SP a professional paper

New Frontiers of Quality Control

by

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ABSTRACT

Methods for quality evaluation and control are being sought in many new areas. Two such areas are (a) computer programming and (b) documentation.

Top management generally has not yet learned to live with computers, nor to take advantage of their possibilities. Control by management of these facilities requires a better understanding, followed by effective methods that will evaluate design and monitor performance. Such methods come within the purview of quality control in its modern, enlarged meaning.

The current search for performance standards considers subjective measures such as supervisor rating, objective measures such as running time, and various indirect statistical approaches. No one can say yet whether any of this groping will find a way, and it may be that some completely new approach to the management of systems work will be required.

Management and science are handicapped by poor documentation, a subject that recently attracted the attention of a Presidential panel. Scientists work at a low level of effectiveness because they have no way of knowing what jobs have already been done, and so must repeat them. Possible remedies are (a) "population control" in the document field; (b) improved distribution methods; (c) upgrading the level of writing. Objective scoring methods have been proposed by R. Flesch and R. Gunning, and these may be useful.

In the final analysis, quality goals (in programming, documentation, or any other effort) are set by management. The fact must be recognized that the productive organization will not bother much with quality if top management's interest is not strongly felt.

NEW FRONTIERS OF QUALITY CONTROL

The March 1965 issue of CONSUMER REPORTS describes a program of quality evaluation for medical and hospital care, begun in 1956 and still continuing. This is only one of the more recent examples of how the demand for quality is being heard in new areas, and how scientists are looking for and finding appropriate measures of quality in unexpected fields. The public is beginning to understand that when a plane crashes, when a submarine is lost, when a missile blows up, the explanation too often lies in inadequate quality control. With this new awareness is coming an enlargement of our ideas of what quality control means; instead of a control chart on a machining operation, we must think of Q. C. as embracing all activities directed toward quality assurance: training, supervision, inspection, maintenance, and user feedback, among others. If Faraday could visit a modern generating plant, he would have a hard time recognizing his baby grown up. Similarly, I think, the development of Q. C. in the future must take it far beyond anything envisioned by the early workers in the field.

New technologies bring with them new problems, and I wish to call attention to two that are particularly urgent. The first concerns electronic data processing (EDP) systems, and one typical question: "In writing a program for a digital computer, how do you tell a good program from a bad one, and how do you increase the goodness of a programmer's output?" The second relates to information and paper work, and to such questions as, "How can we manage a system of reports and documents so that we communicate information, and at the same time do not generate unnecessary wordage?" The problems are, of course, closely related; the "information explosion" that created the second has at the same time stimulated the computer revolution and its attendant problems. I hope in this discussion to convince you that these problems are urgent, to tell you about some attempts being made to find solutions, and to suggest what you yourselves may do about them.

People at the top levels are beginning to realize that the control and use of computers presents them with special problems that they cannot ignore. Just recently, the newspapers carried a White House statement on computers. The Government, so said the report, was concerned about the huge and rapidly growing cost of computers in government, and was proposing steps to investigate whether the money was being efficiently spent. Current investment in computers is said to be around $3 billion, with another billion or more being spent every year. Both computer design and programming methods are changing fast; what was up-to-date five years ago is obsolete or obsolescent today. Only full-time specialists are able to keep abreast of the changes, and even they must work hard to do it. Purchasing agents who contract to buy or develop a computer-based system, and managers who will eventually use the system, have much less knowledge. ELECTRONIC DESIGN (21 December 1964) reported: "Military commanders at all levels are dissatisfied with the limited use they are getting from their computers in command and control applications. Disappointment is greatest at the top, where very elaborate systems, expensive to buy and operate, are not easing the command load... Assistant Secretary of Defense E. G. Fubini (said) that users are not getting what they want from the large systems because they do not know what they want from them or what their needs really are." This may not be the whole story, but it is certainly part of it; managers in general have little more than a vague idea of what a computer-based system can do, much less any standard of performance.

A few years ago, while I was at Case Institute, I spent some time at an Army installation in St. Louis, looking over their system for handling supply and inventory. The system was modern, at least for that time. Requisitions for supplies and spare parts, originating in North America or in Europe, were punched into cards and communicated electronically to St. Louis. There they were fed to a computer, which searched the inventory records, selected a warehouse that had the item in stock, prepared a shipping order and forwarded it to the warehouse, updated the inventory record, and, when necessary, prepared reorder and back-order papers. Human judgment didn't enter at all except sometimes at the very end: if the money involved in a reorder was over a given limit, it was diverted to a human being for review.

Just before I visited St. Louis, the computer had processed an order from Germany for 100 left wings for small observation aircraft. The computer looked in the inventory records and found that six such wings were in stock at Columbus, Georgia. It sent instructions to Columbus to ship these six wings to Germany, made out a back-order for 94 wings, and a reorder for 100 new wings. This order went over the money limit, and a review showed that in all of Europe there were only about 15 aircraft that this wing would fit. Clearly, the order for 100 spare wings was a mistake; the originator probably wanted 100 carburetor repair kits, or something else quite different from wings.

The head of the St. Louis installation was a one-star general. I called his attention to the fact that it would be quite simple to program a routine to check on the reasonableness of any order, with some sort of follow-up for unusual departures from routine. His answer surprised me. I can give it almost word for word: "I am running a supply operation. It is no part of my job to ask whether the men in the field really need something, or what they need it for. If a requisition has been properly authorized, I'll fill it if I can."

Now, what's the point of this story? Is it that cards sometimes get mispunched or that errors creep into communications? No; this much we all know. Is it that we ought to scrutinize error-checking routines to make sure they are adequate? We certainly ought; but this is a detail. The main point is that a responsible manager became so confused when he was working with a computer that he could no longer think straight; he couldn't see the distinction between questioning the computer output and questioning the decision of a field officer. A manager who is not fully aware of what a computer is and what it does takes his enterprise into unknown hazards. Sooner or later he will run into catastrophe.

Much nonsense has been written about computers. They have been called "giant brains" (sometimes "giant morons"); they are said to have memory, do arithmetic, make decisions, compose music, play chess, and so on--to perform, that is, tasks usually performed by intelligent human beings. In exactly the same sense, a common household thermostat has memory, "feels" heat and cold, and makes decisions. All this talk is, of course, metaphorical; and in the particular case of computers I believe we get so deep in metaphor that we lose sight of literal truth. A piece of paper does not "remember" the words we write on it; a thermostat does not "feel" temperature; an automatic transmission does not "decide" to shift gears. All these devices are inert in themselves, acquiring life only by association with a human intelligence. A computer is immensely versatile, and it becomes easy for us to regard it with a kind of spooky awe. Yet a computer is no more than a mechanical (or electrical) extension of the brain of its user, just as a lever is an extension of his arms. Modern computers are in fact remarkably reliable machines, but they are like typewriters: they can't spell any better than the people who use them.

I have been told that a chimpanzee can be taught to drive a car, and even stop and go for red and green lights, but with this difference from human actions: when the chimp sees a red light he stops, period. As soon as the light turns green, he goes. People don't do this; they evaluate the signal with their intelligence and obey it or not, as they think proper. A computer is like a chimpanzee: it obeys the signal. It is possible to instruct a computer, "Obey the signal if..., otherwise don't," but this is merely making up a more complicated signal. The fact that computers obey instructions exactly, mechanically, blindly, is a major source of frustration to beginning programmers. Only people who have actually had the experience (like the Sorcerer's Apprentice) can understand the exasperation of having a servant that does exactly, precisely, literally what he is told, without intelligence, imagination, foresight or insight. Yet, we can't do without computers; we shall have to lean upon them more tomorrow than we do today. Management cannot escape the task of learning to understand computers, of finding ways to evaluate them, of devising reports that will monitor their performance; in short, of solving the problems of quality evaluation and control.

Part of the problem is that the executive who wants the results does not talk directly to the programmer, nor the programmer directly to the machine. Today the working programmer, using a language like FORTRAN or COBOL, is removed by several steps of translation from the actual working of the computer. He knows what he asks the computer to do, but he may not know exactly how the machine carries out his instructions. Several years ago I took a programming course. One problem the students were given was to write a program for the solution of quadratic equations, making provisions for possible complex roots. To prove out our programs, we had to solve several test equations, one of them being

$$9x^2 - 12x + 4 = 0 .$$

The roots of this equation are real and equal, both being +2/3. But when the computer got hold of the problem, it made a conversion of the decimal numbers into the binary system, so that 2/3 came out 0.10101010101010 ..., etc., to the end of a computer word. In the arithmetic that followed, the quantity $(b^2 - 4ac)$ came out, not zero as it should, but something like - .000000000000000000000000001, and so the computer reported that the equation had complex roots. It was easy enough, once the nature of the error had been diagnosed, to modify the program to prevent a recurrence, and that particular error won't happen again with that routine. At the same time, few programmers would assert that any large programmed system is quite error-free, and this is true of the translating routines or compilers that accept the programmer's instructions and translate them into signals that the machine can read. Every program and every compiler is checked out before it is cleared for use, but checkout testing is still mostly a matter of individual skill (and perhaps intuition); as with proofreading a book, we can never be quite sure that we have found the last error.

We have thus a whole field for quality control. A lot of work has been aimed at improving quality, but so far it has been largely uncoordinated. Research now going on at the University of Southern California is seeking ways of predicting whether a programmer-trainee will become a good programmer; unfortunately, nobody knows how to describe a good programmer, much less how to decide whether one good programmer is worse or better than another. Another researcher has proposed to use proofreading theory, estimating the number of undiscovered errors through a curve that shows number of errors found as a function of the number of search hours. Some proposed measures of quality are subjective, resting on assessments by supervisors or examiners. More objective measures estimate such things as running time, debugging time, or number of errors. The statistical theory of the design of experiments might be used to devise better test patterns for completed programs, perhaps to increase the probability that a hidden error will be uncovered, perhaps to estimate the number of errors still remaining. We cannot tell, now, which (if any) of these approaches will lead to a practicable theory of quality control for programmed systems; it may well be that we shall need a completely new approach.

This idea of a new approach must not be taken lightly. It suggests that people who are just learning about computers have perhaps a special opportunity. Once a person has completed his training, he is conditioned to accept the status quo, and it hard for him to see how things could be different. Yet, every existing entity has come to be what it is through a long evolution, during which many decisions have been influenced by chance or by the momentary advantage. It does not follow that because a species has attained a considerable success it will survive: witness the dinosaurs, perhaps the human race. If some really new approach is to be found to the problem of controlling quality in system design and operation, the greatest promise lies with persons whose thinking has not yet been trained to run in the familiar ruts: the managers who are just learning to live with computers, and programmers just learning to use them.

We come now to a second area for quality control: one that has been much neglected, but in which at least some activity is showing. This is the area of documentation.

To get an idea of the magnitude of the problem, let's look at a few data. According to one source, a complete library of current scientific and technical literature would have to contain over twenty million volumes. Every year, 200,000 more volumes would have to be added. In addition, space would have to be provided, every year, for over a million individual papers and special reports. Just to list these, assuming you could get 18 titles to a page, would take over 250 typewritten pages every day. Just to pick up and skim through all these new publications, allowing 15 minutes for each, would provide full-time work for 150 people.

These figures include only scientific and technical material. We can only guess at the volume of reports for management--printed, mimeographed, typewritten, perhaps scribbled on memorandum pads. One estimate says that worldwide business uses 2½ trillion sheets of paper a year: ten billion every working day.

The national defense establishment is disturbed over the paper situation. NAVY MANAGEMENT REVIEW (September 1964, page 9) says in part: "The combat readiness of the fleet is in danger of being smothered under a mountain of paperwork...Officers and men are spending more time in maintaining records on gunnery, for example, than on actual or simulated firing practice... Equipment is being crowded out of ships because of the space required for files." In the old days a war could be lost for want of a horseshoe nail; today it is equally possible for the world to be destroyed because of a misplaced comma or a dangling participle.

In science, the paper situation results in tremendous waste. It is simply impossible for any scientist to read more than a small fraction of the new literature of his field, or even to read the abstracts. It follows, then, that every scientific job has to be done over and over again, because scientists have no way of knowing that it has been done already. According to one published report, a major steel company has established a rule of thumb: if a project is budgeted at less than $100,000, no literature search is made. This rule becomes reasonable when we remember that while we know how big the haystack is, we can never be sure there really is a needle. Even worse: if there is a needle, it may be hidden inside a straw and so escape discovery unless we tear each straw apart; that is, the language of the published paper may be so obscure or ambiguous that only by the most careful and detailed scrutiny can the result be recognized and understood. I would guess that scientists today function at about ten percent efficiency, because they cannot know what their colleagues have done, and so are forced to do it over.

This situation has arisen from a complex of causes, but the chief one seems to be the struggle for status. In university faculties, and to a great extent on industrial research staffs, a man will be recognized and promoted if he does a lot of publishing. Theoretically the quality of his publications should count for something, but in practice it's likely to be quantity. I hear of colleges where advancement comes only if you publish at least two papers a year. Too often in industrial research the department heads are caught up in a routine of committee meetings, briefings, and other administrative work; if they have time left for reviewing papers by members of their staffs, they can still hardly forget that their own performance will be measured partly by the number of such papers that get published. The result is a vast outpouring of trivia. This would do no harm if it could only be segregated and forgotten, but unfortunately the pages on which it is printed are just as durable as any others, and so remain to dilute the tiny output of important research. Needles are as scarce as ever, but haystacks get bigger and bigger.

To make matters worse, many of our scientific papers (and business reports too) are virtual cryptograms. The precedent was set in the old days, when scientists sometimes announced their discoveries in cipher (to establish priority and keep off the heretic-hunters and witch burners). In mathematical work, for example, a writer will tend to use the most advanced mathematics he knows; he will not use simple algebra if calculus will do, and not calculus if he can drag in some higher discipline. This practice has two good effects. It saves space, and so enables the journal to print more papers. It also establishes the author as an expert in abstruse methods. The penalty is that even readers who know the mathematical methods have to work through the paper slowly, and those who don't know them can't read the paper at all.

Poor writing can be costly. In California, in the election of November 1964, voters had to vote on 17 propositions. According to one commentator, a voter needed a vocabulary of 20,000 words to understand the ballots. It has been suggested that on several of the propositions voters were so confused by the wording that they marked the opposite vote from the one they intended. At least some of the cost of providing the voters with a chance to say their say was wasted through slovenly writing. Again in California, in December 1964, the Department of Motor Vehicles sent out cards with the yearly registration notices, reminding car owners that they must install antismog devices on their cars during 1965. The instructions on the card created so much confusion that the legislature, in February 1965, passed emergency legislation that in effect removed the requirement, thus losing all the money and effort that had been spent in preparing the law originally (not to mention the cost of the cards). Much of the documentation in the field of computer-based systems has been unbelievably bad. I know of at least two instances in which an incomplete system had to be shelved because of administrative difficulties. In each case, the work already done was set out in documents; the authors of the documents were then transferred or terminated. I have studied these documents, and I assert confidently that without conferring with the authors, no newly assigned personnel could possibly pick up this work where it was dropped; the documents are too vague, and in many places just incomprehensible. I see no chance that any of this investment can ever be recovered.

What are some possible remedies for the state of our paper work? One, I think, must be population control. Somehow, we must check the sheer volume of trivial paper that gets written and published. Obviously, voluntary restraint will not work here if authors believe that their promotion depends on the number of documents they write; it seems, then, that we are forced to some kind of traffic control system. Somebody must be responsible for saying, "This paper isn't worth publishing." Our journals have referees who supposedly do this; perhaps review boards could pass on company publications. The choice would be an agonizing one, especially when the president of the company writes a piece of trash; but without somehow reducing the quantity of unimportant paper, we shall never be able to get at the important part.

Another partial remedy for the paper flood might be more selective distribution. Perhaps not everybody on a distribution list really needs a copy of the report; maybe he could make do with occasional reference to a library copy. We could even question whether our professional societies are performing the most useful possible service by publishing journals of the usual makeup. Perhaps these societies would serve their members better, not by supplying complete copies to all members regardless of interest, but rather by preparing an annual or semiannual digest of the state of the art in each subfield (such as tropical agriculture or plasma physics) with appropriate references to individual papers. The papers themselves could be prepared by the authors on such duplicating equipment as they had, or perhaps printed at the author's expense by the society. The author could distribute them free or with a charge. Obvious as the objections to such a procedure are, the alternative seems very much worse, for under the present system, members of a professional society get a lot of papers they don't want, and have no way of making sure that they get all the papers that they do want.

But even if we succeed in reducing the total volume of paper produced, and improving its distribution, we still have the problem of getting quality in the papers that are worth producing. The miserable state of technical writing can hardly be exaggerated. In 1963, a Presidential panel reported as follows:

> "Much more obvious than any deficiency in our understanding of the communication process itself...is our inability to use natural English properly. This Panel is gravely concerned...that so many American scientists can neither speak nor write effective English, that the new language of science and technology is turgid, heavy, and unclear." (from the report SCIENCE, GOVERNMENT AND INFORMATION, available from Superintendent of Documents, Washington, 25¢)

The Los Angeles TIMES for 1 October 1964 carried a news item: of 9,000 new freshmen admitted to the University of California, nearly 5,000 were required to take a remedial English course--the so-called "bonehead English." And this, please note, was at the University of California, which accepts only the cream of the high school graduates. Of course, nobody pretends that taking Bonehead English makes finished writers out of the students. The Presidential panel already quoted goes on to say:

> "The seeds of articulateness are sown in the home and at the elementary and high school level. Nevertheless, we strongly suggest that science and engineering departments demand much more expository writing as part of regular courses, and that ability to communicate well be made a firm requirement for graduation from our technical schools."

One might suppose, from the incompetence of our technical people in using English, that they had not had enough English courses in grade and high school. Actually, English is the one subject to which they have probably been exposed every year since kindergarten. The trouble seems to be, not too few courses, but courses of the wrong kind, and perhaps also teachers with the wrong objective (at least from the scientist's point of view). I myself was an English major in college, and I can testify that it is possible to get a bachelor's degree in English and never once hear anything about language as a vehicle for communication. There is a snobbery in the academic world, and though I think it is dying out, yet vestiges remain, so that children still think they show off their command of English by using long words and elaborate sentences.

Sooner or later we must come to this: The study of English as one of the liberal arts, with emphasis on literature, does not prepare scientists (or managers) to communicate effectively with each other. Just what will be done, I don't know; but my guess is that we shall see two distinct curricula in English, flourishing side by side and overlapping only a little. One of these will follow classical lines, devoted mainly to Chaucer and Shakespeare and the Brownings and maybe James Joyce. The other will try to develop skill in communication, without too much attention to rich, beautiful prose. The new courses might not be taught in the English department at all, but perhaps in Psychology or Engineering. The innovation will have to come, I think, at the college level; we don't have properly trained teachers to carry it into grade and high school, and new teachers will have to be educated. Obviously, this process will take a long time.

We can do something to produce results in our own time. Many scientists and managers could write more clearly than they do if they knew what was wanted. This is where quality control comes in. Recent research on learning proves that people learn faster when they get prompt feedback about their performance. We can improve the quality of technical papers by adopting some kind of scoring system and letting each writer know his score. This method may not produce better papers, but it ought to encourage them. It is up to us to choose a good system, in which higher scores will mean better papers.

Several such systems have already been proposed, and have had limited trials. The earliest seems to be that of Rudolf Flesch, who in 1946 published a scoring system based on (a) sentence length; (b) frequency of words with prefixes or suffixes; (c) frequency of personal references (THE ART OF PLAIN TALK, by Rudolf Flesch; paperback edition published in 1962 by Collier Books, N. Y.). Flesch later published another scale that was a little easier to use. Robert Gunning proposed an even simpler measure (the "fog index") based on sentence length and the proportion of long words--3 syllables or more (HOW TO TAKE THE FOG OUT OF WRITING, by Robert Gunning; a 64-page booklet published by Dartnell Corporation, Chicago 40, Ill.). Both the Flesch and the Gunning scales have found some use, but I know of no agency, private or government, that systematically grades the output of its writers using either of these scales, or any other.

(It would take a lot of research to decide whether one of these scales was better than the other, or whether perhaps some entirely new scale would be better still. Nevertheless, the research is entirely feasible; the problem is urgent; and I for one am disappointed that so little effort is being expended.)

We need not sit idle waiting for the research to begin. Even if the scales are imperfect, they have some merits: they are easy to use, and they are objective, not depending on personal opinion. Anyone with a high school education could grade a document using the Gunning scale, provided it was written in English (not, for example, algebra). It would not cost much to evaluate, by this scale, each document produced, and feed results back to authors. The important point is that the problem is urgent, and that if we wait for the perfect solution, we'll wait forever.

The real crux of the quality problem lies in fact with management itself. No organization will be enthusiastic about quality if management is apathetic, or if lip service to quality ideals is not backed up with action. Professor Myron L. White (University of Washington) says in an article in the January 1965 STWP REVIEW (Society of Technical Writers and Publishers) that much "of the responsibility for bad writing...belongs to...management....Consequently, no number of the best courses in the world will, by themselves, greatly improve the writing. Management does not...take writing seriously enough to play a constructive role in improving it....One manager...could not find a place for a near-incompetent engineering aid and finally decided that this man would do all of the writing for the group....All too rare is the manager who pats a writer on the back for...a good job." I think we can improve the quality of our documents, making them easier to understand, and conserving the time of readers, the day we stop talking and do something. The mere knowledge that management would insist on effective writing would go far to raise the standard.

People who control research money tend to favor projects that promise a great deal, even though the promise may not be kept. We all thrill at a spectacular breakthrough, and wish we could produce one ourselves. But the fact remains that progress in science (and management too) must come mainly from evolution: the gradual improvement of tools, the advancement of skill by trial and error, the clarification of small but basic scientific ideas. I do not look for any dramatic novelty in the improvement of computer programs, or of document writing. On the other hand, I am confident that patient, persistent effort will pay off in time. What we lack today more than anything else is the spark, the drive, the enthusiasm that only leadership can provide. Improved quality is an easy cause to champion, and there should never be any question about our dedication to it. When this dedication is well understood, progress must follow. In this effort, as with most others, faith, zeal, and patience are strong guarantees of success.

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