

TECHNOMYOPIA THREATENS OUR NATIONAL SECURITY:¹

A Critique of the Defense Science Board
Military Software Task Report

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ABSTRACT

The United States Department of Defense is wasting very large sums of money on systems that exceed the scale of human comprehension. These expenditures, together with the diversion of talent into areas that are not very productive, are helping to make us a second-rate economic power, and threatening thereby our national security.

While many case studies could, individually, illustrate the situation just mentioned, the 1987 Report of the Defense Science Board--Military Software Task Force serves as a representative example to illustrate how our system is not serving us well.

Some of the contents of the Report are excerpted, and the 38 recommendations are examined as a way to deal first with the Report in its own constrained context. Then the Report is critiqued in respect to that context, and some priorities are proposed for the Board's recommendations, using categories that I identify.

A set of what appear to be implicit assumptions behind the Report is offered, and it is suggested that these form part of the basis for assigning the term "technomyopia" to refer both to the Report and to the larger surrounding situation with regard to defense systems acquisition.

Matters relating to the software dilemma and its management are discussed, with reference to prior nationally-significant institutional foulups in the steel and auto industries, which are historical versions of myopic vision that has cost us dearly.

Some of the major problems related to current practices of the Department of Defense are then discussed, and a few new recommendations are offered. These are believed to be more fundamental than the recommendations in the subject Report.

¹ Most of this paper was delivered at a joint session of the Northern Virginia Chapters of the IEEE Computer Society and the IEEE Society on Social Implications of Technology in the summer of 1988. Recent additions in 1992 augment the original version.

1.0 INTRODUCTION

The United States Department of Defense is wasting very large sums of money on systems that exceed the scale of human comprehension. As a result, taxpayers are going into debt to pay for very expensive products that are ill-conceived, ill-developed, ill-produced, and frequently unworkable. This situation is placing great strains on our national economy, and it is diverting significant amounts of talent from areas that require it in order to maintain national competitiveness. It has also been a major factor in making us the world's largest debtor nation.

"The Competitiveness Index gives the public a clearer method of understanding how America stacks up against our competitors and how our competitive position affects every American worker's well-being. The bad news is that the Index reveals the United States is losing its competitive edge, threatening this nation's future wealth and prosperity," said John H. Young, president and chief executive officer of Hewlett Packard Corporation, and chairman of the Council on Competitiveness.

--The Washington Post, Friday, June 3, 1988, page G1.

The eighties may be viewed by history as a period when the United States went from being economically dominant in world affairs to becoming a second-rate economic power. And history will certainly perceive the mammoth budget deficits incurred during this period both as a response to what otherwise would have been a collapse of the dollar altogether, and as a major contributing factor to the loss of competitiveness in international markets.

During this period, many of the best and brightest young American scholars have been attracted into two areas where their potential contributions to our economic strength have been severely diluted. I refer to the work that is being done in the defense industry and that done in the legal profession. In the defense industry, huge amounts of our national talent are engaged in producing things that often don't work, but even if they did work, many of them would almost certainly never be used. And in the legal profession, many people are working to do such things as transfer assets back and forth from one management to another at considerable expense, support financial transactions that create no values other than for the legal profession, and slow down efforts to be competitive in the international arena. It is well-known, for example that the U. S. has about 20 times as many lawyers per capita as Japan. A value-added tax imposed on most of the activity described would produce no tax revenue.

The causes of these situations are, no doubt, multiple. But certainly the dearth of insightful leadership at both national and state levels is a major factor. The twin abuses of poor investments in national defense and in educating far too many lawyers reinforce each other to weaken our national productivity. Many thousands of small, uncoordinated governmental decisions that may look fine from a local point of view, add up to an integrated, creeping disaster for the country.

My topic tonight, the Defense Science Board Military Software Task Report, is just one of many

examples of how our system is not serving us well. Unfortunately this Report is not unique in standing out from many others of its ilk as being unusually poor. It is just one timely example of many that could equally well be chosen to illustrate a kind of technomyopia that threatens our national security. To see this Report as an isolated event in our lives is to miss the opportunity to exploit its highly-representative example of what needs to be corrected by strong action at the federal level. Yet one must see it first in its own specific context, and on its own terms. After that is done, one can draw on it as a way of illustrating the larger malaise within the Department of Defense, and especially within its system acquisition activities.

I seek to present an overview of the Report as dispassionately as I can in Sections 2-6 inclusive of this paper. Then in Sections 7 and 8 I comment on it in its specific context and propose priorities on the Recommendations in the Report (which the Report does not do). In Section 9, I offer some reasons for using the word "technomyopia" to characterize the Report. In Section 10, I review briefly matters related to managing the software dilemma. In Section 11 I discuss briefly problems of the Department of Defense, especially related to acquisition of systems. I conclude in Section 12 by offering a few recommendations for ways to make improvements, not just in the software arena, but in the general area of defense systems acquisition and design.

2.0 THE GENESIS OF THE BROOKS REPORT

In November of 1984, a memorandum was sent from the Department of Defense (DoD) to its Defense Science Board (DSB), requesting that a Task Force on Software be formed to carry out certain activities to assist DoD to improve productivity in software development. About **three years later** (!), in July of 1987, the Chairman of the Task Force on Military Software (Professor Fred Brooks of the University of North Carolina, and a former high-level IBM executive), forwarded the Report to the Under Secretary of Defense for Acquisition. The report was titled "Report of the Defense Science Board Task Force on Military Software", but in this paper it will henceforth be referred to as the "Brooks Report", in honor of its Chairman.

3.0 AN INITIAL REACTION TO THE BROOKS REPORT

The Brooks Report has three major attributes:

- o A set of 38 recommendations that vary from reasonable to unreasonable, which are neither mutually consistent nor consistent with what is said in the Report
- o Essentially no scientific content, even though one would presume that a report submitted by a Task Force of a Defense *Science* Board ought to reflect some science
- o Certain generic characteristics that qualify it to be viewed as an illustrative example of one of the major problems that DoD presents to the nation: inability to provide sound management to systems acquisition, leading to excessive costs that threaten the fiscal security and thereby the national security of the United States.

The presence of this last attribute is ironic, when one believes that a major purpose of DoD is to defend us.

In the light of this interpretation, I sent a letter to the IEEE Institute newspaper in which I expressed some views about the Report. The letter I sent was edited down somewhat by IEEE to meet space requirements, but its essential content was preserved. As a result of that published version of the letter, an invitation was issued to me to discuss it at an IEEE Chapter meeting.

4.0 THE EXECUTIVE SUMMARY OF THE BROOKS REPORT

I will highlight selected material from the Executive Summary of the Brooks Report. According to the Report:

HIGHLIGHTS FROM EXECUTIVE SUMMARY

A. Many PREVIOUS STUDIES have provided an abundance of valid conclusions and detailed recommendations regarding military software, but most remain unimplemented.

B. Few fields have such a LARGE GAP between best current practice and average current practice.

C. The FIVE CURRENT DoD MAJOR SOFTWARE INITIATIVES (Ada, STARS, SCI, SEI, and SDI) are uncoordinated. Two of them are characterized as follows:

- i) STARS: "little progress...vague and ill-focused plans for the future...recommend that the STARS JPO be moved from OSD to USAF Electronic Systems Division".
- ii) Ada: "...by far the strongest [standard programming] language in sight...state of Ada compiling technology is now such that it is time to commit vigorously and whole-heartedly...development of unified programming environments is required...recommend that [AJPO] be moved from OSD to...USAF Electronics Systems Command..."

D. Concerning DEFENSE ACQUISITION PRACTICES: buy in the civilian market; get a new life-cycle model (dispense with the waterfall model and embody the early specification in a prototype which the intended users can themselves drive in order to see the consequence of their imagining); overhaul DoD STD 2167; revise Directive 5000.29; let several contracts to develop requirements and early prototypes, then a single contract for construction; provide incentives; encourage reuse of software; establish a public market in reusable software parts; and phase out substantial software-building efforts underway within the Services in order to concentrate the available knowledgeable officers upon acquisition.

5.0 THE INTRODUCTION TO THE BROOKS REPORT

I will excerpt selected material from the Introduction to the Brooks Report. The introduction contains the following:

EXCERPTS FROM THE INTRODUCTION

A. **CHARGE TO THE TASK FORCE.** Assess and unify various recent studies; examine why software costs are high; assess STARS; recommend how to enlist industry, Service, and university efforts in a productivity thrust; recommend how to apply R&D funds to get the most increase in military software capability; recommend how to implement an evolutionary approach to use of R&D funds; assess the wisdom of the Ada plan, including fourth-generation languages.

B. **WHAT THE REPORT SAYS THE TASK FORCE DID NOT ADDRESS.** Problem seriousness sizing, non-mission-critical software, Service-specific personnel problems, SEI, SDI, SCI, and new technological initiatives.

C. **MILITARY SOFTWARE.** Has a major role in today's weapons systems; cost \$9 billion in 1985, and is projected to cost \$30 billion by 1990. Deficiencies in software affect overall weapons systems performance and cost quite out of proportion to the software cost itself; timeliness and reliability are more important issues than cost; requirements-setting is the hardest part; the big problems are not technical.

D. **WHY SOFTWARE TECHNOLOGY GROWS SO SLOWLY.** Hardware technology is so fast-growing, software is labor-intensive; the essence is designing intricate conceptual structures rigorously and correctly; further methodological improvements will have to attack the essence--conceptual design itself.

E. **CURRENT SOFTWARE TRENDS.** Microcomputer and personal computer; mass-market for software; technology for software modularization and reuse; rapid prototyping and iterative development; professional humility and evolutionary development.

F. **RECENT RELATED SOFTWARE STUDIES.** The 1982 Druffel study summarized 26 previous studies. Appendix A4 to the Report lists the recent studies (including a speech by former Secretary Weinberger).

6.0 RECOMMENDATIONS OF THE BROOKS REPORT

The Brooks Report contains 38 recommendations. These were not placed in any categories, nor were they prioritized. In order to make it easier to discuss them, I placed them in categories. The eleven categories and the essence of the recommendations under each category are as follows:

RECOMMENDATIONS BY CATEGORIES

- A. **COMMERCIAL/BUSINESS INCENTIVES.** Encourage or mandate that DoD buy commercial software whenever possible, and provide economic incentives to do so (*21% of all recommendations deal with this subject*).
 - B. **SYSTEMS ENGINEERING PRACTICES.** Strive to change the DoD paperwork that encourages outdated practices and encourage the use of newer practices with new paperwork (*13% of all recommendations deal with this subject*).
 - C. **PERSONNEL PLANNING AND EDUCATION.** The Secretary's level in DoD should do personnel planning to reallocate existing personnel, to provide more education for current software personnel, and to emphasize training in Ada (*13% of all recommendations deal with this subject*).
 - D. **REDEPLOY PEOPLE AND PROGRAMS.** Move at least two of the five DoD software initiatives to a new physical location, and put them under a unified command or coordinator. Those now writing software in DoD should be taken off such assignments and moved into software acquisition positions (*8% of all recommendations deal with this subject*).
 - E. **PROGRAM PLANS.** A coordinated program plan for the five DoD software programs should be cooperatively prepared, and used to bring coherence to the total effort. Also the role of User Commands in this plan should be defined (*8% of all recommendations deal with this subject*).
 - F. **PUSH ADA.** The thinking on Ada has all been sound, except possibly for the timing of its introduction, and it should be pushed by top DoD management. A "module market" should be developed for Ada and used to encourage reuse of Ada software (*13% of all recommendations deal with this subject*).
 - G. **REVISE ACQUISITION POLICY.** Four software categories are offered as a basis for formulating new acquisition policy. Acquisition should be sensitive to the differences among these categories. Risk management should be used, with evolutionary acquisition to reduce risk (*8% of all recommendations deal with this subject*).
 - H. **MANAGE BY SOFTWARE CATEGORY.** In line with item G, manage software acquisition using the four categories (*3% of all recommendations deal with this subject*).
 - I. **DEVELOP METRICS.** Develop metrics to measure software quality, completeness, and implementation progress (*5% of all recommendations deal with this subject*).
 - J. **ENHANCE CAPABILITIES OF THE SERVICES.** Give the Services capability for rapid prototyping, and facilities for comprehensive testing and life cycle evaluation of software extensions and changes (*5% of all recommendations deal with this subject*).
 - K. **RESEARCH ON THE STRATEGIC DEFENSE INITIATIVE.** A critical research mass should be focused on software that is unique to SDI objectives (*3% of all recommendations deal with this subject*).
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7.0 COMMENTS

A. *The Task Force did not address fully its charge.* It did not say, for example, "how to enlist industry, service, and university efforts in a productivity thrust", nor did it say "how to apply R&D funds to get the most increase in military software capability". The Task Force had 20 members, and only one or two of these appears to have had any longevity in an academic position.

B. *The Report misrepresents its own content.* While the Report states that it did not address the items listed in 5.0, Excerpts From the Introduction, Item B, the report clearly did so as follows:

- o Item C (Military Software) is clearly oriented toward sizing the seriousness of the problem
- o The recommendations to buy civilian software certainly seem directed more to "non-mission-critical software" than to mission-critical software. For example, one does not imagine that a missile would be guided with a commercial word processor.
- o Recommendations were made about SEI (a total of four, i.e., 11% of all recommendations) and about SDI (just one, i.e., 3% of the recommendations)
- o Although the Report says that the Task Force did not address new technological initiatives, their statement that they do not recommend any is the most negative possible way to address them. One may readily note, however, that the Report did not even mention the concept of "scientific initiatives" (as distinct from technological).

C. *The Report has virtually nothing to say about science.* Amazingly, the Task Force has virtually nothing to say on science, even though the Task Force directed its report to the Defense Science Board. The Board itself was also silent on science in its letter of transmittal to the Under Secretary. One might conclude from this that science has nothing to offer to improve productivity in software development. Is it unreasonable to suppose that perhaps the Task Force had no scientists on it or, possibly, that it does not comprehend the difference between science and technology?

8.0 PRIORITIES

Although 38 recommendations appear in the Report (which I organized into the 11 categories that appear in Section 6 of this paper), there appears to be no prioritization of them in the Report. Prioritization can be viewed (in the words of the Report) as oriented toward "designing intricate conceptual structures rigorously and correctly" [which Ref. 1 deals with rigorously and correctly]. In the absence of any priority structure for the recommendations, I have prepared one myself which, perhaps, is flawed, but is certainly definite and backed up by comments. My priority structure prioritizes the 11 categories rather than the 38 recommendations. Appendix B shows

the priority structure. It reflects the view that some recommendations are much better than others, as well as the fact that success with some of them would be dependent on prior achievement of others of them. I will now discuss the priority structure, beginning with the category of recommendations that I favor most, namely metrics.

A. *The software field has consistently lacked sensible metrics to measure productivity or quality.* I have proposed a metric for measuring software complexity (Ref. 2). The absence of metrics or the failure to use metrics means that many decisions being made in software development and in acceptance are undisciplined by any effective standard. This is one of the truly major distinctions between software and hardware. Hardware benefits from the discipline imposed on engineers and designers by the metrics of physical science, which govern the way people specify, measure, and report on hardware and its performance.

B. *The four recommended software categories are interesting, and the intent behind their proposed use is commendable, though the Report may not be sufficiently specific to permit effective categorization.* The desirability of developing *program plans* for the programs, as well as some overall, coherent, integrating plan seems self evident. One is forced to wonder why Congress is willing to provide so much money for these programs in the absence of good plans. Perhaps the absence of respectable metrics is the key to this as well.

C. *The need to revise acquisition policies is clear to anyone who interacts with the acquisition system, whether it involves just software or other acquisitions.* Also it certainly seems advisable to *provide training* for people in administering acquisition. It is surprising that the Report does not mention the Defense Systems Management College. This College has had responsibility for training program managers for years. It would be a natural place for such training to be done. Yet this College is presently budget-limited to one or two people to do all the software acquisition training related to what is likely to be 10% of the entire defense budget!

D. *The revision of systems engineering practice, while clearly needed, is not likely to be helpful unless higher priority items are carried out.*

E. *Purchase of commercial software and provision of business incentives is a matter for discussion that goes beyond the seemingly authoritative (but not backed up with any detail) statements in this respect in the Report.* The Report seems to presume that software vendors can actually describe their commercial software in sufficient detail that acquisition program managers can make informed judgments about the potential utility of the software in the so-called mission-critical areas. Yet it is hard to believe that when software design is uninformed about how to design "intricate conceptual structures", reliable explanations of software can be furnished. Without such reliable explanations based on good understanding of the "intricate conceptual structures", it is hard to see how critical defense missions could be tied to such software (or for that matter to any software). As the Report itself indicates, the production of such intricate conceptual structures seems to be beyond the capacity of the whole industry at this time, and no suggestions are offered for ways that science might shed light on how to do this.

One wonders just what the Report means by "intricate conceptual structures". Maybe this is a metaphor that is deliberately vague. Many would interpret this literally to mean graphical representations of the structure of large programs (and system concepts). However Brooks himself has stated in his now rather well-known "silver bullet" paper that he sees no merit in graphical representations. Without graphics, we are left only with prose or mathematics as vehicles for communicating structure. It is hard to see how complex concepts which, in engineering, traditionally have benefited substantially from the use of graphics, can be communicated without them--but this is only one of the mysteries surrounding this Report. Anyone who has looked at a patent can surely understand not only why graphics are valuable, but also can see why it is important to do a first class job on them in order to gain the most from their aid in explaining things precisely. Similarly, anyone who has read the support literature provided by software vendors knows that such vendors do not provide such graphics.

F. *While the Ada language has devotees, or some would say fanatical adherents, the Brooks Report acknowledges its complexity as one of the factors that has prevented more use of it.* The criterion used to assess the timeliness of Ada-pushing is the state-of-the-art of Ada compilers. Recent data suggest that taxpayers have supported the development of more than 120 Ada compilers. A private communication from a person intimately involved in this area suggests that only two of these are reasonably adequate. One might ask whether there are not other indicators of readiness for Ada besides the availability of compilers.

The philosophy that the use of a standardized, single language has much to offer the DoD is commendable. However this philosophy alone is not sufficient to recommend the use of Ada. What is flawed in this arena is the concept that people should adjust to and work with whatever level of complexity is bureaucratically imposed upon them, without any clear evidence that people can handle such levels, rather than that one should design systems that take into account human limitations (Ref. 3).

G. *Presenting recommendations for redeployment of programs and people seems like an easy way to avoid thinking about how to solve the problems of low software productivity and high cost.*

H. *No area has seen more informed criticism in recent years than the Strategic Defense Initiative (SDI).* The software part of this conceptual system has had the most informed, outstanding criticism. Nonetheless the Report ignores the criticism, and simply urges more focus upon software issues. Perhaps this shows most clearly the limitations of the Task Force. As long as science and scientific knowledge are ignored, such "political inventions" as SDI will continue to attract funds. Perhaps Albert Einstein, John von Neumann, Norbert Wiener, and other great scientists who have had such constructive influences on American technology are turning over in their graves as a consequence of present management of SDI.

9. SOME IMPLICIT ASSUMPTIONS BEHIND THE BROOKS REPORT

It appears that there are some implicit assumptions behind the Brooks Report which can be seen as symptoms of the disease called "technomyopia". The following are suggested as some of them.

A. Assumptions about the community external to the software community.

- o There is no knowledge lying outside the software community that can benefit it significantly.
- o There is no relevant science that can be brought to bear on software development.
- o Science has no role to play in software development, in cutting software costs, or in enhancing productivity.
- o There is great software available outside the defense community, which DoD ought to be buying in large quantities.
- o The only motivation working for Americans is profit, therefore the profit motivation should be used to make DoD buy the commercial software.

B. Assumptions about responsibility for the current software mess.

- o If anyone is responsible for the current software mess, they are not around now to scapegoat (or if they are, they should not be criticized), and certainly they are not the people involved in the Task Force.
- o The practice of substituting personal (expert) opinion gained through experience in a defective field for science is not responsible for the mess.
- o The defense business split between hardware system design and software system design (i.e., having some companies who do one and other companies who do the other) has proved to be a good idea. The practice is irrelevant with respect to software productivity.
- o It is more important to honor sacred cows than it is to solve the software mess and help rescue the national economy (and sustain the software business internationally).

C. Assumed management principles.

- o Any time you have several organizations that seem individually to be inept or unproductive, that don't plan, and that don't produce, the solution is to put them all together under one management.
- o The only operative incentive for good management is profit, which is sufficient to overcome inadequate knowledge and training.
- o Management is a fine substitute for science, just as "growing" or "building" software is a fine substitute for designing software.

D. Assumptions about recommendations.

- o Never prioritize recommendations.
- o If you're not sure about a recommendation, make the broad claim that you are not addressing

the issue to which it pertains, then go ahead and make the recommendation.

10. MANAGING THE SOFTWARE DILEMMA

A total conceptual solution to the software dilemma exists, which the present establishment is not prepared to recognize or to implement. This is not an unprecedented situation in America.

Some years ago, the Washington Monthly published an article in which they clearly explained the demise of the American steel industry. It was a joint (though relatively uncoordinated) outcome of the actions of three major institutional actors: the steel unions, the steel company managements, and the federal government. Each actor in its own way, each in its own time, took actions aimed to protect its narrow interests or its own perceived mission, which collectively decimated this industry.

In the American auto industry, one can recall when General Motors had 54% of the domestic market. Financial observers said that the only thing preventing General Motors from getting a larger market share was fear of anti-trust action by the federal government. Now General Motors has less than 30% of the market. How times have changed! Is it possible that the same kind of adversarial coalition, each acting to protect its immediate interests, each acting on its own perceived legitimate behalf, is also responsible for the demise of this domestic industry? The same science of quality control made available to Japanese industrial management was readily available to American industrial managers ever since its presentation by Shewhart of the Bell Laboratories in the 1930's. These managers chose to ignore it, partly because they were convinced that quality products could not be made in America at a reasonable price.

Dr. Louis T. Rader, formerly President of Sperry Univac and Vice President of General Electric Company and now Professor Emeritus in the Darden School of Business at the University of Virginia, told me that when a Japanese firm bought the Motorola Quasar television plant, American management was convinced that the product failure rate could not be improved. Yet Japanese management brought the failure rate down substantially, partly by requiring that if any television set that came off the production line failed any tests, the Manager of Quality Control was required to fix it himself. The skillful use of incentives is something that should be familiar to American managers, but pay is not the only incentive available. Of course it is much easier for managers to blame shoddy workmanship for bad product, rather than to institute effective systems of quality management.

The information industries, with international competitors openly declaring that they intend to dominate this market, are not immune to the kind of behavior mentioned in the foregoing. They owe the nation something better than what is offered in the Brooks Report.

Not long ago I met Dr. Ryo Hirasawa who was then the chair of the Department of General Systems Science at the University of Tokyo. That Department, with a faculty of about 35 people, is part of the College of Arts and Sciences. The Department began after the Prime Minister of Japan and his colleagues identified seven areas that were judged critical to the future of Japan.

This area was one of the seven. By contrast, in America, universities are still displaying confusion about how to organize the information area and where to place the administrative power. The use of the word "system" is fairly common, but it is a very restricted concept, as interpreted in the typical American university. As the late Sir Geoffrey Vickers wrote, "...throughout almost the whole of human history, technology has progressed with an uncanny ignorance of the scientific principles which were guiding it", and as he further stated, "...it [the word 'system'] has, however, become so closely associated with man-made systems, technological design and computer science that the word 'system' is in danger of becoming unusable in the context of human history and human culture. I seek to contribute something to its rescue and restoration. For we need it for understanding and for action in human and social contexts far too complex and imprecise to admit of formal modeling". Conceptual stewardship is not a goal in most engineering schools, but restriction of the language to narrow contexts is common practice.

Dr. Harlan Mills, a prominent U. S. computer scientist, mentioned that a book on software that he and two colleagues produced in the late 1970's was judged to be too mathematical for American college faculty and students. Yet the first printing in the U. S. S. R. was 40,000 copies. One of his principal recent suggestions is that, on the basis of available data on software failures, government-procured software should be required to pass rigorous statistical quality control tests, very similar to those to which hardware is subjected, before being accepted. While evidence exists to suggest that this is a meritorious suggestion, no attention is given in the Brooks report to this idea. Absence of it from the Report is reminiscent of the insensitivity to quality control that has long prevailed in much of American industry and which, even today, is still dominant in much of this industry. This is true in spite of the long efforts to give prominence to this idea on the part of individuals such as Professor Deming and Professor Emeritus Tribus.

The availability of a conceptual solution to the software dilemma is of little interest to the software establishment. It has a built-in aversion to listening, understanding, and integrating new ideas into the practice because:

- o Existing management has a vested interest in the state of the art as it is currently practiced.
- o Existing management does not know how to listen long enough and organize the information well enough in their heads to prepare themselves to do the integration [See Ref. 4].
- o If existing management accepted the solution, they would be faced with major management issues relating to implementation with which they have no experience, and with which they are unprepared to cope.
- o As Dr. Paul Gray observed in the Chronicle of Higher Education, and as was observed some years ago by the late James Bryant Conant, the American public has insufficient insight into the difference between science and technology and the need to become educated concerning this difference in order to preserve our national heritage; and, given this handicap, some would insist that the problem is not management's problem, but a problem of the nation as a whole--and leadership (Ref. 5) is so busy with other things that it can't deal with this issue.

Finally, implementation of what is really needed requires more courage than has been evident in most bureaucracies in recent memory. If the ratio of arrogance to courage for today's management in the software arena could be brought from its present large value to somewhere around 1.0, major steps could be taken toward resolving the software dilemma.

The primary focus in the solution would be placed on the theory of relations--that body of knowledge formally introduced into scientific thought by Augustus De Morgan in 1847, and honed further by famous scholars such as Frege and Charles S. Peirce (a now famous graduate of Harvard University whom the then-president of Harvard refused to hire in Peirce's declining poverty-stricken years in spite of William James' impassioned written request, because Peirce was seen by the administration as a trouble-maker). It is that fundamental branch of mathematical logic that furnishes the firm basis for "designing intricate conceptual structures rigorously and correctly" and which provides the basis for a science of design. It is ironic that this scholarly body of knowledge which is not even mentioned in the Brooks Report is the same body of knowledge that underlies the entire information field, including the design of hardware to support information operations. It is the field that underlies the book co-authored by Mills which was mentioned above. And it is a branch of knowledge that can contribute corrective measures in a major, unique, and fundamental way to the rigorous and correct design of conceptual structures in the information field and any other field of knowledge.

11. PROBLEMS OF THE DEPARTMENT OF DEFENSE

The Brooks Report reflects many problems that have been endemic to the Department of Defense. The system acquisition area alone could be the subject of an encyclopedia. A few aspects will be highlighted briefly. The first such aspect is the lack of management continuity, especially in the area of systems acquisition.

THE LACK OF MANAGEMENT CONTINUITY

I know of no business and, especially of no \$300 billion dollar business, that would be permitted to operate without management continuity. Yet this mammoth budget is administered by people who move in and out of government, often lacking management ability, and who are chosen for political reasons. This situation is intolerable, but it offers a simple explanation why that part of DoD that is specifically charged with the education of people for systems acquisition would have a budget of about \$250,000 for education in software acquisition. This is less than one hundredth of one percent of the annual expenditures by DoD on software, which speaks for itself. Lack of continuity of management prevents dealing properly with such overriding matters as these.

To correct this situation, salaries need to be raised well above what is presently being paid for top management, and the Congress (a legislative body without much management know-how) has to learn how to put strong leadership in place for a significant period of time, and stop micromanaging. Continuity of leadership, co-location of responsibility and authority for system design and development, and depoliticization of defense systems acquisition will be traumatic, but it is necessary. The only body that can correct the situation is Congress, and it will never do so unless the American people can somehow learn to comprehend the magnitude and consequences of the waste, as well as the threat posed to the future health of the industry.

The second aspect to be discussed is the terrible decision-making system.

A TERRIBLE DECISIONMAKING SYSTEM

Can you imagine waiting **three years** for the results of a study to try to cut waste and improve productivity? Can you imagine receiving the Brooks Report after such a long time? How can continuity and effective management be found with such indifference to timeliness of information? Can you imagine the situation with regard to Ada, where vested interests are constantly promoting this cognitive nightmare, this camel designed by a committee, and that there is not enough scientific strength applied to this area of decision to allow timely definition of issues and study of decisions? Can you imagine a system that allows continued misallocation of tax funds to the Strategic Defense Initiative, where voices of self-appointed authority tell scientists that this system will work because they say so?

The third aspect to be discussed is the terrible people-calibration problems.

TERRIBLE PEOPLE-CALIBRATION PROBLEMS

It is very wrong to suppose that technologists have the fundamental understanding to guide long-range, large system developments independently of science. It is not the fault of technologists that they are now trying to do so. They have been put in this position by politicians. At one time it was said that "engineers ought to be on tap, but not on top", and this is now more than just a slogan. It is a verifiable statement, when seen in the light of what is being delivered in return for mammoth expenditures. Yet, as Fisher [6] has made clear, there is really nobody in charge. When things are so bad that the IEEE Spectrum itself publishes articles on how bad the designs are, you know that whoever is making the high level decisions is not self-calibrated against any sensible standard. People are being put in positions for which they are totally unprepared by education or experience, and thereby get the message that they are ready to perform. But one must learn to distinguish between feats of intellectual and physical heroism, and activities that are beyond human intellect to carry out at the time and under the prevailing cultural limitations.

The fourth aspect to be discussed is the inappropriate high-level personnel situation.

INAPPROPRIATE HIGH-LEVEL PERSONNEL SITUATION

The military puts its general officers into untenable positions. They are given short-term rotational assignments (one or two years) in positions where several years would be needed to gain the knowledge required to make sound system changes. They are given incentives to make system changes while they are in these short-term positions that will demonstrate their suitability for promotion when, in truth, they cannot possibly make the appropriate changes in such fields as systems acquisition and software development and training. Something has to be done to redesign the on-the-job training of military officers for some kinds of positions. While the health of the services does require that officers be rotated in their assignments, mindless rotation is worse than no rotation. If the length of assignments and the prior education and training cannot be adjusted properly, then high-level management continuity must be turned over to a civilian executive, and the role of the general officers and others who are rotated into assignments requiring long-term understandings must be changed. They should be seen as primarily in learning roles, not in roles that provide incentives for quick reorganizations. There must also be some requirement for communicating with higher-level management boards concerning their achievements in learning what is going on and contributing to it in a staff role, rather than in a command role.

In the absence of such a change, we can expect to continue down the road of trying and failing to compete successfully with people in other nations who value long-term thinking and meticulous learning, as well as systems education and systems thinking, and who have a dedication to thoughtfully articulated long-term national developmental objectives, as well as their own short-term personal advancement.

Finally, at the root of many of the problems of the DoD one finds defective understanding. This is the fifth and last of the problems of DoD to be highlighted in this paper.

DEFECTIVE PHILOSOPHY CONCERNING SCIENCE AND TECHNOLOGY

Somehow the Department of Defense has to learn at the highest levels the differences among science, technology, management, administration, and leadership. These are all valuable concepts, and their integration in one mind places strenuous demands on human learning--especially when our educational institutions compartmentalize the subjects. Somehow we have to find or develop more people in the mold of Generals Marshall and Bradley from World War II, and somehow we have to find a way to get people who have led the software field into its current quagmire out of roles where they cause national productivity to stagnate.

12. A FEW ALTERNATIVES

At the beginning of this article, I said that I would suggest a few alternatives to the recommendations in the Brooks Report. Now I will deliver on this statement, limited by the time available in the presentation and the space available in a paper.

12.1 Generic Design Science and Interactive Management. During the past twenty-two years, my colleagues and I have developed a generic design science that explains how to study, design alternatives, and choose an alternative for a proposed large and complex system. In parallel with that development, there has been a development of Interactive Management, a system that shows how to implement the generic design science in practice.

Design science itself can be broken into three categories:

- o the *specific design sciences*, which underpin disciplinary design, such as electrical design, mechanical design, chemical design, organization design, etc. These specific design sciences embody the fundamental underpinning to modern technology at the detailed level.
- o the *generic design science*, which is virtually orthogonal to the specific design sciences. Its content is founded in anthropological and logical concepts. It is a science focused on conceptualization and representation, involving concepts about human behavior, human beings, their capacities and limitations; involving philosophy and the history of development of logic throughout the almost 2,500 years of its formal existence and evolution; and involving concepts of language and the criteria to be met by language in order to make it compatible with the human mind and its performance in working with complexity.
- o the *general design science*, envisioned as the ultimate integrated body of knowledge bringing together generic design science and the specific design sciences, and which does not presently exist.

The generic design science has been repeatedly tested with real problems and issues, and with people who are engaged with such problems and issues. It works. It provides self-documenting processes that enable people to do exactly what the Brooks Report (correctly) says must ultimately be done: "attack the essence--conceptual design itself". This science enables users to carry out just what the Brooks Report (correctly) says is most critical: "designing intricate conceptual structures rigorously and correctly." With this in mind, an alternative or supplement to the recommendations of the Brooks Report is the following:

That the Department of Defense and/or its defense industry companies dedicate some resources to studying what is already available in this area, and carrying out a carefully designed test of the use of the generic design science through its implementation system called Interactive Management, in the design and development of high-quality software.

Since this recommendation was first made in 1988, it has become possible to report that while this recommendation has not been given any attention, some things have happened that are notable in respect to it. Specifically, the Defense Systems Management College, with the blessing of its Provost, Greg Wierzbicki, and with aggressive leadership from Professor Henry Alberts, has applied Interactive Management repeatedly in a series of workshops to problems of defense acquisition in general. A list of titles of the workshops appears in Appendix C to this paper. The early workshops were held at George Mason University in the then-existing Center for Interactive Management. Almost all the later workshops have been held at the Defense Systems Management College, and have involved numerous well-informed participants from the acquisition community, including both federal government and industrial persons. As a result of these workshops, a redesign of the acquisition system has been largely carried out, and various components of this redesign have been instituted. Perhaps the results of this activity will lend more credibility to the software recommendation, and it may ultimately become possible to see it carried out as intended.

12.2 The Defense Science Board. The Defense Science Board is really a defense technology board. There is a need for a defense technology board, but there is no need to call it a defense science board. Instead, it is necessary to construct a true defense science board comprised of very well informed, practicing, scientists. The roles played by Albert Einstein and John von Neumann in assisting the federal government in moments of dire need can be models for the kind of roles that are required for a defense science board. Very likely it would be desirable to have a small amount of cross membership between a true science board and a technology board.

Not too long ago, DoD had both a Defense Science Board and a Defense Manufacturing Board. The latter was eliminated. What is required is to recognize what is needed and then design the DoD organization so it can benefit from the board deliberations. A true science board would never have accepted the Brooks Report, and would not have forwarded it to higher authority. A true science board would not have been willing to tolerate three years of delay in producing the Brooks Report, no matter what the reasons for its delay.

In the series of workshops carried out by the Defense Systems Management College, reports comparable in scope and complexity to the Brooks Report have been developed repeatedly in less than a month. A nation whose productivity is known to compare very unfavorably with those of its principal international competition cannot afford to ignore this situation, no matter how painful its implications may be.

12.3 The Presidency. Much of the decline in American science and technology in those areas where America is weak has occurred because the President has not accorded to science its proper role in decision making. While it is true that scientists do not speak with a single voice, the role of scientists in the federal administration is murky at best. It is ironic when viewed in the light of history and images of nations that in Germany the scientific community elects to three-year terms the scientists who will advise the government on the allocation of scientific funds; while in America political appointments determine who will offer advice and who will administer the government's principal scientific funding agencies. In recent years, the Congress has chosen to provide funds to local constituencies without regard to qualifications or even interest, establishing operations in critical areas that are staffed with people who are not scientists and who are unknown to the scientific community, and who often will remain so in the future.

It would be appropriate to begin to democratize American science, and to establish and apply honestly criteria for the selection of persons to fill leadership positions in science. One criterion would be that the individuals would have to be scientists. If this criterion alone had been enforced, many of those appointed in past decades would never have qualified for the positions.

12.4 Incentives. An alternative to the cash incentives recommended in the Brooks Report for federal managers to buy commercial software might be to pursue a policy effective in Japan. There, cash bonuses paid to industrial managers of technology are computed from a formula that includes the national productivity of Japan. Perhaps if federal contracts reflected a similar policy, and if boards of directors incorporated such a practice in determining executive salaries (not to mention the requirement that the individual industries themselves show some increases in productivity, the incentive system could work to upgrade effectiveness. Who can presently find any criteria that are applied in setting large salary amounts for corporate top executives in the defense industry (or other American industry) which relate to results?

The front page of the Business Section of the New York Times dated February 9, 1992, shows that between 1960 and 1990 productivity grew in Japan by a factor of 450%. For the same period, in Germany productivity grew by a factor of 220%. In the United States, for the same period, productivity grew by a factor of 145%. These figures are based on data from the Bureau of Labor Statistics. Every indication is that these rates of growth will continue for the foreseeable future, in the absence of some significant change agents.

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APPENDIX A

FIELD REPRESENTATION OF TASK FORCE RECOMMENDATIONS

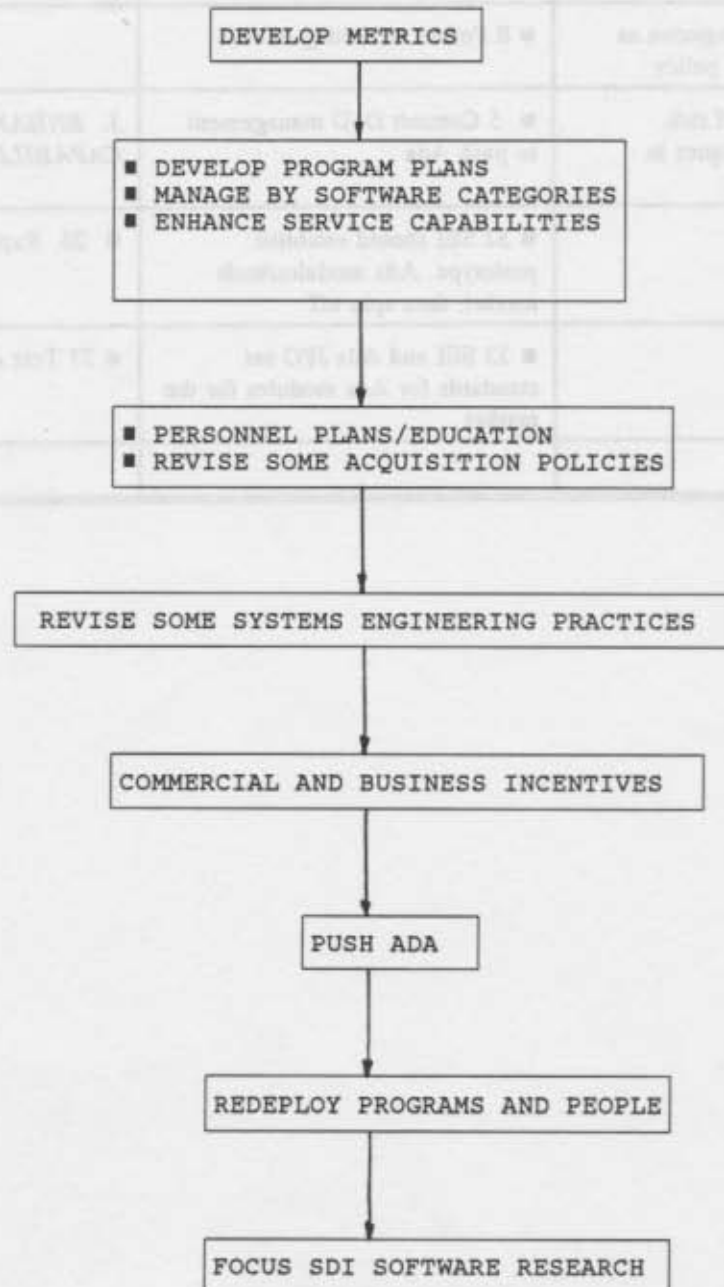
A. COMMERCIAL/BUSINESS INCENTIVES	B. SYSTEMS ENGINEERING PRACTICES	C. PERSONNEL PLANNING/EDUCATION
■ 15 Off-the-shelf subsystems, components	■ 4 STARS should incorporate modern practices and tools in several model programs	■ 9 More Ada training, both technical and managerial
■ 16 Off-the-shelf software tools	■ 10 Allow 4th generation languages where cost-effective	■ 37 Structure officer careers to get managers with deep technical mastery and broad operational overview
■ 17 Productivity incentives	■ 21 Require use of modern commercial practices	■ 34 Plan how to live with software personnel shortages and how best to use available people
■ 18 Profit incentives	■ 23 Mandate iterative setting of specs, rapid prototyping, and incremental development	■ 36 Track personnel skills and project personnel needs
■ 22 Modify intellectual property regulations	■ 24 Eliminate use of waterfall model, institutionalize rapid prototyping and incremental development	■ 38 Enhance education for software
■ 29 Economic incentives for reusable software marketing		
■ 30 Economic incentives to buy modules rather than build them	D. REDEPLOY PROGRAMS AND PEOPLE	E. PROGRAM PLANS
■ 31 Identify subsystem components, modules that can be acquired, and reward such acquisition	■ 1 Move STARS and rebuild it	■ 2 Task STARS, Ada JPO, SEI, SDI, and DARPA SCI to produce joint plan
	■ 6 Move Ada JPO into organization with STARS and SEI	■ 3 Task new STARS director to define program goals, and plan to achieve early results
I. DEVELOP METRICS	■ 35 Use DoD people for acquisition instead of construction	■ 28 Spell out role of using commands in evolutionary and incremental software development
■ 19 For software quality and completeness		
■ 20 To measure implementation progress		

G. REVISE ACQUISITION POLICY	F. PUSH ADA	H. MANAGE BY SOFTWARE CATEGORY
■ 12 Use evolutionary acquisition to reduce risk	■ 7 Keep Ada JPO as DoD staff support	■ 14 As followup to Recommendation 13, develop policy, procedures, and guidance for each category
■ 13 Adopt new categories as basis for acquisition policy	■ 8 Forbid subsetting of Ada	
■ 25 Mandate use of risk management techniques in software acquisition	■ 5 Commit DoD management to push Ada	J. ENHANCE SERVICES CAPABILITIES
	■ 32 SEI should establish prototype Ada modules/tools market, then spin off	■ 26 Rapid prototyping
K. SDI	■ 33 SEI and Ada JPO set standards for Ada modules for the market	■ 27 Test and evaluation
■ 11 Focus		



The diagram illustrates the process of software development, starting with Requirements Determination, followed by Conceptual Design, Detail Design, Manufacturing, and finally Testing. The text is mirrored and difficult to read, but the flow is clear.

APPENDIX B

A SUGGESTED PRIORITY STRUCTURE
FOR CATEGORIES OF RECOMMENDATIONS

The highest priority (best) item is at the top, and the lowest priority item (worst) is at the bottom. Some categories appear as lower than others because they depend on achievement of higher ones to be successful. Categories in the same box are of equal priority.

APPENDIX C

DEFENSE SYSTEMS MANAGEMENT
OR ACQUISITION REPORTS

[The following is a list of titles of workshop reports, all related to defense systems management or acquisition. All of these workshops used Interactive Management. The early reports are based on workshops held at George Mason University at the Center for Interactive Management (CIM). The later reports are based on workshops held at the Defense Systems Management College (DSMC), Fort Belvoir, VA. During the entire period, people affiliated with the Institute for Advanced Study in the Integrative Sciences (IASIS) at George Mason University were involved in supporting the faculty of the Defense Systems Management College, who conducted most of the workshops held in 1990 and 1991. These were conducted at the Defense Systems Management College in a situation room like the one designed and built at George Mason University. The faculty of the Defense Systems Management College will be conducting numerous Interactive Management Workshops in 1992, with continuing support from IASIS.]

<i>Date</i>	<i>Title of Report</i>	<i>Report Prepared By:</i>
Dec. 15-16, 1986	Understanding Defense Systems Management in a Form that Supports Action Planning	Center for Interactive Management George Mason University Fairfax, VA
Nov. 30-Dec. 4, 1987	Acquisition Management Alternatives	CIM
Aug. 1-3, 1988	First Report on Smart Munitions Acquisition Management	CIM
Sept. 12-14, 1988	Second Report on Smart Munitions Acquisition Management	CIM
Sept. 19-21, 1988	Third Report on Smart Munitions Acquisition Management	CIM
Sept. 27-29, 1988	Fourth Report on Smart Munitions Acquisition Management	CIM
February, 1989	Final Report on Smart Munitions Acquisition Management	Office of Munitions, Office of the Under Secretary of Defense The Pentagon, Washington, DC
Mar. 7-9, 1990	Department of Defense Fuze Industry Workshop	Institute for Defense Analyses, Alexandria, VA

<i>Date</i>	<i>Title of Report</i>	<i>Report Prepared By:</i>
Mar. 14-15, 1990	Department of Defense Program Stability Workshop	Defense Systems Management College (DSMC), Fort Belvoir, VA
July 17-19, 1990	First Defense Industrial Base Workshop	DSMC
Nov. 6-7, 1990	Risk Reduction Management Workshop	DSMC
Nov. 14-15, 1990	First Concurrent Engineering Workshop	DSMC
Nov. 27-28, 1990	Requirements/Resource Allocation/Acquisition Process Alignment Workshop	DSMC
Dec. 11-12, 1990	Second Defense Industrial Base Workshop	DSMC
Dec. 17-21, 1990	Second Concurrent Engineering Workshop	DSMC
Jan. 22-25, 1991	Contractor Integrated Technical Information Service (CITIS) Workshop	DSMC
Jan. 28-29, 1991	Summary Report on DoD Workshops on Concurrent Engineering	DSMC
Feb. 27-Mar. 1, 1991	North American Defense Industrial Base Critical Technologies Workshop	DSMC
Apr. 18, 1991	Student Focus Group Workshop	DSMC
May 16, 1991	Student Focus Group Workshop	DSMC
May 20, 1991	Student Focus Group	DSMC
June 3, 1991	Student Focus Group	DSMC

<i>Date</i>	<i>Title of Report</i>	<i>Report Prepared By:</i>
June 17-21, 1991	Technical Managers Advanced Workshop (TMAW)--Redesigning the Defense Acquisition System I	DSMC
July 23-24, 1991	TMAW--Redesigning the Defense Acquisition System II	DSMC
Aug. 19-21, 1991	Industrial Base Study Tiger Team Workshop	DSMC
Aug. 28-30, 1991	Contractor Integrated Technical Information Service Workshop (Dept. of the Air Force)	DSMC
Oct. 15-16	Faculty Training Workshop	DSMC
Nov. 18-22, 1991	TMAW--Redesigning the Defense Acquisition System III	DSMC
Dec. 2, 5, 1991	Faculty PHD Comparability Workshop (Training)	DSMC
Dec. 10-12, 1991	TMAW--Redesigning the Defense Acquisition System IV	DSMC
Dec. 15-16, 1991	Faculty Consulting Practices Workshop (Training)	DSMC

[Some of these reports are available in the IASIS File, part of a special collection of the Fenwick Library, George Mason University, Fairfax, Virginia 22030-4444]

This list is current as of December 22, 1991. Additional workshops are scheduled for 1992.