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### Observations and Opinions—The Future of Information Processing Technology

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## Observations and Opinions

### THE FUTURE OF INFORMATION PROCESSING TECHNOLOGY<sup>1,2</sup>

The day before yesterday, in the beautiful and historic city of Guanajuato, I saw the impressive monuments located there that celebrate Mexico's political revolution—*La Alhóndiga* and the statue of *El Pipila*. But while exploring the city, I also saw a monument that celebrates today's technological revolution—an electronic computer, in the offices of the government of the State of Guanajuato. Indeed, in the present age, the presence of electronic computers has become a prime symbol of the explosion of technology.

But I must be careful in my use of terms. We use the words "revolution," "explosion," and "breakthrough" very freely nowadays. Hardly a day passes without a new "breakthrough" in toothpaste manufacture or the design of raincoats. If we are to avoid a Madison-Avenue dilution of meanings, we must employ these terms accurately and sparingly. We must ask whether we are really justified in applying "revolution" to contemporary trends in technology generally, "explosion" to information specifically.

#### Plus Ça Change; Plus C'est La Meme Chose

Is there in fact, as is so often claimed, an "information explosion"? Why do we think so? If there is one, what does it signify?

Certainly the daily press has no doubts that information is exploding. A single issue of the Sunday New York *Times* yields the following two items:

In the financial section:

Will a full week of shorter trading hours bring happiness to brokerage firms whose back offices are jammed with paper work?

In the news columns:

George A. Miller, a professor of psychology at Harvard, warned that by 2000, the limit of man's mind to absorb information may be reached. "We may already be nearing some kind of limit for many of the less gifted among us, and those still able to handle the present level of complexity are in ever increasing demand."

These two items are simply a more or less random sample from the very much larger number I could quote—the first two that came to hand. The first conjures up a fascinating picture of the Stock Exchange slowly submerging under a tide

<sup>1</sup> Received November 1967.

<sup>2</sup> This is a slightly adapted version of a speech presented at the TIMS International Meeting in Mexico City, August 24, 1967.

of paper; the second promises prosperity to “those still able to handle the present level of complexity”—and I assume that means all of us present here.

How can we assess these developments, and the others like them? How valid are the predictions of the impending Flood? To answer those questions, we must sort out the elements of stability and the elements of change in human affairs.

Change—extremely rapid change—there certainly is along technological and economic dimensions. We know that technology is advancing with great speed. We know that it is *beginning* to make possible for the first time in human history the elimination of acute poverty. We know that it is even providing means for combatting the over-rapid growth of population—the most serious threat to that prospect of banishing poverty.

But (there is always a “but” at this point in the argument), if we measure the world by Man, by his values and his goals, we have good reason to doubt whether it is changing very much at all. Lesson 21 in the Spanish grammar I brought along to this meeting, provides me with a splendid commentary on the stability of human affairs. In translation, the lesson reads:

News! I finish reading the paper. I have learned that prices have gone up. The weather continues to be bad and there may be a storm tonight. No solution has been reached in the dispute between the union and the factory management; it is probable that there will be another strike. It appears doubtful that the political parties will reach an agreement. The international situation is not improving. The other news is the same: accidents, crimes, deaths, births, and weddings.

I am sure the author of that passage intended it as no more than a lesson in Spanish vocabulary. It turns out to be a good description of the human condition—a condition that has not changed much since Greek times. Or since the time of Cervantes—for the adventures of Don Quixote are highly suggestive of events in the world today—even including tilting at windmills.

We must not suppose that with the progress of technology, or even with the progress of our economies, mankind will become deliriously happy. For Man’s aspirations have a way of adjusting to his opportunities. We must not expect that technological progress will produce Utopia; it is reasonable to hope that it will bring relief to acute hardship and acute pain.

### An Essay into Prediction

With these cautions and reservations, let us turn back to the technology itself and examine the changes that are taking place in information production and processing. Ten years ago, at an ORSA meeting in Pittsburgh, Allen Newell and I made some very specific ten-year predictions. I wish I could tell you now—since the deadline for the predictions is almost here—that each one had been exactly fulfilled. Unfortunately, that isn’t the case. But rather than take much time here either to defend or to explain away our past predictions, I will simply make a few general comments about them, and then exercise proper caution by eschewing predictions for the future.

If I were to defend our predictions, my defense would take these lines: All of the predictions were wrong in detail, but they were correct in their general

import: the trend they foresaw and the rate of change. We did not guess correctly how research efforts would be allocated to specific areas, and we did not guess correctly the rank order by difficulty of specific problem areas. Hence, although musical composition, chess playing, and theorem proving by computer have made important progress, they have not yet reached our ten-year targets. On the other side of the account, fundamental understanding of natural language and progress in construction of high-level computer languages have advanced more rapidly than we would have dared predict a decade ago, as have automatic design by computers, visual displays for man-computer on-line interaction, and automatic character recognition.

Hence, in the light of the decade's progress, we remain unrepentant. We see no reason to revise our basic thesis: that electronic computers are general-purpose information-processing devices; that we will step-by-step learn to do with them any kind of thinking that Man can do; that with the help of computer simulation techniques, we will learn (and are learning) how Man thinks, and we will learn how to help him to think better.

#### Attending to the Information That Is There

Grant me the premise for the moment that the technology of information processing is progressing as rapidly as these claims would imply—and the TIMS program at this meeting provides much additional evidence for that premise. If this is in fact occurring, why *won't* there be an information explosion? Let me propose a metaphor to explain why there won't—or needn't—be.

The mountain climber, Mallory, when asked why he wanted to climb Everest, gave his famous reply: "Because it is there." Not all of us accept that reply, at least for ourselves. Not all of us aspire to climb Everest, or would look forward to the prospect with any relish or sense of purpose.

Now it is possible to be just as skeptical about processing information as about climbing mountains. Specifically, *information doesn't have to be processed just because it is there*. The telephone doesn't have to be answered just because it is ringing; the newspaper doesn't have to be read just because it has been tossed on our doorstep.

I hasten to acknowledge that information is sometimes ignored at our own peril. The inexhaustible Sunday *New York Times* again provides an example:

Tag Petersen, a traffic controller at a railway signal station told a court Friday that he permitted a train to go on Thursday although signals indicated the track was not clear. Since he had not heard from another train on the same tracks, he assumed it was in Nyborg, 20 miles to the East, according to schedule, and that the signals on his control board were in error.

In spite of this example, and others of the same genre that could be produced, we are more often guilty of the opposite error—of supposing that all would be well "if we just had more information." I turn once more to the *Times* for an apt illustration:

A Nobel Prize winner at Stanford University thinks it is time for the polls to go to the

people instead of the people going to the polls. "I believe that our engineers are in an advanced enough stage to put a simple electronic voting device in all homes," said Professor Robert Hofstadter, a 1961 prize winner in physics.

A qualified citizen could vote, say, in his own living room. Professor Hofstadter said "modern computers can assemble the data almost instantaneously and flawlessly to give a definite result on the issue."

We recognize this as an example of a pathetically naive belief in the "technological fix." The following is a more frightening example (for, after all, we do not take physicists too seriously when they sound off on politics):

The U. S. State Department, drowning in a river of words estimated at 15 million a month to and from 278 diplomatic outposts around the world, has turned to the computer for help. Final testing is under way on a \$3.5 million combination of computers, high-speed printers and other electronic devices. Officials say these will eliminate bottlenecks in the system, especially during crises when torrents of cabled messages flow in from world trouble spots.

When the new system goes into full operation this Fall, computers will be able to absorb cable messages electronically at a rate of 1,200 lines a minute. The old teletypes can receive messages at a rate of only 100 words a minute."

A touching faith in more water as an antidote to drowning! Let us hope that Foreign Ministers will not feel themselves obliged to process those 1,200 lines of messages per minute just because they are there.

#### Attending Selectively

It is ridiculous to suppose that we can save ourselves from drowning in information by installing faster printing devices. *Lack* of information is not the typical problem in our decision processes. The world is constantly drenching us with information through eyes and ears—millions of bits per second, of which, according to the best evidence, we can handle only about 50.

Saturation with information is no new thing. The movements of the stars, visible to Man throughout the tens of thousands of years of his history, contain all the information that is needed for Newton's Laws of Motions or the Law of Gravitation. The information was there all along. What was lacking, until a few hundred years ago, was the basis for selecting the tiny fraction of it that could be used to establish powerful generalizations.

We cannot avoid living in a world that drenches us with information—whether made by Man or nature—but we *can* select for our processing the information that is likely to be useful to us, and ignore the rest. Gertrude Stein, in the opening pages of *The Autobiography of Alice B. Toklas*, said: "I like a view, but I like to sit with my back turned to it." We can follow Miss Stein's example of independence from the environment of information. Our scientific and technological knowledge, our decision-making and information-processing systems are means for permitting us to turn our back to the view—or to gaze on it very selectively, extracting from it just the parts we want.

In the same vein, most of the contemporary concern about the information explosion in science is misconceived, because it is based on an invalid model of

the nature of scientific progress. Science does not advance by piling up information—it organizes information and compresses it. A generation ago, for example, organic chemistry was a mass of particulars only weakly organized by known theoretical generalizations. Today, although knowledge of organic chemistry has grown vastly, the principles of quantum mechanics provide powerful organizing means for that knowledge. As a result, it is undoubtedly easier today to gain a mastery of organic chemistry adequate for doing significant original work than it was in an earlier era when there was very much less known.

The example I have chosen is a spectacular, but not an isolated one. In the scientific endeavor, "knowing" has always meant "knowing parsimoniously." The information that nature presents to us is unimaginably redundant. When we find the right way to summarize and characterize that information—when we find the pattern hidden in it—its vast bulk compresses into succinct equations, each one enormously informative.

### A Science of Information Processing

Herein lies the real significance of today's information revolution. Information and the processing of information are themselves for the first time becoming the objects of systematic scientific investigation. We are laying the foundations for a science of information processing that we can expect will greatly increase our effectiveness in handling the information around us.

Thus, at a time when we are acquiring devices that will both transmit and process symbols at unprecedented rates, the most important change that is occurring is not the growth of these devices but the growth of an information science or computer science that will help us understand them. It is the growth in our understanding of how information can be transmitted, how it can be organized for storage and retrieval, how it can be used (and how it is used) in thinking, in problem solving, in decision making.

This growing understanding of information processing returns to us the decision of whether information must overflow and we must drown in it. It returns to us that decision, just as advances in medicine return to mankind the decision whether population must overflow, and we must drown in our own numbers.

A major task ahead for science and technology is to design effective information-processing systems for making decisions in business and in government. It is important that we talk about designing "information-processing systems" and not just designing "computers." This choice of terms is not meant simply to emphasize that the computer programming system—"software"—is at least as important as hardware. That is true, but it is only part of the story. The design of such systems must encompass far more than the computer hardware and software; it must handle with equal care the information-processing characteristics and capabilities of the human members of organization who constitute the other half of the system.

For generations to come, although the systems we call organizations will have some mechanized components, their most numerous and most crucial elements

will continue to be men. The effectiveness of these systems in handling problems will depend more heavily on the effectiveness of the thinking, problem solving, and decision making that men do than upon the operation of the computers and their programs. Hence, in the period ahead of us, more important than advances in computer design will be the advances we can make in our understanding of human information processing—of thinking, problem solving, and decision making.

#### **A Task for Management Science**

Management scientists will play a major role in these developments. They will carry a heavy responsibility for raising the level of rationality in the organizational decisions that will affect the fate of millions, sometimes even billions, of men.

Perhaps, if they are effective and fortunate, they will be able to raise the quality of decision making in executive offices and chanceries to the point where the disasters that inept problem solving all too frequently bring on us will become rare events.

Don Quixote symbolizes forcefully Man's frequent and pathetic incapacity to understand the world in which he lives. But Don Quixote, in the end, recognized his own madness and gained his freedom from it.

And so, in a world that sorely needs balance and clarity of thought, in a world where Man sometimes appears dangerously mad, we may be able, with our growing understanding of the technology of information processing, to restore a measure of reason

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