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LIFE CYCLES OF R&D ORGANIZATIONS

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LIFE CYCLES OF R&D ORGANIZATIONS*

by

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In recent years, research and development organizations have had their own kind of "population explosion". Like the human equivalent, such R&D growth has presented management problems.

Not the least of these difficulties is the discovery that there is no automatic harvest of benefits just because a growing R&D organization becomes established. Neither does fertilizing an R&D group with top people ensure a bumper crop of technical productivity. Even the less naive companies are finding that R&D organizations inexplicably grow and decline--that productivity enigmatically waxes and wanes. Like all groups of people working together, R&D organizations can and have to be effectively managed.

Managing such creative professional groups requires, first of all, an understanding of R&D organization dynamics that ensures the technical effectiveness of the group. Effective R&D management requires not only a special understanding of what makes an R&D organization tick, but also an understanding of what gives the organization viability.

To aid in such understanding, I have developed a "wheels within wheels" theory of R&D dynamics that describes the cyclic nature, both short and long term, of such organizations. This theory, based on several years of study, applies to all exploratory groups from manufacturing R&D to basic scientific research. It has as much relevance to industrial R&D groups as to those in

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government or the universities. Generally, the larger the organization, the more valid the theory.

This theory is based on the industrial dynamics approach, which assumes that the problems affecting an organization are the natural outgrowths of the organization's own activities and structure. The approach further asserts that the problems arise from interrelated causes and effects that operate as a series of upward or downward spiralling positive and negative feedback loops.[1] Within these self-contained loops are numerous variables that interact with one another. For R&D organizations these key variables include as varied a group as: the kind of R&D work performed by the organization, limitations imposed on the organization's growth, the organization's attractiveness to outsiders, its technical effectiveness or productivity, the average age of its personnel, the "corporate" evaluation process (how top management rates and responds to the organization), the R&D organization's "marketing" activities, and the size of the organization's budget. Many other variables also affect organizational dynamics.

In this context, the dynamics of R&D organizations are delicately balanced. A change in any of the variables can alter the R&D unit's life cycle. However, the "corporate" evaluation process--what top management in the company, government agency, university or the customer thinks of the R&D unit's capabilities and mission and how it responds to this evaluation--appears to be the most important. It alone has the power of rescuing a technical organization

[1]The industrial dynamics approach is described in depth in Jay W. Forrester, Industrial Dynamics (Cambridge: The M.I.T. Press, 1961). For its application to R&D project management see Edward B. Roberts, The Dynamics of Research and Development (New York: Harper & Row, Publishers, 1964).

from stagnation or a fatal decline and breathing new life into it.

As the organization comprises a series of interlocking closed loops, management attitudes toward an R&D group seriously affect the organization's dynamics. For example, the amount of useful information in the pool of technical knowledge that an organization can bring to bear on its work determines the kind of jobs it gets, and how well it performs these jobs. This eventually reflects back to what the parent organization thinks of the R&D group and its ability to do these jobs.

The information pool is deepened by the knowledge accumulated from past work and by the addition of new employees who frequently bring in new skills and knowledge. In like manner, the information pool is made more shallow by the obsolescence of technical information and as employees leave the organization.

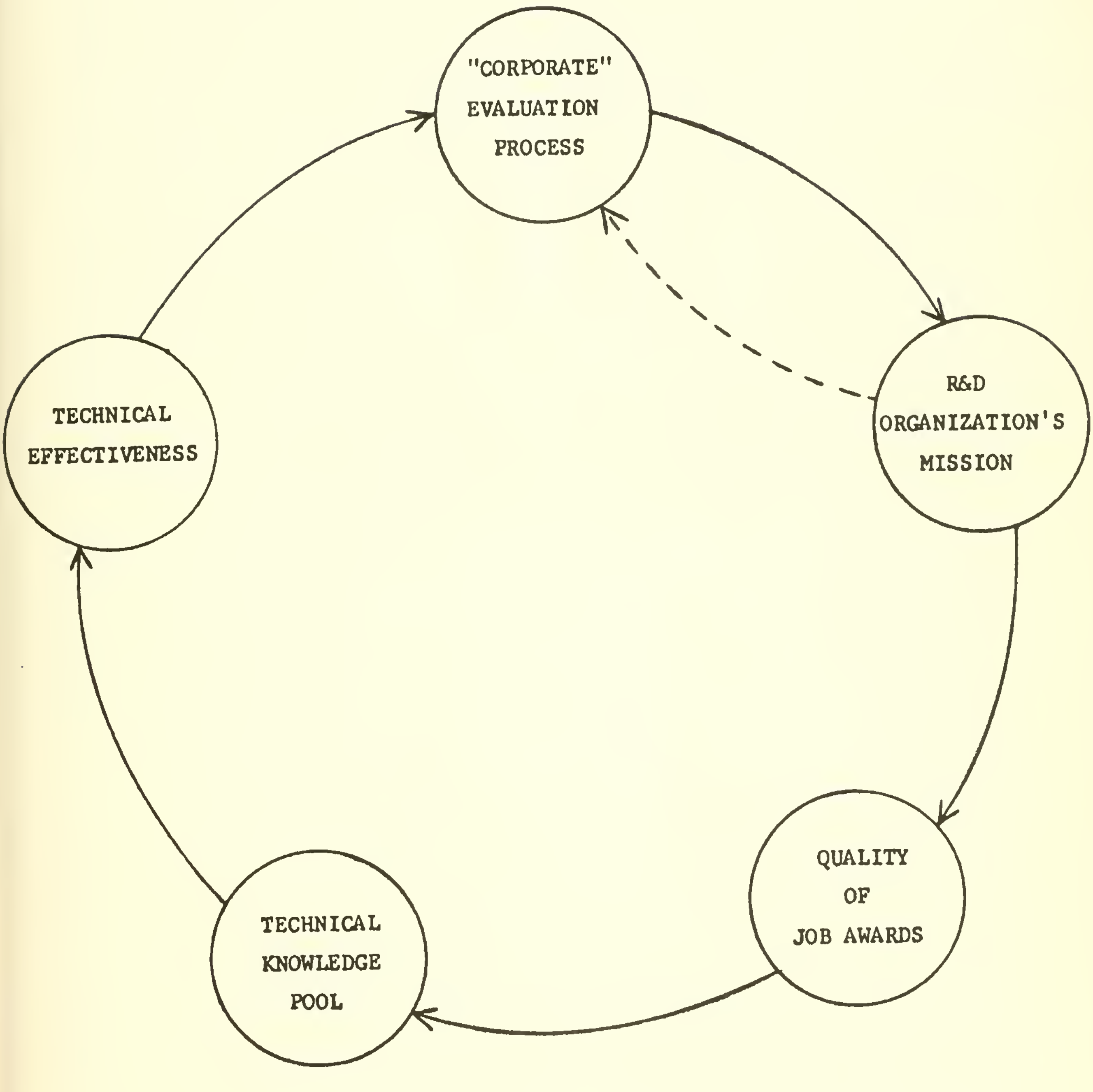
The organization's different R&D activities determine when its accumulated knowledge becomes most useful and when it becomes obsolete. In some types of projects, the knowledge picked up "yesterday" is the most useful to the R&D unit today. This often occurs in solving manufacturing engineering problems. And in a year or two this information may be obsolete as far as the unit's then current work is concerned. But with other project types, the greatest use of the knowledge gained yesterday may be applied, not today or in the near future, but in several years hence. And it may take five to ten years before this knowledge goes out-of-date. Such a knowledge life span is more characteristic of the outputs of applied research activities. The varying usefulness over time of technical information derived from the organization's work should be remembered when assigning goals to R&D organizations.

Management can influence the generation of the R&D organization's pool of knowledge and its effective use by determining the lab's mission or goals. An organization with a low level of technical knowledge can still perform in an effective manner if management carefully tailors the organization's mission to its capabilities, based on available manpower and technical knowledge. Alternately, by assigning more advanced work to the group management can help the organization "learn" its way to a higher level of technical effectiveness.

The foregoing relationships--knowledge-technical effectiveness-evaluation-mission designation-job awards--constitute a single feedback loop (Figure 1). Under usual management policies as one factor moves upward or downward, the whole loop begins to cycle in that direction. The movement not only continues in the same direction, but it increases momentum as the cycle advances. For example, an increase in the pool of knowledge increases technical effectiveness relative to the present R&D mission. This raises the R&D organization's esteem in the eyes of management. Management, in turn, usually tends toward a "natural response" of raising the lab's mission requirements or goals, which results in better jobs being assigned, thereby improving the pool of knowledge, which further increases the organization's technical effectiveness. This response tendency creates a positive feedback loop affecting R&D organizational performance.

Unfortunately, the same positive feedback loop process holds true in the downward direction. Should the organization's technical effectiveness drop for any reason--for example, due to a major breakthrough by competition in an area of technology unfamiliar to the R&D team--the corporate evaluation would decline. In these circumstances the "natural response" of the corporate group

Figure 1. The Evaluation Process and R&D Performance.



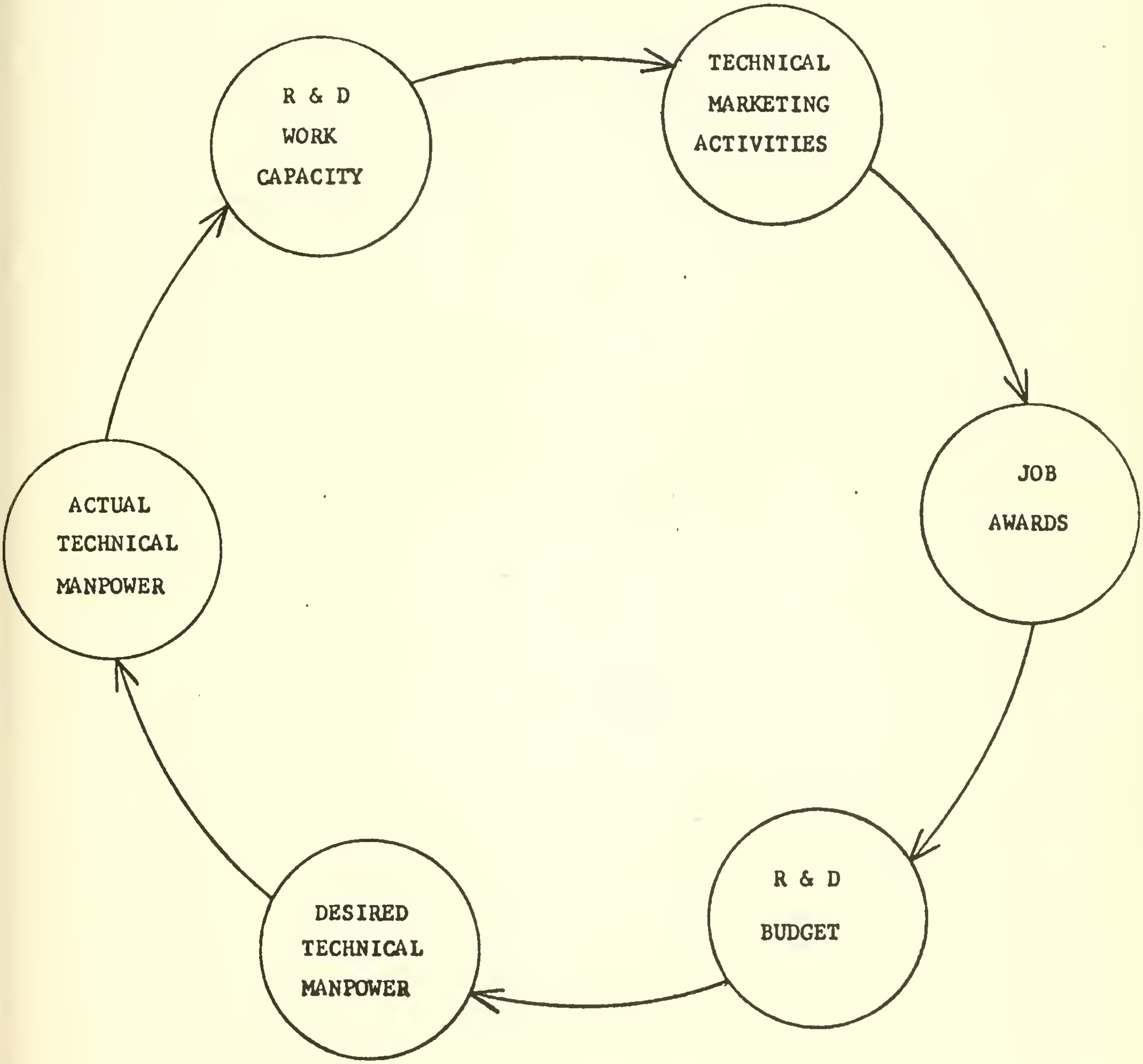
is to shift the goals of the R&D organization downward. Management often assumes that it must turn to outsiders for the advanced technology or that a new advanced research organization must be established elsewhere. In this way the R&D organization's mission is altered and the jobs assigned to it are changed correspondingly. The new less advanced jobs contribute less to the group's pool of technical knowledge, technical effectiveness diminishes further, and the downward spiral continues.

On the other hand the corporate evaluation process can work differently. Instead of shifting the technical objectives downward to match the evaluated organizational effectiveness, corporate management might hold the lab's objectives firm or even increase them to match the new technical demands. New jobs assigned to the organization would be high in their provision of learning opportunities. And although technical effectiveness may remain low for several years, such a "corrective" managerial policy eventually can turn the declining R&D group into an improving organization. Only seldom, however, does top management show the foresight to adopt this "corrective" negative feedback policy instead of the "natural response" described above.

Another feedback loop that affects the R&D organization's life cycle comprises the variables of desired and actual technical manpower, R&D work capacity and marketing activities, job awards and the organization's budget (Figure 2). The larger the R&D work force the more extensive is its capacity for undertaking technical work. Special equipment as well as special skills become more available as the organization grows, permitting the R&D group to tackle a broader range of jobs.

As the organization grows so grow its technical marketing activities. It may seem strange to refer to the marketing efforts of a manufacturing

Figure 2. Technical Marketing and Organizational Growth.



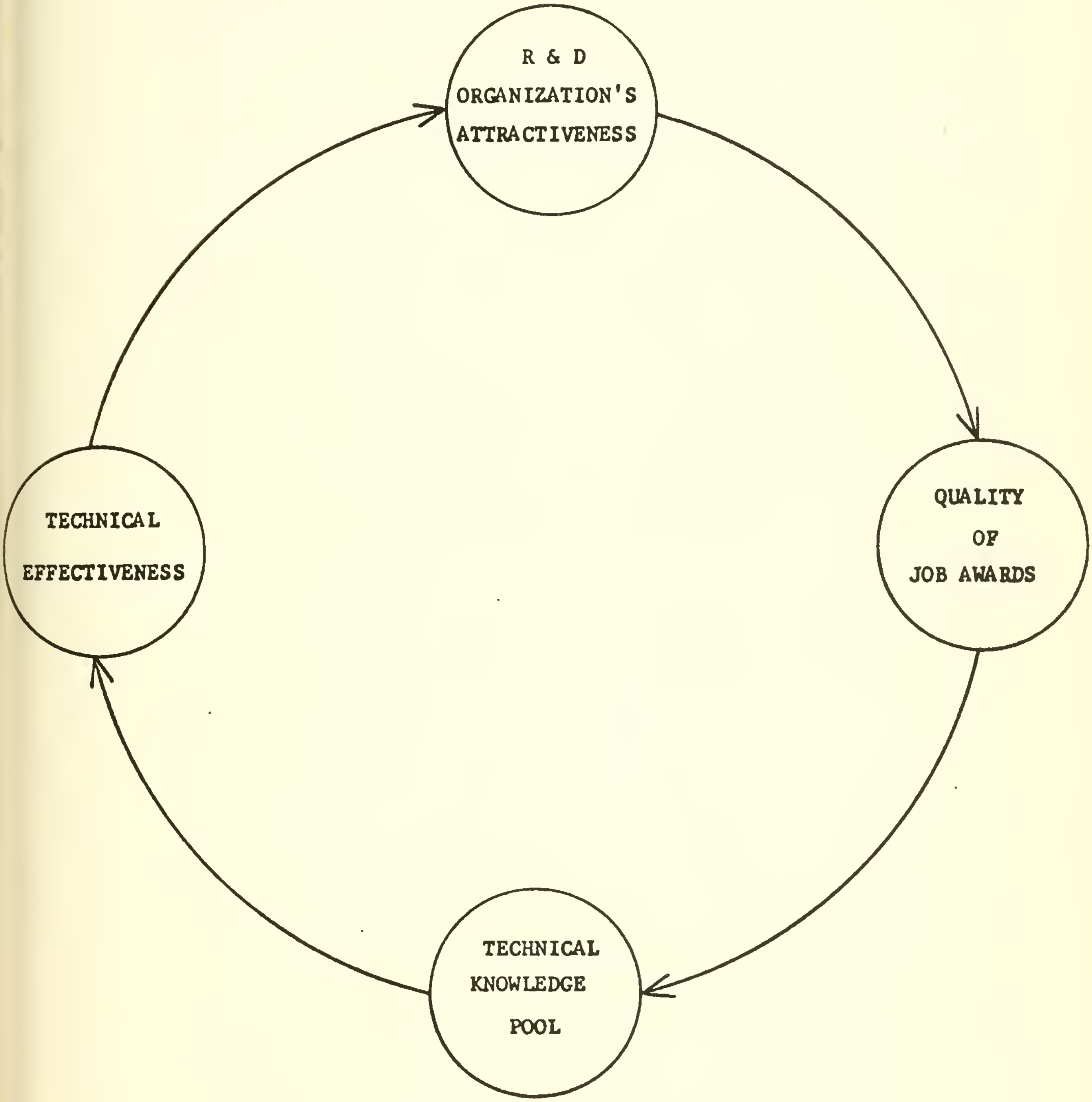
R&D group or industrial laboratory. But "selling", by means of technical discussions and proposals, is an integral part of an R&D organization's life. The R&D scientists and engineers usually sell indirectly through their contacts with their present customers, but sometimes more directly by seeking out new potential customers among company product managers and manufacturing plant personnel. The larger the R&D team, the more its marketing activities. Also as the organization grows its visibility improves, thereby enhancing its implicit marketing activities.

The technical selling brings in more work for the R&D unit, both requiring and providing for a bigger R&D budget. This in turn generates a need for more employees. Eventually the higher number of desired staff leads to a build up in the size of the R&D group, which further increases the group's total technical capabilities. Thus the upward cycle begins anew.

This positive feedback loop can also perform its accelerating function in either an upward or downward direction. If, for example, management were to cut back on the actual manpower level for any reason, this action would tend to decrease the R&D organization's technical capability, which would then lessen the marketing effort, producing a drop in the number of new projects assigned, resulting in a budget cut, and imposing another round of cuts in manpower.

Increasing or decreasing the technical effectiveness of R&D fits into a third feedback loop--the R&D organization's attractiveness--what others believe the organization's capabilities to be (Figure 3). An R&D organization that has high technical effectiveness in the performance of its work tends to draw the better projects. As shown in Figure 3 a higher level of job assignments produces significant additions to the pool of effective technical

Figure 3. Organizational Attractiveness and Job Quality.



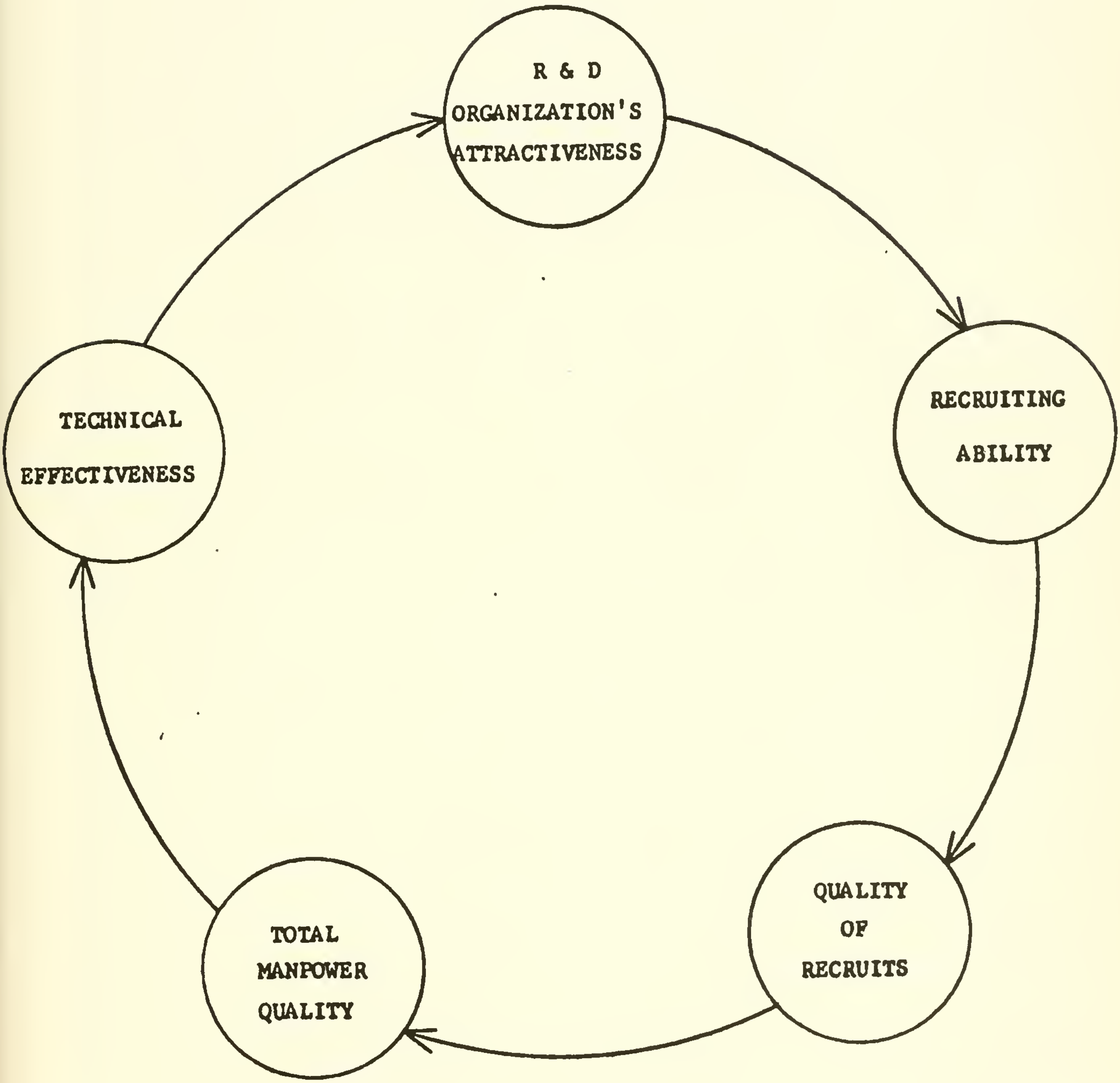
knowledge, which increases the technical capabilities of the people in the R&D unit, boosting technical effectiveness and raising the organization's attractiveness. This again improves the quality of jobs the lab gets to do, further helping to maintain or improve an even higher quality level of work. If, on the other hand, the organization loses its attractiveness for any reason, the system begins a downward spiral. Although not shown in Figure 3 the organization's attractiveness also affects the volume of job assignments the R&D group receives, as well as their quality.

The positive feedback loop affecting the quality of employed people and the nature of the jobs they perform interlock into a manpower feedback loop that is similar to the above phenomenon. Here, organizational attractiveness is viewed as a factor that stimulates the inflow of new people (Figure 4). The more attractive the R&D organization is to outsiders, the greater the organization's recruiting ability and selectivity of staff. The injection of higher caliber employees into the R&D group boosts its technical effectiveness, which increases attractiveness and further enhances the group's recruiting ability.

Conversely, an organization that loses its attractiveness lessens its ability to hire top graduates and people from competitor organizations. As a result the quality of the people hired decreases and the loop begins moving the organization downward as its technical effectiveness drops. Consequently, recruiting ability falls even more.

Once recruiting is considered, we become interlocked into what are probably the two most important feedback loops describing the R&D organization. These bring into play the aging of technical personnel (with its effects on

Figure 4. Organizational Attractiveness and Manpower Quality.



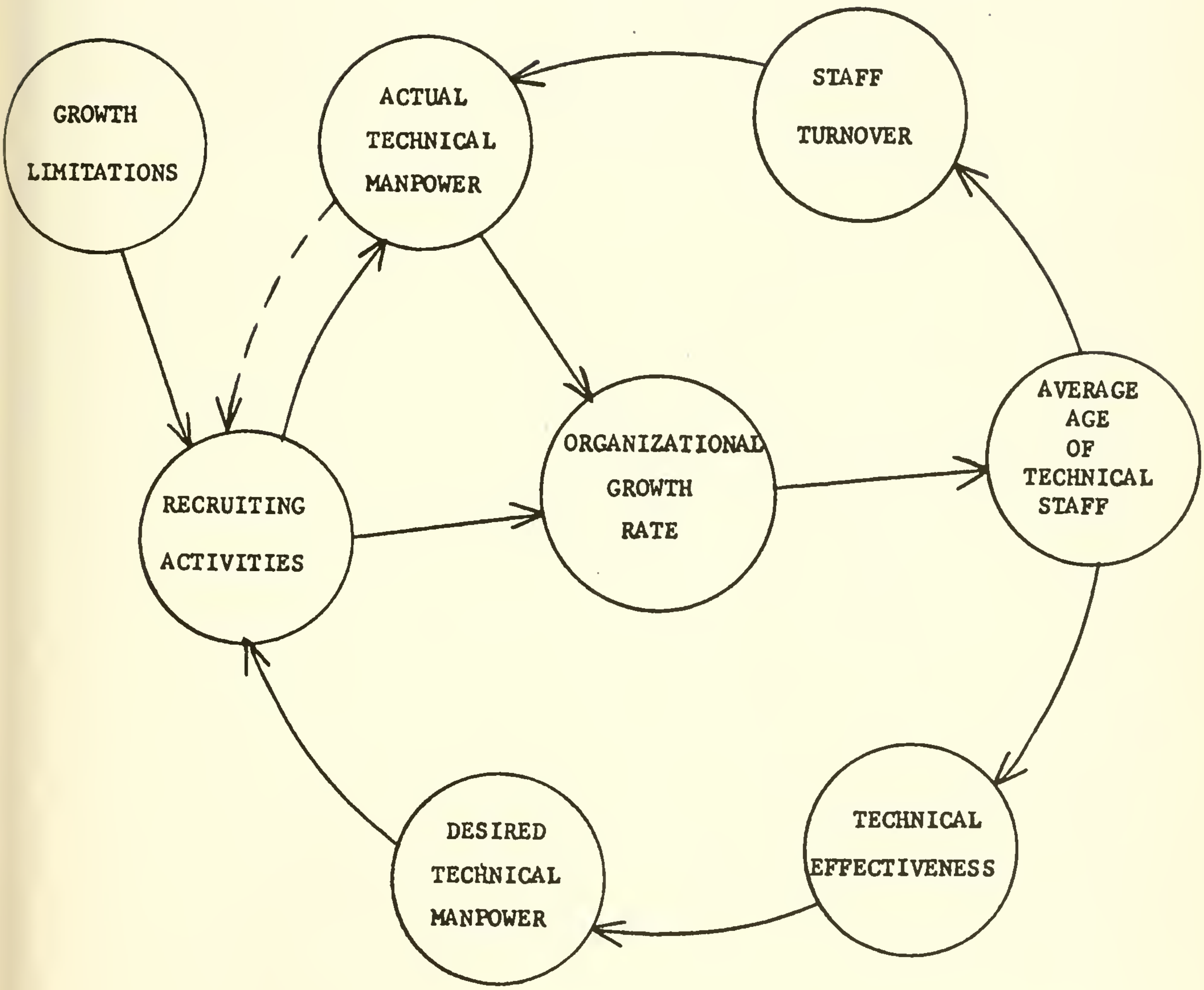
turnover and productivity) and the impact of growth limitations on the R&D organization (Figure 5). As recruiting activities increase the growth rate of the R&D unit, the average age of the technical staff decreases. This increases the group's technical effectiveness by the addition of both new ideas and vitality, adding more boost to the organization's growth potential. An organization showing signs of stagnation usually is staffed with personnel whose average age is increasing or is already high. Most studies of technical organizations generally bear out this premise. The exceptions emphasize the rule.

These organizational studies indicate that new PhD scientists make their major contributions shortly after joining an organization. Thereafter, their technical effectiveness declines. On the other hand, a young engineer's productivity is greatest five to ten years after joining the R&D organization. After that his creative contributions begin to decline too. On this basis, the technical effectiveness of the R&D group depends on a continual inflow of new people.

Also indicated in Figure 5 is the fact that as an organization's average age increases its staff turnover declines. The older engineers and scientists are less likely to leave the organization to seek new opportunities. Decreased turnover diminishes the number of jobs opening up in the R&D group, reducing recruiting activities and restricting the number of new younger people moving into the organization. This causes intensification of the organizational aging phenomenon.

At times this aging problem is somewhat artificially created for the R&D group by the imposition of limitations on its growth. Corporate management, and more often the government in running its own labs, frequently restricts

Figure 5. Organizational Aging and Growth.



the size of R&D organizations "to keep them from getting out of hand". But such growth limits often produce more than what was bargained for!

A recent comparative analysis of two government-oriented laboratories pointed out the correlation between the trend in the average age of the technical staff, and the resulting personnel turnover and overall productivity. One organization whose growth had been restricted by fiat had an aging technical staff and a low turnover. It had slowed down considerably in its production of new ideas and practicable developments for the outside world. By comparison, the R&D unit that was allowed to keep growing, and whose average age did not increase, continued to generate its "products" at an unbounded rate.

These observations suggest that growth limitations, whether by directly restricting the budget or by setting a "head count limit" on the number of employees, can be critical factors in R&D organization dynamics. Although implemented for apparently sound management control reasons, the growth restrictions, once they take effect, can force the upward moving spirals of progress to slow down, stop, and then begin to retrace their paths. First, recruiting slows, then manpower stabilizes, aging sets in and the organization's technical effectiveness loses its edge. The laboratory's attractiveness begins to tarnish, marketing efforts become less successful and the quality level of projects isn't quite what it used to be. The pool of effective technical knowledge dries up a little, technical effectiveness dulls even more, creating a backlash through the whole set of interlocking loops. In short, growth limitations become a reversal factor that changes advance into decline.

Though it may take some time for this decline to become evident to management, management by its own actions can hasten the decline and fall of the R&D effort. As was discussed earlier in reference to Figure 1, confronted with a faltering R&D group, management usually makes things worse (often without realizing it) by realigning the R&D goals to coincide with the organization's apparent lower order of capability. The R&D group is, in effect, down-rated, and the new work assigned to it is poorer in quality. This adversely affects the pool of R&D knowledge and causes a further decline in technical effectiveness. The upshot of these events is that management seems to have confirmed its original evaluation of the R&D situation.

The downward momentum of a declining R&D organization can be slowed, but probably not halted, by the use of several stopgap policies, all of which contribute to a reduction in the average age of the technical staff. Among these techniques are allowing attrition to reduce the average age, and re-assigning aging members to other departments. It should be noted here that a program of continuing employee education, while helpful to the organization's overall effectiveness, does not by itself revitalize the technical organization, although it does alter the duration of the organization's change cycle.

Another way of fighting off the effects of externally imposed growth limits is changing the ratio of engineer-scientists to technician-support personnel from, say, 60-40 to 90-10. This can be done where the "head count" restrictions limit the maximum number of employees available to the organization, but where funds available exceed direct manpower requirements. This approach has been used by some government R&D centers where everything but in-house scientific and engineering activities has been jobbed to outside contractors: technician services, computer programming, even secretarial

and janitorial services. This practice has allowed the government center to continue expanding its professional staff with good results. Of course, when the organization's manpower begins to approach 100 percent technical staff the growth limitation begins to have its usual effect.

Unfortunately few of the countermeasures to imposed size limits have worked effectively. Unless the restraint on growth is temporary, the restrictions eventually set off a decline that almost inevitably results in the technical death of the organization. If the decline is to be stopped and the organization regenerated, management must recognize what has to be done and responsibly carry out the needed actions.

Instead of automatically downgrading the R&D organization mission in line with what appears to be its declining technical effectiveness, management must see in the initial decline a warning signal that the organization needs an infusion of revitalizing influences. Rather than downgrading the R&D group, management should shift its goals sideways or even upward. This positive reshaping of mission, even without added funds or personnel, will likely produce new assignments that eventually regenerate the organization's technical effectiveness. But managerial patience is required to see such a change through to its eventual beneficial outcome.

The mission change can take many forms. Instead of studying speed and feed rates on conventional machining processes, for example, the R&D group can attack metalworking problems from another angle--for example, by studying nontraditional machining techniques, such as electrical discharge machining, electrochemical grinding or laser welding. Another way would be to switch the group from projects involving manufacturing processes to those concerned with engineering design and development. In this way a fixed-size group can

maintain and even rebuild technical effectiveness by the infusion of new demands and challenges. The spirit of innovating objectives can be used as a substitute for the enervating flow of new people into a growing organization.

Not all R&D groups are worth preserving. In some cases, the wisest course may be to let the organization die--even to hurry its demise--and start over. This is essentially what some aerospace companies do when they set up competing R&D project teams to explore two or more approaches to a problem. When the problem is solved, the "loser" organization is then disbanded.

Attempting to design policies for improving the level of usefulness of an R&D organization raises more questions than we can presently answer. I am now trying to employ computer simulation, using mathematical models of R&D organizations, to provide new insights to the kinds of questions that ordinarily depend on intuition: What policy should management adopt in attempting to save an R&D organization once it gets into trouble? Does a corrective policy have to be followed in a dramatic manner, or is it enough to follow such a policy in moderation? How long should a corrective policy be maintained to set in motion the organization's recovery--six months or six years? Are the best intended and pursued policies doomed to failure merely because good engineers and scientists are reluctant to join an organization that has a bad technical reputation?

It is apparent from our description of the feedback loop theory of R&D organizational dynamics that the organization's short-term and long-term cycles are self-induced by a complex process. Adding more meat to the barebones theory presented means adding still more complications. For corporate and R&D management to cope with the dynamics of technical organizations we need both more elaboration of the theoretical structures and more development

of tools like computer simulation for understanding the implications of the theory. Both improvements are likely to be forthcoming during the next several years of continuing R&D growth.

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