and that was the first objective. To evaluate that project in monetary terms would be erroneous, because its fundamental value was in providing higher levels of safety, to say nothing of higher levels of motorists' peace of mind.

When the department wanted to evaluate public participation in the planning process, it again turned to the research council. And the council produced recommendations that dramatically improved the conduct of public hearings. A financial yardstick cannot be applied to that effort either. But the benefits are apparent.

In a more general sense, it is appropriate for management to periodically assess all programs of the organization, at least to match performance against expectation. That is simply good administration, and it can be done with the research program as readily as with most other functions. In such a process, if a program is proving its worth, the assessment almost certainly will lead to renewed and often to a heightened expression of management approval and support.

Clearly, management has a leadership role if the research program is to be effective. Management must demonstrate by its attitude that it recognizes the importance of the program. It must assist in setting the goals and objectives and in integrating the research function into the total organization. The credentials of those engaged in transportation research are too strong, their contributions are far too evident, and their place as members of the transportation team is much too vital for there to be any doubt about management's proper role.

Development of Multidisciplinary Research Programs

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High-technology goals require the focusing of varied skills on chosen targets; thus, the need for a multidisciplinary attack on most modern research and development programs is obvious. The multidisciplinary approach means the mixing and coordination of ideas and capabilities derived from a variety of professional backgrounds. The barrier of the organization chart must be overcome. Because organization charts define boundaries of responsibility and lines of authority, they complicate the process by which ideas flow from one segment of the organization to the other, with deadening effects on multidisciplinary cooperation. Although each of the institute's operating divisions has its greatest strengths in certain disciplines, we encourage creative thinking that leads to entry into new fields. The institute structure is designed to combine the advantages of line responsibility that reside with our vice president with the benefits that come from multidisciplinary, multidivision collaboration. Although not without difficulty, we manage to achieve an effective balance between the two.

Applied research and development is aimed at the translation of fundamental research results into useful products and processes and the exploitation of new and inventive concepts. Particularly where high-technology goals are involved, what is needed is the focusing of varied skills on chosen targets. The carrying of a technological option through its various phases from inception to demonstrated marketability usually requires blending the talents of scientists, engineers, production specialists, economists, and others. The need for a multidisciplinary attack on most modern research and development problems is obvious. In the commonly accepted definition, the multidisciplinary approach is a consequence of the mixing and coordination of the ideas and capabilities derived from a variety of professional backgrounds.

There is another kind of multidisciplinary strength in a research and development organization that is often not thought of in these terms; that is, the innovativeness and fresh insights that come from technology transfer from one market sector to another—the recognition that ways of accomplishing objectives in one field of activity are applicable to other fields as well. The most notable and publicized examples are the spin-offs from national defense and space programs to the private sector.

Historians of science and technology pursue their subject for many reasons, but certainly one of the more important is to attempt to understand how new and creative ideas come into being. On one point there seems to be general agreement: Significant advances do not often come as the result of a planned program for discovery. Rather, they arise from a conceptualization of the problem that departs from the traditional mode of thinking and that changes the very way in which the problem is approached. Newton had before him the same facts that were available to Kepler and to other natural philosophers who attempted to understand the motions of the heavenly bodies. Newton's flash of insight was the recognition that the instantaneous observations of position in space and time are less important than the rates at which these variables change. From this came the concept of the mathematical differential, and from this was born the calculus.

In a similar way, the contribution of the Wright brothers was not in their refinement of values for the aerodynamic coefficients for lift and drag as a function of angle-of-attack. Rather, it was their recognition that the essential barrier to successful flight was the ability to exert control in flight, the capability of overcoming disturbances that arise from wind gusts and other unexpected sources through direct pilot action in a practical way. Lilienthal, the German experimenter, had attempted to do this by pilot gymnastics, which shifted the locations of the center of gravity of the craft, and he failed. The Wright brothers conceived the idea of wing warping and culminated 100 years of striving by others with their own success.

One of the most important responsibilities of the research manager is to encourage staff to engage in speculative thinking. This is sometimes accomplished by bringing together the viewpoints and insights from multiple disciplines; at other times, the route is through the

association of ideas drawn from neighboring technical areas; and occasionally it is the result of the flash of insight that comes to a talented staff member.

At Southwest Research Institute, we create an environment that encourages a multidisciplinary, associative approach to new problems. In common with the other private, nonprofit institutes, our charter requires that we provide a broad research and development service that supports and contributes to the technological advancement of industry, commerce, and the government. Accordingly, each of these institutions is characterized by a wide spectrum of disciplinary capabilities, ranging across the physical sciences, chemistry, various branches of engineering, biology, economics, and, in some instances, the social sciences and management. Projects are undertaken for virtually every sector of industry and government; in our own case, more than 500 projects are active at any one time for more than 300 different clients. The opportunity for cross-fertilization of ideas and experience in the full multidisciplinary sense is thus ingrained in the very texture of our daily operations.

Nevertheless, an effective multidisciplinary operational mode in an organization of appreciable size does not occur naturally. Management must be continually alert and dedicated to reducing potential barriers, and the complexity of the management problem multiplies with the size of the organization.

To begin with, the organization chart barrier must be overcome. There is no question that every enterprise of any degree of complexity must accept the burden of the bureaucracy that flows from a piece of paper imprinted with numerous boxes interconnected by lines. Although the organization chart for a research and development enterprise often has a sophisticated underlying philosophy as its basis, the bureaucratic backwash is inevitable. Because organization charts define boundaries of responsibility and lines of authority, by their very nature they are vulnerable to complicating the process by which ideas flow from one segment of the organization to another. The influence of such rigid delineation of responsibility on multidisciplinary cooperation can be deadening unless the issue is dealt with seriously and with special attention.

A second problem is that of communication within the organization, which is a particularly difficult one for a contract research and development activity, such as Southwest Research Institute, that simultaneously serves a large number of sectors. If the purpose of interdisciplinary cooperation is to encourage innovative thinking by staff members who have diverse backgrounds, training, and skills, how can they all be kept aware of the technical challenges and the project opportunities that exist in areas outside those that absorb their immediate attention and to which they are capable of contributing? Equally important, how can staff members be motivated to take time out from their busy schedules to think about such matters?

Another area that requires constant attention is the selection of staff for projects to ensure a proper multidisciplinary balance. In recent years, the term "matrix management" has become a formal part of management vocabulary; it embodies the idea that a project manager should be free to recruit project staff from all areas of the organization in order to fill a needed complement of skills. The project manager thus works horizontally through the organization, cutting across the vertical structure that reflects the line-authority pyramid. In some organizations, matrix management works quite well; in others, it encounters difficulties.

It is axiomatic that long-range planning mechanisms for a research and development organization should place special emphasis on the multidisciplinary perspective. If the overall plan for the future is permitted to become an aggregation of goals independently established by the line elements of the organization, each characterized by a parochial point of view, the maximum benefits that can be derived from a broad, multidisciplinary approach will not be realized.

We have found that the most successful operating philosophy for the overall growth and development of the institute is to give each of our 11 operating technical divisions wide latitude and considerable autonomy in the conduct of individual programs. Each division is established as an independent cost center and, in essence, each is an entrepreneurial group that conducts its own business under the leadership of a vice president. Our senior management staff is small—the president and four corporate vice presidents (one financial) to coordinate the activities of more than 1700 staff members. We view the function of senior management as analogous to that of a holding company headquarters for a technical conglomerate. So long as a division's performance is in line with expectations, we leave it alone.

At first glance, our organizational philosophy appears to be the very antithesis of how to design a structure to encourage multidisciplinary cooperation. But this is not the case.

As the first step in promoting a multidisciplinary viewpoint in our project activities, we define the boundaries of topical coverage for our divisions relatively loosely. Although each division has its greatest strengths in certain disciplines and market areas, we encourage creative thinking, which leads to entry into new fields. We adhere to this policy even when it results in overlap between divisional interests. In some instances this leads to a spirit of competition rather than cooperation among our divisions. We accept a certain level of internal friction from this source and depend on our senior management to control and defuse such situations. Of course, organizational changes are a means of solution when all other efforts fail.

In the transportation field, for example, where the institute conducts a broad spectrum of project activity, the total program is currently dispersed among 10 of our 11 technical groups. One of the reasons for this wide distribution is our practice of informing all groups of project possibilities that flow from outside contracts and sources. Each division is invited to indicate willingness to participate in the framing of a program response. The final decision regarding which division will take lead responsibility and the definition of the roles of the various collaborating groups are decided in conference chaired by senior vice presidents.

Since many of our projects are relatively small in size and area extensions or offshoots of prior divisional activities, a large number are handled as single-division efforts. In order to ensure that the range of necessary talents is available, a flexible approach is adopted when it comes to disciplinary staffing within divisions. Within the bounds of remaining financially sound and within budget, each vice president is free to add scientists, engineers, and technicians to promote self-sufficiency of operations. The alternative organizational philosophy would be to staff our divisions along largely disciplinary lines.

Matrix management is used for larger programs and for innovative programs that tax the capabilities of individual divisions. Our means of employing this technique are relatively conventional; primary management responsibility is assigned to a project manager located in a lead division; collaborating talents from other divisions are assigned to the project staff according to predetermined agreement or as new project needs arise. Since

bureaucratic or other organizational obstacles may arise in large matrix-managed programs to impede their progress, review meetings are held by senior management with project managers and key personnel at least four times a year.

The long-range planning strategy for the institute is shaped by a number of considerations, some of them special to our kind of organization. Since we are committed to serving a broad spectrum of industrial and governmental needs, the inflow of projects is to some extent a function of the demands placed on us by our clients. The levels of activity in different areas may increase or decrease; the current emphasis may be on longer-range research or close-in development. Counteracting these external influences, which if left unchecked would result in a highly opportunistic program, are the internal strengths we build into the organization through the planning process and its implementation.

Our internal planning channels the allocation of institute resources (such as staffing emphasis, facilities, and internal research funds) so as to emphasize the development of program excellence in selected target areas. A target area is characterized by offering rewarding research and development challenges to the staff; it is a field of current importance to industry or government, or it is a field we believe will become important in the not-too-distant future. It is an area with resource needs that the institute will be able to meet. Our goal in each target area is to become a recognized center of excellence on the national and international scene.

For each target area, a planning task force is appointed, consisting of key members of the technical staff and of divisional managements. The responsibility of the task force is to guide and coordinate the total institute effort within its range of interests. Accordingly, the membership is chosen on an institutewide basis and emphasizes the multidisciplinary viewpoint. Each task force meets at the call of the chairperson, and at least once each quarter it meets with senior management present.

Our task force structure is, in a sense, an extension of the matrix-management technique as applied to the conduct of specific projects. The chairperson of the task force occupies a position analogous to that of the project manager but, rather than being accountable for the well-being of a single project, the responsibility is to ensure that the total strength of the institute is joined together to achieve program excellence.

The institute structure is designed to combine the advantages of line responsibility that reside with our divisional vice presidents with the benefits that come from multidisciplinary, multidivision collaboration. Although not without its difficulties, we manage to achieve an effective balance between the two.

How To Get Commitment To Productivity

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To get commitment to productivity by subordinates, the first essential is that managers have positive assumptions about people that (a) work is natural for them, (b) they will use self-direction and self-control when committed to objectives, and (c) they are responsible. The second essential is for managers to make clear to their subordinates how their performance contributes to the mission of their organization. In this process there must be agreement on the basis for evaluating the subordinate's performance. The manager is responsible for carrying out this performance evaluation at designated times and for confronting substandard performance as soon after it happens as possible. Another essential for managers is that they support subordinates by providing needed resources, training, and their own time to employees when needed. It is recommended that managers give positive recognition to subordinates whenever possible. Managers must also manage differences by allowing subordinates freedom in achieving the results expected of them on their jobs within the agreed limits. Conflict must be surfaced and resolved in order to clear the air for honest problem solving. Finally, managers have to be willing to give the needed time for interaction with subordinates. The organization has the responsibility to provide the necessary management training to managers to enable them to carry out the management function in a competent manner and to achieve a commitment to productivity in their work force.

What is the meaning of commitment and productivity? These are key words in the effective operation of an organization. They are easy to talk about but often hard to achieve.

COMMITMENT

Dictionary definitions of commitment include a pledge to do something and a state of being bound emotionally or intellectually to some course of action. In other words, it comes from within (inner directed). I make the decision on what I am committed to do, and my decision is based on my value system—what is important to me. Each of us has different values and, consequently, different reasons for being committed to the same course of action.

It is necessary to accept this basis for commitment and to manage with this assumption about people. McGregor was talking about this when he identified two sets of assumptions about people and their relations to work. He labeled these theory X and theory Y (1).

Theory X assumptions are that people dislike work, have to be forced and controlled to work, and have little ambition. These assumptions are outer-directed, and control is external. These assumptions are in conflict with the premise that commitment comes from within a person.

McGregor's theory Y assumptions about people are that work is as natural as play and rest, that they will use self-direction and self-control when committed to objectives, and that they, under proper conditioning, will accept and even seek responsibility. These theory