Engineers find it extremely distracting when people are casually turning pages of noisy newspapers only 2 ft away from the paper design of the world's most sophisticated "widget." For this reason, reference texts and abstracting materials should be grouped in functionals areas which are less apt to be noisy than browsing areas. The objective is to get all the company library functions into one central location so as to provide maximum visibility of the contents of the library. In our company, all materials except internally generated reports are the responsibility of the Library Services Manager. Individual departments within the line divisions maintain responsibility for internal reports.

At Sanders Associates we try to make our library as attractive and service oriented as possible by using various colored shelving to indicate functional areas. For example, brown shelving indicates current journals alphabetically arranged in the reading area, yellow shelving is for bound journals and circulating books, blue is for core-reference books, and gray designates our abstracts and bibliographic index section arranged alphabetically by title.

Our technical library has an area of about 5100 ft^2 with an annex of 800 ft^2 located elsewhere. At the entrance there is a xerox machine and bulletin boards publicizing all of the relevant technical society meetings, technical conferences and workshops. For example, the IEEE Calendar for the month is always posted here.

A view of the functional areas of the Sanders Associates Technical Library, Nashua, NH, appears in Fig. 4.

SUMMARY

By following this plan the Sanders Associates Technical Library doubled its utilization while the company's number of technical staff members remained at a constant level. Our scientific and engineering personnel are increasing their use of library resources for maintaining knowledge of the state of the art in their specialties. This kind of technology transfer is very necessary for any company for survival and growth in a competitive environment.

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Improving the Maze of University Administration in High Technology Education

R. W. NEWCOMB, FOLLOW, IEEE, AND N. DeCLARIS, FELLOW, IEEE

***Abstract*—An examination of university administration of high technology education is made from the viewpoint of the individual professor. This leads to the introduction of the Inverse-Pyramidal Decisional Tree and the Informational Maze. Arguments on the resulting signal-flow graph show that tie-sets of the maze lead to inherent potential bottlenecks which interfere with innovation at its source. Considerable improvement in the administrative structure results from the introduction of appropriate cut-sets via a maze breaker.**

I. INTRODUCTION

THE ADMINISTRATION OF engineering educational programs at research oriented universities involves the management of high technology programs. Such programs, however, bring forth special problems that are scarcely present in industrial or even most governmental high technology operations. Indeed these problems are rarely touched upon in reference works on technical management [1], [2]. Here we present the administrative structure of some such universities in a format we do not find considered before and from that show how certain problems result. Finally a viable solution is given.

Within a university, as in most other organized institutions, authority is channeled along very narrow lines. In the university, however, information is encouraged to spread very widely. Indeed, a primary product of a university is information and efforts that are made to insure its dissemination lead to the passage of information to numerous corners. Now, for the creation of information of substance the professorial faculty remains supreme. It, therefore, should come as no surprise that, especially within a research oriented university, projects [such as courses, research proposals, invitations to distinguished personnel, etc.] are initiated to an extremely high degree by the professorial faculty on topics of their own choice rather than as responses to specific policy directives or through the initiative of upper level management as one most often finds in industry. Consequently, the faculty are expected, indeed required, to be entrepreneurial, and

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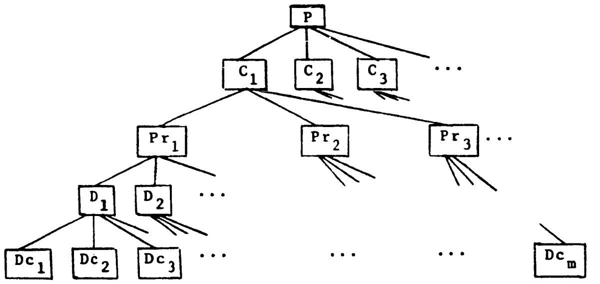

Fig. 1. Pyramidal university organizational administrative line chart: P is the President, C_i is the ith Chancellor, Pr_i is the ith Provost, D_i is the ith Dean, and DC_i is the ith Department Chairman.

highly individualized undertakings are the rule rather than the exception. This has led us to look at the administrative structure of the university as seen by the eyes of (engineering) professors rather than through the eyes of management, as is classical. This change in viewpoint leads to some startling conclusions, one being the inverse-pyramid effect and the other an horrendous maze, as we show here; in order to put some "engineering substance" to our findings we use the systems theoretical tool of signal-flow graphs applied to an informational flow graph introduced in the next section.

Since at points the treatment may seem technical to some, we suggest that the reader keep a practical example problem in view so that all concepts can be made meaningful in terms of the problem. For this we suggest that the reader consider himself as a professor trying to get his university to obtain approval at the highest administrative level of a proposal, say for a joint microwave-circuits laboratory cooperative venture between his university in the U.S. and one in another country, say France. In such a case it should be noted that for such a cooperative venture to be effective more than just agreement between two professors at the respective institutions is needed. Thus since facilities of the institutions (such as libraries, offices, laboratories, equipment, etc.) would be used, all personnel associated with the facilities would have input into their inclusion in the venture. To insure the proper authorization and cooperation of affected units it is necessary that approval be obtained at the highest administrative level. However, prior to the issuance of this approval for a faculty initiated proposal the highest administrative officer will naturally seek information and possibly concurrence from all affected subordinates to insure that the objectives and expected results of the project can be reached.

II. INVERSE PYRAMIDIAL TREE AND INFORMATIONAL MAZE

In Fig. 1, we present the type of organizational chart that one may expect to see explaining the administrative operation of a university campus. It should be observed that when filled in to completion this chart is pyramidal in form and is useful in explaining management's view of the operation. A general directive would most often flow from a given block to all attached blocks below; management initiated undertakings would essentially follow this downward flow. In this the Department Chariman, DC, acts as the project leader being

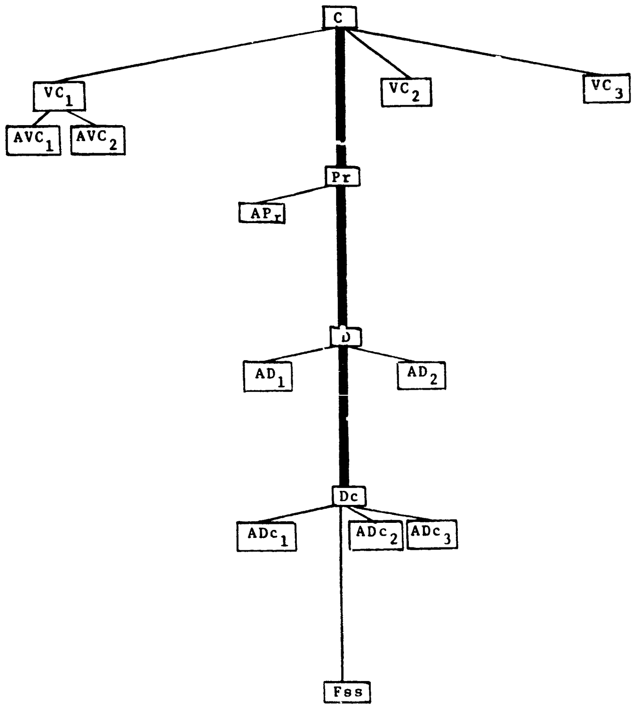

Fig. 2. Inverse pyramidal decisional tree (of University campus organization) ▬ is the line function (Fig. 1), —— is the staff function, A is the Assistant or Associate, V is the Vice (Chancellor), and Fss are the Faculty (Staff and Students).

in charge of the faculty (staff and students) and the Chancellor, C, acts as the formal interface with bodies outside a given campus of a university system which is managed at an even higher level under its President, P.

Consider our suggested example. Should a Chancellor initiate the desired agreement, he can obtain the President's concurrence, make the agreement, announce it to his Provosts, Pr, who in turn announce it to the Deans, D, thence to the Department Chairmen, who in turn inform the faculty (and staff and students), Fss. The operation is most likely smooth and relatively trouble free.

But normally it is the faculty who initiate such proposals. Thus we turn to Fig. 2 which is obtained from Fig. 1 by traversing it from bottom up and inserting staff assistants with line-titles for each line position met. For example, it is standard for the Chancellor, C, to have several Vice-Chancellors, VC, one for Academic Affairs, one for Administration, and one say for Student Affairs, and each VC to have one or two assistant or associate Vice Chancellors, AVC. The need for assistant staff is of course felt by every administrator along the "spinal chord" (C-P-D-DC) of the line. Now for a faculty member to obtain approval for a proposal to be formally sent out of the office of C, it is necessary to get approval of each block along the spinal chord. Each member of the spinal chord, however, will seek staff advice, if for nothing more than courtesy. Consequently, there will be information flow between various parties in the decision tree of Fig. 2 and more often than not this information will flow in loops. For example, Fss in Fig. 2 may initiate the

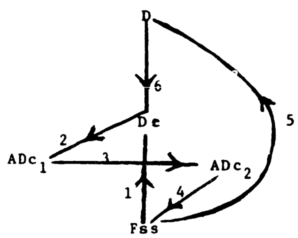

Fig. 3. Two information loops. L_1: 1-2-3-4; L_2: 5-6-2-3-4.

desire for approval of C by sending a proposal to DC, who then sends it to ACD_1 for advice; if the topic affects those in the domain of ADC_2 it may be sent there and then back to Fss for clarification of a point, as shown in Fig. 3. After four traversings of information branches, the proposal has traversed an "information loop" and is back to the proposer in the example of Fig. 3. If the proposer feels some frustration, he may overstep DC and go, as seen by path 5 in Fig. 3, to D, who in turn will almost automatically return it to DC, path 6, who may then return it to ADC_1, placing the proposal back on the former path (branches 2, 3, 4). Several things should be noted from Fig. 3. First, the desire to advance a proposal up the spinal chord of the decision tree of Fig. 2 is countered by an administrative tendancy to send it down an information flow graph which contains loops (as in Fig. 3). Thus the possibility at least exists that the proposal could travel the same loop many times. Moreover things rather unique to the university take place. Besides the tendency for almost all truly creative proposals to be initiated by Fss is the practicality of Fss shifting the consideration to a higher level, as D in Fig. 3, when it gets bogged down at a lower level, as DC → ADC in Fig. 3, of the information flow graph. The practicality of this shifting is safe-guarded by academic freedom and insured by the tenure system. One technique used to counter it by the administration is to insert ever increasing loop lengths. Is this really possible in a nontrivial way, though in practice?

To investigate the extent of this possibility we draw an information signal-flow graph for the system (leading us to Fig. 4) as follows. For each block of the decision tree of Fig. 2 we associate a distinct number, 1 to $n = 16$, and draw a node (dot on the paper) of the graph; these nodes are drawn in the same relative position of Fig. 2 with Fss considered the first (foot) and source node (as the inserter of information to be processed) and C considered the nth (= 16th) and sink node (as the one to finally receive the information formulated into a proposal suitable for transmission outside of the system). Between any (and every) node N_j of the graph and every other node N_k we draw a directed branch to represent the transmission t_{kj} of information from N_j to N_k. Assuming that the information I_k at N_k is an additive combination of (possibly nonlinear) transmission functions $t_{kj}(\cdot)$ of informations transmitted from nodes N_j we have

$$I_k = \sum_{j=1}^{n} t_{kj}(I_j) \qquad k = 1, \cdots, n. \tag{1}$$

The result is a signal-flow graph [3]. Since the result has

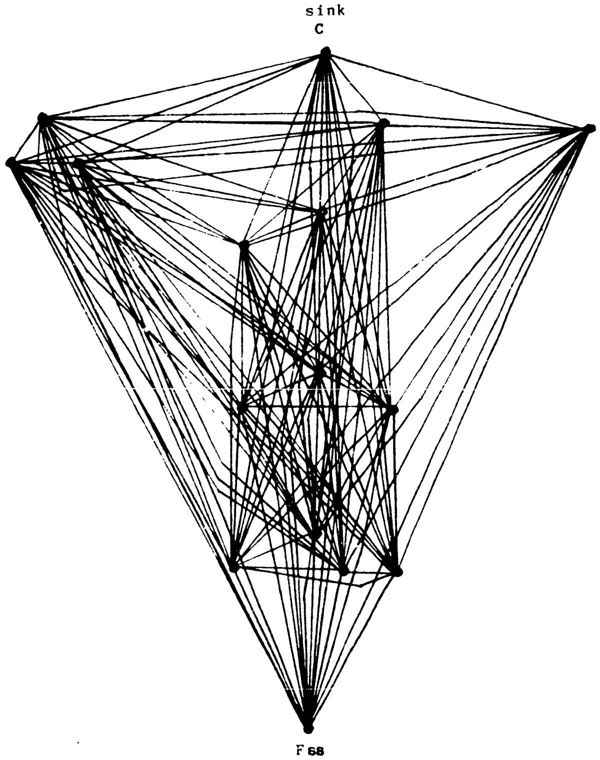

Fig. 4. Informational maze for Fig. 2. (Each line represents two one-way transmission paths.)

$(n-1) \times n = n^2 - n$ [=240 for $n = 16$] flow-graph branches, the graph becomes excessively unwieldly and we combine into one undirected branch the two directed branches connecting any N_j with any N_k and call the result an *information maze*. Thus Fig. 4, the maze for the tree of Fig. 2, contains "only" 120 branches. Note that the branches in the information maze which can be put into one-to-one correspondence with the branches of the decision tree of Fig. 2 actually do form a tree of the complete graph which is the maze, in the language of mathematical theory of graphs [4] and, in this same language, the addition of any further branch to the tree forms a tie-set with the tree branches in the resulting loop. That is, each loop of the maze defines a tie-set and the traversal of several loops simultaneously leads to nestings of tie-sets, that is, multiple loop feedback.

Given the information maze of an administrative system we can apply systems theoretical techniques to its signal-flow graph. For example, one can see that it is conceptually possible to linearize the transmittances and then calculate the linearized transmittance between the source node (Fss) and the sink node (C) through Mason's formula [3],

$$T = \frac{1}{\Delta} \sum_k P_k \Delta_k \tag{2}$$

where

T is the source-to sink graph transmission; the sink signal per unit of source signal,

P_k is the transmission of the kth source-to-sink path,
Δ is the graph determinant, and
Δ_k is the cofactor of the kth path (the determinant of that part of the graph not touching the kth path).

Here the system determinant is given by

$$\Delta = [(1 - L_1)(1 - L_2) \cdots (1 - L_m)] \tag{3a}$$

$$= 1 - \sum_k L_k^{(1)} + \sum_k L_k^{(2)} - \sum_k L_k^{(3)} + \cdots \tag{3b}$$

where

L_j is the jth loop transmission [with the understanding that we shall drop terms containing products of touching loops]
$L_k^{(r)}$ is the product of the kth possible combination of r nontouching loop transmissions.

Carrying out these calculations alone for Fig. 4 is a considerable effort. Even without this we can make some important observations. For these observational purposes we note that to a high degree the transmittances t_{kj} represent physical delays, D_{kj}, written in systems theory terms as $t_{kj} = \exp(-D_{kj}s)$ [where s is the derivative operator]. We make the idealization that this is true, and that all branch delays D_{kj} are equal to an "average" delay D (of perhaps two weeks time). Then, as the jth loop transmission L_j is given as the product of the transmittances of the branches in the loop, we have $L_j = \exp(-m_jDs)$ where m_j is the number of branches in the jth loop. We now can see that an infinite delay can be inserted by any single loop in the system, that is, partial fraction expansion of (2) contains, from (3a), a term

$$T_j = \frac{a_j}{1 - L_j}$$

$$= a_j[1 + L_j + L_j^2 + \cdots]$$

$$= a_j \sum_{k=0}^{\infty} L_j^k, \quad a_j = \text{residue}. \tag{4}$$

Using $L_j = \exp[-m_jDs]$ (4) becomes

$$T_j = a_j \sum_{k=0}^{\infty} \exp[-km_jDs] \tag{5}$$

which has terms of delay km_jD for arbitrarily large k (i.e., infinite delay).

In short Fig. 4 has an extremely large number of paths which can cause complete blocking of a proposal inserted at the source (i.e., by a professor, student, or staff) needing transmission through the sink (i.e., endorsement by the Chancellor). There is seen to be a strong contrast in getting information up through the maze versus down along the spinal chord to the staff. That is there is a nonbilateralness of information flow going up versus going down; only the people at the bottom see the loops of the maze to the point of severe frustration, frustration which more often than not leads them to give up.

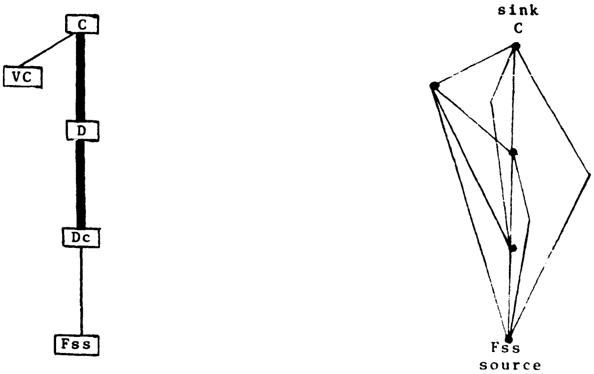

Fig. 5. Tree and maze for decade earlier. (a) Tree. (b) Maze.

As can be well recognized we have simplified the picture immensely. For example, the administrators of the decisional tree of Fig. 2 usually have other staff that get in the picture (as, for example, under Pr an administrative assistant for facilities) and they call upon innumerable committees; all of these simply add nodes (and branches at an exponentially proportional rate) to the information maze. And transmission of information is not really a linear process, there being involved such things as "decisional hysteresis" [5] which add nonlinear terms to the expansion of (2). For sure an important inclusion in the nonlinearities of the $t_{kj}(\cdot)$ are those which force the transmission along certain branches to be zero until the information leaving the jth node is judged ready to traverse the branch to the kth node.

None of these factors change the essence of the following conclusion based on (5): infinite delay in the educational administrative system under discussion is possible in an uncountable number of ways.

III. BREAKING THE MAZE

As time goes on, in order to cope with complex management situations, the decision is made to increase the number of administrators in the system. When this is done in an institution where high technology education is undertaken, the considerations of the previous section become very pertinent. For example, Fig. 5(a) shows the decisional tree for the system of Fig. 2 but recorded a decade prior. There being but 5 nodes in the tree of Fig. 5(a) there are only $n(n-1)/2 = 10$ branches in the informational maze of Fig. 5(b); clearly it was simpler, to handle the maze a decade earlier (though infinite delay was still possible). For sure, the management and functioning of education is getting more and more complicated and something needs to be done to instate smooth operation. This is especially true in the case of education, since upon its initiatives (creativeness of thought) depend the innovations and inventions necessary to maintain a technologically oriented society.

We see several solutions possible to the problems engendered by running a proposal through the information maze of a system, such as shown in Fig. 4. Among solutions that appear

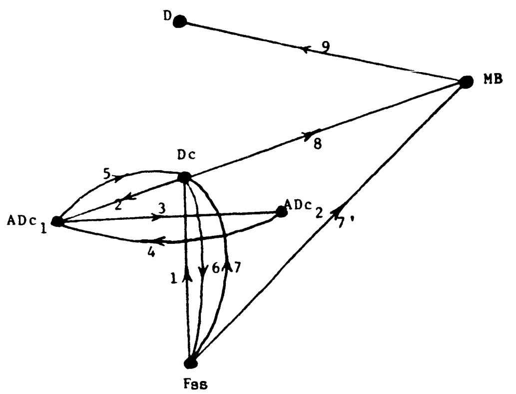

Fig. 6. Action of a maze breaker.

to us are 1) revert to simpler administrative chains, 2) insert "maze breakers" into the chains, 3) scrap the system and start over with one designed to prevent administrative loops. It is highly unlikely that those who introduced the tree of Fig. 2 would agree to reversion to the tree of Fig. 5(a). Similarly, scrapping an existing system is generally difficult to accomplish, especially if the operation is an extensive one. Consequently, the "maze breaker" solution merits some study as an attractive means of improving an existing system.

What we consider as a "maze breaker" others may look upon as an arbitrator or ombudsman, except that we would build certain distinctive characteristics into the position. Specifically, we would take as a "maze breaker", MB, an individual outside the administrative system of the institution who acts on request of a proposal initiator, Fss, to jump considerations of the proposal from one level of the spinal chord of the decisional tree, say DC, to the next higher level, say D, after the proposal has been stuck in a loop. This inserts another node, MB, into the graph and although technically the insertion of a new node to the graph introduces new tie-sets, its importance is in the new cut-sets formed by cutting the branches incident on the MB node. In the flow of information in the maze these cut-sets cut the tie-set loops thereby eliminating the problem these latter created. Thus the new branches added to the graph are very special one way branches.

An example to illustrate the concept is given through Fig. 6. Here we consider a proposal which traverses 1-2-3-4-5-6-7 at which time the initiator Fss sees that progress is bogged down. So Fss initiates a request, 7's to the maze breaker, MB, to have the maze broken by forcing the proposal from DC to D; MB checks that indeed progress is slow, recalls, 8, the proposal and transmits it, 9, to D, the next higher level.

Until the proposal arrives at the highest level, C in our trees, the same procedures would be followed. However, once the proposal gets stuck in a loop containing C, the maze breaker would function in the more classical manner of an ombudsman, attempting to get a fair resolution to any conflicts causing a bottleneck. It is important to realize that this is not a scheme to bypass the administration's responsibility for evaluating and allocating resources in the University but a mechanism to adjust—depending on the situation and the merits of the individual case—the level at which this responsibility will be discharged.

IV. DISCUSSION

Given an administrative organizational line chart, as illustrated by Fig. 1, for a university incorporating faculty engaged in high technology activities, such as engineers in a research oriented university, we have shown how this leads to an inverse-pyramidal decisional tree, as illustrated by Fig. 2. This decisional tree is made of two parts, a connected spinal chord consisting of 1) the decision makers in the organizational line chart who are responsible for decision affecting a given faculty, staff, or student, and 2) line-title designated administrative staff who advise people on the spinal chord. Within a university, and this is somewhat its uniqueness, proposals are initiated by the individuals at the foot of such trees, for example an engineering faculty member wishing to engage in a high technology activity, and it essentially becomes the job of the initiator to push a given proposal up the spinal chord. In the case of noncontroversial activities this may not be too difficult, depending upon the political environment of the institution. In the case of highly original proposals, however, and often the good ones associated with high technology are highly original, considerable resistance to the flow of information concerning the approval of the proposal can occur. The decisional tree turns into a complete graph, here called the informational maze (as illustrated in Fig. 4), for which one graph-theoretical tree is the decisional tree. Information circulating on the maze can get stuck in loops and the proposal bogged down, even for years or forever, no matter how much effort the initiator exerts. If the decisional tree involves n positions, the informational maze becomes a graph with $(n^2 - n)/2$ branches; its size increases immensely with increasing n (as we have seen for $n = 5$, ten branches, for $n = 16$, one hundred and twenty branches). Since the decisional tree appears to consistently increase in size with time, proposals get increasingly harder to process as time goes on unless something is done to counter the problems associated with an ever increasing maze.

Here we have put forth a maze breaker as a possible solution to the problem of getting blocked proposals back on the path of approval. The actual details of implementation of the maze breaker will depend upon the nature of the institution. We have given, however, some of the key characteristics, these being that the maze breaker acts to raise the level on the spinal chord for consideration of the proposal, subject to reasonable conditions (for example that the proposal can be considered as stuck in a loop) and that once the proposal reaches the top the maze breaker can turn to play the role of an arbitrator. One could look upon the maze breaker in the same way one looks upon the added bridge proven to be needed by Euler to solve the Seven Bridges of Königsberg problem [6].

In presenting these ideas we have used data from a situation familiar to us, though with modifications to make the concepts general. It is interesting to note that in the decade covered by our example the decision tree increased from $n = 5$ to $n = 16$, a more than three-fold increase of directline and line-named staff administrators (In the time since preparing Figs. 2 and 4 we learn of four more AVC's to be added under VC_3 in the figures while VC_2 must certainly have some AVC's; thus $n \geqslant 20$, i.e., at least 190 branches in one instance of the actual maze). At the same time the professorial faculty decreased from 43 (12 full, 13 associate, 18 assistant) to 29 (12 full, 16 associate, 1 assistant), indicating less availability of faculty time and effort to push innovative research through the university. In short, our experience indicates the practicality and need of the concepts treated here. We believe also that a forward looking solution to the maze breaking problem is necessary, and without delay in a number of educational institutions, to insure eminence of the U.S., or any other country, as a society advancing through high technology (for which innovation in the educational system is of the utmost importance).

The final version of the paper benefited from useful comments received by two unknown referees. The authors would welcome communications and discussions in private or in print from individuals with related experience and/or expertise. One of the main objectives of the paper is to stimulate discussion out of which several adaptations (differing in detail) will evolve to suit different environments.

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Technical and Management Notes

The Coordination of Engineering Development Between Component Companies of a Multinational Corporation

P. H. REYNOLDS

Abstract—**A large corporation, consisting of a number of individual profit centers, has developed techniques to encourage cooperative programs between suitable component companies with similar interests, for their mutual benefit.**

Although the study on which this paper is based was performed in relation to a large multinational corporation, many of the principles discussed apply to any situation where several separate engineering operations require coordination.

I. INTRODUCTION

A large multinational corporation has a division consisting of a group of companies located in four different countries. All are concerned with some aspect of electrical or electronic measurements. The purpose of forming the division was to promote mutual cooperation for mutual benefit. The sum of their efforts should be greater than if they each operated independently.

It was quickly recognized that engineering cooperation would make an important contribution to achieving this result. This conclusion was based on the concept of selling and, where economic, manufacturing products at more than one location. These products must be carefully selected to meet the following requirements.

1) The new product must add to the receiving company's total product line, without any overlap of existing products.
2) Each partner company is more effective in selling than the other partner in some geographic area or specialized market.

The corporation was fortunate to have had experience of operating in this way between two of its companies over a period of many years. This example was examined and the following principles were stated.

1) Identification of product lines in the companies in the division which share significant common technology, marketing, and/or other characteristics.
2) Development of integrated product lines and coordinated marketing and engineering where shared product lines are identified.
3) Provision of sales and service facilities allocated on a geographic basis or tailored to the requirements of a special segment of the market.
4) To achieve all of the above without giving up anything of value.

II. IMPLEMENTATION

To carry out the program the following points were found to be important and therefore worth special attention.

1) Unification of drawings and documentation. It should be possible to manufacture any design at any location with a minimum of redrafting. However, special prob-

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