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ON THE OBSOLESCENCE OF SCIENTISTS AND ENGINEERS

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In recent years the engineering profession has roused itself to confront the spectre of obsolescence head-on. Its spokesmen have warned of the dire results of obsolescence; its managers have organized conferences and symposia on obsolescence; and its educators have developed retraining programs to ward off the effects of obsolescence [1]. As is often the case in this country, however, relatively little attention has been given to the careful delineation of the problem so that remedial measures might be taken in an orderly and effective manner [2]. Instead, a great variety of programs were hurriedly developed and implemented before the actual dimensions of obsolescence were firmly established. To help correct this oversight, however, this essay will attempt to identify the nature and causes of obsolescence among engineers and scientists. Specifically, I shall describe several distinct types of obsolescence that commonly occur among technical and scientific workers, and I shall identify certain complexes of socio-cultural forces that contribute to an accelerating obsolescence among workers in scientific and technical disciplines. The propositions that are advanced here were gleaned to a large extent from twenty intensive interviews with middle- and upper-level technical personnel in ten industrial, academic, and governmental laboratories in the Northeastern and Midwestern regions of the United States [3].

To begin, it is not difficult to define the essential nature of obsolescence. Obsolescence exists when an individual uses viewpoints, theories, concepts, or techniques that are less effective in solving problems than others currently available in his field of specialization [4]. Because he is not familiar with the best technical way of performing his assignments, the obsolete engineer or scientist takes longer in solving technical problems, and the solutions he proposes are less effective than those of his more up-to-date colleagues. Thus, he is unaware of at least some of the information and techniques that are relevant to his area of responsibility, and as a result of his ignorance his work is not as useful or productive as that of others who are less obsolete.

Obsolescence, however, is not simply a problem of stupidity or laziness. Personal weaknesses of this kind may well contribute to technical obsolescence, but they should not be confused with obsolescence. Those who are aware of the best technical solutions to a given problem but fail to apply them because of laziness or a lack of insight into the precise nature of the problems they are facing—these workers should not be regarded as obsolete. Not every instance of ineffectiveness, therefore, can be laid to obsolescence. But, when ineffectiveness does stem basically from a lack of awareness of the technical knowledge that is relevant to a given problem-area, we are dealing with obsolescence.

Obsolescence, moreover, is not a simple, unitary phenomenon. There are several types of obsolescence that differ from one another in terms of their etiologies, their effects upon the individuals involved, and in terms of the remedies that must be used to neutralize their effects. The most comprehensive type of obsolescence might be described as *professional obsolescence.*

If we regard the professional member of a discipline as someone who has mastered the knowledge and techniques of his discipline, it follows that professional obsolescence refers to those whose technical competence does not embrace the farthest reaches of knowledge and technique comprising their discipline. A formal definition of this type of obsolescence can be represented as follows:

$$O_p = \left(1 - \frac{LPK_d}{LAK_d}\right) 100$$

O_p refers to the level of an individual's professional obsolescence, LPK_d to the level of his knowledge in his discipline (possessed by the individual), and LAK_d refers to the level of knowledge actually available in his discipline. Thus, when the engineer's knowledge of his discipline is complete, the ratio LPK_d/LAK_d is unity, and his professional obsolescence is zero. But, as his professional knowledge diminishes, the ratio $LPK_d/$-LAK_d approaches zero, and O_p approaches 100.

Complete mastery of a discipline is probably quite rare in any given profession. Accordingly, most members of most fields are to some degree professionally obsolete. Nevertheless, it is probably also true that there is considerable variation in the degree of professional obsolescence among the members of most disciplines, and it is this variation that is of interest, not the presence or absence of professional obsolescence.

A second type of obsolescence is based upon the individual's lack of knowledge of his own technical specialty. Most serious students of a discipline are obliged to focus their interests upon certain sectors of their discipline and to ignore other sectors. In their areas of specialization, however, they should be expert, and to the degree that they are not, they exhibit a second kind of obsolescence. We might refer to this type as *areal obsolescence.*

It can be defined as follows:

$$O_a = \left(1 - \frac{LPK_a}{LAK_a}\right) 100;$$

where O_a refers to the level of the individual's areal obsolescence, LPK_a

to the level of the worker's knowledge in his own special area, and LAK_a to the level of knowledge available in this area. The magnitude of O_a ranges between 0 and 100, but most specialists will undoubtedly fall somewhere between these extreme values.

It is conceivable, of course, that some individuals will have more than one specialty and, therefore, more than one areal obsolescence score. But whether the individual acknowledges more than one area of specialization or not, his level of professional obsolescence will depend directly upon the cumulated degree of obsolescence he displays in all of the several areas making up his discipline. Thus, an individual's areal obsolescence contributes directly to his professional obsolescence.

It should not be inferred, however, that there is a perfect correspondence between these two types of obsolescence. The generalist in any given discipline is likely to exhibit moderate levels of obsolescence in most, if not all, of the specialized areas of his discipline but a relatively low degree of over-all or professional obsolescence. The specialist, on the other hand, will probably exhibit high levels of obsolescence in every area except his own and, therefore, display somewhat higher professional obsolescence than the generalist. His specific expertise is reflected in a low level of areal obsolescence, but his rather narrow focus is reflected in a high level of professional obsolescence. More generally, then, a low degree of areal obsolescence does not necessarily imply a low degree of professional obsolescence, even though high levels of obsolescence in several areas do imply a high degree of professional obsolescence.

A third type of obsolescence that must also be identified is that in which the individual's knowledge is compared with the body of knowledge that is relevant to the specific technical tasks he is required to perform in his current position. Thus, some specialists who have achieved a high sophistication in a particular area eventually come to fill administrative posts in their organizations where an up-to-the-minute knowledge of their discipline is not absolutely essential to their effectiveness. These individuals, of course, would probably display rather high levels of both professional and areal obsolescence, but, since technical obsolescence is not a serious handicap for them, they should not be regarded as obsolete on this basis alone.

A precise measure of their obsolescence should, therefore, take into account the knowledge that is essential to their effectiveness in their *current* position, and only if they fall behind in this area should they be regarded as obsolete. This type of obsolescence might be described as *ex officio obsolescence*, and symbolically it can be represented as follows:

$$O_x = \left(1 - \frac{LPK_x}{LNK_x}\right) 100;$$

where O_x refers to the level of the individual's ex officio obsolescence,

LPK_x to his level of technical knowledge relevant to his office, and LNK_x to the level of technical knowledge needed by individuals in that office. Again, O_x ranges beteeen 0 and 100, but here most individuals will probably display rather low levels of obsolescence since those who display high levels are quite ineffective and, therefore, unlikely to remain for any length of time in such positions.

These, then, are the three major types of obsolescence that must be distinguished from one another if we are to get a precise picture of the nature of obsolescence among scientists and engineers. Each of these types, as already suggested, is distinct both in its causes and its effects upon the individual; but it is also true that these three types can and probably do converge in different individuals in a multitude of ways. Thus, while one scientist may exhibit a high level of ex officio obsolescence but little professional and areal obsolescence, another may exhibit little ex officio obsolescence but high levels of professional and areal obsolescence. The mix of the individual's over-all obsolescence, i.e., the relative contribution of each type to his over-all problem, is an important clue to the exact nature of his problem and should be carefully evaluated before any effort is made to remedy his obsolescence.

TABLE 1

THE EIGHT POSSIBLE COMBINATIONS OF PROFESSIONAL, AREAL, AND EX OFFICIO OBSOLESCENCE

	Individual Patterns of Obsolescence							
	Professional	*Generalist*	*Specialist*	*Trainee*	*Inept Generalist*	*Inept Specialist*	*Non-technical Worker*	*Incompetent*
Types of obsolescence								
Professional	−	−	+	−	−	+	+	+
Areal	−	+	−	−	+	−	+	+
Ex Officio	−	−	−	+	+	+	−	+

NOTE: A plus indicates a high degree of obsolescence; a minus a low degree.

Now, if we assume for illustrative purposes that there are only two magnitudes of obsolescence, high and low, it is apparent that there are several ways in which these three types of obsolescence can combine in individuals. Table 1 lists these combinations and provides descriptive names for each.

The Professional is someone who shows little obsolescence of any type and, therefore, presents no problem at all. The Trainee similarly presents little problem in that experience alone will eventually erase his obsolescence. He has a good grasp of his discipline and of the knowledge and techniques of his specialty. All that is lacking is a mastery of the techniques of his office, which in all probability he will develop as he practices his craft.

If, however, his ex officio obsolescence represents something more basic—e.g., an obtuseness that makes it difficult for him to apply his knowledge, it is difficult to see how *any* remedial program could relieve his problem. The Incompetent, i.e., the fellow who is obsolete in all three levels probably also presents a hopeless picture. His situation often reflects basic personal weaknesses that a simple retraining program is not likely to remove. More drastic steps may be indicated, e.g., psychotherapy, but these kinds of treatment programs are beyond the scope of this discussion.

The Generalist, as we have already seen, is someone who has a rather good understanding of his discipline as a whole but whose knowledge of any specific area is slightly lacking. Such an individual may be teaching in engineering departments where research is not heavily emphasized, or he may be a highly skilled scientist who has risen into administration in his firm. If an up-to-date knowledge of a given area is useful in his position, bringing him back to a high level of sophistication should present little difficulty. His weaknesses are superficial and a retraining program focusing on the specific gaps in his knowledge should be sufficient. It would not be unduly expensive nor would it take a great deal of time. Hence, the prognosis for this type is quite hopeful.

The Inept Generalist presents a somewhat more complicated picture. He is both ex-officially and areally obsolete, which may indicate that his areal obsolescence is a serious handicap to him in his position, i.e., his weaknesses as a specialist stand in the way of his performing adequately in his office. If this is the case, his difficulty can be relieved fairly easily. A rather intensive retraining program in those recent developments that are responsible for his areal obsolescence should solve his problem. If this diagnosis is incorrect, i.e., if his problem is not basically one of areal obsolescence, then it may be more fundamental and, therefore, much less tractable.

The non-technical worker who is obsolete in everything but the specific procedures of his office probably needs little help. He may be someone who was trained in a scientific discipline and once worked as a scientist or engineer. His current position, which may be in management, does not require a technical knowledge, and for this reason there is no immediate reason why such an individual should be alarmed about his obsolescence.

The Inept Specialist, on the other hand, has every reason to be alarmed. Since he is obsolete in everything but his area, his position may not require the kinds of skills he does have, or he may not be able to apply the skills he has in his position. If the former is the case, a change of position would be indicated, but if the latter is the case, it is hard to see what can be done to improve his lot. In either case, however, retraining does not seem to be indicated.

Similarly, the Specialist who is professionally obsolete does not require immediate or intensive remedial efforts. He is probably rather narrow in his knowledge, but thus far it has not meant any serious problem for him in his office. The Specialist, however, is highly vulnerable to any radical changes that his discipline may undergo in the future, and for this reason it is probably in his long-range interests to improve his familiarity with other areas beyond his own specialty. Periodic survey courses which would involve only moderate expense and time would probably serve his needs quite well.

It is clear, then, that the solution to the scientist's or engineer's problem depends upon the pattern of obsolescence he displays. No one remedial program is going to serve everyone's interests. Indeed, some obsolete workers are beyond help altogether. The efficient utilization of retraining and remedial programs, therefore, requires an evaluation of the kinds of obsolescence present in each case and the causes behind them. Without such knowledge, the administrators of retraining programs are operating by guess and intuition alone.

The causes of something as complex as obsolescence could not help but be rather complicated and variegated. As there are several levels of obsolescence, there are probably also several levels of causal factors. Proceeding from the most concrete to the most abstract, it is no doubt true that personal weaknesses of various sorts contribute to the obsolesence of scientists and engineers. Those who are intellectually dull, those who are temperamentally phlegmatic, those who are psychologically constricted are likely to experience greater degrees of all three types of obsolescence than their colleagues who do not evidence such traits. These factors which attach to the scientist's own person are probably the most pervasive and the most difficult to remove. But they are within the province of the psychologist and beyond the scope of this analysis.

Several respondents identified an entirely different complex of factors that seem to contribute primarily to the areal obsolescence of engineers. According to these informants, areal obsolescence is most likely to occur among engineers when they are allowed to settle complacently in a rather narrow area that has not been evolving very rapidly. Their complacency seems to prevent their anticipating or participating in the radical developments that may be about to unfold in their area, and their routine involvement in their discipline seems to dull any desire to acquaint themselves with these developments, once they have occurred. Thus, considerable areal obsolescence tends to develop among engineers and scientists when their area of specialization has recently accelerated in its progress after a long period of quiescence.

Now, specialists are utilized in a variety of settings, some of which confront them systematically with precisely those conditions that encourage their areal obsolescence. According to several informants, the automotive industry is a good example of just such a setting. The technical problems involved in building automobiles have largely been resolved by now, and consequently the technology of automobile production is not changing very rapidly. Contributing to this stagnation, according to one reporter, is the auto industry's lack of interest in basic research. The major concern in the industry seems to be profits in the short-run, and anything that jeopardizes this goal, including basic research with no immediate pay-off, meets with serious resistance. But, since an active research program is one of the factors that makes for technical growth in an industry, the auto companies receive relatively little stimulation from their research departments. Thus, the course of least resistance for automotive engineers is to settle into a stable technical area without disturbing it too profoundly, i.e., they are invited to become stagnant in a relatively stagnant area. Basic innovations, however, are inevitable in every technical sector and when they occur in the auto industry, these are precisely the engineers that will be swept aside into areal obsolescence.

Curiously enough, areal obsolescence is probably least prevalent among those industries that are moving most rapidly, e.g., in defense industries. We interviewed executives in several electronic firms, two governmental laboratories, and in one aerospace firm, and according to these informants the problem of professional and areal obsolescence is not serious in these organizations.

It is well known that the defense industry in this country has undergone profound changes in the last twenty years which have had important consequences for engineers and scientists involved in defense work. During the Korean War and World War II, firms involved in defense work were required to turn out weapons and materials in much the same fashion that the automotive companies turn out cars today. Each model was not overly complicated in its engineering, but it was produced by the tens of thousands. Hence, most of the engineers in defense industries were involved in design and production work, and only a few were engaged in research and development.

With the advent of nuclear weapons, supersonic aircraft, guided missiles, and space travel, the technology of defense suddenly became quite sophisticated, requiring engineers who were familiar with many highly technical and rapidly developing areas. Moreover, with the increases in firepower that accompanied these breakthroughs in weapons systems, the need for thousands upon thousands of units dwindled and the emphasis shifted to the production of custom-built weapons designed for highly specific missions. Thus, in contrast to the situation twenty years ago, defense industries today utilize a substantial proportion of their engineering talent in research and development work, while design and production work absorbs, relatively speaking, a much smaller proportion. And, as the technology of weapons systems has become increasingly sophisticated, engineers in defense-oriented firms are obliged to keep abreast of this developing technology or get out of the field altogether. Those technical people that remain, therefore, are typically quite current in their special areas. In defense firms today, the scientists and engineers are in the forefront of many advancing disciplines and do not display a significant degree of areal obsolescence.

There is a second factor that also helps to prevent areal obsolescence among technical people employed in defense industries. As we have already suggested, modern defense contracts often provide for only a few hundred units of highly sophisticated equipment. The technology behind this equipment, moreover, is generally evolving quite rapidly. Thus, no firm doing a substantial amount of defense work can depend upon the same standard product-line year after year as the automotive industry does. Rather, it must constantly design new weapons systems and redesign and otherwise improve the older systems by utilizing swiftly developing technologies. The engineering and scientific personnel in defense firms, therefore, are constantly facing new problems that only vaguely resemble ones they have faced in the past.

They are never allowed to settle comfortably into a narrow niche, and although they may be nagged by a sense of never having fully mastered any project, they are *forced* to maintain a competency in several allied fields simultaneously. This kind of shifting and adjusting, however, tends to prevent areal obsolescence because it tends to encourage a continuous process of re-education on the part of the scientist and the engineer.

The hue and cry raised recently in the literature regarding obsolescence is directly linked, therefore, with changes in the defense requirements of the nation. With the shift from production to research and development, engineers and scientists who had become accustomed to the relative stability of a production-oriented defense industry found themselves hopelessly inadequate to perform research and development assignments. Their knowledge was outdated and their experience too narrow. Their obsolescence, however, only became apparent when they were asked to solve problems that were no longer routine. But if many of the specialists in defense firms were manifestly obsolete, their colleagues in non-defense firms like the auto industry were in no better shape. Hence, recent defense contracts calling upon a knowledge of sophisticated technologies could only be fulfilled by the young engineers who were just graduating from the better engineering schools in the country. It is no accident, therefore, that the newer electronics and aerospace firms have clustered around Boston and Pasadena.

There is another aspect to the problem of obsolescence, however, that is most clearly seen when we contrast engineers in the academic community with those in industry. Many of the engineering and science departments in educational institutions are actively engaged in basic research, and consequently most academic scientists and engineers are forced to maintain a close familiarity with the latest theoretical developments in their specialities. They may often lack the practicing specialist's finesse in solving specific problems, but they are usually thoroughly familiar with the latest concepts and techniques in their disciplines. Professional and areal obsolescence, therefore, is comparatively rare among academic scientists and engineers.

The practicing engineer, however, is not ordinarily conducting research into basic problems. Rather, he is usually engaged in designing unique solutions to highly specific problems. His effectiveness depends to some degree upon his engineer's intuition, which he develops through experience with problems in his area. The average engineer, therefore, by virtue of his specific responsibilities, is drawn relentlessly away from abstract theories and general principles toward the concrete and pragmatic. As he continues in his profession and gathers experience, he often becomes an accomplished master of manipulating the concrete—but he also often becomes increasingly illiterate as far as theoretical explanations of his accomplishments are concerned. This means that the one channel that might help him remain broadly current in his profession, i.e., the technical literature, is gradually closed to him as he slowly loses an ability to comprehend what it is trying to tell him. Moreover, the fact that the technical literature is dominated to a large extent by engineers in the great centers of engineering education compounds his problem, because the emphasis in these centers is swinging more clearly in a scientific, theoretical direction. In essence, then, because the average engineer is usually called upon to design solutions for specific and concrete problems, his expertise tends to take a pragmatic, *ad hoc* turn, while at the same time his interest in and comprehension of theoretical analyses grows progressively weaker. If left to himself, therefore, his natural tendency is to become increasingly obsolete both professionally and areally.

The scientist in both industry and educational institutions, however, is in a somewhat different position. The very nature of his occupation, research, forces him to scrutinize the literature and digest the latest theoretical developments. Thus, by virtue of his responsibilities the average scientist is much more likely to keep up-to-date in the theoretical developments of his disciplines and much less likely to become either professionally or areally obsolete. These remarks, of course, also apply to the academic engineer who is systematically engaged in a research program.

Ex officio obsolescence was not covered in these interviews with the same thoroughness, but our informants were able to suggest several factors that might contribute to its prevalence among scientists and engineers. Ex officio obsolescence seems to arise most commonly when the specialist is assigned a primary responsibility that is closely related to his technical expertise but at the same time given assignments that interfere with his devoting the major share of his time to this responsibility.

This inefficient diversion of the specialist to secondary duties can be found in many different settings and is accomplished in a variety of ways. In some defense firms, for example, scientists and engineers are often expected to explain the nature of their complex technical designs to military and defense department officials and, according to some informants, this function can at times occupy the major share of the specialist's time. While he is involved in these tasks, he is not developing his technical skills and, accordingly, there is some danger that he will lose the expertise that was the basis of his usefulness in the first place.

Much the same kind of diversion to secondary matters also occurs in the academic world when a creative researcher is promoted to an administrative post and submerged in administrative duties. Again, the basis of the appointment—the man's professional eminence—is progressively undermined, because he is not able to continue his professional duties. Unless he demonstrates real skill as an administrator, he will become ex-officially obsolete as his professional reputation diminishes.

A somewhat different version of the same process can also be seen in certain governmental laboratories. In these laboratories long delays are often required in the development of important projects, because a governmental review board must pass upon the value of such projects at several different stages in their development. These periodic halts tend to dull the specialist's interest in the problem at hand. Although these delays do not directly involve the scientist or engineer in peripheral activities, they do force him to divert his attention from the immediate technical problems. And, if the specialists involved do not utilize these delays to develop and expand their professional skills, eventually they too will fall into ex officio obsolescence. Thus, ex officio obsolescence seems to develop most readily when the specialist's basic contribution is technical in nature, but because of the nature of his position, he can only devote a small proportion of his time to defining and solving technical problems. Essentially, then, his growing obsolescence is encouraged by the nature of his position.

Unfortunately, my respondents had very little to say about the causal factors behind professional obsolescence. This is an age of specialization, and the greatest threat facing the specialist is areal obsolescence. Their lack of interest in professional obsolescence may reflect, therefore, the growing segmentation of the engineering profession and the declining importance of the generalist in American science and engineering. But whatever the reason, little information was gathered on this vital subject.

In conclusion, then, I have suggested that obsolescence must be analyzed into several distinct types and that these types can be combined in different individuals in different ways to produce several distinct symptom-patterns. I have examined in detail the causal complex that seems to be behind areal obsolescence, the most virulent and contagious form of the disease, and I have sketched some of the forces that may be responsible for less wide-spread but equally dangerous forms, ex officio and professional obsolescence. Thus, I have sought to refine the conceptualization of technical obsolescence and to suggest some of the factors that probably encourage it. The propositions expressed here were based for the most part upon the observations of those who are most directly concerned with the problem—the managers of scientists and engineers. To advance our understanding even further, however, it will be necessary to put these hunches to an empirical test, since those who are most intimately involved with a problem are not always its clearest observers nor its fairest critics.

REFERENCES AND FOOTNOTES

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2. The only objective study of obsolescence that has been published thus far was reported at the annual meeting of the American Society for Engineering Education in June, 1964. See Samuel S. Dubin and H. Leroy Marlow, "Keeping Up-to-date: Replies from 2090 Engineers," The Department of Continuing Education, Pennsylvania State University, University Park, Pennsylvania.
3. My informants included one executive officer, several vice presidents and presidential advisers, several project managers, four department heads, and one research associate in a university laboratory. The organizations that were represented by at least one interview included the Argonne National Laboratory, Arthur D. Little and Company, the Adage Company, Massachusetts Institute of Technology, McDonnell Aircraft, the Mitre Corporation, Northeastern University, Raytheon Company, the University of Chicago, and International Business Machines.
4. The formal definitions of professional, areal, and ex officio obsolescence were first worked out in discussion with Professor William Evan, Massachusetts Institute of Technology.