estimating practice hint that much more than cost analysis is involved:

- Cost analysis is tied to the past, but the estimate is a look at the future.
- Cost data itself depends on operating results and policy decisions, sales forecasts, make-buy policy, the volume of other products, facilities available.
- Cost overruns are taken as direct evidence of poor estimating, but a fair share are due more to poor management after the job is sold.
- Costs are only a *part* of management's decision to quote or proceed with a program.

Failure to recognize this interdependence of estimating with other management arts may be the root of our difficulty. On this basis, then, the proper aims and scope of estimating will be the prime subject of this discussion, after we develop specific background on typical estimating practice and the issues it raises.

Two types of companies are illustrated—others could be used, but these two are of particular interest, as we shall see. The estimate itself may be either for quotation to customers or for management review prior to approving company support of a large project. Both circumstances are of equal importance, for either course commits the company to a major series of actions during which it risks loss of funds and misallocation of valuable resources.

A commercial manufacturer

Chart I, page 34, outlines the estimating procedure for a typical commercial company. The key steps of the estimate or data required by it are listed down the left side, and the major participating departments across the top. The circles indicate the functions performed by each department, and the flow of data and advisory relationships are indicated by the lines connecting them. The basic flow is from Design (A) to Schedule (B) to Price (C) to Cost (D) to Top Management (E) which, of course, makes the decision. There is a great deal of feedback between departments on crucial aspects of the estimate, as indicated by the lines which connect different departments crisscross fashion.

In a commercial company, selling price and other marketing require-

ments dictate the ground rules. The estimate starts with a forecast of sales volume and shipping prices based on established distribution patterns. These data constitute parameters governing not only production costs, but all phases of design, development, and production planning as well.

Generally, the commercial manufacturer's estimate involves relatively minor changes in existing products or manufacturing processes. They may seem big at the time, but, as we shall see later, they usually are rather modest in scope. The objective is generally greater reliability, lighter weight, easier servicing, longer life or other factors of improved customer appeal. The design engineering department's participation in the estimate is therefore modest, limited to preparation of revised drawings and specifications and conduct of some tests. Since development costs and timetables will be minor in relation to the total estimate, even a substantial error is not too significant. This generates a real weakness in commercial estimating skills. When such manufacturers do face major development programs, they find it difficult to program the effort accurately and so incur a disproportionate risk of error, as many have learned to their sorrow.

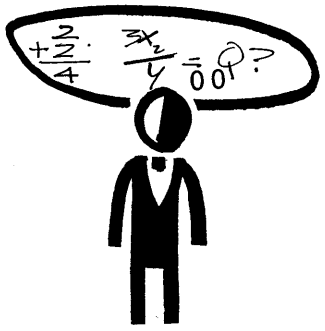
Manufacturing problems

Scheduling of a new program mainly relates to tooling and production change-over problems, with related vendor support. Facility and tool requirements may be sizable in dollars, but they are familiar types and involve familiar rearrangement or expansion moves. Production programing is therefore simple, so that again the commercial company's skills in this basic management art are only partially developed. This is not always recognized by the analysts who become fascinated with the impressive mechanization of procedures.

Much commercial manufacturing involves a high degree of machine-controlled operations, so that labor content is low, well-defined, and easily monitored. Therefore, direct labor costs can be based on fixed industrial engineering standards for run time, plus allowance for setup based on lot sizes appropriate to the product and company experience. Since the change in product design and manufacturing process is minor, the effect of shifts in make-buy relationships (more ticklish to estimate) is slight, and the principal difficulty is in the impact of change-over on the small area of scrap and rework costs. Consequently, where sizable start-up costs are involved or a major new product introduces high unit labor costs, the commercial company has much less estimating capability, and it is often reduced to a cautious phasing in of small changes over a period of time. Similar considerations apply to estimating material, predicated on stable make-buy policies and considerable experience by vendors on the important materials. Accuracy is high, but again the skill of estimating new designs and materials is not developed.

Shop overhead costs frequently run 25 per cent or more of the sales dollar. Although reporting of these costs is traditionally the butt of criticism by management analysts, the commercial company does a careful job in estimating overhead on the whole. Data are computed for many burden centers, and there is examination of variable as distinguished from fixed, cash versus noncash, and sunk versus uncommitted costs—though often with wistful backward glances at less sophisticated concepts. Some companies even apply industrial engineering standards to overhead elements, though many who say they do simply rearrange crude budget data into a "standard cost" format.

One result of this close examination is worth further comment. With reasonably good prediction of long-range markets, much thought has been given by some commercial manufacturers to the cyclical pricing effects of the distribution of fixed overhead. The costs of basic manufacturing organization and facilities are relatively fixed throughout the ordinary fluctuations of business. Therefore they should be given no more weight in a year of low volume than in one of high volume. Ordinary costing techniques result in greater allocation of fixed costs to each unit in a year of lower volume, and so affect the estimating process by generating a push to higher prices at the very time when they are least supportable.



One approach to this is to ignore fixed costs entirely in making the price decision (see below). Another is to allocate them to units each year on a fixed "standard volume," a projection of average unit output for five or ten years ahead. Obviously the *investment* in those fixed costs must prove profitable over the same cycle, or it should not be made. But *allocation* of that investment to the units made each year should be appropriate to that year's volume, so as not to affect the estimating problem disproportionately. Many questions are resolved by this broader approach.

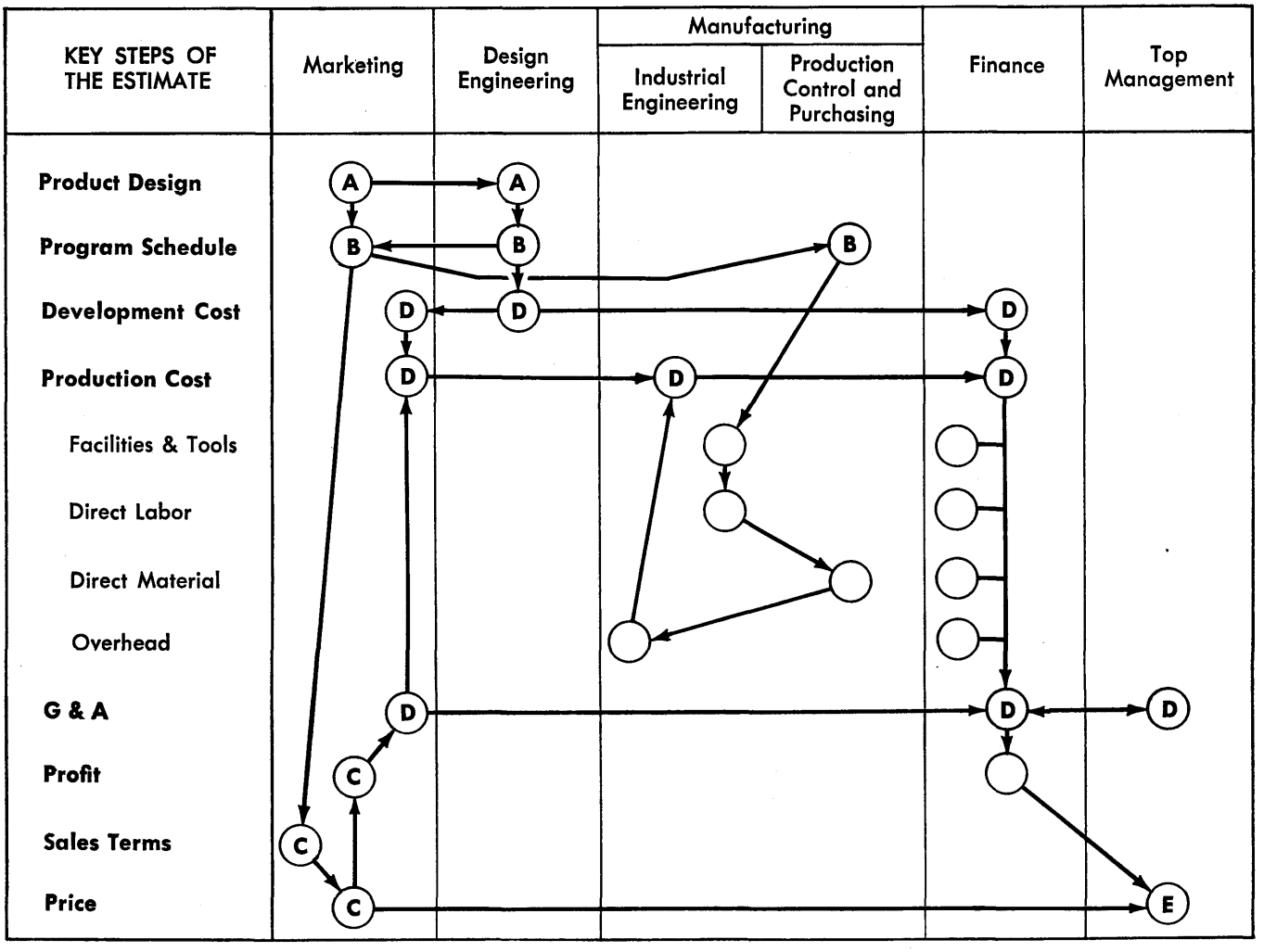
Other considerations

Selling and administrative expenses receive careful treatment in keeping with their size (7 to 40 per cent of sales). Sales promotion and advertising alone can be sizable, and are assigned to specific products on the basis of well thought out promotional plans. Warehousing and similar distribution costs may even be subject to the same industrial engineering analysis applied to manufacturing operations.

Establishment of the final selling price, with associated distribution pattern, sales terms and discounts, is dominated by Marketing. The relation of the product's price to

Chart 1

NORMAL ESTIMATING PROCEDURE
Commercial Hardware Manufacturer



competition is a primary consideration for commercial business; price comes first. Profit is determined by what can be worked out in the cost area to fit the general price guideline, and a program may well be dropped if intensive "value engineering" results in a margin not adequate to justify the risk. In addition, some companies have moved well into the abstractions of economic analysis to determine the way in which changes in unit price affect the rate of unit sales volume (the demand curve). By measuring how price cuts increase the rate of sales and price increases reduce it, and by combining this analysis with data on *variable* unit cost, one can often estimate with tolerable accuracy the price at which company profit will be maximized. This price will in turn define the rate of sales to be expected, which itself will establish the impact of fixed costs and final company profit. The whole procedure hinges on marketing analysis, which during the past three decades rapidly has become more sophisticated within commercial companies.

Similar analysis may be applied to promotional costs. Some companies have gone far in determining the sales impact of a dollar's worth of additional advertising or dealer contest costs, even by area of the country. Such costs affect *both* unit sales rates and variable unit costs, but will also permit evaluation of the company's most profitable combination of selling price and promotional cost. This certainly complicates the pricing and estimating decision beyond the point of simplicity comfortable to many managements. But such analytical techniques define the right issues and force the entire estimate to grapple with concepts actually relevant to the business decision at stake.

Throughout the entire estimating process there is constant feedback of the facts or decision at one step upon those at others. This is stimulated through the constant participation of Marketing and Finance, whose key personnel generally take a broad view of the entire proce-

	TOTAL	MARKETING	ENG'G	MFG.	FINANCE
Design	4	2	2	--	--
Schedule	7	3	2	2	--
Cost	25	6	3	6	10
Price	6	4	--	--	2
Total	42	15	7	8	12

Figure I

dure. The degree of interaction may be crudely suggested by counting the number of circles (duties performed) and lines (advisory relationship) which connect different departments in our flow chart:

Marketing has 36 per cent of the activity according to this count, with almost 30 per cent assigned to Finance. The Finance contribution is even higher where that department plays a key role in broad management planning and policy formation, as it does in many commercial companies. (See Figure 1, above.)

A technical products company

During the past thirty years, companies in certain industries have found themselves under increasing pressure for rapid technological advance in their products. During that time, research and development has advanced to such a dominating position as to make change a virtual way of life in such industries as aerospace, electronics, atomic energy and instruments. The same thrust has also affected the make-up of those in command of such companies, since the emphasis on technical accomplishment encourages technical background for those in key management spots.

Born of defense needs

Such industries originally appeared in the field of defense oriented products, reflecting acute needs by the military not only to capitalize on but also to stimulate advances in science and engineering. However, the progress of the scientific revolution during the last three decades has caused generally rapid expansion of industry sharing its fruits. The strength of the trend may be illustrated by the fact that the number of patents issued yearly jumped in twelve years from 32,000 to 52,000, one-fourth faster than the national output. The number of doctor's degrees granted in engineering jumped explosively by 20 per cent a year in 1960-61. Coming closer to industrial operations, research and development expenditures climbed almost one-fifth each year from 1954 to 1958, and kept right on climbing by 12 per cent annually through 1961. These costs alone are now 3 per cent of our whole national output! Each of these developments contributes to the huge volume of business now done by companies operating in highly technical areas.

What is that volume? As one approach, a simple tabulation of sales volume for thirty-eight major technical products companies totals around $26 billion for 1961; adding the R&D expenditures by other sectors of the economy, total activity was some $35 billion. As another, value added by the technical companies[1] exceeds 35 per cent of all hardgoods manufacturing;[2] when R&D by other sectors is added, total technical products activity is within a quarter of equaling that by all other hardgoods manufacturing! It seems, then, that the time is not far when the two types of manufacturing will be *equal!*

Since technical companies are so sizable and are still increasing their impact on the economy, appraisal of their estimating practices should be instructive. Chart II, page 36, therefore illustrates them briefly. Generally the chart shows much less interdepartmental feedback than was true for the commercial manufacturer, as portrayed by the simplicity of the flow pattern. But more basically we shall see that major problems exist in areas rarely significant for the commercial manufacturer and have required new management tools. At the same time, operating conditions for technical products companies influenced them to overlook the need for certain conventional management practices accepted by commercial manufacturers after long and bitter experience.

Estimating R&D

From the nature of technical industries, product performance sets the sales pace. A revolution in design creates sales, and the development cycle then governs manufacturing. This is just the reverse of the commercial manufacturer's procedure. Time is of the essence, since the new design can be obsoleted overnight. Development is costly and complex, involving close coordination of design, prototype manufacture, performance test, and final production. This complexity of co-ordination is compounded by extreme time-compression and the multiplicative effect of many small failure probabilities. Further, subsystems are often major development tasks in themselves, and, being performed by outside sources, they can embody the seeds of catastrophic failure or delay to the entire program.

However, one excuse used to justify poor estimates can be refuted: that such estimating involves predicting the basic creative process, which is no more possible for technical matters than for artistic ones. Now it is certainly true that we would not initiate a formal project to produce a painting equivalent to the Mona Lisa for a specified sum of money within a given period of time. The result *might* be achieved, but the probability is low —even with "expert" personnel. But this reasoning, while true, is irrelevant. Even a major breakthrough in the technical products field (such as the V-2 missile or the atom

[1]Value added for the electrical machinery, instrument, and aircraft industries, as reported for 1961.

[2]Value added for all durable goods manufacturers, excluding basic metals production.

bomb), while it demands every ounce of the creativity within its key participants, is not comparable to the fundamental discoveries of physics or mathematics that are the true analogue to artistic creation. Such breakthroughs are simply an elaborate engineering development of previously proven concepts and theories. As such they are subject to careful planning and predictable time schedules, even though with margins of error and an occasional total failure.

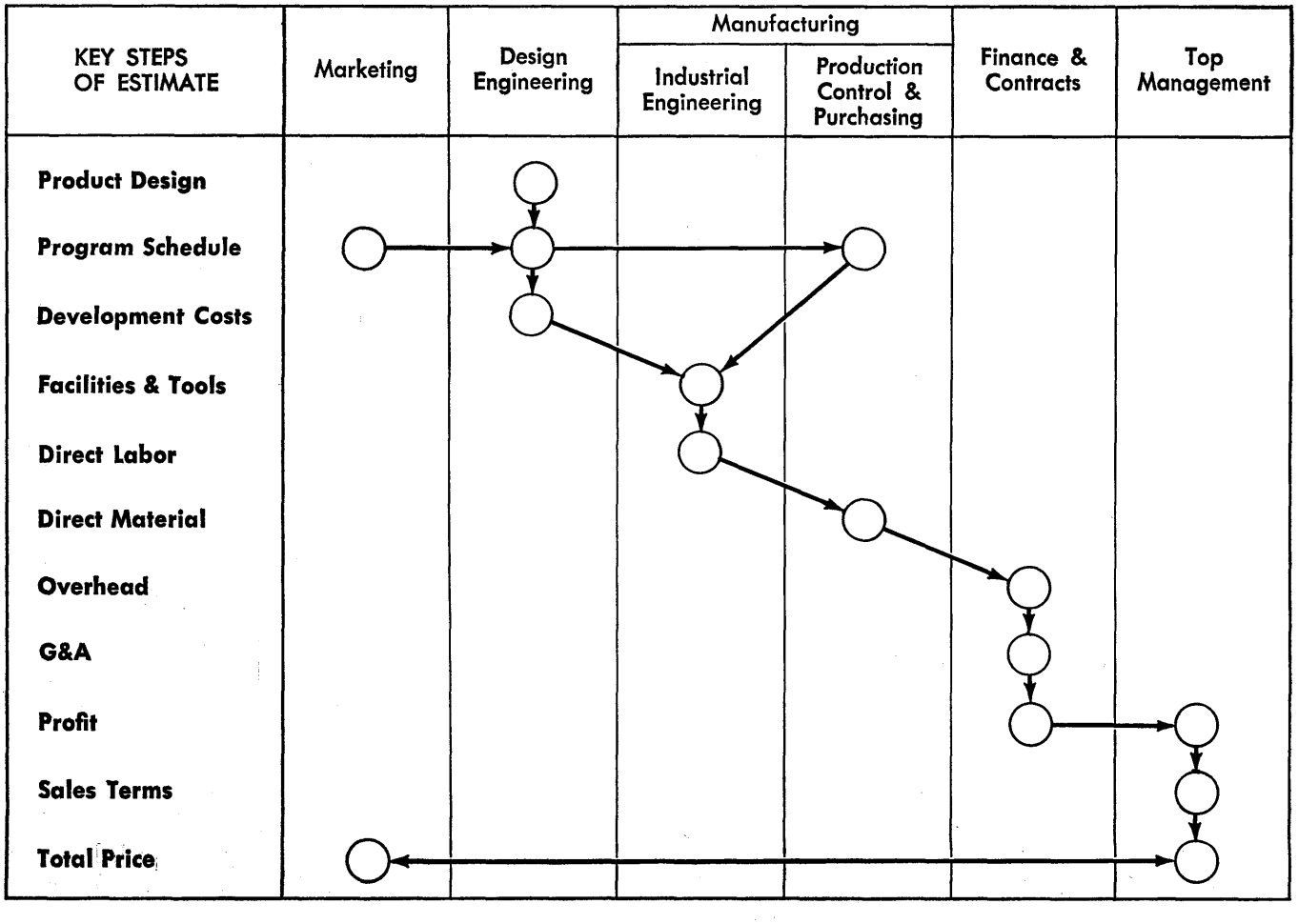
Production time compressed

It is the unique contribution of the technical products industries—especially those in the aerospace field—to have developed effective techniques of planning and coordinating complex development and production projects with fantastic time-compression. The ordinary industrial engineering Gantt chart has been exploited to such an extent that what began as a mere difference of degree has become a difference in kind from all previous estimating techniques. These industries and their Defense Department customers have gone on to invent further refinements such as network scheduling and critical path analysis, which again are developments of previous ideas to such a massive degree as to become brand new methods. Not content with this, they are attacking the classic economic problem of establishing the relationships of cost, time, and other resources to the ultimate product result. The day may not be far off when rather realistic multidimensional "models" of the development cycle can be constructed for physical inspection by company managements and careful exploration by their computers. Such an achievement will be of enormous importance to the entire economy, and must be attributed to the greater technical sophistication of the managements in these industries.

These major contributions to the management art have not been achieved without shortcomings. The difficulties involved in such estimating often encourage abuses, reflecting personal and corporate objectives. For example, there is sometimes a lack of interest in the accuracy of cost or time schedules. Estimates are sometimes on the optimistic side, which certainly helps

Chart II

NORMAL ESTIMATING PROCEDURE
Engineering Products Company



to get the business, but results in overruns "often ranging from 300 to 1000 per cent," according to an assistant secretary of defense. One serious case: the Skybolt Missile which, according to Secretary McNamara, rose in estimated total cost from $0.9 billion in early 1961 to over $2.2 billion in mid-1962. Sometimes estimates are pessimistic and increase the cost base on which profits are calculated under certain types of contracts.

It is not unusual for managements to justify their underestimation of a new technical program by their intention—and ability—to confuse issues and auditors sufficiently to obtain the necessary further funds, and similar techniques can support overestimating. But these practices affect corporate, professional, and personal integrity and therefore have lasting effects. Such compromise eventually shortchanges the technical products industry in getting the full value of its unique contributions.

Estimating direct labor

Estimating production labor costs for these companies is also an unusual problem. New processes and materials require new make-buy decisions, which introduce major elements of uncertainty. The costs of completely new items themselves, even with a freeze on the original design, are always difficult to estimate accurately. But the fact that designs employ "state-of-the-art" concepts also means that engineering changes will be introduced long after production begins, with substantial effects on the level and predictability of costs.

Once more the technical products companies—again the aircraft manufacturers—have developed wholly new techniques for estimating direct labor costs and manpower. The technique revolves around the "learning curve" idea, a fundamental pattern most appropriate to products produced in low volumes (under 5,000 units) but having high unit labor content. Its basic characteristic is described conventionally as follows: if unit N has a certain cost K, unit $2N$ will have a cost RK where R is a constant ratio reflecting the degree of cost reduction from unit N to unit $2N$. Where R is 80 per cent, the 10th unit, for example, is 80 per cent of the cost of the 5th unit, and the cost curve is said to have a "slope" of 80 per cent. Such costs plot as a straight line on log-log paper. Among other contributions, learning curve analysis permits reasonably accurate prediction of the effect of engineering changes on production costs. No other technique does this. It, too, is a tool created to master the effects of time-compression.

But despite the demonstrated power and indispensability of the learning curve idea to technical products estimating, even the aerospace companies have known serious difficulty in using it. We are familiar with the enormous losses reported by all U. S. manufacturers after introduction of jet-powered equipment, which far exceeded the effects of lower than anticipated sales volume and the technical revisions necessary in some cases; and many military aerospace projects suffered major overruns. There is evidence that many such overruns occurred through failure to recognize the existence of an "S-Curve" pattern in early production, affecting the first 100 units or so. Study of this pattern indicates that costs of the first 250 units can be over one-third above that projected by the ordinary straight-line learning curve. Other shortcomings in use of the learning curve have occurred through failure to measure the factors controlling the "slope," to identify clearly the unit for which learning occurs, and to measure the effect of lead times on the degree to which the S-Curve will exceed the ordinary straight-line learning curve.[3]

The tendency of some managements to estimate programs loosely, discussed in relation to R&D estimating, affects direct labor as well. And in both labor and material costs, the bad habits developed through lack of rigid estimating integrity in Government programs lead to major overruns and profit drainage in commercial applications of technical products. But these applications have no angel to subsidize overruns through egineering changes or cost reimbursement contracts. The project must stand on its own feet—such a change is not easy to create in the large group of specialized functions, each with its own bureaucratic momentum, which comprise the technical products company.

Learning curve analysis

Learning curve analysis affects scheduling and facilities utilization equally as much as labor costs. The rapid drop of unit cost has an inverse effect on unit output when manpower is constant. This effect is like that experienced by the Sorcerer's Apprentice, unable to contain the multiplication of effects which he himself set into motion. At some point it is necessary to program major manpower reductions if production is to be held within company financial limits and customer requirements; in turn, major rearrangements of production lines and crew assignments must occur if economic operation is to continue. Careful definition of such requirements is essential to estimating and production scheduling, to which learning-curve techniques add a whole new dimension.

Use of this advanced technique in estimating manufacturing labor is certainly weakened by the accounting practices of technical products companies. Most confuse the very definition of direct labor by including overhead personnel such as inspection, engineering, liaison, materials handling, and shop clerical personnel. This prevents clear-cut measurement of direct labor tasks and efficiency, since nothing similar to the industrial engineering standards for production personnel exists for these functions. It therefore confuses the estimating process and af-

[3]For further discussion, see "New Concepts of the Learning Curve" by the author, *Journal of Industrial Engineering*, July 1960.

fects its accuracy, while unnecessary costs occur through the protection of these personnel by the halo of direct labor classification.

It is common to hear criticism of learning-curve techniques by commercial manufacturing personnel, who feel that the strong pattern of labor cost reduction for technical products simply indicates gross inefficiency in the early stages. Their criticism gains credence from the numerous instances in which such is partly the case. But as a broad evaluation it reflects misunderstanding of the circumstances surrounding introduction of complex state-of-the-art products. Estimating this process—and managing it later—requires understanding of whole new dimensions of cost and schedule analysis, and recognition of that dimension is a fundamental contribution by the aircraft industry. Its further development and application to electronics and other technical industries is inevitable, although proceeding more slowly than need be.

Fabrication estimates poor

Commercial industrial engineers do properly criticize estimating of fabrication activities. Technical products companies in general, and aerospace in particular, have grown up with a considerable disrespect for close control of these costs. This has occurred because development and assembly costs are predominant early in the program, because lot sizes rarely reach long-run proportions, and because the large number of machines and the short runs complicate cost accumulation. But even fabrication cost and personnel become more important as product design is completed and assembly proceeds rapidly down the learning curve. Eventually fabrication—which follows a much less rapid rate of cost reduction—becomes a large proportion of current cost: how large will depend on the total number of units produced. Commercial manufacturers have solved problems of cost accumulation and estimating for complicated fabrication situations, and techniques are available for adapting these solutions to fabrication of technical products. Only the will seems lacking.

Estimating overhead

The overhead cost of manufacturing technical products runs even higher than for commercial operations. After adjusting for the peculiar accounting treatment in which technical companies place some overhead functions in direct labor, manufacturing overhead may run 30 per cent of sales or even more. To this must be added sizable costs of field service, engineering liaison, and company-funded product improvement costs amounting to another 10 per cent of sales.

Despite the size of these costs, their part in the estimating procedure seems the weakest of any for a technical products company. This results from the poor definition and measurement following from the primitive accounting systems in effect. It is not unusual, for example, for a plant of five to ten thousand men to be represented in estimating and product pricing by two or three burden centers; the corresponding commercial practice might well involve ten or more. Under these conditions there can be little separation of fixed and variable costs to provide guidance in estimating new programs, and, where sizable changes occur in the mix of processes or products, major errors are inevitable.

Closely related is the lack of data on utilization of equipment, a heritage of the history of technical companies to whom much equipment was furnished by the Government at little or no charge. Furthermore, the huge tooling costs required by revolutionary products advances may be thrown into overhead for allocation to all products on the basis of direct labor or similar broad indexes, when not furnished free by the Government and so totally ignored in cost statements. Either way generates gross distortion of current operating costs and discourages accurate estimating.

As a result of such loose practice we often observe a technical company, entering new fields or fighting the inroads of competition, failing to sell its services because of unrealistic overhead rates. We hear comments by its management that such types of businesses "just aren't profitable enough" to justify the effort, or that the company's "cost of doing business is too high for that product" and that its efforts had better be spent in other directions. Such conclusions may be unjustified, a fact which would be realized if realistic accounting and estimating practices were to show true variable and cash product costs. The costs themselves eventually would drop as a result! And of course there is the opposite circumstance, where business is underbid with possible serious profit dilution and unexpected working capital needs.

Reasons for poor estimates

The situation exhibits such paradoxes as to cause wonder if there aren't deeper reasons for its existence. There do appear to be such:

1. The primitive accounting practices used permit manipulating direct and indirect cost classifications in estimating Government business. In such business direct cost bears an aura of respectability, in contrast to overhead cost. Raising the amount of direct classification lowers the *apparent* overhead rate, which is a habitual issue with

handicap the estimating procedure

Government buying agencies despite the lack of comparability between companies and lack of correlation with total cost.

2. Low apparent overhead rates ease justification of overruns, since a large portion can be plausibly attributed to a simple following of direct cost by indirect. This objective is directly related to the tendency to underestimate a program to get the business, with confidence that subsequent engineering changes can obtain full cost recovery.

3. The lack of detailed information on overhead costs dulls the sharpness of outside questions regarding internal operating efficiency. It also cuts the embarrassment to which internal departments are subjected by the management itself.

Protection through confusion

We have here a tendency of the large bureaucracy to hide its shortcomings with a cloud of confusion. The tendency is powerful, as shown by the persistent weakness of overhead estimating and resistance to installation of elementary controls on overhead. Unfortunately, there is a reverse effect: in confusing their opponents in this game, management confuses itself too, and—worse yet—trains subordinates in miserable habits. It has only itself to blame for the serious effects on the estimating procedure, and on the inability to meet estimates once a job is sold.

There are those apologists who suggest that the practices discussed could not have had the serious effects outlined here—for don't we have a competitive system which weeds out inefficient operators? And haven't many technical products companies survived and flourished? This is true in the long run. But in the short run they are often protected from close competition, with its cleansing effect on estimates and control procedures. For their products are rarely directly comparable, and price has been less of a factor than delivery and technical performance. In 1961, for example, only one-third of all defense contracts were competitively bid. This has played an important part in permitting the managements of technical companies to avoid upgrading their estimating and control practices to the level reached by commercial companies.

Pricing

The pricing decision, once basic program estimates have been made, tends to be a simple application of G&A rates and a "markup" for profit. In contrast to the commercial products company, there is rarely a specific analysis of the relation of price to the size of the market. Rather than a two-valued decision, an oversimplified decision is made on a single price, and it is assumed that a single market quantity will be the result if the business is gotten at all. This is simply one more hangover from past days of defense business.

There is relatively little feedback of marketing and investment factors. The marketing function is mainly involved in product intelligence, with its frequent associate, the Contracts Department, handling superficial details of coordination, preparation, and submission of the estimates developed. While product design and technical superiority often do create the market, the time has long since come when several sophisticated products may be available to meet one major need. Therefore, price elasticity, promotional effort, and field support are essential to guessing the ultimate buying decision.

In summary, a much simpler estimating process exists for the technical products company than for the commercial manufacturer. Tabula-

Many technical products companies have survived and flourished . . . but most of them have been protected from normal competitive pressures. Their products are often unique; thus price has been less of a factor in acceptance than production reliability and product performance. The result: there has been comparatively little pressure on management to upgrade estimating and control practices to the level common in commercial companies.

	Total	Marketing	Eng'g	Mfg.	Finance
Design	1	—	1	—	—
Schedule	7	2	3	2	—
Cost	12	—	2	5	5
Price	2	2	—	—	—
Total	22	4	6	7	5

Figure 2

tion of duties and advisory relationships from the flow chart appear in Figure 2 above.

The technical company takes only about half as many steps as does the commercial company. Of equal significance, Marketing and Finance account for two-fifths of the total, compared with almost two-thirds for the commercial operation. Despite its major contributions to the estimating art, the technical products company procedure has serious shortcomings.

A redefinition of estimating

Now let's draw some conclusions from the examples which we have just discussed at length.

The procedures followed by the two companies are complementary in strengths and weaknesses. The commercial company is strong in its marketing evaluation and in control of product design to market considerations. It is accurate in manufacturing costs and may make sophisticated evaluation of final price against market elasticity and promotional and manufacturing costs. Finance and Marketing play a notable part in the entire procedure, and the degree of feedback generated by their participation is indicated by the flow chart's complexity. The commercial company is weak in estimating development cycles for major new products and the manufacturing costs when such products are placed into production and in the related scheduling techniques. In contrast, the technical products company is strong in the latter but weak in the former areas. Though it has made major contributions to the estimating art over the past twenty-five years, it often fails to reap the rewards as a result of these weaknesses.

In a way these different areas of strength and weakness are not surprising. It is common for American business to develop its procedures and capabilities by simple reaction to outside forces. Each of these two industry groups reflects different rates of technical progress, marketing maturity, and competitive pressures, and most of the differences in their estimating can be traced to one of these three sources.

Whatever the cause, the situation means that neither type of company normally can handle the other's estimating problem. This is unfortunate, because many influences drive each increasingly into the other's field of endeavor.

Trouble in commercial market

The years since World War II are replete with efforts by aerospace firms to diversify into commercial fields: commercial aircraft, appliances, aluminum boats, mobile homes, industrial instruments, plastic foam for household use, or industrial uses of military electronic equipment. Success has been quite erratic, mainly because commercial production and marketing techniques differ sharply from those followed in defense applications, even when design is similar. The powerful demands on special management skills can rarely be met in time by the same organization.

The commercial manufacturer is increasingly forced by competitive pressure to undertake R&D and ultimate production of products much more sophisticated than those on which the business was built. He is meeting surprising problems in living with R&D schedules and budgets, and persistent difficulty in phasing the new item into production facilities and in controlling the manpower required. Often the dismay of the commercial manufacturing man at his failure to meet such plans is exceeded only by the embarrassment of the treasurer.

Common areas of weakness

In addition to these complementary weaknesses, however, both types of industry are weak in other areas. For example, both companies approach estimating mainly as a matter of cost analysis. This is well illustrated by the fact that in the tabular summaries of each company's estimating procedure, cost considerations amounted to 60 per cent of the total for the commercial manufacturer, and 55 per cent for the technical products company. Despite extensive marketing orientation by the commercial company and R&D programing by the technical company, hassles over costs dominate the estimating procedure and tend to take over the final top decision.

Furthermore, both companies are weak in determining the full effect of a program upon total company operations — what is sometimes

called "program integration." The tendency is strong to make only rough checks of a program's impact on facilities, organization, personnel, and return on investment; lack of a firm decision to proceed seems to deter all but a few companies from working out the full implications of a proposal.

There is also a general failure to determine all elements of investment required in a proposed program—particularly working capital investment. It has been amply demonstrated that working capital (accounts receivable, inventories, etc.) requirements are fully as important as fixed assets and tooling in evaluating the rate of return for a major change in operations.[4]

Such weaknesses can be fatal, and estimating procedures and tools must be improved. With the wealth of experience and insight generated by the two major facets of our industrial economy discussed above, we should be able to arrive at guidelines for the benefit of both, with application to other sectors as well. No system will abolish problems. But a broader view of the estimating process will give a better chance to avoid major blunders.

So we are led to re-examine the purpose of the entire estimating activity. What should it aim at if we are to avoid the frustrations and pitfalls of existing practice? And how can we reach that goal?

Stripped to its bare bones, the real purpose of an estimate is to help top management define a proposed action clearly, so that it can:

- Evaluate the consequences for the entire enterprise,
- Decide what to do about it, and
- Control the results.

To do this job, estimating must be viewed as an exercise in simulation. It is actually a model-building task to explore the realistic impact of a new program on future company operations. The three steps listed constitute an important test of the adequacy of an estimate. If any one of them cannot be taken for a given estimate, that estimate will be identified as likely to produce major error, internal controversy, and top-level uneasiness. From these steps flow several prescriptions for the broad outlines and specific content of a sound estimate.

Program definition

The estimate must provide a complete picture of the project involved, be a complete *plan* of steps involved, and only incidentally a cost statement.

It simply is not enough to buy off on an estimate by saying, "We did it before at $50 per pound and we can do it now for 5 per cent more (or less)." The seat of the pants is a blunt instrument. We must replace this kind of thinking with specifics. How will the job be done? Is there time, floor space, equipment, trained people, vendor support?

For technical product companies this requires closer measurement of sales potential and price-volume relationships, proper appraisal of overhead costs, more internal feedback of data and decisions, upgrading of estimating integrity. Commercial companies must pay closer attention to definition and phasing of R&D with production activities and to the new dimensions of cost phenomena when radically new products are produced. They must also be willing to explore network scheduling and advanced techniques of cost analysis which are beginning to permit unheard-of precision in minimizing flow times and optimizing cost-time relationships. The sophisticated analysis developed by technically oriented companies can contribute greatly to the profits of commercial companies; the main hurdle is in the minds of the managements involved.

For both types of companies, it is essential to make complete evaluation of capital requirements. Even working capital needs can cut the return from a new program to an intolerably low level by raising total investment as much as 75 per cent through sharp differences in the flow time of inventory, the collection period from customers, and terms available from suppliers.

Having clearly defined the proposed course of action, we must then measure its effects on the total enterprise. Many areas of operations and basic strategy must be covered by integration schedules, which interweave the new project with all other major plans and decisions by the company's management. In particular such areas as the following should be carefully worked out:

Sales and operating profit
Penetration of the company's total market
Financing needs
Facility utilization
Manpower needs, utilization, and sources
Overhead
Organization structure
Breakeven point
Return on investment

Certainly top management cannot be expected to make a proper decision on anything less than the foregoing.

Program control

Last but by no means least, the estimate must provide a sound basis for control of the project. If it doesn't do this, none of the foregoing is enforceable, and neither top management nor anyone else

[4]See "The Special Importance of the Make or Buy Decision," by E. B. Cochran in "Modern Approaches to Production Planning and Control." American Management Association, 1960.

can really afford to take the entire procedure as anything but an interesting exercise. No plan is worthwhile unless it contains within itself the levers by which control may be exercised.

To permit control the estimate must first be comprehensive: that is, it should cover all areas of performance bearing on accomplishment of the program. Any checkpoint usable by management in evaluating routine operating performance is a candidate for inclusion: the ratio of market penetration and its trends; the detailed milestones contained in a master plan of development and engineering tests; dates of facility and tooling completions; procurement of long lead-time components; dates of first unit production and of specified rates of output and shipment; the organization structure of key positions; detailed budgets on manpower and costs of direct labor and material; important variable overhead costs; inventory required by type, location, and point in time. A final broad financial summary merely reduces accomplishment in all these areas to (deceptively) simple projections of sales, profit, investment, and return, and is itself a useful control document only when properly supported by such operating data.

Efficient performance assured

It is wise to base all estimates on efficient performance, which there should be a fifty-fifty chance of reaching at any given time. This provides a reasonably consistent basis for control reporting throughout the company, and permits management itself to provide the necessary safety factors all in one decision, avoiding the pyramiding of safety factors so often found.

Of course, there are further requirements of control. Performance must be defined by responsibility area, since that is the only means by which corrective action can be taken. Care must be taken to plan commitments, since this permits control to be exercised over certain large items before the horse is out of the barn. Data shown in the plan must be compatible with the reporting system, since that system is the major means by which the need for corrective action will be defined —this will require changes in most reporting systems as often as it will restrict the plan's format.

If the plan isn't easily controllable, then it is of doubtful validity. That generally means that it has not been thought through. It is worth repeating that cost overruns reflect poor planning and control after the job is sold as often as they do bad estimating per se. If the estimate doesn't contain such planning before the decision is taken, not only are the projections less likely to be correct but the tendency is almost irresistible to forget about making the detailed plans after the job is obtained.

Effect on estimating organization

We have seen that estimating should involve complete definition of a program and of its effects on all company operations. It follows that it must be separate from the operating functions of engineering, manufacturing, and marketing. Therefore it must report either directly to top management, or through a top-level staff function which does. It can also be concluded that since a large portion of the task pertains to profit analysis and investment in facilities and working capital, the estimating function must have prompt access to key financial data and be capable of evaluating it. Let us now consider what these requirements entail for organization placement of the estimating function.

One possibility—with considerable attractiveness—is that of a separate programing office reporting directly to top management. Such a function may well have not only the estimating responsibility but also certain closely related planning functions such as market analysis, sales forecasting, and facilities evaluation. This is sometimes done by the aerospace industry, and it works quite well where other staff departments are not qualified to handle the forward planning and complex co-ordination always involved in preparation of large estimates.

Finance should be responsible

However, serious conflict and duplication can result when the analysis functions involved in estimating costs are separated from the financial department. Finance reports the cost and other statistics essential to all departments, and has long been considered mainly a data processing service. But because of its relatively objective position, its placement astride the lines of communication, and the increasing importance of advanced management control techniques, Finance is being given far-reaching responsibility for evaluation of company performance and of related plans.[5] This is also inherently economical, since operating results and plans must be anlyzed simply for Finance to select significant areas, condense the relevant data to save management time, and make reports realistic and accurate. As the financial function increasingly acts as a broad planning and control function, its responsibility for data accumulation and audit is progressively overshadowed by its analytical activity. The referenced discussion gives further reasons why this should have occurred. Where it has, the creation of a separate programing office will dilute planning and control functions through conflict

[5]See "What is a Controller," E. B. Cochran, *The Journal of Accountancy*, July 1955.

Estimating is too often handled as an exercise in cost analysis . . .

of interest and duplication of functions with Finance.

There is another possibility, with considerable utility in some situations and strong adherents in many companies. That is, to establish program managers reporting to top management. This is actually a variant of the first approach, but it carries the further assignment of line co-ordination responsibilities once the program becomes activated. It has the advantage not only of focusing attention on all phases of a new product program in the estimating phase, but of applying the same emphasis to actual operations. This achieves a unity of approach in both planning and operations, comparable to that occurring if the program were set up as a separate operating division, which may actually be the final result.

The approach is often used by the aerospace industry and in merchandising organizations where emphasis on marketing considerations is so intense that the marketing product manager is granted a wide scope of authority.

Objectivity is compromised

However, in a manufacturing and engineering environment, this solution has many drawbacks in addition to those mentioned above. First, the objectivity of the planning process itself is seriously compromised by the interest which the product manager has in generating a favorable decision on his proposal. This necessitates a thorough evaluation of details by an outside group, generating unavoidable duplication. Second, it encourages empire building. as more facets of each company function are sought by the product manager, once the project is operational. Third, new product line assignments generate major controversy, while frequent shifts due to rapidly moving technology stimulate maneuvering by candidates to acquire prize assignments, extend their "empire" or widen their scope of authority.

A third possibility

The third major possibility is that of a strong estimating group in the analytical area of the financial department. This solution meets the main objections to the first two, and can be a good one. But it has its own trap: it cannot be effective when the estimating group is primarily staffed with accountants. Estimating, as is true for many areas of analytical work, requires a particular combination of industrial engineering, financial, and marketing talent if proper feedback and planning are to be the result. Such personnel have been rare in the past, and the emphasis on specialization necessary to so much of the financial profession has generally meant an increasing inability to grapple with the broad problems of estimating.

However, as the arts of program planning and profit planning themselves have become wider spread, and the breadth of graduate business education has increased, the supply of personnel trained in such work has improved. But if a choice must be made, it is better to establish a separate planning function at first—then transfer it to Finance—than to place the function in Finance when adequate personnel are not available.

Concept too narrow

To summarize: Estimating is too often handled as an exercise in cost analysis. This leads to what is euphemistically called "poor communications" between management and the estimating profession. But such phraseology simply papers over the real problem. The heart of the matter is the narrow concept of estimating held by many practitioners—from the professionals themselves to the executives to whom they report and who rightly criticize the inadequate results.

A review of estimating practices illustrates this thesis. Taking two widely different major areas of manufacturing, we saw that each is strong in certain areas but weak in others, reflecting their histories. Both emphasize cost too much, and so make major decisions without essential facts. Naturally, this creates major errors in cost projection.

Estimating is planning

Against this backdrop, we are led to view the estimating process as comprehensive *planning,* requiring extensive feedback between participants at all states of preparation.

Reduced to its essentials, an estimate is actually a major step in company planning. Therefore it must be:

1. A realistic master plan for product development, testing, phase into production, and operations.
2. Inclusive of working capital and facilities requirements.
3. Integrated with other company plans on the basis of their probable success.
4. Evaluated against total company objectives for market position, sales volume, profit, and investment.
5. A sound basis for operating controls.

It is therefore suggested that an estimate should be considered an exercise in simulation: a *model* of company organization and operations under the new conditions posed by the program under review. This concept has real consequences for the organization responsibility of estimating and for the type of personnel who handle it. And without proper implementation there, achievement of the goals developed is impossible.