NBS TECHNICAL NOTE 832

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Report on Planning Session on Software Engineering Handbook

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Report on Planning Session on Software Engineering Handbook

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REPORT ON PLANNING SESSION ON SOFTWARE ENGINEERING HANDBOOK

Software Engineering Handbook Planning Committee
R. G. Canning, Chairman
S. L. Stewart, Editor

This report from a planning committee sponsored by the National Bureau of Standards, the National Science Foundation, and the Association for Computing Machinery discusses the need for, coverage of, and audience for a proposed Software Engineering Handbook.

Key Words: Programming, quality software, software engineering.

1.0 INTRODUCTION

A planning session was conducted in Washington, D. C. on March 4-6, 1973, as the first step in what hopefully will result in a handbook on software engineering. The planning session was conducted under the auspices of the National Bureau of Standards, the National Science Foundation, and the Association for Computing Machinery.

Participants in the planning session included:

Mr. Joel D. Aron, IBM Federal Systems Division
Mr. Anthony D'Anna, Western Electric
Dr. Edsger W. Dijkstra, Technological University Eindhoven
Dr. Dennis W. Fife, NBS
Dr. Aaron Finerman, Jet Propulsion Laboratory
Prof. Robert W. Floyd, Stanford University
Mr. John Gosden, Equitable Life Assurance Society
Mr. Harry T. Larson, California Computer Products, Inc.
Mr. Charles P. Lecht, Advanced Computer Techniques Corp.
Dr. Barbara H. Liskov, M.I.T. Project MAC.
Dr. Daniel Teichroew, University of Michigan
Mr. Richard G. Canning, Canning Publications, Inc. (Chairman)

In addition, the following sponsors were present:

Dr. D. D. Aufenkamp, NSF
Mr. Walter Carlson, IBM, representing ACM
Mr. S. Jeffery, NBS

The goals of the workshop were stated as follows: Define

<u>What</u> is most urgently needed?

<u>Who</u> is the target audience?

<u>What</u> should be covered in the Handbook?

<u>Who</u> should create it?

What is most urgently needed?

The participants identified two main areas of concern -- first principles for software engineering, and the managing of software engineering of software. The material should be based on an understanding of the programmer's decision process--what decisions the programmer is expected to make. For each significant decision, the available alternatives should be identified, with at least a brief discussion of the advantages or disadvantage of each alternative. The discussion should be in terms of general principles that can be applied, ones that have been tested in use. Guidelines should be presented for using each of the general principles, along with examples of use, and cost-effectiveness trade-offs.

The participants also felt that the Handbook should give recommendations on the managing of software engineering, so as to provide the environment in which the engineering of software can best be accomplished. This material should include first principles of successful management for R&D type projects, which can be applied to software development projects. The material should also point out that the managerial decisions, and even the project organization, can have a significant effect on the architecture of the software.

Who is the target audience?

The target audience for the Handbook was identified in terms of the staff of one large business organization, as an illustrative example -- but the same situations exist in engineering and scientific programming. In addition to job categories, the current approximate percent of total staff was given for each category.

Category	*Job*	*% of staff*
A	*Large system architects*	*1*
B	*Large system project managers*	*1*
C	*Computer scientists (Ph.D.s)*	*1*
D	*Business system analysts with little knowledge of programming*	*10*
E	*Professional programmers, experienced, interested in keeping up with the technology, have initiative to do self-training, capable of recognizing that others have already solved a particular problem.*	*22*
F	*Craftsmen programmers, less experienced, have less initiative, are less likely to recognize that a problem has been solved*	

by others; willing to use a Handbook, if directed. 44

G Dull programmers, with little or no interest or initiative; just doing a job. 22

In the next three to four years, the "center of gravity" may shift downward from F toward the G category, based on present trends in the organization under discussion. After that period of time, the F category may represent only 22 percent of the total, and the G category 44 percent.

In addition, the participants recognized the growth in the number of users who perform programming-type functions but whose job titles are not "programmer". These people include engineers, operations researchers, etc., who use the computer perhaps via a time sharing terminal. So an additional category, H, might be added -- the nonprofessional programmers.

RECOMMENDATION: As far as the "first principles of software engineering" are concerned, the main target audience is the E category.
Material of interest to categories A, B, C, and D, might also be included.
Write the Handbook so that it can be read by the category F people. (Some participants recommended that F people be included with E people, as the main target audience.)
The Handbook should not be aimed at the G and H categories.

One participant commented that many people in the target audience may be turned off by the term "software engineering." None of the group could estimate the impact of this on the acceptance of the Handbook, should it be true. Another participant suggested that a "better title" is needed. Others favored the proposed title. There was no consensus on this point.

RECOMMENDATION: As far as managing software engineering projects is concerned, the prime audience is the project manager with from 5 to 20 people under him. The Handbook should help him get his job done. Further, a different set of management techniques is needed for very large projects, employing scores to hundreds of people. This audience probably should not be chosen as the prime target for the Handbook.

It was observed that various levels of management between project management and top management perhaps unknowingly can impose undesirable pressures or constraints that influence system architecture. Management selects the approach, the programming languages, the installation standards, the measures, and the project organization. By default, *management may become the system architect. One of the goals of the Handbook should be to make the several levels of management aware of these architecture-influencing decisions.*

2.0 GENERAL DISCUSSION OF CONTENTS

2.1 Potential Breadth of Subject

The creation of a new software-using system involves many components beyond the software itself. These components include the hardware, programs for the hardware, people, and procedures for the people. The ways in which these components are used are influenced by the technology, by financial considerations, by inter-organizational politics, and by intra-organization psychology. In theory, the Handbook could address this whole subject area.

The types of decisions involved in creating a new software-using system includes those on the software (make or buy), the hardware (selecting major components, selecting minor components, etc.), procedures ("operator" procedures, interfacing with other systems, etc.) and people. Also, the scope of the software must be defined; it can include source code, object code, documentation, firmware, logic embedded in LSI chips, and so on.

RECOMMENDATION: *It was the consensus of the group that the Handbook not be concerned with all of these aspects, as important as they may be to the overall success of the new system.*

Instead, the Handbook should be concerned with computer program design, construction, and quality assurance. Computer programs include both software systems and application programs.

2.2 Potential Depth of Coverage

It would not be desirable to aim the Handbook at too low a level of capability. There should be no implication that "anybody can be a software engineer by using this Handbook."

At the same time, it is recognized that the majority of today's practicing programmers received their original programming training from computer manufacturer or employer training courses -- at least, of the F and G level programmers. Only a small percentage have received computer science education at the masters, or even bachelors, level.

The major portion of the software engineering portion of the Handbook should be addressed to the level E professional programmer, as roughly defined above. As mentioned previously, the Handbook should be understandable by the level F programmers. While some of the material can be addressed to the levels A, B, C, and D, such material probably should be clearly identified as for those audiences.

2.3 Kinds of Programs

A variety of kinds of computer programs were identified for which the first principles discussed in the Handbook would apply. These included applications software (scientific, engineering, business, military, space and process control), and systems software (operating systems, compilers, assemblers, data management, etc.). Further, the systems software might be developed for an existing machine, or for a machine which itself is still under development.

RECOMMENDATION: The same general design techniques can be used for both application software and systems software. However, the design decisions can be more complex for large systems of either type.

Two types of computer programs were identified for which the principles discussed in the Handbook probably would <u>not</u> apply. These were: hybrid computation programs, and <u>ad hoc</u> problem solving programs which would be used only one or two times.

2.4 Desired Changes in Tools

It was contended by one participant that the programming language used for a given program, or set of programs, influences the way the programmer conceives the program design. It was further contended that the most popular existing languages--FORTRAN, COBOL, and ALGOL 60--exert undesirable types of influence and are not appropriate vehicles for guiding the programmer's thought. Further, the largest gains from software engineering will come from using more appropriate primitives. It was felt that the Handbook should try to force such needed changes.

It was further contended that it will be difficult to find language-independent first principles for program design. The programming language that is used permeates the design.

There was not a consensus on these contentions. In rebuttal to them, it was argued that perhaps 90 percent of the first principles of program design <u>are</u> language-independent. Further, regardless of opinions about the existing languages, the fact remains that they will continue to be used for the bulk of the programming for some years to come. The engineering of software must take into account that these languages will be widely used.

The question of how strongly the Handbook should press for significant changes in the tools thus did not get answered at this meeting.

3.0 POTENTIAL STRUCTURING OF THE HANDBOOK

The participants saw the structure of the Handbook as consisting of three main sections: rationale for using the Handbook (about one percent of the total pages), managing the engineering of software (about nine percent of the total pages), and software engineering (about 90 percent of the total pages).

The first section would include not only the rationale for using the Handbook but also the goals of the Handbook, how to use it, and criteria for making design decisions. (One participant believes that one percent of the total pages is not enough for this section.)

The section on managing software engineering should include the "time structure" of a software project, and first principles of successful management of projects of this type. There was mixed opinion as to whether professional responsibility and ethics should be included.

The software engineering section was viewed as consisting of three parts. One would be the architecture part, dealing with the highest level design decisions. Next would be the engineering part, the next level of design decisions, wherein the technology is used to achieve a design that meets the postulated criteria. Finally, there would be the construction part, involving the lowest level of design decisions, such as the details of program segmentation. Further details on this section are included as an Appendix.

4.0 THE NEXT STEPS

A brief discussion was conducted on how best to proceed with the Handbook project. While a number of suggestions were advanced, there was no consensus on how best to proceed. This subject really was outside of the charge of this planning meeting; the meeting was to concentrate on the problem definition stage of the Handbook project, involving the aspects of <u>*what*</u> *and* <u>*who*</u>*, rather than* <u>*how*</u>*.*

Since no consensus was reached, and since the sponsoring organizations had representatives in attendance, it was agreed that these representatives would decide on the plan of action for the next steps, based on the recommendations made in this report.

SPONSORS' ACKNOWLEDGEMENT

This report was prepared by Richard G. Canning, Chairman of the NBS/NSF/ACM Planning Committee for a Software Engineering Handbook. The committee members provided extensive supplementary material and comments on an earlier draft of this report. All of this material will be of assistance in the future development of a software engineering handbook. Even though space precludes reprinting all the comments, Mr. Canning has incorporated them in the report insofar as was practical.

The sponsors would like to thank the members of the committee for their fine work and Mr. Canning in particular for his double duty as chairman and author of this report.

APPENDIX I. SPECIFIC SUGGESTIONS FOR SOFTWARE ENGINEERING TECHNIQUES CONTENTS

System/Program/Data Architecture

Deals with defining the overall structure.

Involves selection of an architecture.

Present survey of theories on program structuring and examples of how to use them; for instance, with combinatorial type problems, structure so that the number of cases adds rather than multiplies.

Present guidelines for modularizing system, programs, and data so as to minimize chances of errors. Minimize the number of interconnections between modules.

Present concepts of structured programming and proof of correctness.

Present survey of useful abstraction patterns and the various forms found in computer programs, including parallelism.

Codify the constraints where the architect may have little or no freedom of choice (as in the case of the hardware, or operating system).

The data must be structured, as well as the system and the programs. Includes both file structuring and data base structuring. Show relationships between data modules and program modules.

System/Program/Data Engineering

Discuss criteria for judging a design: maintainability, utility, effectiveness, availability, resilience, extensibility, defensive design, modifiability, economics, understandability, transferability, reliability, simplicity, generality, and flexibility.

Promote the understanding of: modularity, design methodology, effect of scale (magnitude) of projects, the desire for quality software as opposed to acceptable software, identifying hardware design features that result in unresolvable conflicts for the software, and the ability to judge a priori if particular tools will apply to a job, and how well.

Discuss use of models and quantitative techniques for making design decisions.

Discuss quality assurance. With regular design, involves a test plan developed at the outset. With structured programming, involves proof of correctness, where testing and integration occur throughout construction, and not after it.

Discuss ways to adapt to changes in system specifications, providing for change in original design via scaffolding; use of configuration control and formal change control; repair and maintenance; patching.

System/Program/Data Construction

List of available tools:

Languages--benefits and drawbacks of particular languages, including data manipulation and data descriptive languages; how to choose a language; some tricky features of common programming languages.

Operating systems--benefits and drawbacks; if choice is available, how to choose an operating system.

Data base management system--same as operating systems.

Testing aids.

Construction aids.

List of available techniques, including pros and cons of each:

Sorting techniques

Data compression; data coding

Searching

Validation techniques

Queuing

Paging

Segmentation

Parsing

Listing processing

Query processing

Translation techniques--compilation, interpretation, generation

Implicit versus explicit data definitions

Survey of program construction techniques, with examples; example: use of "superfluous" code for mapping problem into more manageable form.

Display technology

Benchmarking

Concurrent processing

How to interact in multi-programming environment

Effect on design of various construction techniques

Instrumentation, monitoring

Use of models for estimation of resources required and for making design trade-offs.

Hashing methods

Overlay techniques

Flow charting (as a design tool, more than as a documentation method).

Decision tables

(Comment: when several alternative versions of a technique are available, as in the case of sorting algorithms, might present a decision table for aiding in the selection of the most appropriate algorithm. In addition, might illustrate by comparing several algorithms.)

(Question: how to discuss proprietary techniques, such as automatic flowcharters or program module test beds?)

List of standards and conventions, including documentation standards

National standards and conventions: ADCII, EBCDIC, etc.

Samples of typical (but good) installation standards

Useful tables

Random numbers

Powers of 2

Probably exclude: tables of instructions for particular computers and/or operating systems.

Question: What use of samples of code? In which programming language? (One participant observed that samples of code must be used to illustrate first principles -- and that several high level languages should be used.)

Question: Should the Handbook teach how to construct algorithms?

Acceptability testing

Test plan preparation

Acceptance testing

Test case generation

Proof of correctness, with today's limitations

Volume and functional test drivers

Test beds for modules

Systems integrity packages; testing for no deterioration since last update; in simplest case, a test problem.

Methodology for desk checking.

Quality assurance of documentation.

(Reference was made to the very short time required for quality assurance testing under the IBM Chief Programmer Team approach, for the New York Times Information Retrieval System.)

Large scale systems

A chapter perhaps should be devoted to special considerations that must be given to the design and construction of large systems.

Concepts involved include:

Autonomous sub-systems versus a man-layered hierarchy

Phasing of sub-systems

"Creeping commitment" for retaining options as long as possible.

APPENDIX II. SPECIFIC SUGGESTIONS FOR SOFTWARE ENGINEERING MANAGEMENT CONTENTS

The techniques of managing software projects are very similar to the techniques used for managing R&D projects where the design has a high degree of uncertainty.

Traditionally in the software field, projects have ended up over cost, over schedule, and deliver less performance than promised. Better management techniques can help to alleviate these problems.

First Principles of Managing Software Projects

Define the problem to be solved at the outset; state the system requirements in a language that is understandable by the users; get user management approval of these requirements and problem statement.

Make the design easy to change; implies a modular design.

Consider the idea of the "creeping commitment", for large projects and/or those where the design is very subject to change.

Identify alternative solutions, then select the best of the alternatives according to criteria.

Quality assurance should not be separated from construction. Plan the quality assurance at the outset, using either proof of correctness or conventional testing. The constructor must demonstrate that a module meets its specifications.

Once the design selection has been made, institute a change review and approval process, so as to control changes.

Every software engineer is a manager, even if just of himself. He must plan his activities, so that management techniques are as appropriate to his work as design techniques. He should apply first principles to the resources under his control, and try to influence his boss to use those first principles. The fact that a particular manager does not understand the principles of software engineering should have no influence on the profession of software engineering.

Recognize that constraints imposed by management are of two types--mandatory and negotiable. Recognize, also, that some "mandatory" constraints are really negotiable.

The structure of a project organization will have a vitally important effect on the architecture and engineering of the resultant system, since it defines the lines of communications. Both democratic and autocratic project structures are being proposed these days, with *some instances of impressive performance under autocratic structuring.*

A "Standard" Project Discipline

Problem definition

Define system
Decompose into parts
Define parts
Decompose into sub-parts

Develop system specifications, for new system

Perform system design and test design; institute formal change procedure

Perform program design

Perform program building and quality assurance

Perform system test and integration

Perform conversion, operation, and maintenance

Comment: Project administration functions would be conducted in parallel with the above activities. Also, installation standards should be employed.

Comment: Measures are needed by which the individual programmer can tell how much progress he has made, and how much he still has to do, to finish the job.

Comment: A reduced version of the above project discipline may be needed for small projects, and for to-be-used-one-time-only programs.

Questions:

Should the Handbook include guidance for executive management, since they often make constraining decisions? (One participant argued that such material should be included, if at all, only in the opening tutorial section.)

Should the Handbook address the question of training management in some aspects of software engineering?

Should the Handbook address the subject of the professional responsibility and ethics of the software engineer?

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This report from a planning committee sponsored by the National Bureau of Standards, the National Science Foundation, and the Association for Computing Machinery discusses the need for, coverage of, and audience for a proposed Software Engineering Handbook.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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