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THE DIFFERENTIAL PERFORMANCE OF INFORMATION

CHANNELS IN THE TRANSFER OF TECHNOLOGY

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While there appears to be today rather general agreement[1] that the existing channels for communication both within and between the scientific and technological communities are not performing as well as might be desired, when one looks a bit below the surface of these opinions there is an astounding lack of understanding of the way in which the channels actually function.

In order to close this gap in our understanding of the communication process in science and technology, a number of research studies have been undertaken over the past few years, with the development of descriptive models of the existing communication systems as their goal.

An understanding of the manner in which scientists and engineers presently obtain that information which they need, while a major contribution, is still not quite sufficient for our purposes. In addition,

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[1] See for example: The Weinberg Report (President's Science Advisory Committee, 1963); Faegri (1956); Fozzy (1962); Glass (1962); for a dissenting voice: Bar-Hillel (1963).

we would like, if possible, to know more about the eventual impact which various information gathering practices have upon the quality of the research[2] being performed. Such a knowledge would then allow us to predict the effects which potential changes in the information services provided will have upon the scientist's or engineer's work.

To attain this extended goal, we obviously require a criterion measure of performance for research.

Although techniques for determining absolute performance measures on the results of an R&D project have yet to be satisfactorily devised, the relative quality of solutions to the same problem can be assessed rather easily by a competent judge. This, of course, is the technique employed by experimental psychologists in laboratory studies of certain kinds (creative thinking, for example) of human problem solving behavior. A number of persons are presented with the same problem and a panel of judges is asked to evaluate the relative quality of the answers. The parallel nature of the experimental design allows the psychologist to compare the behaviors observed and relate certain general behavior characteristics to the quality of the solutions produced.

Since we cannot yet afford to hire a sufficient number of scientists and engineers and assign them the same research problem, we must instead search for instances in which such parallelism has occurred

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[2] For ease of presentation, the term "research" will be used here in a generic sense, encompassing any and all activities from the basic to the developmental end of the R&D spectrum.

either adventitiously or in order to accomplish some goal quite independent from our own. Such instances have presented themselves in a number of contexts, and we are presently engaged in studies of several types of parallel situations. The results which I shall present today stem from our first foray into the domain of parallel research and constitute the third of a series of interim reports on a continuing research program. The first series of parallel projects studied is made up entirely of government supported efforts performed in industrial laboratories. All but one set of these projects are quite clearly developmental in nature and can be considered to fall within the realm of technology. The single deviant pair involved a rather fundamental investigation in physics and displays some rather interesting consequent differences in the information-related behavior of the investigators. Some of the differences will be pointed out as we go along, but first a word about the methods by which the data were obtained.

RESEARCH METHODS

Once a parallel project has been located, its work statement is obtained from the government laboratory that is to award the contracts, and analyzed and factored into a reasonable number of subproblem areas (generally subsystems). The breakdown is then checked with the technical person who prepared the work statement, and data collection forms based upon it are designed. After all data have been collected from the contractors, the technical monitor is revisited and asked to provide a confidential evaluation of each lab's performance on each subproblem. The data presented today were gathered by means of a form which we have dubbed the Solution Development Record and from pre-and post-project interviews with the individual scientists and engineers.

The Solution Development Record is a research tool which provides a record over time of the progress of an individual engineer or group of engineers (or scientists) toward the solution of a research and development problem. The lead engineer responsible for each subproblem is asked to provide a weekly estimate, for each alternative approach under consideration, of the probability that it will be finally chosen as the solution to that subproblem.

Figure I illustrates the listing of alternative approaches identified from the contract work statement, when so specified, and from the responsible engineer when he is interviewed prior to beginning the task. Blank spaces are always provided so that new approaches may be reported as they arise. If at some point in the design the respondent were considering two technical approaches to rendezvous at Uranus, and he were completely uncommitted between the two, he would circle 0.5 for each, as shown. Eventually as the solution progresses, one alternative will attain a 1.0 probability and the others will become zero. By plotting the probabilities over time, we obtain a graphic record of the solution history.

The Solution Development Record, by economizing on the respondent's time, provides a quite efficient record of a project history. When the

FIGURE 1

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Solution Development Record

Manned Uranus Landing in an Early Time Period Study

General United Aerospace Corporation

Name ______________________________ Date __________________________________

Estimate of Probability that Alternative will be Employed

Subproblem #1: Method of rendezvous at Uranus

Alternative approaches:

orbital rendezvous mission with excursion vehicle	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
orbital rendezvous mission without excursion vehicle	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
direct mission	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
______________________________	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

Subproblem #2: Design of the electrical power supply subsystem for the space vehicle

Alternative approaches:

hydrogen-oxygen fuel cell	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
KOH fuel cell	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Rankine cycle fast reactor	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Rankine cycle thermal reactor	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Brayton cycle reactor	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
______________________________	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
______________________________	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
______________________________	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

project is completed, each respondent is presented with a time-plot of his probability estimates, and is interviewed at some length to determine causes and effects of design changes reflected in this record. The plot thus provides a stimulus to the man's memory and assists the investigator in gathering a detailed record of each project.

In considering the sources of ideas, the unit of analysis employed is "messages received" (Menzel, 1960). In other words each message which the engineer or scientist receives, which suggests to him an alternative solution is coded for the channel whence it arrived.

A listing of the most frequently cited information channels is shown in Table I. This does not imply that each idea can be traced to a single one of these channels. More often than not a single alternative will result from messages received from several channels; for example, someone on the lab's technical staff might refer the engineer to an article in a trade journal, which in turn leads him to a vendor who provides more complete information on the alternative. In such a situation, where several channels contribute to a single alternative, equal credit is given to each source.

CHARACTERISTICS OF THE SAMPLE

The nineteen projects under consideration, involved the following nine general problems:

1. The design of the reflector portion of a rather large and highly complex antenna system for tracking and communication

TABLE I

Typical Information Channels Considered in the Study

literature:	books, professional, technical and trade journals and other publicly accessible written material.
vendors:	representatives of, or documentation generated by suppliers or potential suppliers of design components.
customer:	representatives of, or documentation generated by the government agency for which the project is performed.
external sources:	sources outside the laboratory which do not fall into any of the above three categories. These include paid and unpaid consultants and representatives of government agencies other than the customer agency.
technical staff:	engineers and scientists in the laboratory who are not assigned directly to the project being considered.
company research:	any other project performed previously or simultaneously in the lab regardless of its source of funding.
personal experience:	ideas which were used previously by the engineer for similar problems and are recalled directly from memory.
analysis and experimentation:	ideas which are the result of an engineering analysis, test or experiment with no immediate input of information from any other source.

with space vehicles at very great distances.

2. The design of a vehicle and associated instrumentation to roam the lunar surface and gather descriptive scientific data.
3. An investigation of passive methods for transfer of modulation between two coherent light beams.
4. A preliminary design of an earth-orbiting space station.
5. The design of a deep space probe, and appropriate instrumentation.
6. The preliminary design of an interplanetary space vehicle.
7. The preliminary design of a special-purpose manned spacecraft for cislunar missions.
8. The development of a low thrust rocket engine for maneuvering manned spacecraft.
9. An investigation of possible mission profiles for manned expeditions to another planet.

RESULTS

An example of the time plot of solution development records for a typical subproblem is shown in Figure 2. The problem, in this case, is the design of a position feedback subsystem for a very large and complex antenna system. The work statement for both labs suggested approaches α, β and γ. Both rejected these, however, and generated

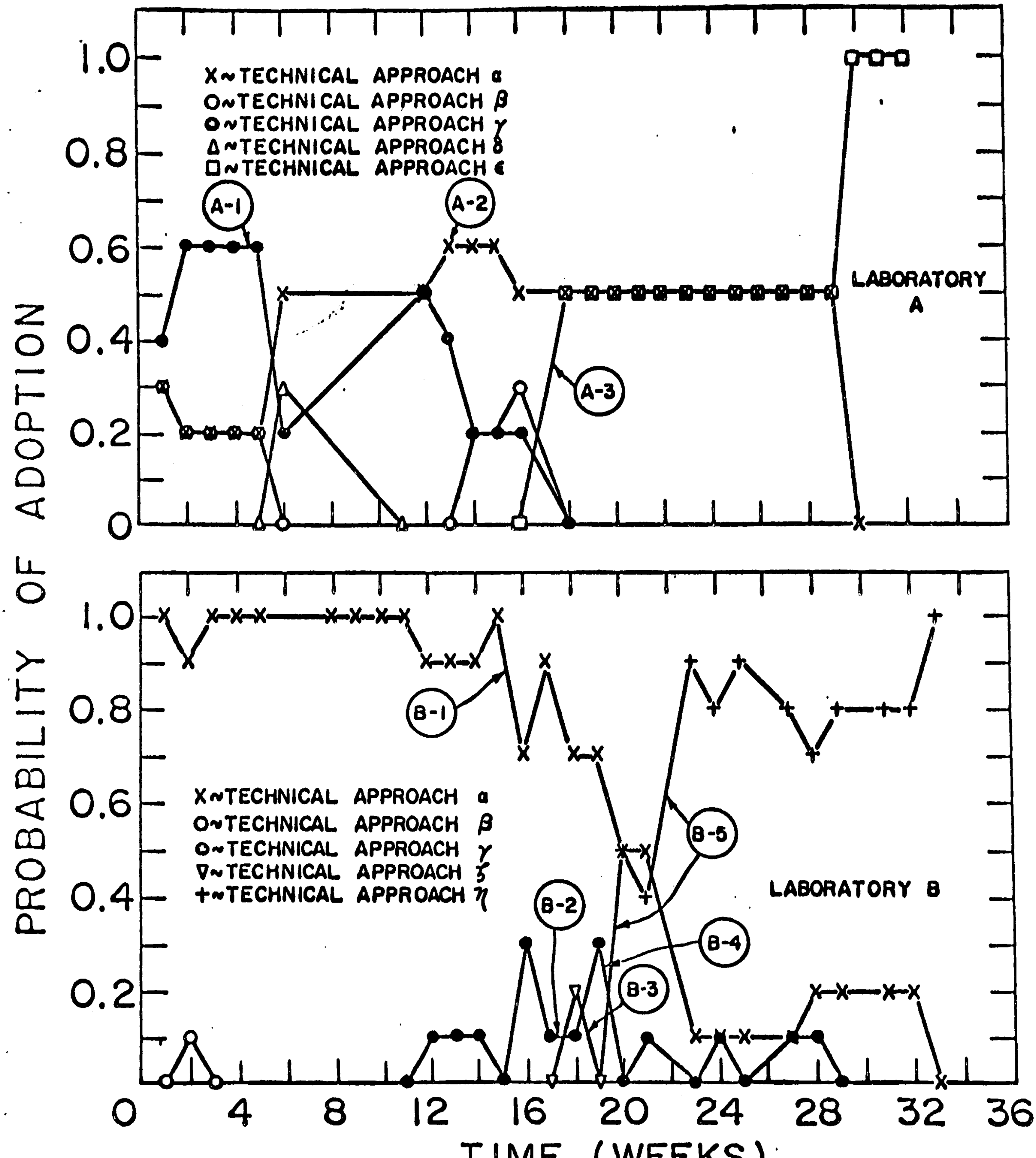

FIGURE 2

DESIGN OF SUBSYSTEM TO DETERMINE ANTENNA POSITION two new approaches each (δ, ϵ, ζ and η). In both labs one of the new approaches resulted from difficulties incurred by the currently preferred approach; the other resulted from receipt of new information, and was independent of the state of approaches currently under consideration.

Alternatives such as these can now be evaluated at two levels. First the engineer himself decides upon one of several possibilities as the best solution to the subproblem; thus evaluating this alternative as preferable to the others under consideration. At a second level, the customer's relative evaluation of the solutions to each problem reached by the two or three research groups is available. So, each group selects one alternative as its solution to the problem, and then the solutions submitted by the two or three groups are evaluated relative to each other by the government technical representative. Working from the solution evaluation backward to the sources of the alternative provides two measures of performance for the information channels.

Acceptance by the Engineer

Table II and Figure 3 show total frequency counts for messages received and accepted from each of the eight channels. Seventy-two alternatives could not be attributed to a channel, either through the unavailability for interview of the knowledgeable engineer, or through inability to obtain this information during the interview.

These data show quite a diversity in both the relative use and performance of the eight channels. When considering those channels which provide new inputs to the individual[3], we find that the customer and vendors are most used by engineers, and that the literature is the least used channel. For the scientists, on the other hand, the literature is most used and no ideas whatsoever originated with vendors or the customer.

The most important aspect of these data, however, lies in the fact that the channels used with the greatest frequency are not the ones which provide the greatest number of acceptable ideas. A chi-squared test performed on the data for both scientists and engineers shows a significant ($X^2 = 19.55$, $p < 0.01$) difference in the allocation of acceptances and rejections among channels.

Looking at relative performance on this basis shows the three channels which might be considered to involve "expert" sources to have the highest performance. These three channels, technical staff, company research, and external sources all produce very high acceptance rates among engineers. None of the expert channels were used to any extent by the scientists, but the one external source which produced more than a single message had the highest acceptance rate found. This, however, might be spurious since the external source in this case was the scientist's former mentor, during graduate studies,

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[3] All except analysis and experimentation, and personal experience.

TABLE 11

Messages Recieved and Messages Accepted by R&D
Scientists and Engineers as a Function
of Information Channel
(Nine Parallel Sets Comprising 19 R&D Projects)

channel	messages received	messages accepted	acceptance ratio
literature			
scientists	18	6	0.33
engineers	53	21	0.40
external sources			
scientists	5	5	1.00
engineers	67	32	0.48
vendors			
scientists	0	0	---
engineers	101	33	0.33
customer			
scientists	0	0	---
engineers	132	41	0.31
technical staff			
scientists	1	0	0
engineers	44	24	0.55
company research			
scientists	1	0	0
engineers	37	20	0.54
analysis and experimentation			
scientists	3	1	0.33
engineers	216	72	0.33
personal experience			
scientists	7	4	0.52
engineers	56	17	0.30
unknown	75	6	---

Differences in acceptance ratios between the following channels are statistically significant at the 0.01 level: technical staff and vendors, external sources and vendors, technical staff and customer, company research and customer, external sources and customer. The difference between ratios for external sources and vendors is statistically significant at the 0.05 level.

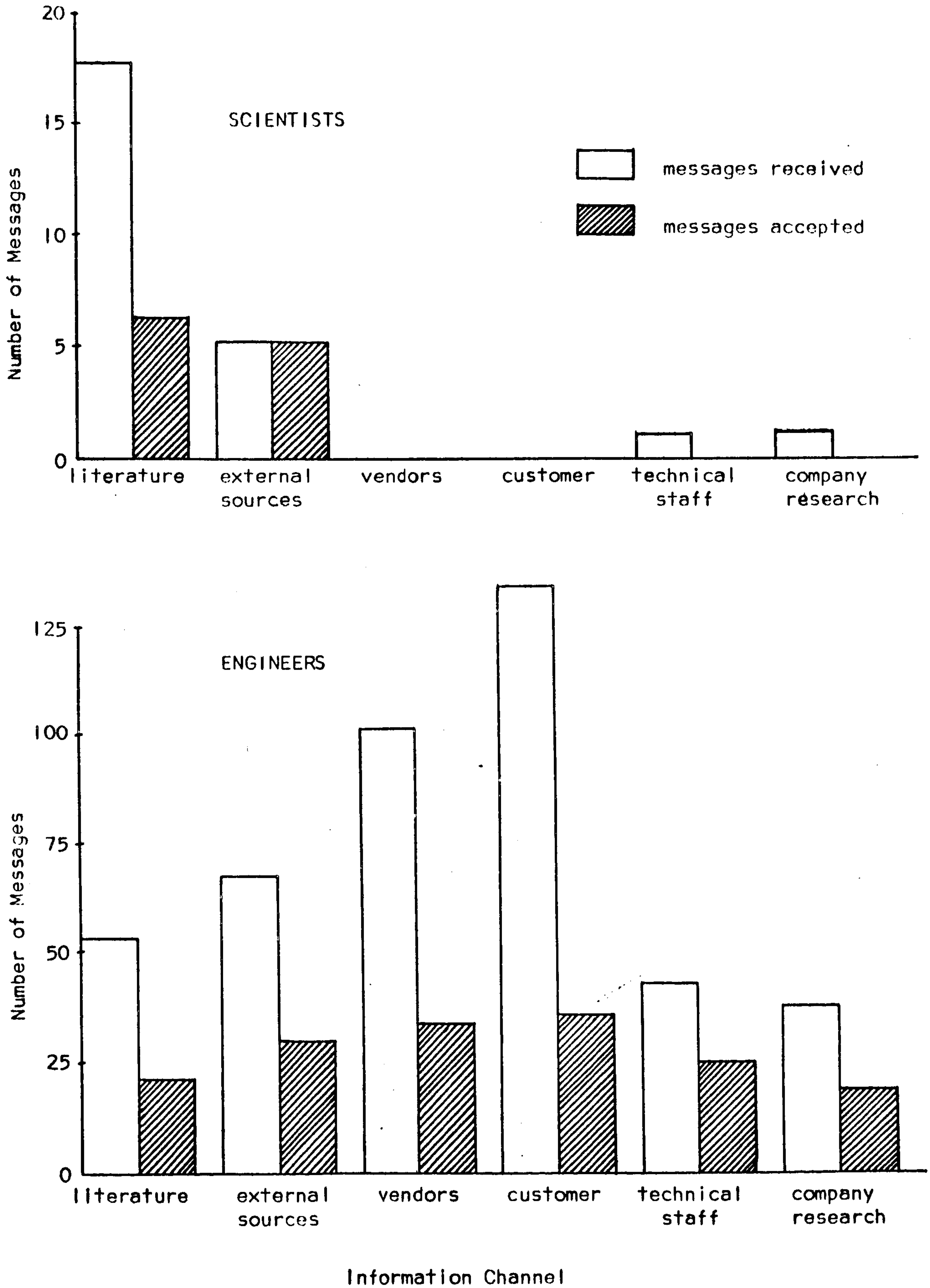

Figure 3. Messages Received and Messages Accepted by R&D Scientists and Engineers as a Function of Information Channel

a capacity which could enable him to have a distortedly high acceptance rate for his ideas. So, while no hard conclusions can be drawn concerning scientists, it is quite clear that engineers are quite prone to accept ideas from someone they consider "expert". That this does not generalize to all interpersonal sources is witnessed by the very low standing of vendors and customer representatives. While low acceptance of the former's ideas should surprise no one, the low acceptance rate for the customer's ideas indicates a rather refreshing amount of intellectual honesty on the part of our engineers.

Evaluation by the Customer

For 27 of the 82 subproblem pairs, relative evaluations of the solutions were obtained from responsible technical monitors in the customer agencies. In the remaining 55 pairs, scores were either tied or no evaluation was available. This relative evaluation permits a comparison of the information channels used to arrive at solutions judged superior to those presented by other teams.

Table III shows the proportion of both higher and lower rated solutions which derived from information obtained through the eight channels. In other words, taking literature as an example, eleven percent (or three) of the 27 higher rated solutions were based, at least in part, on information obtained from the literature. Twenty-two percent (or six) of the 27 lower rated solutions derived, in whole or in part, from information gained through this channel.

Again, the "expert" channels stand out. Two of the three, external sources and company research demonstrate signficant differences in performance, and the differences are in opposite directions. The performance difference for the third "expert" channel is not statistically significant.

The hypothesis to be tested here is based upon the findings of Allen and Marquis (Allen, 1964) for R&D proposal competitions. The use of information sources outside of the laboratory was found in that case to be inversely related to the technical quality of proposals, while use of sources within the lab was weakly but positively related to quality. The hypothesis predicts that poorer performing groups will rely more heavily upon sources outside of the lab, and better performing groups more upon sources within the lab.

In order to test the hypothesis, the actual number of solutions derived from each set of channels is aggregated in Table IV. Since a solution can result from several messages, each received over a different channel, those solutions to which internal channels only contributed are compared with solutions resulting only from external channels. To complete the set, a third category has been included. This category comprises solutions deriving from neither internal nor external, and solutions derived from both in combination. A chi-squared test rejects the null hypothesis of no difference in the performance of internal and external channels at the 0.03 level of statistical significance.

TABLE III

Sources of Messages Resulting in Higher and Lower Rated Solutions (27 subproblem pairs)

Information Channel	percentage of solutions suggested by messages received through each channel: 27 higher rated solutions	27 lower rated solutions	level of statistical significance
literature	11%	22%	0.14
external sources	7.4	26	0.03
vendors	30	30	0.50
customer	56	44	0.21
technical staff	22	15	0.24
company research	22	7.4	0.06
analysis and experimentation	44	52	0.29
personal experience	11	11	0.50

The percentages in Tables III and V are distilled from 2 X 2 contingency tables in the following manner:

Taking the first row, literature as an example, the original contingency table looked like this:

solution rating

	high	low
number of solutions based at least in part on messages from the literature	3	6
number of solutions not based on messages from the literature	24	21
	27	27

3/27 = 11%

6/27 = 22%

A somewhat more general test of the information gathering behavior of the engineers working on each subproblem can be performed by comparing the sources used in generating all of the solution alternatives which were considered for the subproblem. In other words, general information seeking behavior varies as a function of the individual and his particular circumstances. Table V shows that a comparison at this level strengthens the conclusions reached on the basis of comparing the sources of solutions alone.

Higher and lower performers again show little difference in their use of the literature, vendors, and analysis and experimentation, and in their reliance upon personal experience in generating solution alternatives. Poorer performers once again rely more heavily upon external sources, and better performers upon sources within their own laboratory i.e., upon their technical staff and other company research programs.

DISCUSSION

Three rather striking differences are observed in the performance of the information channels studied. First of all, there is a wide variance in the frequency with which the several channels are used. Considering only the channels external to the project group, the customer agency and vendors are found to supply almost three times as many suggestions of solution alternatives as do the lab's technical staff or its other research programs. The actual acceptance of these

TABLE IV

Sources of Messages Resulting in
Higher and Lower Rated Solutions
(27 subproblem pairs)

Information channel	number of higher rated solutions suggested	number of lower rated solutions suggested
Channels Outside the Laboratory external sources or vendors but not technical staff or company research (ESUV) $\cap$ (TSUCR)	6	10
Channels Inside the Laboratory technical staff or company research but not external sources or vendors (TSUCR) $\cap$ (ESUV)	7	1
Other Channels both or neither (TSUCR) $\cap$ (ESUV) or (TSUCR) $\cap$ (ESUV)	14	16

$X^2 = 5.63$, $p < 0.03$

TABLE V

Sources of Messages Resulting in All Technical Alternatives Considered by Engineers Submitting Solutions Receiving Higher and Lower Ratings (27 subproblem pairs)

Information Channel	percentage of alternatives suggested by messages received through each channel: 85 alternatives associated with higher rated solutions	85 alternatives associated with lower rated solutions	level of statistical significance
literature	8.2	14	0.11
external sources	5.9	15	0.02
vendors	21	26	0.23
customer	44	46	0.38
technical staff	12	4.7	0.05
company research	15	3.5	0.004
analysis and experimentation	48	38	0.08
personal experience	11	8.2	0.30

messages is inversely related to the frequency of use. Two of the least used channels, technical staff and company research yield the highest acceptance ratios. It appears that what might be called "expert" channels show the highest probabilities of having an idea accepted.

Comparing the sources of both solutions and rejected alternatives for higher and lower rated problems, shows a marked difference in the performance of channels, depending upon whether they originate within or outside of the laboratory organization. Those originating within the lab perform far better than those originating outside.

The importance of this finding to those concerned with promoting the transfer of technology cannot be overstressed. But before delving into its implications in more detail let us marshall a bit more support for its existence.

As remarked earlier, this is not the first time that the phenomenon has appeared. It was first revealed in the study of R&D proposal competitions (Allen, 1964). The proposal competitions studied varied widely in the nature of their problem and ranged throughout the research spectrum from quite fundamental basic research studies to hardware-oriented development and test projects. Across this wide range of problem types, teams which relied more heavily upon outside information sources were found to produce poorer quality solutions. In fourteen of fifteen instances, correlations between the extent to which outside sources were used and rated technical quality of the proposals were found to be negative. The mean rank order correlation for 15 competitions was -0.30 ($p < 0.001$). The data indicate that lack of technical capability within the lab was largely responsible for at least the decision to use outside sources. Inverse relations were found between the use of such sources and both the size of the lab's technical staff and its ratio to the total employment of the lab. Laboratories which do not have the necessary technical manpower resources attempted unsuccessfully to substitute through reliance upon outside technical personnel.

Similarly the study of Shilling and Bernard (1965), shows consistent inverse correlations between the extent to which "paid consultants" are employed by industrial bioscientists and eight measures of laboratory "productivity and efficiency". All of these correlations are statistically significant at the 0.05 level or beyond. Furthermore, the authors found the use of paid consultants to be the only factor "which clearly and unequivocally differentiates (university from government and industrial) laboratories."

The present data (Tables III, IV and V) of course, reveal a similar performance differential. So the evidence which has accumulated is indeed quite convincing, but it does not as yet explain the situation which has been found to exist. One clue lies in the finding of an inverse relation between the size (both absolute and relative to total company employment) of a lab's technical staff and the extent to which outside sources are used during proposal competitions. This suggests two factors which must be operating. First, those teams, or more precisely those laboratories whose research teams rely on outside help possess other characteristics which more likely are the actual cause of the poor performance. The most plausible of these is simply the lack of the required technical competence within the lab. Certainly, the use of an information source can seldom be held to directly <u>reduce</u> quality. Rather, it is the initial lack of knowledge on the part of the R&D team members which would be directly responsible. Some information sources are more capable than others of counteracting this initial condition. This introduces the second factor: sources outside are either less well-informed, which is rather unlikely, or there exists an impedance at the organizational boundary, which restricts the flow of information. Why is it that the organization should impose such an effective barrier to communication? Before addressing the question directly, let us first examine an instance which at first appearance runs counter to the evidence thus far.

Hagstrom (1965), who studied 179 prominent researchers in the formal (mathematics, statistics and logic), physical and biological sciences, found a strong positive correlation ($Q = 0.85$)[4] between extra-departmental communication and productivity in terms of papers published. The correlation between productivity and intra-departmental communication is considerably lower ($Q = 0.42$). Now how does this relate to the earlier findings and how can the apparent contradiction be resolved? Well, first of all, Hagstrom's measure of extra-

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[4] Yule's Q correlation for dichotomous data. No significance level is given.

departmental communication was, it should be noted, restricted to communication within the individual's academic discipline. Furthermore, the organization in Hagstrom's case is somewhat different; it was a university department; all of the other results stem from studies of industrial organizations.

It follows that, the differences in the effectiveness of extra-organizational communication found between the two situations can be attributed in large part to two factors:

1. The relative commitment of the individual to the organizations or social systems at hand, and

2. the degree to which the boundaries of these organizations are formally structured.

In this context, Hagstrom's scientists confronted a low impedance in communicating across the bounds of their academic departments (but within their disciplines), because the academic department elicits a lower degree of commitment from most academic scientists than does their professional discipline, or "invisible college". At the bound of the latter, we should expect to find a higher impedance that at the bound of the academic department, but not so high as at the periphery of a more formalized organization such as an industrial or government laboratory. Here, we bring in our second consideration. The difficulty lies in the nature of the bureaucratic form of organization.

The impermeability of bureaucracy to the influx of information and technology has been deplored by many social scientists in recent years. Bennis, for example (1966), in cataloguing the many criticisms which have been leveled at bureaucracy includes the charge that it, "cannot assimilate the influx of new technology or scientists...," Katz and Kahn (1966) provide us with some explanation for this, revolving about two major points:

1. In order to control its intake of information and thereby avert the possibility of being so overwhelmed that the resulting condition is one of pure noise, the organization establishes a "system boundary" which defines the appropriate region for organizational activities, and "...constitutes a barrier for many types of interaction between people on the inside and people on the outside."

2. Every organization like every individual develops a coding system with which to order its world. This coding scheme, in turn, enhances the efficiency of communication among those who hold it in common. It can, however, detract from the efficiency of communicating with the holders of a different coding scheme.

The two points are clearly complementary. The first is accomplished, in part, through the second. System boundaries, are to some degree defined and maintained by a distinction in coding schemes. The boundary of course, is not intended to be completely impenetrable. The organization must have some exchange with its environment. In order to allow this and yet control the degree, it establishes a limited number of officially recognized channels through which communication must be directed, and we have, for example, libraries purchasing departments and field offices through which information must be funnelled. In the situation with which we are presently concerned, the official limitation of channels probably occupies a secondary position, as an impediment to communication. Engineers (often to the dismay of librarians and field office managers) are generally quite uninhibited in short-circuiting such devices. It is rather the development of coding schemes which best explains the evidence which we have seen.

Let us now briefly review these results. First of all, several studies of industrial and government scientists and engineers have shown an inverse relation between extra-organizational communication, contrasting with direct relation between intra-organizational communication and performance. Second, in Hagstrom's study where the organization (an academic department) appears to occupy a subsidiary position to a more inclusive social system ("invisible college" or academic discipline), and where the communication process measured was external to the first entity but <u>internal to the second</u>, a strong positive relation was found between the extent of communication and performance. Third, in the instances in which external communication bears an unfruitful relation to performance, there is evidence that it is not this communication, <u>per se</u>, which degrades performance but other factors, such as lack of the required knowledge by the engineer or scientist seeking information. The internal channels are better able to compensate for this deficiency, than are external ones.

Applying the rationale of the shared coding scheme produces a rather simple and straightforward explanation. In industrial and governmental situations, the laboratory organization dominates the scene. These organizations demand a degree of loyalty and affiliation far outweighing that required by academic departments. In addition, the members of industrial and governmental organizations acquire through common experience, and organizational imposition, shared coding schemes which can be quite different from the schemes held by other members of their particular discipline. This is not true of the academic scientists. They generally feel more aligned with scientists who share their peculiar research interests than with a particular university or department, and would therefore tend to share a common system of coding with such individuals outside of their department. In other words, the "invisible college" now becomes the mediator of of the coding scheme. Following this line of reasoning a step further, one would predict that were inter-disciplinary communication among scientists measured, the results would show some loss in communicative efficiency. An inverse relation with performance in this case might or might not exist, depending upon other factors, but we would predict some loss in efficiency when compared with intra-disciplinary communication. The problem is compounded when, as is often the case, incompatibilities between the two coding schemes go unrecognized, or when identical coding systems are assumed which do not in fact exist.

There, of course, are possible measures which can be applied to reduce the organizational boundary impedance. One which may well take place under uncontrolled circumstances is a two-step process in which certain key individuals act as bridges linking the organization members to the outside world. Information, then, enters the organization most efficiently when it is channelled through these individuals, who are capable of operating within and transforming between two coding schemes.

The possible existence of such individuals, who in effect straddle two coding systems, are able to both function efficiently in the two and perform a transformation between them holds promise for their potential utilization in technology transfer. In other words, it appears that information must be gotten to its user by an indirect route. Attempting to bridge the organizational bound directly is not the most efficient path. Rather, the "technological gatekeepers" in the lab must first be reached and it is only through these men that the boundary impedance can be effectively surmounted.

CONCLUSIONS

This study has measured the relative performance of six channels in transferring technical information. The research technique employs the vehicle of parallel R&D projects to provide a control over the substance of the problem and a relative evaluation of solutions. Data are gathered by means of Solution Development Records and lengthy interviews with the engineers. The ideas considered for solution to each problem are thus associated with the channels whence they came, and measures of performance are generated for the channels.

The principal conclusions of the study are:

1. There is a serious misalignment between the quality of the ideas generated through the channels studied, and the frequency with which these channels are used by engineers.
2. Literature is not greatly used, and is mediocore at best in its performance.
3. Better performing groups rely more than the poorer performers upon sources within the laboratory (the technical staff, and other company research programs) as contrasted with sources outside the lab.
4. A mismatch in information coding schemes appears to be responsible for the ineffectiveness of communication across the organizational boundary. The possible existence of key individuals (technological gatekeepers) shows promise of providing a means of surmounting this organizational boundary impedance.

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