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THE INFORMATION CENTER CONCEPT

by Francois Kertesz

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THE INFORMATION CENTER CONCEPT

Scientists and engineers study the technical literature in order to avoid duplication in research and thus to eliminate unnecessary work. However, in certain fast moving fields of research, expensive experimental studies are carried out inevitably in areas which have been adequately described in the literature.

Of course it is rather difficult to document such cases, mostly because nobody will admit after he has worked for a long time on his pet project and has spent large sums on experimental equipment, that the work was really unnecessary and the problem could have been solved by searching the literature more carefully. The area of patents is a special case because the examiners are eager and often able to show that the supposedly new material has been discovered years before.

A few cases from both engineering and pure scientific fields were cited recently by D. J. Simpson of the University of Glasglow[1]. He mentions that the U. S. ballistic missiles program was held up for 4 months because no flow control valve was available for liquid oxygen; only after the problem was solved, did the Air Force find out that one of its own employees tackled the same problem when he was assigned the job to design valves for use in high altitude balloon flights. Eugene Garfield[2] cites a paper which claimed the development of a new method for analyzing peptites, although the same method was reported four years earlier. A later correction acknowledged that the claim was mistaken. In his book, Little Science, Big Science[3], Derek de Solla Price estimates that about one-tenth of the United States research and development budget is spent on unsuspected duplication of effort.

It is of interest to note that occasionally even experts in information handling may overlook new developments in areas outside of their technical competence. One of the trusted reference handbooks used by geologists gave year after year an obsolete formula for the flow of water in underwater streams. The geologist editor simply reprinted the formula given in an old reference and did not keep up with the latest chemical engineering developments concerning liquid flow.

Even though every research and production man wants to keep abreast of the literature, the current "explosion" of publications makes it physically impossible to read everything of interest. After all, about one million technical articles are published in the open literature, in addition to the same number of reports or limited-circulation technical memoranda. It is obvious that new tools had to be developed to help the hard-pressed technical men. The situation is much more difficult than it was in years past. During the slow-moving earlier days of science it was possible to rely on personal correspondence; as a matter of fact, the letters of the greats of the past, from Newton to Einstein, often represent high-quality scholarly work, worth preserving for posterity. It is ironical that certain tools of modern technology, the jet plane and the direct-dial telephone make it easy to get in touch with colleagues while improved versions of another, much older invention, the printing press (and perhaps the Xerox machine), keep building barriers between scientists.

There are two basic drives motivating the users of technical literature: the desire to keep abreast with the field, and to obtain a specific answer to an urgent, current question. The technical man satisfies his current-awareness requirement by subscribing to the more important technical journals in his field, giving them a cursory look as they arrive. All too often, he finds that he is forced to put journals aside, hoping to have a quiet moment when the job pressure eases off sufficiently to give him some time for browsing. In order to find answers to a specific question, the technical man usually searches through old issues of journals in the library. These methods are not too efficient. During the years, new tools have been developed to improve the technique of the man-literature interaction. These tools include abstracting and indexing of the articles published in the journals, preparation of review articles, modern computer-based storage and retrieval methods and a more recent concept, the information analysis center. All these techniques tend to compress the literature by factors ranging from 10 to 100 or even more. The problems of the information centers will be examined in this paper.

A technical man who works in a fast-moving field probably is not interested in the old literature because the "half life" of the publications in his area is short. In other cases, old data conserve their usefulness for long periods. Thus, there is a great difference in the approach of an archaeologist and a nuclear engineer to the crowded literature as the rate of obsolescence varies greatly with the field. A fifty-year old paper on the life-cycle of an agriculturally important insect is of interest to a present-day agricultural engineer but a physicist working on laser development may usefully limit the range of his search.

This brings up the general problem whether we should be concerned at all with old papers in their original form. S. A. Goudsmit of Brookhaven National Laboratory believes that we should not. He asked the question "Is Literature Worth Retrieving?"[4], concluding, at least as far as physics is concerned, that old original articles are seldom a helpful source of information because notations and techniques used are unfamiliar to the modern reader, making the content hard to understand. Of course, the information contained must be used again, but not necessarily the paper itself in its original form. The new knowledge developed in a paper might be absorbed in a new theory, a data compilation, or other collection and finally may emerge as a new theoretical formula.

As we shall see more clearly later, this is precisely the goal of the information center: to preserve the new increment of knowledge of a technical article, making it available to the technical community in a useful, convenient form, relieving the reader from the arduous task of mining the sand of literature for the few grains of gold. The center itself must maintain a convenient storage and retrieval system, to be used primarily by its staff of experts. The technical community receives this knowledge after it has been "filtered" through a human brain.

Although new knowledge is more efficiently transmitted, this has an undesired side effect: the chief reward of the scientist, recognition by his colleagues, is taken away from him.

It should be kept in mind that scientific publications have a dual role: to transmit information and to satisfy the urge of the author for recognition. An excellent example is presented in the recently published book of Professor J. D. Watson, "The Double Helix", which illustrates the universal human behavior, even at the olympic level of the Nobel-Prize-winning scientists. The current tendency to publish papers credited to multiple authors reduces the pride of creativity. The list of authors is sometimes as long as the credit line after a movie musical but at least, as Dr. Goudsmit said, in the movie we know who wrote the lyrics.

It is of interest to note that there are no team papers in theoretical fields. Groups of people, such as committees, are at their best when they criticize and point out faults, but no constructive work is done around the table. Committee reports are usually written by one or two persons; the final product has the benefit of the criticism and suggestions of the other members. It has been pointed out that "a camel is a horse designed by a committee".

On the other hand, multiple-authorship papers have at least one benefit. If the senior author, in whose laboratory the work was carried out, has a great reputation in the field, the presence of his name increases the papers "visibility". This has to do with the so-called "Matthew effect", -- a term coined by Robert K. Merton[5] who was inspired by the Gospel according to St. Matthew: "For unto everyone that hath, shall be given, and he shall have abundance; but from him that hath not, shall be taken away even that which he hath". He found that scientists of considerable repute receive more recognition for their scientific contributions than those who have not yet made their mark. The same cumulative principle operates in systems of social stratification: the rich get richer at the rate that makes the poor become relatively poorer. From the viewpoint of information transmission efficiency, the name of a famous scientist on a team paper serves as a label indicating excellence, inducing people pressed for time to read an article that might be otherwise overlooked.

In view of this eagerness on the part of the technical community to read publications by well-known people, it would be of great benefit if well-known scientists and engineers could be motivated to spend a larger portion of their time in the preparation of review articles and monographs. It has been suggested that the "elder statesmen of science" in particular, free from administrative or teaching duties, be asked to devote their time writing up the state of the art. Such articles would be a great help to the novice in the field, compressing the mountains of literature*. If the budding scientist could read a single paper to be brought up to date, he will have more time for creative scientific work.

The information center keeps track of material within its scope and is thus able to supply the monograph or review-article author with the needed papers. This is an important function because it assures the writer that he will not overlook potentially important works and does not have to be concerned with document retrieval problems. This is an important point because researchers and engineers are by nature doers rather than readers; they do not like to spend their time reading other people's papers. There is a point of no return in literature search that each person must decide for himself. Very few technical men would reach for mathematical tables to find squares of numbers but they might probably look up cube roots. Occasionally, it might be easier to determine the melting point of a compound than to search for scattered, contradictory data. The methods used to acquire new information have been examined repeatedly[6]. The best and most efficient method still is: "ask the man who knows". That man could be down the hall or could be an expert whom you know personally but lives on the other end of the country. Even if he doesn't know the exact answer he can save you a tremendous amount of time by directing you to the right source.

This system has been formalized and several large and small organizations sprung up during the past few years to bring together the man who wants to know something and the expert who knows the answer. In the United States, these organizations include the Science

* In the field of the SU(6) symmetries there are about 300 recent literature references.

Information Exchange of the Smithsonian Institute and the Clearing House for Scientific and Technical Information of the Library of Congress.

The formally organized information-handling tools servicing the scientist and engineers include the abstract journals, various indexing organizations and the many private and government-sponsored alerting services; among the informal tools the journal clubs, operating during lunch hours could be mentioned. Each technical man covers a number of journals and during the group luncheon he reports on articles of interest to his colleagues.

This review of information-handling and gathering methods leads us directly to our chief topic, the modern information tool that came to bloom during the last few years, the information and data analysis centers. Although, they represent indeed a recent development, they are deeply rooted in earlier practices and habits of scientists. The concept was known under other names, as Monsieur Jourdain, Molière's Would-be Gentleman knew the ways of polite society.

Information centers are formally organized groups of technical men for handling technical information in great depth, in a narrow, well-defined field, and in a timely and efficient manner, primarily for their peers. This definition emphasizes timeliness, thus eliminating monographs which usually take several years to prepare, teaching and preparation of popularizing technical articles.

The novel feature of the concept lies in the formalized structure. The people involved in this activity are experts in their field; in many cases established their own reputation by their own research. Quite often the information activity is carried out on a part-time basis to ensure that the staff retains its technical competence.

G. S. Simpson, Jr., one of the leaders in the field of information centers, underlines the fact that the output must be authoritative and analytic in character, providing a rapid answer[7].

Let us list some other definitions of information analysis centers*. Panel No. 6 (Information Analysis and Data Centers) of COSATI (Committee

* The word "analysis" is an integral part of the concept. In actual daily use it is omitted, but it should always be kept in mind.

on Scientific and Technical Information of the Federal Council for Science and Technology) accepted the following definition[8]:

"An Information Analysis Center is a formally structured organizational unit specifically (but not necessarily exclusively) established for the purpose of acquiring, selecting, storing, retrieving, evaluating, analyzing, and synthesizing a body of information in a clearly defined specialized field or pertaining to a specified mission with the intent of compiling, digesting, repackaging, or otherwise organizing and presenting pertinent information in a form most authoritative, timely, and useful to a society of peers and management."

The overall idea of the information center was strongly endorsed in the Weinberg Report[9], which emphasizes:

"... knowledgeable scientific interpreters who can collect relevant data, review a field, and distill information in a manner that goes to the heart of a technical situation are more help to the overburdened specialist than is a mere pile of relevant documents. Such knowledgeable scientific middlemen who themselves contribute to science are the backbone of the information center; they make an information center a technical institute rather than a technical library. The essence of a good technical information center is that it be operated by highly competent working scientists and engineers -- people who see in the operation of the center an opportunity to advance and deepen their own personal contact with their science and technology. Proliferation of the specialized information centers will therefore require many such "information scientists": dedicated and knowledgeable technical men who help interpret and assimilate the literature for others working in the field."

The need to establish an information center is due to the same types of pressures within a technical field which result in the creation of other information tools, such as a specialized primary journal or an abstracting service. Practitioners notice that a narrow, clearly defined field of science or engineering suddenly "explodes". The number of papers published keeps increasing; specialized meetings and symposia are organized with increasing frequency and the usual information sources become clearly inadequate. The users usually try to find an ad-hoc solution, attempting to keep up with the growing activity first informally, within a major project. When the work of such a group is formalized, a new information center is born. At the start, this means that the management of the laboratory or sponsoring government agency recognizes the need for the service and provides the subject expert with the necessary secretarial and documentalist assistance.

While most centers are devoted to a narrow field, others use an interdisciplinary approach to research data. Thus, in one center nuclear safety problems are analyzed by a meteorologist, a chemist, a nuclear engineer, a theoretical physicist, a chemical engineer and other subject specialists. In another case, mathematicians examine and obtain new conclusions from scattered biological observations.

The most important feature that differentiates the information center from a special library or document collection, is that the output of the center is not the same as its input. In order to organize its own work, the center needs all the tools of the documentalist and the librarian. The material has to be classified, indexed, abstracted, stored and retrieved but before it is given to a user it is subjected to a transformation.

The output of centers is quite varied, depending on the need of the user. It may consist of a selected and evaluated bibliography, a critical data compilation or collection, an expert opinion to a specific technical question, a state-of-the-art report, an opinion about availability of certain types of materials, or previously unavailable formula. The activity of the center is in this case similar to that of a theoretical physicist who studies experimental data in order to derive the law governing them, expressing his findings in the form of a universally valid formula.

Some of the services are tailored to the need of the individual user; they may include operation of a selective dissemination of information (SDI) service, providing the participants with a list of current papers closely related to their field of interest. In other cases, the staff of the center may provide consulting services. There are centers which act as the command post of activities carried out in widely separated geographical locations. They assist the sponsoring agency as management advisors, help in the organization of meetings and facilitates the personal contact among the scientists involved.

In the United States, the information center concept was greatly boosted in the previously cited 1963 report of the President's Science Advisory Committee's Panel on Science Information[9]. The report emphasizes that "knowledgeable scientific interpreters who can collect relevant data review a field and distill information in a manner that goes to the heart of a technical situation are more help to the overburdened specialists than is a mere pile of documents". It identifies the role of the "scientific middleman", himself a contributor to science, underlining that information centers should not be an adjunct to libraries or publishing ventures but should be established in large multipurpose laboratories, universities, or industrial centers where active work is going on, to fulfill the requirements of a technical institute.

The technical men who staff the centers know what is best suited to their field and are able to choose their tools accordingly. They must know also how to use the skills of documentalists and librarians. They must organize the material as indicated by the growth rate of the publications or other special features, using computerized or manual systems best suited to the subject. They are the ones who should choose the storage and retrieval tools.

Data compilation groups represent a special subset of information analysis centers. They extract numerical information from the published literature and attempt to reconcile contradictory values by critically examining the experimental methods used and possibly also using personal judgement on the quality of the work. The output consists of the "best values" of a given set of numerical data, relieving the experimenter who is designing an experiment from the task of choosing between contradictory sets of values. In many cases, the scientific prestige of leaders of such compilation groups exceeds that of the experimentalists. As an example, the Nuclear Data Group's output was instrumental in the development of the shell model of the nucleus; no physicist or engineer working in the field would undertake a major project without checking the pertinent values in the latest compilation of the Thermophysical Properties Research Center.

The importance of critically evaluated data as a natural resource has been formally recognized by the creation of the National Standard Reference Data System operated at the National Bureau of Standards under the supervision of Edward L. Brady[10]. The aims of this activity include the promotion of critical-evaluation and data-compilation projects, coordination of related work sponsored by government agencies and operating a national center for standard reference data.

Data banks represent another kind of organized collection of numerical data. In modern environmental sciences, such as meteorology or oceanography, data are often collected more rapidly than the theoreticians are able to use them. This is especially true in the new field of space science: satellites and space probes supply an overabundance of numbers. They serve as the basis to calculate the Van Allen belt, the true shape of the Earth, etc. These collections of raw data must be maintained by experts, in a form convenient for the users.

As may be expected from the variety of information centers, the users of their services also cover a wide range -- from "pure" research scientists to design engineers and production men. Persons in the forefront in basic research usually need less assistance. They usually belong to a select informal group called by Derek deSolla Price[11] an "invisible college", keeping in continuous touch with each other, and making use of very effective informal means of communication. Persons who need information center activity are the active experimentalists and especially the design engineers who as a general rule change their field of activity before they have a chance to become fully acquainted with the problem. Such a person usually is not interested how a certain value was derived but he wants to be sure that the value he uses is the best one available at that time. An engineer may be given the assignment to design a stirrer for a chemical reactor. In that case he might want to know what alloy to specify for the construction shop, given the composition and the pH of the solution that must be stirred, but he is not necessarily interested in the various electrochemical theories of corrosion or the testing methods used for selecting the best alloy. A few months later, he might collaborate in the design of a nuclear reactor, working on shock absorbers for control rods. In this case again, he will want to make an intelligent choice of commercially available materials on the basis of mechanical properties, keeping in mind the limitations and requirements arising from nuclear considerations. The reasons for selecting one alloy over another are of less interest to such a person than to a solid-state physicist or theoretical metallurgist.

This points out the necessity for the information center manager to keep always in mind the character and composition of his user population. Most centers operate on a homogeneous level, that is, their users are themselves generators of new information. In some cases, there is a slight differentiation between these groups. Scientific data may be rearranged to make them better understandable and applicable in industry; on other occasions, research engineering techniques must be adapted to the requirement of shop foremen. The nature of the collection is determined by such considerations.

Organization of the input and output system depends also on the nature of the subject matter: some fields, for instance, nuclear safety, are somewhat diffused; other areas are "hard". They can be easily indexed, stored and retrieved because they refer to a well-identified concept, e.g., a specific reactor, a chemical element, a nucleon, or an engineering process. Development of a suitable thesaurus requires considerable effort and usually represents the major portion of the initial organization of a center. Systems experts, documentalists, and special librarians should be called for assistance at this stage because in most cases the subject specialists do not have the necessary background when starting an information activity. Collaboration of the two types of experts yields excellent results.

This collaboration between information and subject matter experts is further enhanced by involving technical men from the host institution as part-time staff members of the center. They receive a liberal education in information handling and bring valuable expertise to the center. Preparation of state-of-the-art reports by these subject specialists is facilitated by the fact that the participants do not have to dig out the background material; the documentalists and other information specialists provide them with the needed articles. The technical man thus gains additional competence. This helps to overcome the traditional antagonism of scientists and engineers toward technical literature work in general.

In order to give an example of a large, multipurpose laboratory acting as a host to a number of information centers, it might be of interest to review briefly the scope of the centers currently operating at the Oak Ridge National Laboratory. The centers are part of one of the research divisions of the Laboratory; they are under the supervision of the division directors and are thus part of a working technical community. The writer acts as the coordinator of the centers.

The *Accelerator Information Center* collects information on the hardware used in accelerator design. Being in direct contact with accelerator designers, it keeps track of technological improvements in this field.

The *Actinide Research Information Center*, about to start its formal operation, focuses its attention on the chemical properties and separation methods of transplutonium elements.

The *Atomic and Molecular Processes Information Center* collects and evaluates data in the fields of heavy particle-heavy particle, electron-heavy particle, photon-heavy particle interactions, particle penetration in macroscopic matter; interactions with static or quasi-static electric and magnetic fields; surface ionization; the structure of atomic and molecular systems, and transport phenomena and average properties in gases.

The *Biogeochemical Ecology Research Collection* organizes tabular information on concentration of elements and isotopes in plants, animals and other components of ecological systems, attempting to estimate rates or probabilities of transfer between parts of these systems. Its main purpose is to collect case studies for theoretical analysis and to predict stability and change in the system.

The *Charged-Particle Cross Section Data Center* compiles nuclear cross sections for charged-particle induced reactions. The "best values", presented in graphic and tabular form, represent a valuable tool for theoreticians and experimentalists in the nuclear field. Reactions involving mesons in the exit channel are outside of the scope.

The *Civil Defense Research Collection* collects and organizes civil defense research information in a great variety of fields, which include studies on measures of warning and protecting the public in case of enemy attack and furthering the recoveries of society during the post-attack period. The disciplines involved encompass engineering, physics, social science, biology and agriculture.

The *Computer Handling of Reactor Data-Safety* is developing a system for organizing safety-related information about the design features of commercial nuclear power plants, primarily to assist AEC's Division of Reactor Licencing in the evaluation of research proposals. The computer program is designed to ascertain the user's need, providing him with a highly selective output.

The *Criticality Data Center* is concerned with process specifications for the storage, transportation and chemical and metallurgical treatment of the three most abundant fissile isotopes, collating the relevant data to make them applicable to nuclear safety problems.

The *Office of Saline Water Materials Information Center* covers the corrosion performance of equipment used in all types of desalination processes.

The *Engineering Data Collection*, primarily for internal ORNL use, maintains a reference file of engineering drawings, manufacturers' specifications and spare parts lists, making available standards issued by government agencies, technical societies and suppliers to field engineering groups.

The *Information Center for Internal Exposure* interprets data on radiation originating from internally deposited radionuclides. Instead of serving the technical community at large, the center submits the evaluated experimental data to appropriate subcommittees of the International Commission for Radiological Protection.

The *Isotopes Information Center* examines the actual and potential application of radioactive and stable isotopes for the benefit of industrial users. The center thus attempts to translate the large body of scientific results into specific instructions for agriculture and engineering; medical questions are covered to a lesser extent.

The *Molten Salt Information Center* focuses its attention on the chemistry of molten salt systems, emphasizing aspects of interest to molten salt reactors.

The *Nuclear Data Project*, one of the earliest compilation groups, analyzes information on nuclear level properties, such as energies, moments and transition probabilities; from the available material plausible decay schemes are derived, attempting to reconcile discrepancies in the experimental findings.

The *Nuclear Desalination Center* covers the field of nuclear desalination; its scope includes energy sources, distillation processes, studies on the newly developed concept of agro-industrial complexes and water utilization.

The *Nuclear Fuel Technology Information Center* specializes in the evaluation of publications on the properties, processing, fabrication, application, performance and economics of nuclear fuels and cladding materials.

The *Nuclear Safety Information Center* also cuts across various disciplines in order to provide licencing experts and nuclear design engineers with evaluated material on the containment of nuclear facilities, fission product release, transport and removal, meteorological consideration, instrumentation and reactor kinetics.

The *Photographic Reference Collection* performs an internal service to the ORNL staff, keeping track of the about hundred thousand photographs of the equipment and buildings of the Laboratory.

The *Radiation Shielding Information Center*, originally organized to cover the area of shielding of reactors and radiochemical plants, now includes in its scope weapons shielding problems and protection against radiation near accelerators and in space.

The *Research Materials Information Center* acts as the central agency on the availability, assaying methods and physical properties of high-purity, inorganic research materials.

The *Machining and Gaging Information Center*, under the supervision of the sister Y-12 Plant (also operated by the Union Carbide Corporation) which possesses a well-equipped, modern machine shop, provides a comprehensive service in the field of high-accuracy, close-tolerance metal removal and measurements.

In the local usage, the term "information center" refers to a group providing an analytical function, as described above; a "collection" is usually a document collection where no critical evaluation is carried out. Quite often, the "collection" is a preliminary stage, before a full-fledged information center is established.

The usefulness of information centers has been generally accepted by now. Various agencies of the federal government are among the chief sponsors of these centers; it is estimated that there are about 120 federally supported information centers in the United States[12]. If the privately-owned centers of the country are counted, the total might reach several hundred.

National and international networks are slowly developing and within the next decade the centers are expected to undertake an ever-increasing role in scientific information handling. This might possibly result in the elimination of certain functions, assumed today by primary journals. The output might be refereed and inclusion in it could carry as much prestige as publication in a well-known journal.

At the present time, the greatest need is education of the technical community about the usefulness of the centers. Unfortunately, this latest helper of the scientist and engineer is not well known yet and needs more publicity. This could be best achieved by incorporating information handling in the regular curriculum. The problem was examined at a meeting of the American Society for Engineering Education Conference on Information Sources, Systems and Media in Engineering Education at Lehigh University, May 19-20, 1966[13]. Instead of crowding additional information-handling courses into the curricula it was recommended that the teachers orient their daily teaching, so as to force the students to turn to information tools to supplement textbooks and conventional sources. Such an assignment, for instance, may inform the student that about ten years ago a dam broke in Southern France. He will be asked to find out the reason for the accident and propose methods for preventing it. This would force students first of all to search through the indexes of the daily papers to find out when and where the accident occurred. Once he established the date and place of the event, he must turn to technical journals to find out how the engineering community viewed this event. Finally, he must rely on his own knowledge and ability to search through the literature to propose a solution.

Another example given in this report involves the determination of the torsional breaking strength of the human ankle. This would force the student to utilize all the tools of research, short of experimentation. He must study the literature of two major disciplines - engineering and medicine - one of which (depending on his specialty) is not familiar to him. Of course, no correct data are available since the failure limits of the ankle in torsion have never been empirically determined; even approximate calculations of skiing-accidents forces are lacking. However, there is substantial information on torsion on long bones and on simple hinge joints (the knee). The students will not find completely relevant data but would become familiar with information-handling tools in other areas and would be required to propose solution to the problem on the basis of related but insufficient data. They should be indoctrinated to try to find an information center, the subject field of which lies close to the area of their interest.

It is quite probable that they will find such a center, no matter what field they are involved in. Information handling systems are undergoing a rapid change and it may be confidently anticipated that within a decade instead of hundreds, we will have thousands of information analysis centers available for consultation and assistance. Once the current (and especially the future) technical community is fully indoctrinated, and much remains to be done on that score, the information-collecting practices of scientists will be profoundly affected. Networks of "information wholesalers", large services developed by the major technical societies, will collect systematically the material in special disciplines, such as chemistry, physics, biology, engineering, etc., government agencies will do the same in large mission-oriented fields of atomic energy, space science, etc. in which because of the size, the government must play the primary role. The actual interpretation of the material for the benefit of scientists working in the narrow, specialized fields, will be assumed by the information analysis centers and critical data compilation groups.

Thus, the future of information centers appears to be promising. Dr. A. M. Weinberg feels that their staff will play a role similar to that of the keepers of sluice gates of the irrigation system in ancient Pakistan who had advanced knowledge of the water flow and ultimately became the rulers of the country. The information handlers of our time are such gatekeepers of science and technology; although nobody expects them to rule, they will probably exert a very important influence on the future of mankind.

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