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Cover design by Charles P. Shealy, Office of Aerospace Research
Half the world is driven by technological power, and half by the passion to gain this power. For the seekers, there is a shortcut that was not available earlier. They need not generate the knowledge that leads to power; they can draw on the existing fund. For knowledge there is, and to spare. The problem is how to share it, to get it where it is desperately needed. And in this sharing the giver loses nothing, but even gains, by helping span this gulf that bisects and divides our world.

Joseph E. Stepanek

[Ref. 72]
Large and small nations, irrespective of their level of industrialization, have a common interest in their state of technological progress. The attainment of higher levels of production, the development of improved and new processes and products, bring prosperity, higher living standards, and the stimulus for further achievements.

Israel seeks accelerated rates of industrial expansion. Low in many natural resources but high in actual and potential skilled manpower resources, Israel is capable of exploiting a product of our age -- scientific information. In this, Israel can compete favorably with the most technologically advanced nations.

How scientific results can be converted into salable products of industrial operations rests, in part, on industrial experience and permissive research budgets that are yet scarce in Israel. However, the ability to identify potential areas for exploitation, the ability to extrapolate from the known to the unknown, the ability to perceive relationships among hitherto unrelated bits of data, foresight, intuition -- these are also necessary raw materials for science-based industries. These factors do not depend on gross national product or, necessarily, on prior experience. They depend, rather, on fertility of the mind produced by education, training, and an environment conducive to their growth.

"Technology transfer" is under intense scrutiny in the United States. This term refers to mechanisms for transforming research results into practical applications. Studies to date suggest that there is no best procedure, no best environment, for nurturing technology transfer. Nor are there predictive tests that conclusively identify men with creative or innovative abilities. Studies do suggest, however, that different forms of information transmission must occur to spark man's mind (or men's minds) and to effect communication of ideas through decision channels at a level of understanding sufficient for acceptance and action.
It is the contention of this paper that, though phenomena resulting in technology transfer may not be amenable to complete formalization, they can be materially aided and possibly multiplied several fold through proper attention to the role of information in the various phases of the transfer process from scientific research to production.

A variety of enterprises have evolved, probably most extensively in the United States, to make scientific and management information accessible to user groups. In the main, however, their services are not personalized or exhaustively comprehensive and place the burden on the user to be his own information sifter and searcher. This paper does not presume to predict the Optimal System for information transmission. It hypothesizes only that economically profitable, viable information systems are possible at the present time for many environments. For each instance, though, comprehensive analysis and careful planning are prerequisites that encompass evaluation of the knowledge gained thus far about systems, retrieval techniques, and human information-seeking behavior and realistic appraisals of actual and potential user groups and needs and available sources of information, manpower, machines, and money.

Israel appears now in a good position for self-examination for information system development for technology transfer. She is beginning to emphasize the importance of applied and industrial research. A Center for Scientific and Technological Information has been established within the National Council for Research and Development. Several studies of manpower and information resources, organizational structures for research and development, and government science policy have been made. Capability for the design and implementation of information systems is growing steadily through educational programs and operational experience. Moreover, Israel presents an almost unique environment, at this time, for exploring the practicability of a national-scale network of interacting subsystems capable of satisfying the various management and technical information requirements needed for a rapidly advancing economy.
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- Foreword
- Introduction
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- Performance of Information Services: specialized information centers; selective-dissemination-of-information systems; commercial information services; limitations and constraints on systems; personalized communication schemes; large service organizations
- Requirements for Information Systems: hardware capabilities; software evaluation and potentials; human information processing constraints on systems; "change" or information-transfer agents
- Payoffs from Information Systems: performance and cost effectiveness; economic policies; characteristics for technical progressiveness; an information facilities network
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INTRODUCTION

This paper is written from the viewpoint that information systems are rapidly becoming a necessity for growing technology-based economies.

Three usually unrelated sources of information are used for documentation. The first is history-of-science literature. The more factual these records are, the clearer a picture they present to this author of the crucial role of information transmission in almost all accomplishment. The second is broadly characterizable as management-science literature. This considers both economic and political milieus, as well as, more narrowly, the structure and behavior of organizations and the performance of people within them. The third is the information-sciences literature that concentrates on the design and operation of information systems, both at the systems level and at the level of individual hardware and software components.

None of this wealth of knowledge and experience conclusively establishes the viability of the information systems that are proposed here. These are systems of our time, made possible by and demanded by current scientific and technical achievements. These have created the requirement for systems. These also provide the tools for accomplishment.

CASES OF USE OF INFORMATION

Elaborate and expensive schemes are being developed today, at least in affluent countries, to promote the transmission and use of information. Some of these schemes are discussed in the section below on "Performance of Information Services." This section is concerned less with schemes than with phenomena and human behavioral characteristics that seem to be related to flow and use of information in a fundamental way.

For the past fifteen years, anthropologists, sociologists, and indus-
trial economists have been studying the diffusion of information on new products and processes in various communities. How do ideas become known? How does the knowledge spread? How does information gain acceptance? How does it get put to use?

In 1962, Everett M. Rogers published a landmark survey of over 500 diffusion studies /1/. Ironically, there had been little diffusion of results on diffusion from one discipline to another before Rogers' work. Over half (286) of the studies he discusses pertain to the diffusion of farm innovations reported by rural sociologists. Nevertheless, the generalizations he made appear applicable to such instances as innovations in education, the use of new drugs, and the introduction of new processes in industry. The main thrust of Rogers' work is that diffusion depends as much on psychological and sociological factors as it does on the substantive information to be diffused.

Rogers' main generalizations /2/, adapted to an information frame-of-reference, are as follows:

1. Diffusion depends on four crucial elements: (a) items of information: (b) communication of them from one individual to another: (c) the environment or social system: (d) the time period.

2. Information diffuses more rapidly in modern social systems typified by a developed technology, a high value on science and education, cosmopolitanism (interaction with persons outside the system or in other than local areas), and carefully and economically rational planning, as distinguished from traditional environments.

3. Acceptance of new information proceeds through five stages of con-


Rogers' scholarly effort itself reflects the information retrieval difficulties faced by the individual researcher. His study is particularly weak on diffusion in industrial environments. He does not cite another comprehensive survey - John Jewkes, et aL, The Sources of Invention, London: MacMillan & Co., Ltd., 1958 - that could have provided him with much relevant data.

/2/. Rogers suggests that his generalizations be viewed as ranging "some-where between hypotheses and principles." At many points, he notes areas needing research.
ceptualization: awareness, interest, evaluation, trial, and adoption.

4. Rate of acceptance is a function of characteristics of the information, as perceived by the individual in his social system (emphasis by this author). Rogers highlights five characteristics:
   (a) relative advantage of the information over that which it supersedes /3/;
   (b) compatibility with existing information and with values set by cultural norms;
   (c) degree of complexity to understand and use;
   (d) divisibility or extent to which information can be accepted in stages (trial on the installment plan); and
   (e) communicability or degree to which information can be transmitted to others or its embodiments observed.

5. Individuals are classifiable into five categories on the basis of their acceptance rates:
   (a) innovators (the first 2.5% of the population);
   (b) early adopters;
   (c) early majority;
   (d) late majority; and
   (e) laggards.

Adopter distributions follow a bell-shaped curve over time and approach normality.

6. Earlier adopters are in closer contact with origins of new information. They use a greater number of different information sources; the sources are more impersonal and cosmopolitan. They tend to be younger in age; have higher social status and a more favorable financial position; engage in more specialized operations; have a different mental ability; and frequently are opinion leaders /4/.

7. Opinion leaders /5/, individuals who influence acceptance deci-

/3/. A crisis sometimes sharpens the focus on relative advantages. Launching of the Sputnik produced a re-evaluation of U. S. policy on research and development programs.

/4/. Rogers suggests that innovation "offers a fertile field in which to test theories of deviant behavior."
sions of c:he.'s, conform to social system norms but differ from their followers in information sources (more impersonal, technically accurate, and cosmopolite), in social participation, in social status, and in innovativeness. Personal influence is greatest at the evaluation stage of conceptualization (see 2. above); on later rather than earlier adopters; and when inadequate information creates uncertainty [6].

8. Change agents, persons who are employed to transmit information and influence acceptance decisions, are most effective at the trial stage of conceptualization; are more important to earlier adopters; and are more successful with the higher status portion of their clientele. The change agent faces complex communication problems in his linkage role between two social systems [7].

* * * * * *

Though histories of invention, inventors, and industrial achievements do not emphasize information flow patterns, as the diffusion literature does, these patterns are embedded in the histories. How do they compare with Rogers' generalizations? How do they match with the way today's scientists, engineers, and managers acquire, transmit, and use information? A few case studies are examined below from an information viewpoint.

The first is a trace of some of James Clerk Maxwell's research as reported by T. K. Simpson [8]. Simpson's objective was to discover whether Maxwell attempted direct experimental verification of the theory of electromagnetic propagation through a medium. His study shows that:

[5]. A number of descriptors have been used in the literature to characterize these individuals. Rogers cites the following: key communicators; leaders; informal leaders; information leaders; adoption leaders; fashion leaders; consumption leaders; local influentials; influentials; influencers; tastemakers; style setters; sparkplugs; gatekeepers.

[6]. Rogers notes the paucity of studies on non-followers.

[7]. Rogers suggests that the change agent should be responsible for improving his client's competence to evaluate information and for changing his social norms rather than for influencing acceptance per se.

(a) Scientists of the period relied on three modes of communication - personal correspondence within peer groups, scientific publication, and personal visits.

(b) Maxwell did not conduct the experiments because he viewed his work slightly differently (i.e., as a theory of optics) from the way we interpret it with hindsight.

(c) Prominent scientists like Hertz did not keep up with all of the literature, even in a main area of interest.

(d) Later publication (by Helmholtz) sometimes receives greater attention and broader citation than original work (by Joseph Henry).

(e) Personal correspondence (between Maxwell and Faraday) gave the communicants an information advantage with respect to unpublished work.

(f) Extensive independent, but collaborative, research (Rowland in America, Helmholtz in Germany, and MacKenzie and Nichols in Canada) stimulates and advances scientific inquiry.

(g) Timing is important to discovery. Hertz's successful measurements of electromagnetic wave propagation in air were made possible because he was able to perceive his objective from a cumulation of bits of knowledge and the orientation of his professor, Helmholtz; also, he had a method of measurement for achieving it.

(h) Knowledgeable individuals (like G. G. Stokes) can fail to recognize discoveries even when they are demonstrated. Stokes' inability to recognize a "vivid instance" of electromagnetic propagation thereby discouraged D. E. Hughes from publishing his results.

(i) Management device: (the Berlin Academy prize) can serve as a stimulant to scientific inquiry.

** * * * * *

A. W. Thackray studied the Dalton period to discover the origin of John Dalton's chemical atomic theory. He observes that Dalton's thinking

emanated from his lifelong interest in meteorology. Dalton first proposed a theory for mixed gases. He successively progressed from questions of heat, gas physics, and meteorology to wider chemical problems as he perceived the need to determine relative particle sizes and weights. Thackray suggests that:

(a) Dalton's atomic theory had no origin; it rather evolved as he was required to formulate rules to make his theory of mixed gases explicit.

(b) Chemists saw no significance in Dalton's particle-weight calculations until an explanation of his method of calculation and demonstrations of its applicability were subsequently published.

(c) Thomas Thomson, a chemist and first expositor of Dalton's method, was slow to recognize the full significance of Dalton's work. His textbook description, after three years of direct communication with Dalton, was cautious and tentative. Dalton's views were not accepted until Thomson published a paper using Dalton's method. (Thomson, in earlier books and letters, had been highly critical of Dalton's mixed gas theory.)

(d) Dalton and Thomson were both ignorant of weight tables published in Europe about ten years before Dalton's.

* * * * *

R. McCormmach's paper on Henri Poincaré's introduction to quantum theory shows that the confrontation occurred at a private, five-day conference in November 1911, attended by about 20 physicists from different countries /10/. Poincaré would not have been invited if the conference had been limited to persons working in the field. Max Planck could identify only 4 well-known physicists who qualified. The proceedings are history and show that no one contributed more to the discussion than Poincaré. In the eight months before his death at 58 years of age, Poincaré developed a strong proof for quantum theory and commented that he found it difficult to decide which of the accepted premises of physics to abandon next. This vignette shows that:

(a) Age is not a bar, either to the acceptance of new ideas, or their

creative development, or to the rejection of once firmly held opinions.

(b) Even members of a closely knit intellectual group differ widely in their willingness to receive and their ability to understand and exploit information. Joseph Larmor declined an invitation to attend the Congress, saying he had not been able to keep up with progress in the field. Poincaré's piercing questions sharpened Planck's perception and influenced the direction of Planck's later work. Several physicists of the period tried to explain away the premises behind Poincaré's mathematics.

(c) Ideas develop along a continuum of thought. As Poincaré influenced Planck, he was influenced by H. A. Lorentz, president of the Congress, who emphasized central questions that appear in the main argument in Poincaré's study.

(d) The development of ideas knows no national boundaries. Poincaré's work spread rapidly through England, aided by a 1914 translation by C. G. Darwin; a 1913 address by James Jeans, a Congress attendee, at a meeting of the British Association; a 1912 paper of J. W. Nicholson, a Cambridge colleague of Jeans; and a 1914 monograph of Jeans that publicized both the work of Poincaré and the related substantiation of the Dane, Niels Bohr, who visited England after hearing from E. Rutherford about the 1911 Congress.

(e) Attitudes influence the acceptance of ideas. The British were lukewarm to Planck's abstract statistical reasoning, but they could follow Poincaré's mathematical analysis and his concrete picture of a mechanism. Discussion of Einstein's light-quantum hypothesis, called by Planck a speculation that had missed the target, was a glaring omission at the Congress, perhaps because his method of reasoning from statistical fluctuations was unfamiliar. Earlier work of Paul Ehrenfest, a Viennese living in Russia, that yielded Poincaré's results by another route, became known after his correspondence with Poincaré.

Planck observed: "An old man will be inclined to ignore the hypothesis, the enthusiast will welcome it uncritically, the skeptic will seek grounds to deny it, the productive man will test it and fructify it. Poincaré, in the profound paper he dedicated to the quantum theory, proved himself youthful, critical, and productive." Ibid, p. 40.
F. M. Scherer's account of the Watt-Boulton steam engine venture is a saga of efforts to convert ideas to industrial application. The genesis of this invention occurred in the instrument-making shop of James Watt at Glasgow University. Watt, asked to repair a small Newcomen engine, wondered why it consumed large amounts of steam and, presumably while strolling on the Glasgow Green, he decided to try condensing steam in a vessel separate from the operating cylinder. He quickly translated the idea to some form of device, but 11 years passed before the idea was realized in a commercial, full-scale prototype. Watt needed money for model building that he first obtained from a University friend, then from an entrepreneur, Dr. John Roebuck. Matthew Boulton bought Roebuck's bankruptcy interest and opened a shop in Soho for research and development. Whether Watt would have pursued his idea without the prodding of Roebuck (who encouraged him to obtain patent protection) and Boulton (who gained a patent extension and financing) is problematic. Whether Watt impeded his own progress by refusing to delegate work to others, by pursuing fruitless experiments on large numbers of cylinder variations, and by a negative attitude to the pursuit of invention is also problematic. This history emphasizes that:

(a) Information per se does not yield practical applications. Quite different types of effort from that leading to discovery are often required for commercial production.

(b) Adequate funds and their judicious management are essential for applied research and exploratory development. Watt discontinued work for long periods when he lacked money.


/13/. In 1769, seven years before success, Watt wrote to Roebuck: "Consider my uncertain health, my irresolute and inactive disposition, my inability to bargain and struggle for my own with mankind: all which disqualify me for any great undertaking." In 1785, with his debts paid, he wrote to Boulton: "On the whole, I find it now full time to cease attempting to invent new things, or to attempt anything which is attended with any risk of not succeeding, or of creating trouble in the execution. Let us go on executing the things we understand, and leave to rest to younger men, who have neither money nor character to lose." Ibid, p. 173, 174.
(c) Knowledgeable entrepreneurship can be critical to successful applications. Roebuck understood the engine as an aid to pumping water from his coal mines. Boulton envisioned a world market, perceiving the broad applicability of the invention. Boulton was a risk taker but, gaging the reward, he actively participated in managing his Soho plant and in technical work, and he was able to transmit information to secure financing and sales.

(d) Different levels of perception and types of information processing are necessary for the transformation of ideas to applications. Watt had scientific curiosity. He retained this, resuming invention (double-acting engine; a converter for reciprocating to rotating motion; etc.) after the commercial prototype was built. He had little skill in applied research and exploratory development, seeming unable to select fruitful alternatives without exhaustive trial and error. This should have been delegated more extensively to engineers and craftsmen. Boulton contributed business acumen, entrepreneurial effort, and sufficient managerial ability to carry the venture to financial success.

* * * * * *

Other records suggest that:

- The mission orientation of research sponsors influences research directions and can shorten time periods required for development, if not for discovery. Wallace H. Carothers and several Harvard colleagues were invited to the duPont laboratories to work freely -- on polymers. The group produced a range of neoprene polymers and then - nylon fiber. Development of the fiber took four years (1935 - 1939), $6 million, and a team of 230 technical experts /14/.


This book is a basic text for the consideration of causes and consequences of industrial innovation. Case histories are included for 51 notable inventions. The authors wonder whether nylon would have enjoyed this development effort if the discovery had been made in a university and non-exclusive licenses were dispensed to chemical and other firms.
Isolation of a scientist from sources of information can adversely affect his research progress and his ability to communicate the significance of his work. Both Army and Navy experts and Robert H. Goddard exhibited instances of myopia. Goddard, always secretive in his research, needed prodding to brief the military on his missile developments. Unaware of their needs, he was unable to convince them of the significance of his work, and he was relegated to minor projects. Lacking either vision or funds, the military discontinued his early projects and paid little attention to results that were not immediately applicable to hardware. By contrast, Theodore von Kármán and others, who published freely and led team efforts, saw their work exploited far beyond what they could individually have achieved (/15/).

Discovery can arise from the recognition of an unlooked-for relationship between items of information (the so-called serendipity factor). During experiments in a Ford Motor Co. laboratory on the wettability of nickel for titanium carbide, an accident occurred. Nickel touched and dissolved part of a molybdenum shield; the nickel-molybdenum compound demonstrated perfect wettability for titanium carbide. After five years of research and development, Ford is using the compound and licensing it for use as a superior, lower-cost cutting tool material than tungsten carbide (/16/).

The "state-of-the-art" strongly influences the exploitation of information, the generation of new information, and the quality of both. Papers contained in a symposium volume honoring the centennial of H. C. Sorby's discovery of microstructure in steel reflect a portion of the history of the development of metallurgy. Metallurgy progressed through three stages:

1. a protoscientific period to 1885 dominated by empirical methods and some efforts to understand phenomena;
2. a theory-constructing period stimulated by chemical science of the 19th Century; and
3. the period since about 1920 introduced by the application of X-ray


diffraction to metals and alloys.

Metals science acquired its base from work in chemistry, electricity, magnetism, and thermodynamics. Scientific metallurgy had little effect on metallurgy technology until the 1920's when theory, particularly physical theory, became sufficiently advanced to explain and predict phenomena. Progress in the modern period is also directly related to the development of new instruments and experimental techniques that, in turn, have aided the advancement of metals science. This mutually reinforcing progression has carried with it the identification of new materials requirements and the willingness of industry and government to sponsor basic, as well as applied, metals research /17/.

* * * * * *

A broader perspective on past, and present, events shows the influence of national and international groups on macro patterns of information production, transmission, and use. Colonization, for example, transferred such technological know-how as knowledge of rubber tree cultivation from European experimental gardens to Asia and Africa, and Cornish mining techniques to Australia. Industrial expansion consolidated communications between the nations of Western Europe and North America, at least on empirical and traditional technology /18/. Today's current volume of scientific research in the United States, as well as emphasis in such areas as atomic energy, aerospace sciences, and medical sciences, reflects national objectives. Effects of U.S. actions can be seen in the decisions of other nations to increase their investments in scientific research. The U.S. level may have been influenced by U.S.S.R. achievements in space flight. Information flow patterns that Great Britain is now fostering for industrial ex-


The author obtained the information in the above text from John G. Burke's review of the Symposium volume in Technology and Culture, vol. 8, no. 1 (Jan. 1967) 82-86.

ploitation of technology may, in turn, be adopted by other countries. New
channels for information exchange have appeared with the creation of inter-
national bodies ranging from the United Nations and the Organization for
Economic Co-operation and Development (OECD) to the European Molecular Bio-
logy Organization. Other new patterns are being developed as nations nar-
row the technology gap. /19/

---

Comprehensive analyses are beginning to be made of individual and
organizational factors that influence the generation and acceptance of ideas
within today's industrial environments. One of these studies examined the
selection and processing of ideas in 34 small and moderate size U.S. firms
(10 to 1000 employees) engaged in electronics manufacture /20/. Data were
gathered on a total of 390 ideas reported by 86 managers and engineers over
a six-week period (plus six additional weeks for seven firms). The ideas
were of the following types:

- Change of input material: 37
- Change in production method: 175
- Change in design of product: 84
- New product: 58
- Other (service facilities, etc): 47

In eleven instances, the ideas were classified in two categories. The ideas
were associated with the following sources of information:

- Self: 205
- Employee: 102
- Business associate: 49
- Customer: 30
- Supplier: 26

/19/. *Services for Small-Scale Industry.* Geneva, Switzerland: Internation-

See also: Max Ways. "Why Japan's Growth is Different.* Fortune,*
vol. 76, no. 6 (Nov. 1967) 127-9, 245, 248, 250, 252, 257-8, 260, 262, 266.

/20/. Robert Burton Martin. *Some Factors Associated with the Evaluation
of Ideas for Production Changes in Small Companies.* Evanston, Illinois:
The total reflects the multiple-source origin of a number of the ideas.

Basing his investigation both on prior economic and sociological studies and pilot tests, Robert Martin established fourteen propositions that were subjected to analysis through questionnaire and interview techniques. The data negated his initial assumption, that the processes of idea selection and idea evaluation are influenced by the same variables in approximately the same way. For the phase in which ideas are selected for evaluation, he observed the following distinctions among propositions and individuals receiving ideas for evaluation:

<table>
<thead>
<tr>
<th>PROPOSITION</th>
<th>All Evaluators</th>
<th>Production Managers</th>
<th>Company Presidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The more employees in a firm, the larger the flow of perceived ideas for evaluation</td>
<td>Supported</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>2. The greater the risk-taking propensity of the idea evaluators, the larger the flow of perceived ideas for evaluation.</td>
<td>Partially supported</td>
<td>Not supported</td>
<td>Supported</td>
</tr>
<tr>
<td>3. The greater the age of the idea evaluator, the smaller the flow of perceived ideas for evaluation.</td>
<td>Not supported</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>4. The greater the idea evaluator's dissatisfaction with sales and cost levels, the larger the flow of perceived ideas for evaluation.</td>
<td>Not supported for dissatisfaction with sales levels.</td>
<td>Some support for dissatisfaction with cost levels.</td>
<td></td>
</tr>
<tr>
<td>5. The greater the formal education of the idea evaluator, the larger the flow of perceived ideas for evaluation.</td>
<td>Not supported</td>
<td>Supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>6. The greater the exposure of the idea evaluator to outside contacts and sources of information: (a) business travel, (b) attendance at trade shows, (c) attendance at professional meetings, (d) reading professional, trade, and business publications, the larger the flow of perceived ideas for evaluation.</td>
<td>Supported for (d)</td>
<td>Supported for (c) and (d)</td>
<td>Supported for (a) and (c)</td>
</tr>
</tbody>
</table>
7. The greater the freedom of the organization to alter its product, the larger the flow of perceived ideas for evaluation.

Reasons given by the evaluators for the acceptance or rejection of an idea related to the propositions in the following way:

<table>
<thead>
<tr>
<th>PROPOSITION</th>
<th>All Evaluators</th>
<th>Production Managers</th>
<th>Company Presidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The more employees in a firm, the larger the flow of ideas accepted.</td>
<td>Supported</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>2. The greater the risk propensity of an idea evaluator, the larger the flow of ideas accepted</td>
<td>Not supported</td>
<td>Weakly supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>3. The higher the age of the idea evaluator, the smaller the flow of ideas accepted</td>
<td>Not supported</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>4. The greater the idea evaluator's dissatisfaction with sales and cost levels, the larger the flow of ideas accepted</td>
<td>Supported for moderate levels of dissatisfaction</td>
<td>Not supported</td>
<td>Supported for cost levels</td>
</tr>
<tr>
<td>5. The greater the formal education of the idea evaluator, the larger the flow of ideas accepted</td>
<td>Partially supported</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>6. The greater the exposure of the idea evaluator to outside contacts and sources of information (a to d above), the larger the flow of ideas accepted</td>
<td>Supported for (d) only</td>
<td>Supported for (a) only</td>
<td>Supported for (a), (b), &amp; (c)</td>
</tr>
<tr>
<td>7. The greater the freedom of the organization to alter its product, the larger the flow of ideas accepted</td>
<td>Partially support.</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
</tbody>
</table>

 Evaluators occupied the following job categories with respect to the ideas distributed among them:

- President or vice-president and general manager: 106
- Manufacturing or production vice-president: 27
- Chief engineer: 65
- Manufacturing or production supervisor: 61
- Manager of quality control: 19
Various types of engineers | 73
Plant manager | 22
Production or production-control supervisor | 14
Other | 3

Among unexpected findings is the absence of correlation of idea selection and evaluation with dissatisfaction over sales. The experiment, however, was conducted during a high sales period. The lack of support for education (proposition 5), except among production managers, is associated with the low level of technical sophistication of most of the products. The variations in significance among types of outside contacts and sources of information appear related to the roles of the different evaluators. The president, as the interface between the organization and the environment, relies on personal communication from professional sources. Managers, and to a greater degree, technical employees, depend on the literature as well as on professional contacts as information sources. Distinguishing the evaluators with respect to the status of their organization as autonomous or as a division within a corporation did not affect the results. [21]

* * * * *

Though best ways are not yet known for promoting human information processing and information transfer, sufficient guidelines exist for empirical approaches to the institution of conducive environments. The Bell Telephone Laboratories, for example, are applying a "total process" or systems concept that is expected to improve information flow and the discovery-to-applications cycle [22]. Britain's new Ministry of Technology has the specific mission of increasing industry use of existing knowledge. To achieve

[21]. See also Robert Charpie. "The Business End of Technology Transfer." In Proceedings of a Conference, op. cit. (ref. 16), 46-52. The Union Carbide Corp. receives about 500 new ideas annually but accepts only one per 100 to 200 to examine beyond initial appraisal.


this objective, the Ministry has begun to interface a large number of engineering and aircraft industries with almost all of the government's research establishments that are now under its jurisdiction. Consolidations in the aircraft, shipbuilding, and computer industries are beginning to show economic gains 22a/. Industry is re-examining itself to understand how it has been absorbing technology and why only an estimated 30% of available technology has been used 22b/. Industry is also beginning to acknowledge the importance of human factors in the information exploitation process and the need for new organizational structures and collaborative information schemes.

Information handling is a discipline to itself. It appears today to be emerging from the protoscientific to the theory-constraining stage.


16
PERFORMANCE OF INFORMATION SERVICES

This section, like the former one, makes no attempt to be comprehensive but seeks only, by example, to illustrate patterns for their implications on information acquisition and use.

A variety of formal mechanisms for transmitting information are prevalent, at least in the United States. These are:

- Investigator-generated documents (journal articles, reports)
- Secondary-source documents (treatises, review papers, instructional texts)
- Newsletters (of special-interest groups)
- Abstract periodicals
- Accession lists (books- and documents-received lists)
- Bibliographic compilations (annotated and unannotated)
- Selective information services
- Conferences (followed, and sometimes not, by proceedings)
- Specialized study institutes (accompanied, and sometimes not, by texts)

This section concentrates primarily on secondary-source services (e.g., abstract periodicals, selective information services). Specifically excluded is consideration of most of the "user surveys," studies of use of services by actual or potential clienteles. Several of the more informative of these have been summarized elsewhere /23/. They give some indication of services that are used, but little on human factors aspects of use, i.e., why information is sought, how it is processed, and how it influenced courses of


/24/. Researchers in the field could learn from the diffusion literature. Most user studies examine particular types of services rather than the acquisition behavior and interests of the individual. Many studies are accomplished by impersonal questionnaire, responses to which may or may not accurately reflect circumstances. For example, if a person acquires many books, journals, and abstract periodicals, does he necessarily use them? If he uses some but not others, why? If he acquires little, is he bereft of information, or does he have other sources? Etc.
action /24/. It is thought that a look at the services themselves might enable better comparison with their acceptability and their likelihood of being patronized.

* * * * *

The specialized information center has become a popular mechanism for serving a group of users having similar interests. The services that had been provided /25/ by Battelle Memorial Institute's Transducer Information Center (TIC) fit with this author's concept of the activities this kind of center should perform. TIC's services included the following:

A Quarterly Accessions List (abstract bulletin) that announced a selected sample of Center acquisitions (16% of acquisitions during the final reporting period)

A semi-annual compilation of transducer research and testing contracts

Visits to transducer users and manufacturers (66 user and 138 manufacturer organizations during the reporting period)

Summary reports in areas of growing interest (one on nuclear radiation effects on transducers was prepared during the reporting period)

Responses to requests for information (over 1000 were processed in the final 16 months; 58% were non-technical, such as requests for TIC publications)

Reference services to Center visitors /26/

TIC users included government agencies and universities as well as transducer users and manufacturers, a total of 348 regular clients as well as occasional inquirers. It depended for information principally on announcement bulletins of government documentation centers and technical and scientific journals /27/. During the final period, it processed 2287 items of the following types:

/25/. Sponsorship of the TIC was discontinued in September, 1967.


/27/. Its main sources were the Defense Documentation Center's Title Abstract Bulletin (TAB); the National Aeronautics and Space Administration's Scientific and Technical Aerospace Reports (STAR); International Aerospace Abstracts; the Interservice Data Exchange Program's (IDXP) Summary Sheets and Reports; and over 50 technical and scientific journals.
The flow chart in Figure 1 shows the document handling system. The Center's annual budget was about $80,000.

TIC provided what might be called "active" information services. An extreme type of a "passive" service would furnish only information specifically asked for. This author classifies libraries and information centers that acquire on their own initiative but do not supply any materials except in response to requests as "passive." Most of TIC's services, by contrast, reflect the high degree of subject proficiency and awareness of information needs of its clients on the part of its professional staff. The abstract bulletin, for example, was a reference guide to many users because it had passed through two technical screenings -- the first for selection of materials for the Center's collection, and the second a subset of these. The contract compilation gave managers and program directors reasonably current information needed for their project planning. A discouraging finding of user surveys is low incidence of use that correlates to some extent either with lack of knowledge of the existence of services or lack of knowledge of how to use the services. TIC staff visits to researchers and manufacturers provided two-way education. TIC members briefed on services but they, in turn, learned about the work and information needs of their customers. Through feedback, TIC became aware of particular problem areas for which special information products were needed. This led to the preparation of three TIC-generated summary reports for which staff members searched information sources and subject fields other than their own to insure comprehensiveness. TIC, located in Ohio, literally went to the user through a branch office in Los Angeles, an area having the greatest concentration of manufacturers and users of transducers in the U.S. Notably, the only service TIC customers appeared disinterested in was a monthly compilation of tables of contents of journals.
Spurred by the manipulative capabilities of computers, many information system designers have been intrigued by the possibility of providing personalized information services to users. The term, Selective Dissemination of Information, or SDI, has become generic to this concept. Ideally, an SDI system should match user information needs with the items stored in the system and give the user all of the items applicable to his needs but none of the items that are not applicable. A refinement on this is a concept of weighting the descriptors by which the user defines his needs, to limit, should he desire, the number of items he is furnished to a pre-specified "most-applicable" cut. Another refinement is a provision for "feedback" to enable the user to alter his "profile" of descriptors at regular intervals. Several additional refinements give the user various options, such as an ability to specify the type of system output, e.g., bibliographic, abstract, or full-document information. The cost accounting assumption is that SDI will be but one component of a fully integrated information system, with costs of data preparation shared with other operations such as accession-list, catalog-card, and book-index production. Despite the existence of some SDI systems, implementation appears still in a proto-scientific stage.

As part of the U.S. Army's technical library improvement program [28], the Information Dynamics Corp. (IDC) surveyed twenty SDI systems [22]. Many of the systems use the machine-readable products of one or more of the large documentation centers with consequent limitations based on the configurations and constraints of these inputs [22]. IDC found no commonality in criteria by which systems evaluate their operations. Thus, the "results reported" elements in the system descriptions appended to IDC's report are

[28]. The Army Technical Library Improvement Studies, or ATLIS, program.

[49]. The text refers to the following sources: Defense Documentation Center; National Aeronautics and Space Administration; National Library of Medicine; and Chemical Abstracts Service.
difficult to interpret. For example, statistics from the IBM Technical Information Retrieval Center, Yorktown Heights, that serves 1200 users in the U.S. and 250 in Europe, show 79.1% relevance as marked on returned notices. This drops to 45% if calculations are based on the total number of notices sent. Other systems separate responses that request documents from those expressing interest but not wanting documents. The NASA SDI system, with 700 users, reported 50 to 60% relevance based on a 60% return. The statement: "15% to 18% requested documents" defies further quantification.

Only one system, IBM's SDI-3, that uses a 1401 computer, furnished a cost analysis. No comment is made in the survey on cost effectiveness. SDI-3 monthly costs to process 50 items with abstracts daily are:

<table>
<thead>
<tr>
<th>Fixed costs:</th>
<th>Personnel</th>
<th>$ 4100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 826 card punches</td>
<td>480</td>
</tr>
<tr>
<td></td>
<td>Punched cards</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Contingencies</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>$ 5130</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable costs:</th>
<th>(per 100 profiles at 5 notices per person per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8K 4-tape 1401</td>
</tr>
<tr>
<td></td>
<td>(5 hrs/day extra shift, 40% of prime shift rental)</td>
</tr>
<tr>
<td></td>
<td>Forms</td>
</tr>
<tr>
<td></td>
<td>Photocopies</td>
</tr>
<tr>
<td></td>
<td>(900 sheets/day)</td>
</tr>
<tr>
<td></td>
<td>Contingencies</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>

Estimated cost per profile per month: $ 9.53
Unit cost (2000 profiles per month): $ 7.00

IDC also provides the following costs for operating a printing cycle for 3000 input documents disseminated to 600 users who receive an average of 150 notices (1000 characters distributed over 20 lines of text):
Computer Printing Costs

<table>
<thead>
<tr>
<th>Key and verify 3000 abstracts:</th>
<th>Offset Printing Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>On keypunch (19¢ ea) $ 2850</td>
<td>On typewriter or Flexo-writer (35¢ ea) $ 1050</td>
</tr>
<tr>
<td>Record:</td>
<td>On offset masters (10¢ ea)</td>
</tr>
<tr>
<td>On magnetic tape 10</td>
<td>On offset press 450</td>
</tr>
<tr>
<td>(5 min, $120/hr)</td>
<td>(15 hrs, $30/hr)</td>
</tr>
<tr>
<td>Print:</td>
<td>Total: $ 1800</td>
</tr>
<tr>
<td>On 1000 line/min.</td>
<td>$ 5110</td>
</tr>
<tr>
<td>printer (30 hrs, $75/hr)</td>
<td></td>
</tr>
</tbody>
</table>

IDC's minimum configuration for an SDI system is a digital computer, three magnetic tape transports, a high-speed printer, and punched card input/output equipment.

IDC's subsequent nine-month pilot test of a prototype SDI system for the U.S. Army Natick labs appears to have been less than satisfactory. The test used a 1000-document sample and 25 subjects having a broad range of interests from the Clothing and Organic Materials Division. A vocabulary was generated based on three thesauri as the test progressed. Lack of a completely integrated subject vocabulary is stated as the most limiting factor in the experiment. In the fourth of four production runs, a comparison of manual and machine selections yielded relevance percentages of 55% and 45%, respectively. Participants appeared interested in retaining SDI outputs that included abstracts, but their minimal responses suggest an absence of real involvement, possibly because they knew the experiment was to be short lived.

* * * * *

Unique among service organizations is the Institute for Scientific Information in Philadelphia. Founded in 1956 as Eugene Garfield Associates,


It has developed and adapted a variety of mechanisms to enable users to retrieve information from the steadily growing journal literature. It now provides, for fees, ten services:

The Science Citation Index (SCI), a list of current citations to earlier papers;

Index Chemicus, a weekly (biweekly before 1967) graphic abstracting and indexing service to new chemical compounds and their syntheses;


Current Contents in three editions: Physical Sciences, Life Sciences, and Chemical Sciences, weekly compilations of tables of contents of foreign and domestic journals in the respective subject fields; over 1600 journals are represented (foreign language contents are translated to English);

Automatic Subject Citation Alert (ASCA), an SDI system furnishing weekly reports to users; initiated in 1965;

Original Article Tear Sheets (OATS), dissemination of original journal pages of any paper reported, abstracted or indexed by the above services;

ISI Search Service, custom searches in response to requests; and

ISI Magnetic Tapes, contents vary, furnished weekly /32/.

/32/. The costs for the services are as follows:

SCI - $1250 (educational) and $1950 (industrial) for the first copy, $625 for the second copy, annually, for the years 1964, 1965, 1966, each of which is an eight-volume cumulation. The 1961 Index, in five volumes, costs $700.

Index Chemicus - $350 (educational), $700 (industrial), annually.

Encyclopaedia Chimica Internationalis - the educational and industrial rates are, respectively, $600 and $1200 for 1960-62; $325 and $750 for 1962-63; $300 and $600 for 1963; $400 and $750 for 1964.

Current Contents - the Life Sciences and Physical Sciences editions each cost $60 (educational) and $100 (industrial) annually; Chemical Sciences costs $100 annually.

ASCA - $100 (U.S., Canada, and Mexico); $110 (other, airmail) annually

OATS - $2 per article (up to 20 pages); $2 for each additional 20 pages or fraction.

ISI Search Service - $25 for the first hour, $10 for each succeeding hour.

ISI Magnetic Tapes - cost depends on the file purchased, starting at about $5000 per year.
A version of Current Contents was conceived in 1953 when Garfield was a member of the Johns Hopkins University Welch Medical Library Indexing Project [33]. This first effort, for the library science, documentation, and computer journals, as well as a second for the management and social sciences literature, died for lack of customers. The third attempt, begun in 1958 for the life sciences, resulted from customer demand [34]. ISI estimates that Current Contents are read by over 60,000 scientists weekly.

The Science Citation Index (SCI) is patterned after Shepard's Citations, a research tool that has been used by the legal profession since 1873 [35]. It is based primarily on an association-of-ideas concept, i.e., on the premise that an author cites earlier papers because of a subject relationship he has found between them and his own work. This type of association avoids the semantic ambiguities that arise in the use of words for subject description and the omission of relationships that might not be obvious to a casual reader or third-party indexer. Citation indexes are effective, however, only to the extent that bibliographies in published papers refer to prior work. Analysis of SCI data shows that the average published paper is cited less than once each year. The average number of sources citing a particular reference did not increase appreciably as SCI expanded its coverage (see Figure 2). The data thus negate the assumption that usual citation practices would give an unwieldy number of sources for a reference [36], although the low incidence of citation may reflect unfamiliarity with prior work. ISI files disclose instances of duplication. Figures 3, 4, and 5 show sections of the Index. The citation section for the journal litera-

[32]. The principal objective of the Welch Project was to study the application of machine methods to handling the medical literature. Its findings were used in the creation of the National Library of Medicine's Index Medicus.


In this paper, Garfield discusses difficulties he had encountered in searching the literature. Might one infer that he perceived the need for an SCI-type tool as a result of his own experience?

<table>
<thead>
<tr>
<th>Year</th>
<th>1966</th>
<th>1965</th>
<th>1964</th>
<th>1961</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cited references</td>
<td>3,400,000</td>
<td>3,336,000</td>
<td>2,128,113</td>
<td>1,395,530</td>
</tr>
<tr>
<td>Different journals cited</td>
<td>20,000</td>
<td>20,000</td>
<td>20,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Book reviews indexed</td>
<td>30,000</td>
<td>25,000</td>
<td>16,116</td>
<td></td>
</tr>
<tr>
<td>Authors whose works were cited</td>
<td>460,000</td>
<td>439,000</td>
<td>323,889</td>
<td>257,900</td>
</tr>
<tr>
<td>Source journal items indexed</td>
<td>300,000</td>
<td>235,801</td>
<td>151,639</td>
<td>101,944</td>
</tr>
<tr>
<td>Author entries in Source Index to Year's literature</td>
<td>576,000</td>
<td>576,000</td>
<td>390,838</td>
<td></td>
</tr>
<tr>
<td>Source journals (approx)</td>
<td>1,600</td>
<td>1,147</td>
<td>700</td>
<td>613</td>
</tr>
</tbody>
</table>

Figure 2. Statistics for Science Citation Index

![Figure 3. Science Citation Index (journals section)](image-url)
Figure 4.

Science Citation Index (patents section)

Figure 5.

Science Citation Index (Source Index)

ture, Figure 3, is alphabetic by first author of the cited reference. The "type code" identifies the nature of the paper as an abstract (A), editorial (E), letter (L), patent (P), review (R), etc. The U.S. patents section, Figure 4, is numerically ordered by cited patent number. The source index,
Figure 5 provides complete bibliographic information and "see" lines for all secondary authors. A Permuterm subject index was added in 1967.

Index Chemicus, introduced in 1960 (Figures 6 and 7), reports on new chemical compounds, their synthesis, molecular formula, and structure. Over 130,000 compounds were indexed in 1966. Entries are published an average of seven weeks after appearance of the primary journal. IC is thus frequently used as a current awareness tool and as a registry for new compounds. An

Figure 6.
Entry from
Index Chemicus

Figure 7.
Indexes from
Index Chemicus
additional display in the 1968 IC alerts the reader to the presence of particular categories of information in the paper (Figure 8) [37]. Inclusion of Wiswesser Line Notations in the magnetic tape versions of IC is being planned as a substructure searching capability. IC has an estimated readership of 10,000 chemists, approximately 50% of them outside the U.S.

The input to ASCA, ISI’s SDI system, is the same as that of the Science Citation Index. ASCA gives a wider choice to users than most SDI systems in types of items by which they can designate their areas of interest. Machine searches can be made on words, phrases, and word stems; on authors’ names; on organizational sources; on journal sources; on particular paper, book, or patent citations; and on combinations of these. Users can reshape their profiles weekly. ASCA is closely associated with the OATS service that supplies copies of papers a user may elect to obtain after being noti-

**Figure 8.**

New Index Chemicus Feature

This display alerts to NEW RXN, a novel reaction.

**Figure 9.** Sample ASCA Report Illustrating Response to Organization Question

---

field of their existence. An optional service, ASCAmatic, furnishes copies of papers with the ASCA report. The present ASCA system incorporates two sets of modifications made to the original 1965 system to increase a user's flexibility in selecting search terms. The flexibility, however, demands of users a form of self-discipline in formulating their profiles /38/. The ASCA report (Figure 9), through combinatorial options, can be a browser's tool or a specific and precise current-awareness device. The recently instituted ISI search service was designed with a view to the small user who cannot afford purchase of ISI's magnetic tapes or the SCI volumes /39/.

Since ISI's income is solely from sales, user acceptance can be inferred from the growth of its services, both in scope and diversity. The coverage accords with ISI's and other estimates that, of the 50,000-odd scientific and technical journals being published in over 65 languages, less than 1300 account for over 90% of the significant reports (approximately 250,000 papers per year). Journals continue to be added, nevertheless, to augment ISI's capabilities in specialty fields. The progressive expansion of ISI's services is indicative of more than user acceptance. The papers cited here reflect a continuous effort by Garfield and his staff to explore new approaches to information handling and retrieval. Not all of these have been or are profitable. Through tests and studies of user response, services have been modified or discontinued. ISI's services and experiments have, in turn, been educating users to potentials realizable from information systems. Garfield expects the cost of services to remain stable or decrease as appreciation for information services increases. Moreover, with proper planning, they can become increasingly varied and specific to individual requirements. The services made practical or enhanced by availability of the Science Citation Index input encourage further developments.

* * * * *


In theory, periodicals that provide abstracts and indexes to subsets of the journal and report literature should be powerful tools for current awareness and retrospective search. The following practical considerations impose drawbacks to realizations:

- Costs
- Volume
- The "language" problem
- The manpower problem

The average estimated cost to process an item is $30 if it is abstracted and $7.50 if it is only indexed [40]. Thus, the cost to abstract and index the 250,000 papers per year noted above is $7.5 million. Federal government documentation centers together handle an estimated 250,000 items [41]. Most of these are technical reports, the cost burden doubles. However, these totals only reflect the science and technology literature. To serve the field of science and technology, such items as engineering drawings, data bases, patents, and trade publications would have to be added. Excluded from this discussion are other fields such as the social sciences and the humanities that must cope similarly with quantities and varieties of information.

The "language" problem is alluded to in the Information Dynamics Corp. SDI experiment and with reference to the Science Citation Index above. This is a problem engendered by at least three factors: changing terminology or meanings associated with terminology over time; varying degrees of overlap in synonymy among terms; and the imprecision of language for describing concepts that introduces ambiguity. A total of 876 man-weeks, including 556 man-weeks of lexicographers, were consumed to produce the 17,000 descriptor Defense Documentation Center - Engineers Joint Council Thesaurus of En-


[41] The System Development Corp. survey gives a total of 234,282 items abstracted by all federal centers in 1965. The centers do not abstract all accessions. The survey shows that, of the 234,282, only 30,651 abstracts were written in-house; the remainder were author or contractor prepared. Ibid., p. 99.
Language and classification problems contribute to thesaurus compilation and the creation of controlled vocabularies for indexes. The value of a controlled vocabulary is noted above. To establish one acceptable to users and the using system is a difficult chore. For the DDC-EJC Thesaurus, the terms of 145 selected vocabularies were merged and evaluated. Decisions on the sequencing of terms proved the most perplexing to the Thesaurus team. In some instances, a clear rule could be formulated (e.g., "radar antennas" instead of "antennas, radar"). In others, order affects meaning ("nitrogen organic compounds" vs. "organic nitrogen compounds"). Others necessitate spelling conventions ("electro optics," or "electro-optics," or "electrooptics"). Still others affect both the size of the vocabulary and the classificatory conceptualization that must be made by the indexer and searcher (e.g., should "automatic transmission fluids," "automatic transmission," and "transmission fluids" all be vocabulary terms, or should the first be derivable from coordination of the latter two, or ... etc.).

The "needle-in-the-haystack" problem refers to hidden information. The relevant paper in the obscure journal is one example. Of greater frequency, papers in proceedings volumes remain unknown because they are not individually abstracted or indexed. There is an even greater likelihood that significant results in papers that are abstracted or indexed are not reflected in the abstracts or index terms. Often, the information system demands this omission because of restrictions on the length of the abstract, or on the allowable number of index terms. Perhaps as often, abstractors and indexers do not perceive a particular significance or do not have time, in a production operation, to study the contents for significance. Of particular concern at the so-called "cutting edge" of science and invention are papers that report the new or novel, but in old terminology, so that they are overlooked.


The project cost $438,386.
The general scarcity of skilled manpower is compounded in the abstracting and indexing professions. Though a consensus suggests the desirability that this work be done by subject specialists, it is accorded second-class status by many employers. The exacting nature of the work and unattractive salaries are further deterrents.

Budget limitations, if no others, have placed practical ceilings on the range of all abstracting and indexing services. The result has been a proliferation of services to fill gaps and satisfy specialized information needs. The 550-odd services presently operating in the United States may give as much confusion to users as they do help. They emanate from professional societies, government agencies, industrial organizations, universities, and commercial enterprises who market services as their principal products. The cost of this productivity is estimated at $50 million annually [43]. Several studies of duplication have been made. John Martyn checked the references in comprehensive bibliographies on specific subjects against abstract periodicals appropriate to the subject fields. Results averaged for 19 bibliographies containing 3093 references disclosed that 21% of the references appeared in no abstract periodical, 27% were abstracted once, and 52% had been abstracted more than once [44]. A common pattern is the following for 432 references in a bibliography on the biological control of insect pests and weeds:

<table>
<thead>
<tr>
<th>References</th>
<th>% of Total</th>
<th>Times Abstracted</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>7%</td>
<td>0</td>
</tr>
<tr>
<td>106</td>
<td>25%</td>
<td>1</td>
</tr>
<tr>
<td>99</td>
<td>23%</td>
<td>2</td>
</tr>
<tr>
<td>84</td>
<td>19%</td>
<td>3</td>
</tr>
<tr>
<td>95</td>
<td>22%</td>
<td>4</td>
</tr>
<tr>
<td>17</td>
<td>4%</td>
<td>5</td>
</tr>
</tbody>
</table>

Studies to recommend a plan for eliminating unnecessary duplication [45] and using available resources more efficiently are themselves beginning.

[43]. Ref. 41, p. 8.
to proliferate. One of the most recent of these concludes that abstracting
and indexing services "must be viewed as a subsystem within the framework
of a national document handling system" [46]. The investigators found a
lack of reliable data on which to base comparisons of abstracting and index-
ing services, or on which to base tests enabling such comparisons. That li-
mit ed successes could be achieved within the framework of the National Fed-
eration for Science Abstracting and Indexing Services (NFSAIS), a coopera-
tive society of non-profit services, suggests that broader ventures may be
possible [47]. Though strong government leadership is proposed, a central
question seems to be the degree of involvement the federal government has,
may wish to exercise, or may wish to delegate to a government or non-govern-
ment body, and the limits of its jurisdiction.

* * * * *

Reminiscent of communication that used to flourish among scientists,
the Information Exchange Groups (IEG) sponsored by the National Institutes
of Health (NIH) between 1961 and 1966 are success stories despite their dis-
continuation. The plan for each group was to identify a sharply focused
field of scientific inquiry, select a chairman who would ensure that every
active worker in the field would become a member, and maximize communication
among them. The central IEG office in Washington transmitted any communi-
cation submitted by a member to all members of his particular group, dispatch-
ing to members outside the U.S. by air mail. A "communication" was anything
a member chose to submit -- a pre-publication manuscript, a comment, a re-
quest for information, a protest, a disagreement, etc. Members were expec-
ted to treat the items, called IEG Memoranda, as personal communications,
i.e., not as part of the literature, and to honor priorities of discovery
disclosed through this medium. David Green, chairman of IEG No. 1 (for the
field of electron transfer and oxidative phosphorylation), reports that his
group exchanged only 27 memoranda during its first two years, but "the

[45] Repetition is not necessarily duplication, since an item may be ap-
propriate to several subject areas.


[47] Ref. 41, p. 160-162. The report also discusses on-going collabora-
tion within international organizations including the International Council
of Scientific Unions (ICSU) and UNESCO.

34
floodgates opened" thereafter, almost 800 memoranda being distributed during the next four years. The membership of IEG No. 1 was 725 at its demise, 329 being residents in 32 countries outside the U.S. /48/. Green estimates that about 90% of the important papers in his field were being circulated to members at least six months before they appeared in journals. Green writes:

"The days of library hunting were over for workers in the seven fields" (there were seven Groups).

The Groups were terminated when the editors of five biomedical journals, acting together, advised the NIH that they would not publish any manuscripts that had been IEG Memoranda. Green disagrees with the editors' decision (not with NIH's) for several reasons. First, three who represented society publications acted without consulting their publication committees. Principally, however, Green views the Group as a forum valuable in the creative phase of scientific discovery, while hypotheses are being formulated and experiments conducted. Communications at this stage are not suitable for publication. He distinguishes this from the time for publication that follows "when the dust has settled." "The IEG re-established debate and dialogue among scientists." Moreover, he notes that the journals do not like controversy and are satisfying "only a diminishing part of the needs of the scientific disciplines in respect to communication of information." Workers in foreign countries reported that they were able, for the first time, to be current with their U.S. colleagues. "The end of IEG meant the return to scientific isolation of a large number of investigators in laboratories outside the U.S."

The 1966 cost for printing and distributing Memoranda for the seven IEG's was $416,000. The annual cost per member was $140, or $1 for every $73 of research cost. Two of the groups were not successful. This Green attributes to "the choice of the right umbrella to hold an IEG together."

* * * * *

Not to be overlooked is the yeoman's service possible from large documentation centers. Though their breadth of coverage precludes their serv-
ing the specialist comprehensively, and though processing times and distance from originating sources of information mitigate against current awareness value, their reliability as a source of some information with some currency should not be underestimated. When their budgets provide for the costs of bibliographic compilation or retrospective searching and the duplication of documents for distribution, they obviate the need for similar activities in fragmented fashion at many smaller installations. This can be a particularly effective resource either at the beginning of a search to obtain a general orientation, or toward the end to check for omissions.

The Defense Documentation Center is an exemplification of this type of facility. With an operating budget of $10,091,000 in Fiscal Year 1966, DDC's 472-man civilian staff (4 military) performed the following services:

Announced 47,891 new titles in its semi-monthly Technical Abstract Bulletin and added 776 unannounced new titles to its collection /49/. Satisfied 677,000 requests for documents (632,183 in "hard copy," 44,817 in microform). (Requests from shelf stock were filled in an average of 2.1 work days, and from reproduction in 6.1 work days.) /50/

Compiled 17,403 bibliographies (99% machine processed) in an average of 3.3 work days each (each furnished an average of 137 citations)

Maintained six field offices in major research and development areas in the U.S. (Boston; New York City; Dayton, Ohio; Los Angeles; San Francisco; Washington, D.C.).

Its manpower expertise and computer facility (Univac 1107) were employed during the period for the design and implementation of a storage-and-retrieval system for resumes of Department of Defense-sponsored research projects (called the Work Unit Data Bank System). Engaging up to 561 of its 100-odd systems and programming staff and 11 contract personnel, DDC produced an operational system for 18,594 resumes and provided 924 management reports (285 requiring special printouts) by the end of the Fiscal Year. Members of its staff also participated in the Thesaurus project discussed above /51/.

/49/. The DDC collection contains approximately 850,000 reports in all areas of science and technology.

/50/. A total of 1,506,996 requests were received during FY 66. Through a cooperative arrangement with the Clearinghouse for Federal Scientific and Technical Information (CFSTI), CFSTI filled 665,763 of the requests (506,763 in hard copy, 68,501 in microform).

REQUIREMENTS FOR INFORMATION SYSTEMS

In this section, the author undertakes to discuss three fundamental components of systems:

- hardware,
- software, and
- people.  /52/

The author claims no expertise in hardware or software design or development. Though the behavioral scientist frowns, sometimes, on others invading his realm, in a sense all individuals have some expertise based on their experience as members of the set. In a similar sense, information systems are not the exclusive province of systems specialists. Each man, each group of men, is a system or one of many subsystems, depending on context and point of view. This section relies on experts in their areas of expertise. The author tacitly assumes the prerogative of a reviewer.

* * * * * * *

The photograph in Figure 10 is intended to take the place of the proverbial thousand words. It is not included here for the inference that a super-computer can be anyone's tool, or that the 360/91 is an ultimate in super-computers /53/. Its cost (about $1.5 million for the 2-megabyte core, $1.5 million for the central processing unit) exceeds the budgets even of

/52/. There is a fourth component -- planning. This could be part of required "software" for a system but, although software, as it should be conceived, takes account of the objectives of the system and, thus, the environment, its examination of factors in the environment is relatively superficial. Planning is, or should be, antecedent to any systems work. Its purview is, thus, different, and it appears important, therefore, to consider it separately. This is done in the next section on "Payoffs from Information Systems."

/53/. The other 91's to be delivered may, in fact, be 95's, with memory cycle times of 120 nanosec. compared with the 91's 780 nanosec. The Control Data Corp.'s "super," the 7600, with a central processing unit price of $5 million, may be twice as fast as the 95. See "Goddard Starts Up the First Model 91" and "Look Ahead," Datamation, vol. 14, no. 3 (March 1968) p. 99, 101 and 17, respectively. The Goddard article gives other performance data for the 91 and compares it with other "supers."
Inner workings of the universe and problems of space exploration will be studied by the largest computer in user operation, the IBM System 360/Model 91, according to NASA. Recently installed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, the Model 91 will explore theoretical astronomy, sub-atomic physics, global weather forecasting, and questions on the precise structure and environment of the earth. Now in full operation, the 91's test performance exceeded NASA specifications, according to IBM officials. With a maximum rate of 13.6 million additions a second, the new computer has up to 50 times the arithmetic capability of the IBM 7090. In addition to its speed, the 91 has a number of other features, including a main memory which is subdivided into 16 storage elements from which the processor can fetch information in an overlapped mode. Each subdivision has a storage-protection "combination lock" using monolithic circuits to prevent accidental cancelling of data in memory. Estimates are that each day the computer will solve more than 1,000 problems involving about 200 billion calculations. From its inception, the Model 91 has been a limited IBM program. It was developed to advance the state of the computer art and serve a relatively small number of users. IBM is no longer accepting new orders, but has scheduled delivery of all systems now on order within 17 months.

Figure 10. "Super-Computer Serves NASA." Data Systems News, vol. 9, no. 3 (Feb. 1968) p. 3.

With the advent of third-generation computers and inexpensive mass storage devices in 1962-1963, the concept of computer-based information storage and retrieval passed from the hypothetical to the possible. Future hardware developments, such as larger internal memories, more parallelism of internal operations by the use of cheaper and simpler electronic components, and higher speeds suggest a reversal of recent trends toward general-purpose machines. Hardware, rather than software, may determine the appropriateness of a machine for business or scientific applications. A third class of machines, for information retrieval, can now be introduced.
Lawrence Berul recently surveyed the peripheral equipment available for information retrieval applications. These, associated with computers, facilitate man-machine interaction and the inexpensive production of a variety of information outputs. Terminals with cathode-ray-tube displays and keyboards enable input, editing, and searching at remote stations and on-line (i.e., in "conversation" with the computer). High-speed printers, equipment for photoreducing printouts, and devices converting magnetic tape records to microfilm are streamlining the production of announcement media. Photocomposers (Photon, Mergenthaler’s Linotron, RCA’s Videocomp) yield printed products of graphic arts quality. Inexpensive (e.g., Xerox’s Magnavox Teletypewriter renting for $35/month) but slow speed (6 min. for an 8½ x 11-in. page) facsimile equipment can deliver graphic material to remote locations over standard voice-grade telephone lines. Roll and unit-record microfilm are low-cost means of providing back-up files containing full texts of documents. Thus, subsystems for input, output, and remote access, shown in Figures 11 and 12, are state-of-the-art.

Berul’s five-year projections include:

- Computer stores of up to 20 million bytes at 2-10 cents/bit
- Segmentable mass random-access memories
- Extensive software tailored to information storage and retrieval
- $1000 - $2000 terminals (today’s cost $5000 - $10,000)
- $1000 - $5000 automated microfilm retrieval systems (simplified access-by-address-only systems)
- Greater use of unit-record microfilm (aperture cards, microfiche)
- Somewhat wider use of "fax"


/56/. National Cash Register’s Photo-Chromic Micro-Image System (PCMI) reduces up to 3200 pages to a single 4 x 6-in. microfiche at a rate of 1000 pages per hour. Duplicate microfiche can be produced in quantity at 50¢ to $1 per copy. Viewers rent for $10 - $15 per month; attachments can provide hard copy.

/57/. High-speed equipment, such as Xerox’s Long Distance Xerography, that transmits up to 8 pages/min, requires monthly rentals of $550 and $650 for the scanner and printer, respectively, with surcharges of 2¢ and 3¢ per foot, respectively.
Figure 11. Computer-Based Input-Output System

Figure 12. Computer-Based Remote User System

58. Four technical reports, that probably were behind the state-of-the-art by the time they were published, are cited here because of their comprehensive and critical analyses of computer and peripheral equipment performance and cost:


Software must serve three masters: the user, the hardware, and itself. Software is the package of procedure and computer programs that translate the user's requirements into formats acceptable to the machine. The degree to which this can be efficiently accomplished depends, in part, on characteristics of the software that has been used. Extensive and imaginative effort has been applied to creating software, both for effective management of the machine's components (operating systems) and for the convenience of the user (specific processors and "higher level" (user-oriented) programming languages). /59/ The programmer has designed assembly languages for himself and compilers that make particular languages "understandable" to various machines.

Though software becomes more important to system operation, performance, and cost with increasing hardware complexity, flexibility, and size, no methods exist for definitively evaluating a given software package. There are no standard measures of performance. Tools for evaluation are inadequate. Performance is difficult to predict, much less guarantee, before or during development /60/. In his description of the evaluation guide developed by The Rand Corp. to assess candidate systems, J. D. Tupac gives reasons for this situation /61/. Software evaluation usually weighs functional capabilities against performance, at a time when neither hardware nor software is available and job mixes are not determinable. Needs of users are not conveniently generalizable. Even viewpoints of software experts differ. Tupac illustra-

/59/ Various estimates place the number of user-oriented languages that have been developed at 350 to 500. Eighteen languages are analyzed in:


/60/ The development of standards and methods of evaluating software are among the major objectives of the National Bureau of Standards' Center for Computer Sciences and Technology under the directorship of Dr. Herbert J. Grosch. See Data Processing Management in the Federal Government. Hearings before a Subcommittee of the Committee on Government Operations, House of Representatives, 90th Congress, 1st Session, July 18-20, 1967, p. 69-106.

tes with the question: "What is a 'good' compiler?" Should the criterion be speed, efficient object code production, minimum storage, diagnostic and debugging features, powerful language features, or ease of use? Software, though significant, is only one element in system selection. Rand's guide, with about 125 items distributed within four main categories, each with subcategories, includes the following:

- Hardware
- Software
  - Supervisor
  - Language processors
  - Data management
  - Other programming support
  - Conversion considerations
  - Manufacturer support

The weighting of each differs for different users and different environments. Rand weighted software slightly higher than 50%, the subcategories listed above in Rand's order of decreasing weight.

Software tailored for information retrieval is lagging because of difficulties designers face with language and other problems noted above (p. 26-29). When items can be identified, such as elements in bibliographic records and descriptor terms, programs can be developed for manipulating them. This kind of processing differs little from that of inventory control. All items are pre-selected and all relationships among items are pre-determined by the man in the system. Languages for pattern recognition, problem solving, and analyzing natural language that may give machines more sophisticated processing capabilities are presently research novelties [62].

The new and coming hardware could influence software approaches to information retrieval. Cheaper, smaller, and faster circuitry in central processing units will introduce economic parallel processing. Extensive low-cost circuit redundancy may become feasible. Large, inexpensive memories and cheap, repetitive circuitry may permit the direct design of large associative

or content-addressed memories, thus alleviating the need for complex data arrangements and complex programming for rearrangement or search. Sophisticated query languages may be replaceable by simpler content-addressing schemes. The growth of internal storage capacities suggests the possibility of larger machine words and more common use of wired double-precision half words. Small input/output buffers with data handling and memory facilities could reduce the requirements on software for formatting and transfer. Operations can be centralized for large groups of users who share the same data base, though their information needs and programs differ. Alternatively, "personal"-size computers may be competitive with large central units for given programs in given languages. An ultimate goal is a single language or a small number of languages for specifying various storage and retrieval operations. Charles Fanwick, considering these portents, recommends that hardware and software designers abandon competitiveness in favor of collaboration, with systems analysts, for the realization of optimal allocations of hardware and software in future systems /63/.

* * * * * *

Too often, preoccupation with the complexities of hardware and software obscures the role of man in information systems. The intellectual operations he must continue to perform in the selection of input and the formulation of search strategies share priorities with hardware and software as subjects of research. Above all, the value of the products of a system to its human users measures the raison d'être of the system. This subsection considers activities directed toward aiding man at both the input and the output ends.

As noted above (p. 31, 32), language and classification problems are barriers to the representation of concepts for storage and subsequent retrieval. A variety of statistical methods are being explored for their applicability to the machine processing of natural language strings /64/.

/63/. Charles Fanwick. Trends in Computer Hardware, op. cit. (ref. 54).

Results suggest that statistical procedures can accomplish much of the work involved in constructing a vocabulary and in generating relationships among terms in the vocabulary. Single word distribution measures may be able to provide estimates of the generality or specificity of terms. Statistical association measures may yield classification tables.

Whether terms are processed manually or mechanically, however, their usefulness depends on their interpretation to the man in the system. To examine people's difficulties in associating terms with concepts and in establishing relationships, Morris Rubinoff et al. presented 513 substantive terms selected from programming textbooks and manuals to 78 graduate students and computer engineers. Each person was assigned twenty terms and was asked to designate synonymic and generic-specific relationships for each of the twenty with the rest of the vocabulary. The experiment permitted a comparison of the decisions of three individuals for each term. The responses showed a lack of consistency among individuals in recognizing synonymy, and misunderstanding or confusion about hierarchic-generic relationships. Directional biases were observed, i.e., a person, given a term A, recognized its synonymy with B but, given B, did not perceive its synonymy with A. Relating such terms as "column sort" and "radix sort" with the generic "sort" gave no confusion, but relating "grammar" with "language" did. Thus, the ability of machines to generate arrays of terms is paced by methods of achieving man-man communication.

How man formulates his information needs and proceeds to satisfy them has escaped the attention of most information retrieval specialists. These questions are of concern, however, to industrial engineers.


/66/. Of over 1000 research projects current in 1966 in the field of information storage and retrieval, only 5-10% were directly behavior related. About 50% of the reports of these projects are characterized as "low grade" with respect to research methods or experimental design. See Melvin H. Marks. Behavior-Related Research in Information Storage and Retrieval. Rochester, N.Y.: University of Rochester, Nov. 1966. NSF Grant GN-396.
psychologists, and communications scientists. An analysis of the behavioral characteristics of man as an information seeker describes the search process as one that
must be learned,
is stable over long periods,
develops according to traditional stimulus-response learning theory,
and that cognitive decisions are based on subjective expected utilities.

For current awareness, by contrast, that occurs more frequently and is not aimed at finding a particular piece of information, activities are often discontinued when they don't readily reward. Man exhibits long delays in learning to use the information services available to him in his environment, depicted in Figure 13. Researchers Albert Rubenstein and Gustave Rath comment that "changing fields or organizations should lead to a much greater source of new experiences, but these new experiences require time before they change one's information-seeking behavior." People prefer short search sequences to long ones. They generally proceed from simpler (personal contact, telephone calls) to more complex techniques (use of libraries, written inquiries), though the first step varies with the information being sought (e.g., the use of libraries or letters to obtain specific documents). In an experiment that supplied X-ray crystallographers with services they reported directly applicable to their needs but had not previously heard about, 52% of the service packets were not opened; only 19% were used.


This study is part of an extensive program at Northwestern University on research on the management of research and development. In its eighth year, this program includes projects on idea flow in R & D; strategies for the organization and diffusion of research in developing countries; and transition and interface problems between phases of research, development, and application. See Program of Research on the Management of Research and Development, Annual Report, 1965-1966. Evanston, Illinois: Northwestern U., Sept. 1966. Rept. AD-658,897.
Studies of reading habits confirm the Rubenstein-Rath findings. A poll of 2200 scientists and engineers (1755 responses) in two industrial organizations disclosed that 75% spent less than one hour per week on contract reports, 65% spent one to five hours weekly on technical magazines, 40% spent one to five hours weekly on professional journals, and less than 50% read review journals [68].

In an empirical study of information flow that queried 2000 scientists and engineers in 13 establishments of 4 corporations and 1200 members of the Institute of Electrical and Electronics Engineers, Richard Rosenbloom and Francis Wolek report that 55% of information transfer occurs through inter-

They show the following acquisition patterns for 1523 corporate respondents:

<table>
<thead>
<tr>
<th></th>
<th>Scientists</th>
<th>Engineers</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>633</td>
<td>890</td>
</tr>
<tr>
<td>Interpersonal comm', local source</td>
<td>18%</td>
<td>25%</td>
</tr>
<tr>
<td>Interpersonal comm', elsewhere in corp.</td>
<td>9%</td>
<td>26%</td>
</tr>
<tr>
<td>Interpersonal comm', external to corp.</td>
<td>16%</td>
<td>11%</td>
</tr>
<tr>
<td>Written, corporate documents</td>
<td>6%</td>
<td>12%</td>
</tr>
<tr>
<td>Trade publications</td>
<td>9%</td>
<td>11%</td>
</tr>
<tr>
<td>Professional documents</td>
<td>42%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Differences among fields within science and engineering were small in comparison with the aggregate data, though life scientists and chemists showed greater use of the formal literature than physicists and mathematicians in data processing. Slightly fewer than half the acquisitions resulted from specific search; one-third were contributed by volunteers. In one-sixth of the instances, recognition of need occurred after the information was acquired, principally because it was pointed out by the volunteer (40% derived from "competence-oriented" activity such as browsing, reviewing new developments). Among individuals in the same corporation, those in research laboratories relied more on external interpersonal communication and on professional documents than those in operating divisions. Of special interest, respondents in an advanced development division of a data corporation had extensive interpersonal communication with members in other parts of the corporation, probably reflecting their mission. Rosenbloom and Wolfe tentatively suggest a relation between an individual's productivity and his commitment to advancing his professional skills through education, professional memberships, and the reading of professional periodicals. They conclude that "informal media for information transfer should be recognized as valid and effective mechanisms" and that "the organization within which the technical

work is performed is, of itself, a principal mechanism for information storage and its transfer to operational purposes." /70/

These studies of human information processing behavior make evident some of the reasons why today's formal information systems can satisfy only part of man's information needs. Are additional mechanisms possible that can overcome communication barriers and instill both efficiency and effectiveness into naturally occurring information flow processes?

The experience of agricultural extension services and change agents furnishes much guidance for the promotion of information transfer. Additional to these, formal schemes for the transfer of technological information have been flourishing since the early 1900's. Specialized information centers that have appeared in the United States and elsewhere over the past fifteen years /71/ are but a recent type of service organization. Germany's Handwerkskammern or Artisan Trade Associations were founded in 1900, the Copenhagen Technological Institute in 1906, and the European Productivity Activity in 1953 /72/. Thus, the information transfer activities (visits to clients, identification of knowledge gaps, etc.) of Battelle's Transducer Information Center personnel (p. 18 above) are part of a tradition that already has a history. Beneficial refinements are presumably being sought through the continued establishment of other organizations. For example, a main purpose of the Office of Technology Utilization of the National Aeronautics and Space Administration and its regional dissemination centers is to "assess the most effective means for channeling new technologies into promising directions, including civilian industries" /73/. Another U. S. government program, that of the Office of State Technical Services in the Department of Commerce established in 1965, is to achieve "wider diffusion

/70/. Ibid. p. 124, 127.


and more effective application of science and technology in business, commerce, and industry." Its second annual report estimates that some services reached 35,000 firms and 100,000 individuals through about 1200 units organized during Fiscal Years 1966 and 1967. In the United States, technical service men from material and equipment suppliers have been information transfer agents par excellence. A 1956 Small Business Administration publication advises users as follows:

"Technical service men are sent out to provide all the information necessary for the customers to understand the manufacturer's new product, and to discuss with the customers their reactions and possible new developments using the new product. In many instances, the supplier will actually work out new developments for companies that do not have a sufficiently large or well-staffed research organization to do this work for themselves.

"Technical service of this kind is made available free of charge by the major suppliers, so that they can increase their sales. But generally, technical service involves a fair exchange -- the more information the small company can provide as to its requirements, the more willing and able the supplier will be to offer assistance. Then both will be able to benefit later from expanding markets. In the same way, the small company will find that by furnishing technical service to its customers in turn, so far as possible, sales will increase. In fact, it is at this level that technology will be of greatest immediate benefit to the small company. (emphasis by this author)


See also State Technical Services Newsletter published by the USTS. This informative bimonthly (the March - April 1968 issue is vol. 4, no. 3) announces new grants and describes the activities of ongoing programs (including technology transfer experiences). It also contains abstracts of reference literature in the technology transfer field and abstracts of NASA Technology Survey reports.
"The basic thought behind technical service is that 8 out of 10 uses for a new product are developed by its users -- not by its producers. But new products are introduced into today's markets so frequently, and there is so much technical knowledge now available to industry that the consumers must rely on the specialists for aid. And this is readily available to the small business operator through technical service." /75/

The next section, "Payoffs From Information Systems," discusses profits that have been realized through organized information transfer services. These data substantiate the following observation that ends this section. Existing knowledge about requirements for information handling systems is not scarce. What appears to be lacking is the exploitation of this knowledge in new enterprises, and a willingness to cope with difficult, basic problems in new research undertakings.
The U.S. Navy defines "systems performance effectiveness" as "a measure of the extent to which a system can be expected to complete its assigned mission within an established time frame under stated environmental conditions" /26/. For quantitative measurement, an evaluation method is needed that specifies requirements, performance variables, and decision criteria. This author has found no quantitative methodology for information systems beyond procedures that assess the efficiency of operations in terms of staff, equipment, and facility costs compared with numerically determinable volume flows. In their survey of criteria for determining the effectiveness of library services as distinguished from the efficiency of library operations, C. J. Wessel and B. A. Cohrsen conclude that conceptualizations have not developed beyond vague notions of maximal response to service or product demands /27/. James Schlesinger of The Rand Corp. questions emphasis on models of cost effectiveness that divorce systems from such environmental realities as the quality of their data bases, their non-quantifiable and changing objectives, and socio-economic and political factors with which they interrelate. "Far too much attention ... has been wasted in this strange dialectical tilting ground." /28/. Sales of a product on a free market are a measure of the product's worth to customers. This viewpoint has limitations because of buyer ignorance and trade-offs between the cost of search for a better, cheaper product and needed returns /29/. Nevertheless, the success of many commercial

information service ventures (see ref. 40) attests to some customer satisfaction. Occasionally, savings can be directed related to the possession of items of information. For example, weather forecasts, tailored by services from Weather Bureau data to a particular client's operations, permit a comparison of gains vs. losses, given an item of information, with the cost of obtaining it (80). Cost accounting, however, is difficult to apply to systems that enhance the diffusion of ideas. Historical dependencies were examined in a study that traced events in the discovery of the DNA (deoxyribonucleic acid) code through bibliographic citation data. Topological network diagrams show 65 "nodal" papers written by 89 investigators; only 11 of the papers did not cite earlier nodal work. A weighting assigned to each node determined by the number and type of citation connections to and from the node properly identified key papers (81). The diagrams enable factual conjecture on effects of the absence of particular nodes on subsequent work. If an information system were desired to collect bibliographic data to emphasize significant nodal papers and thereby stimulate the exploitation of their results, what criteria should be established for the system? What are permissible bounds on performance variables? How should value be ascribed to discoveries like that of the genetic code? What variables can reliably predict discoveries from present networks that enable the computation of estimates for anticipated system effectiveness?

Despite the absence of direct cost/benefit data, systems enjoy government and private support based on an attitude to economic growth that emerged after World War II. This attitude postulates that progress can be guided and accelerated through deliberate action and planning. Traditional economic-growth models that emphasized capital accumulation have been su-


perced by those showing that technical progress is responsible for up to 90% of increases in real product per person employed, and crediting education with 42% of the increase in real national income per person employed. If innovations basic to economic growth do emanate from fundamental research, then information systems are an essential link between research and development activities. Indeed, one prestigious group of experts attributes the differential growth of technologically based enterprises in Boston and Philadelphia primarily to superiority of communication -- scientific and technical between entrepreneurs and universities, and financial between entrepreneurs and banks.

In the late 1950's, C. F. Carter and B. R. Williams surveyed various British firms and found that technical progressiveness is related to financial success. They developed a checklist of characteristics for distinguishing firms. These items are:

1. Good information sources.
2. Readiness to seek information and knowledge of practice from external sources.
3. Willingness to share knowledge - technical, managerial, and commercial.
4. Willingness to acquire knowledge on license and to enter joint ventures.
5. Effective internal communication and co-ordination.
6. Deliberate surveying of potential ideas.


7. Consciousness of costs and profits in research and development departments (if any).

8. Routine procedure for costing projects for investment decisions.

9. Good management techniques (work study, methods study, budget control systems, production planning).

10. High status of science and technology in firm (when relevant).

11. Scientists and technologists on Board of Directors.

12. High quality in chief executive(s).

13. Able to attract talented people.


15. Willingness to arrange for effective training of managerial and technical staff.


17. Good quality in intermediate management.

18. Ability to stimulate managers.

19. Effective selling policy.

20. Good technical service to customers.

21. Ingenuity in adapting to material and equipment shortages.

22. Readiness to look ahead; policy for anticipated developments.

23. High rate of expansion (rate of increase of assets).


Their data gave little support to the following items:

25. Industry has strong scientific or technical background.

26. Adequate buildings or site.

27. Scientific or technical training of top management.

28. Resistance to innovation on shop floor.


They found technically progressive firms among non-science-based industries. Old buildings did not preclude the use of modern methods. A significant number of high-quality executives were not scientists. Few firms encountered problems arising from the conservatism of foremen and operatives. Financial shortage was only an occasional problem. They conclude that "technical progressiveness is related to the general quality of the firm."

"The use of science is not an optional extra to be attached to the firm, but an expression of the whole attitude of the firm." They observed that attention to general quality, reflected in the above characteristics, not only preceded technical change, but often was a necessary condition for making it.

The advisory services discussed in the preceding section have helped many groups broaden their technological base. The assistance, and the results, vary in type and magnitude. Payoffs include:

- Elimination of research duplication -- a search for information by the Danish Council on Scientific and Technical Research before starting research on workman's clothing saved $14,000 appropriated for a study and brought a clothing manufacturing industry to Denmark. [85/]

- A new industry -- research in a Burmese institute on a U.S. rice bran oil extraction process adapted it to the tropical climate and local solvent supplies for local manufacturers. [86/]

- A higher level of industrialization -- technical assistance and accompanying capital loans totaling under $1 million increased gross value of production by $21 million in less than ten years under a rural industrialization program in Mysore, India. [87/]

- A new product -- research by the Copenhagen Technological Institute for a small firm yielded a method of manufacturing adhesive cellulose tape. [88/]

- A new industry -- development by the Copenhagen Institute's experimental station of a new method of extracting tannin from Danish trees was put into production. [89/]

[88/]. International Labour Office, op. cit. (ref. 19), p. 98.
Better productivity -- recommendation by the Swedish Government Handicrafts Institute of a more efficient machine saved a paint manufacturer 7,000 crowns per year. \[90\]

A new product -- Collaboration of the Swedish Institute with an inventor resulted in the realization of his invention at a cost of 10,000 crowns in lieu of an equipment purchase for 60,000 crowns. \[91\]

Payoffs, however, should be viewed with caution. They give advisory services useful feedback and justify sponsors' support, but they are only gross indicators of the information milieu that is needed to produce them. Specialists in the diffusion process, advisory services, and human information processing behavior agree that success in information transfer requires an environment rich in a variety of information sources. The following kinds of information facilities, operating collaboratively, appear necessary for an effective transfer environment:

- **Information documentation facilities** -- with active acquisition and dissemination programs.
- **Research, development, and testing (RD&T) facilities** -- for in-house and as-requested work, including the development of standards.
- **Counseling facilities** -- for technical, managerial, and financial advice and guidance.
- **Training facilities** -- primarily for the documentation and counseling facilities.
- **An administrative facility or facilities** -- primarily for focusing activities pertaining to coordination, quality control monitoring, and systems development.

It is the nature of information transfer work that payoffs to users and the economy are visible mainly through counseling activities. When counselors need specialists for the solution of particular problems, the results of RD&T contributions can be directly assessed. Sometimes payoff can be traced to information obtained through abstracting services, technical bulletins, and exhibits produced by documentation facilities, or trade

\[90\]. Ibid, p. 61.
\[91\]. Ibid, p. 62.
fair and mass media announcements of counseling facilities. These latter occurrences are windfall profits. Information packages that are prepared for group audiences create awareness, stimulate thought but, except when they are detailed "how-to" texts, require follow-up by generalists from the counseling facilities or specialists from the RD&T facilities to promote implementation. Training facilities must be content to base their effectiveness on the performance of those whom they recruit and prepare for information roles. Administrative facilities, often the sine qua non for efficient operations, rarely share in payoff glory.

The author has found no proposal to examine the above facilities from a total system point of view, as components of an interactive information transfer network. Developments in some nations (e.g., Japan, the Netherlands, Denmark) and among some groups (e.g., Europe's productivity centers) reflect system planning. Several appeals have been voiced for an international structure. Taizo Ishizaka, chairman of the Federation of Japanese Economic Organizations, suggests an international exchange for technical information. This, combined with international movements of personnel, could "speedily translate scientific discoveries into improved living standards for the people of the world". Rapidity of achievement is questionable. Several Pugwash Conference working groups addressed the problem of an international system, Group 5 at the Thirteenth Conference in 1964 proposing a World Center for Scientific Information for "systematic, co-ordinated and, as far as possible, integrated effort." Why, Bentley Glass inquires, has this proposal lagged?

The experience of advisory services provides many answers. The attainment of interactive, productive relationships with user groups is a gradual, up-hill process, mostly because of man-man communication problems and the lack of adequately trained personnel, rather than financial or other insufficiencies. Communication difficulties that impede the development of information storage and retrieval structures were discussed in the


preceding section. Other types of man-man problems also loom large. Coun-
selors often must probe to discern and separate real from imagined users' 
needs. Both parties must adapt in the transfer process, the counselor to 
the user's constraints and the user to the counselor and to the counselor's 
resources. Human resistance must be overcome to accepting externally gen-
erated information, and new attitudes must be stimulated for the adoption 
of new procedures. Change agents capable of performing these varied tasks 
are in short supply. The European Productivity Activity estimates that one 
counselor cannot adequately serve, through direct contact (the most effec-
tive interaction), more than 75 firms annually. Statistics on practice in 
Europe in 1959-1960 disclosed a ratio closer to 1:5,000 /94/. Moreover, 
the planning and implementation of any particular facility are sufficiently 
demanding to preclude a facility's assumption of responsibilities beyond 
those relevant to immediate objectives /95/.

No systems approach should be expected to materially affect any fa-
cilities operations over a short range. If employed, however, particularly 
in regions where facilities are already close knit or are not far advanced, 
tangible payoffs in more effective use of personnel, financial, and mater-
ial resources should begin to be realizable within three years /96/. A 
consensus among specialists on information transfer is the indivisibility 
of the information needs involved in transfer. Technical information, mar-
keting information, financial information, and management information are 
all interrelated for the industrial exploitation of knowledge. If informa-


/95/. An excellent guide for planners is: Eugene Staley and Richard Morse, 
Co., 1965. Staley and Morse discuss both program planning in the large and 
realistic stepwise strategies for transfer facilities and users.

/96/. Three years is the author's guess based on reported experience of 
periods required for planning, training, and initial start-up. Three years 
is a short time, but newcomers can circumvent much faulty trial and error 
by availing themselves of a wealth of existing knowledge that many organi-
izations offer to share.

One guide to sources of information is: Donald R. Liggett, Small 
Industry Development Organizations, A Worldwide Directory. Glencoe, Illi-
and their publications and services are described.
tion handling and dissemination facilities assume this viewpoint, the whole of their efforts can be more than the sum of the parts.

**EPILOGUE**

This paper has not explicitly related its contents to Israel and to the Information Processing Association of Israel for whom it was written. This is the purpose of this section.

Israel, this year, celebrates her Twentieth Anniversary. Israel’s immigration policy is responsible for a "unique dualistic situation," an environment ranging from highly sophisticated levels of development to patterns prevalent in undeveloped societies /97/. Israel subscribes to the thesis that education and exploitation of scientific and technical knowledge are essential to her social and economic well-being. She has begun, under government and private sponsorship, to establish institutions to implement this thesis. Her experiments and achievements in education are well known /98/. The government, through the Ministry of Development, makes technical and economic studies to aid large- and small-scale industries. The Israel Institute of Productivity, founded in 1951, maintains an advisory service and conducts surveys and training programs for industry. Other organizations give management and financial assistance /99/. Private groups, such as Yeda in Rehovoth, have begun to link the research potential of Israel’s scientists with industry /100/. Currently, a large-scale assessment of

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/99/. *Small Industry Development Organizations*, or. cit. (ref. 96)

Israel's economic position is under way. In preparation for an Economic Conference held in Jerusalem during the first week in April, 1968, a number of informative reports were issued /101/. These, together with a recent review, for UNESCO, of Israel's science policy and research and industrial structure /102/, are valuable reference materials for planners and designers of information systems and services.

It is not the object of this paper to review Israel's information handling activities. These have been made evident. Contributions of scientists in areas of theory and critical analysis are reflected in the literature /103/. Israel's information resources (special libraries, information facilities) are being documented /104/. Since 1961, a Center of Scientific and Technological Information, an agency of Israel's National Council for Research and Development, has been investigating and developing information services for industry. Israel's small but maturing information processing

/101/. See, for example:


See also: Shlomo Gonen, ed. Scientific Research in Israel. Tel Aviv, Israel: Prime Minister's Office, National Council of Research and Development, 1968.

/103/. See, for example:


community is represented in the International Federation of Information Processing and has begun to build a software industry for home and export markets /105/. Universities, government installations, and private firms are planning and augmenting computer sciences curricula and software training courses.

This paper has the object, rather, of complementing the foregoing activities. In recounting the experiences of others with respect to information systems and services, some of the characteristics of human information processing behavior, limitations inherent in present systems, and expectations for future systems, this paper is intended as a guide and reference aid. The author is convinced that effective information systems and information services can be achieved, and that they are necessary elements of modern industrial societies. Successful systems most assuredly presuppose adequate operating budgets. However, the import of this paper is that money alone cannot buy systems. Payoff is a function, first and foremost, of the quality of the people in the system. Willingness to learn; ingenuity in adapting knowledge and experience to environment; forethought in planning; skill in implementation -- these are the human requirements and the pacemakers. The field of information systems and services offers challenge and opportunity to people of large and small countries, alike, who are capable of applying their own resources to the exploitable commodity, information.

This is primarily a bibliography of bibliographies. The references listed below are compilations of various types that pertain, not necessarily exclusively, to information transfer and the technological exploitation of knowledge. This is not a comprehensive listing, but only a guide to literature the author has found useful.

References are listed alphabetically by title, names of authors or compilers following in parentheses, where known.


This document describes, in considerable detail, publications of the various agencies and their information facilities and services.


Bibliography on Information Science and Technology (Frances Neeland). Santa Monica, Calif.: System Development Corp. This is a continuing bibliography, begun in 1965 in support of the then American Documentation Institute's Annual Review of Information Science and Technology. Part I of the Bibliography for 1966 is AD-635,200.


This is also a continuing bibliography. Slightly annotated references are grouped by subject.

A continuing bibliography. Slightly annotated references are grouped in 15 broad subject categories.


Annotated projects are grouped in subject categories. A continuing series; Current Projects for 1964 is NSF 65-16.


Unannotated references grouped by subject with a brief preliminary discussion.


See entry for Selected Rand Abstracts below.

Long-Range Planning and Technological Forecasting: An Annotated Bibliography. (Peter R. Stromer). Sunnyvale, Calif.: Lockheed Missiles & Space Co., Nov. 1963. Special Research Bibliography SRB-63-12; Rept. 5-47-63-1; AD-441,618.

References are alphabetic by author with a subject index. A sequel has the same title and compiler, with the title addition, Supplement 1, Feb. 1965, SRB 65-1, Rept. 5-10-65-3, AD-457,949.


Unannotated, alphabetic by author.


Abstracted references are grouped in 8 broad subject categories.

Selected Rand Abstracts. Santa Monica, Calif.: The Rand Corp.

Issued quarterly, and cumulated annually. Vol. 1 covers the 1963 literature, vol. 6 the 1968 literature. The abstracts section is ordered numerically by accession number, with indexes by subject, author, and serial number. (See Index of Selected Publications of The Rand Corporation above.)
References related to chapter discussions constitute a valuable guide to reports of the experiences of many information services.


References are grouped by subject, by specific industries, and by geographic area.


Grouped by country, government and private facilities and their publications and services are summarized.


Abstracted references are grouped by serial number with author and subject indexes.


Annotated references alphabetic by author, and a brief analysis based on them.

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In view of the growing need for and interest of computer sciences personnel in information systems, and activities in most advanced and developing countries in computer sciences curricula, the following reference is added:

INFORMATION, AN EXPLOITABLE COMMODITY

This paper examines information systems from the viewpoint of implementations based on current knowledge and experience. It reviews studies that report on how information has been and can be communicated for its exploitation. It discusses various types of systems and schemes that have been developed to aid the information processing, including the specialized information center, large-scale documentation centers, selective dissemination of information systems, commercial information services, and small-group communication channels. The role of machines in information processing is considered with respect to current and potential hardware and software. Limitations and constraints imposed on formal information-transfer mechanisms by man's information-processing behavior are postulated as requiring human interfaces to effect optimal use of information. An information facilities network is suggested as a structure for providing necessary documentation, transmission, and use of information. The network includes facilities for acquisition and control; advisory and counseling services; training of documentalists and information specialists; research, development, and testing support; and administration and coordination. Information activities are related to payoff, particularly with respect to technologically developing societies and potential small-industry users.