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January 1, 1976 - March 31, 1977

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This report describes the progress made under contract N00014-75-C-0266, project no. NR 049-345 during the period January 1, 1976 - March 31, 1977. Included are the description of the reports distributed, activities undertaken, and activities of the personnel supported by the contract.

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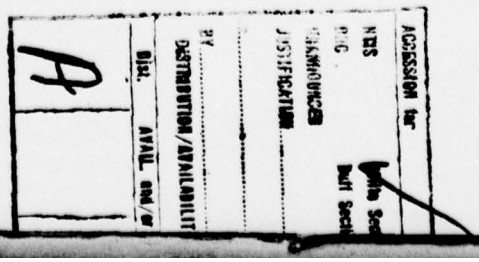
The reports produced during this period included the following:

1. An Operations Research Approach for the 'Design to Cost' of a Complex Radar System
2. Evaluation of Network Services
3. Experiments in Minicomputer Networks
4. A Comparative Evaluation of Versions of BASIC
5. Modified Bayesian Procedures in Reliability Testing
6. Management Evaluation of Network Performance with Security Measures
7. Computing Auditing: The Problems vs. SAS no. 3
8. Characteristics of Application Software Maintenance
9. Maintenance Questionnaire and List of Respondents
10. Description of Computer Network Analysis Model

The first report is a reprint of an article that appeared in the Israel Journal of Engineering (April 1976; 15-24). The second paper was given as an invited paper at the Annual meeting of the ACM and appeared in the Conference Proceedings (ACM 76, 218-220). The third paper is a technical report on some of the experiments conducted for the Naval Electronics Laboratory Center in 1976. This work is continuing and will be described below. The fourth paper is a reprint of an article that appeared in the Communications of the ACM (April, 1976, 175-181). The fifth paper is a chapter in the book Theory and Applications in Reliability (C. P. Tsokos, ed., 1977 - in press). The sixth paper was presented as an invited paper at the Eurocomp Conference on Computer Performance and appears as a chapter in Computer Performance Evaluation, On line Publishing (1976, 651-658). The seventh paper is a



technical report and is scheduled to appear in the March, 1977 issue of the CPA Journal. The eighth and ninth papers are results of new work in the area of software maintenance. The eighth paper has been submitted to the Communications of the ACM. The tenth paper is a technical report describing the computer network model used in the analysis.

A major area of interest during the period was the analysis of application software maintenance. During this period the literature was reviewed, a questionnaire prepared, distributed, and analyzed. The questionnaire and list of respondents appear in [9]. The results of analyzing the maintenance questionnaire data are presented in [8]. The questionnaire was pretested and then distributed to 120 organizations located on the West Coast. Responses totaled 69 at the time of writing the paper. The total responses to date have been 78. The results of the analysis are presented in detail in [8]. The results will be briefly summarized here.

Very little research has been done previously in this area. This is somewhat surprising since it has been cited that over 60% of the total life cycle cost of the system occur in maintenance and enhancements. Furthermore, sources cite that systems groups spend almost 50% of their efforts on maintenance and enhancement.

The effort in this area is being directed toward determining problem areas and what is being done in regard to maintenance. After this has been done, analysis and modeling methods can be used for examining maintenance. To

determine properties and characteristics of maintenance a questionnaire was developed. The questionnaire is in two parts. Part I deals with the systems and programming department and contains 12 questions in the following areas:

- industry category
- annual budget for software and hardware
- number of personnel in department (systems analysts and programmers as well as aggregate)
- division of tasks among staff in maintenance and new application work, and in analysis and programming
- management structure
- current percentage of effort in maintenance
- relative importance of maintenance compared to development
- reallocation of effort between maintenance and development, given hypothetical budget increases and decreases
- evaluation of adequacy of current levels of staffing

The second part of the questionnaire dealt with the application software undergoing maintenance and enhancement. Respondents were asked to select a system which has been operational for at least one year, represents a significant investment of time and effort, and is of fundamental importance to the organization. For this system they answered 38 questions on the following topics:

- name of system, function, and end users
- number of personnel in user groups*
- number of personnel in user groups actively involved in the system processing cycle*

- date system became operational
- number of programs maintained and number of source language statements broken down by language*
- distribution of source statements according to origination year*
- percentage of system dealing with on-line processing*
- total number of machine language statements*
- hardware/software environment of system
- use of distributed processing and/or data base management systems
- number of files, average size of data base*, percentage of data base updated by time period*
- number and form of predefined user reports*
- productivity tools used in development
- time spent on maintenance*
- division of effort among types of maintenance activities*
- percentage of maintenance effort on on-line programs and in communication with user*
- number of people involved in maintenance of the system, the levels of their programming experience, when they began to work on the system, and task allocation in terms of analysis and programming
- formal procedures for maintenance request handling, number of requests received
- formal procedures for making changes to programs, and number of changes made

- formal procedures for trouble reporting
- existence of auditing, documentation, cost accounting procedures and chargeback methods
- problem areas in maintenance of the system

In the above list, for the items marked with an asterisk (*) the respondents also answered the question: "Check the applicable statement: the above answer is: ___ reasonably accurate, based on good data; ___ a rough estimate, based on minimal data, or ___ an estimate, not based on any data."

The report [8] presents the initial results of statistical analysis. The plan for the future includes a revision of the questionnaire and survey to a wider audience. Respondents have been enthusiastic about the study and have supported the project financially by providing keypunch and computer facilities.

Of the respondents listed in [9] the distribution of allocation of effort for maintenance and new development was

Maintenance and enhancement	48.0%
New development	46.1%
Other activities	5.9%

The breakdown of activities within maintenance was

Category	Activities	Relative Frequency
Corrective	Emergency fixes, routine debugging	17.4%
Adaptive	Accommodation of changes to data inputs and files, and to hardware and system software	18.2%
Perfective	User enhancement, improved documentation, recording for computational efficiency	60.3%
Other		4.1%

Of the effort, perfective maintenance is by far the biggest area of effort. This is supported in Table I which indicates that user demands for enhancements and extensions are perceived by management to be the biggest problem area.

Respondents were further asked to rank possible problem areas in maintenance. This is summarized in Table I. The table columns are arranged by problem area, statistics, and relative frequency. The statistics are based on the coding: 1-not a problem, 2-somewhat minor problem, 3-minor problem, 4-somewhat major problem, 5-major problem. Items marked with an asterisk indicate technical problem areas.

The predominant problem cited as more than minor is that of user demands for enhancements and extensions. Following this are two technical issues (quality of original system and its documentation) and one management issue (competing demands for personnel time). Frequently mentioned problems such as hardware change, turnover of maintenance personnel, and motivation of maintenance personnel showed up surprisingly low (means of 2.14, 2.46, and 2.03, respectively).

In addition to the twenty-four areas that are mentioned in the questionnaire, respondents were encouraged to list other problem areas. Areas mentioned included quality of operations personnel, turnover in user organization, high learning curve due to large system, and retaining personnel at implementation time.

TABLE I PROBLEM AREAS

Problem Area	Statistics			Relative Frequency					
Rank	Mean	Median	Std. Dev.	Not Prob.	Somewhat Minor	Minor	Somewhat Major	Major	No Resp.
1. User demands for enhancements, extens.	3.42	3.72	1.25	7.2	20.3	11.6	36.2	18.8	5.8
2. Quality of syst. docum.*	2.99	3.03	1.33	17.4	15.9	26.1	20.3	14.5	5.8
3. Competing demands on maint. personnel time	2.95	3.00	1.39	17.4	24.6	8.7	29.0	13.0	7.2
4. Quality of original programs*	2.94	2.92	1.42	20.3	18.8	18.8	18.8	17.4	5.8
5. Meeting scheduled commitments	2.79	2.73	1.21	14.5	26.1	21.7	21.7	7.2	8.7
6. Lack of user understand. of syst.	2.66	2.53	1.19	17.4	29.0	21.7	20.3	5.8	5.8
7. Availability of main. program. personnel	2.66	2.53	1.27	20.3	26.1	21.7	17.4	8.7	5.8
8. Adequacy of syst. design spec.*	2.52	2.3	1.37	29.0	21.7	17.4	14.5	10.1	7.2
9. Turnover of mainten. personnel	2.46	2.13	1.46	36.2	17.4	13.0	15.9	11.6	5.8
10. Unrealistic user expectations	2.45	2.50	1.18	26.1	20.3	29.0	13.0	4.3	7.2
11. Processing time of system*	2.31	2.00	1.33	36.2	20.3	13.0	17.4	5.8	7.2
12. Forecast. personnel requirements	2.30	2.03	1.28	33.3	23.2	13.0	17.4	4.3	8.7
13. Skills of maint. personnel*	2.20	1.94	1.24	34.8	26.1	15.9	10.1	5.8	7.2
14. Changes to hardware and software*	2.14	1.97	1.10	34.8	26.1	20.3	11.6	1.4	5.8
15. Budgetary pressures	2.09	1.82	1.18	37.7	27.5	11.6	13.0	2.9	7.2
16. Adherence to program. stds. in maint.*	2.08	1.94	1.04	34.8	26.1	23.2	7.2	1.4	7.2
17. Data integrity*	2.06	1.88	1.12	34.8	29.0	20.3	1.4	5.8	8.7
18. Motivation of maint. personnel	2.03	1.82	1.10	37.7	27.5	17.4	7.2	2.9	7.2
19. Applic. run failures*	2.00	1.90	.92	29.0	44.9	13.0	5.8	1.4	5.8
20. Maint. programming productivity	2.00	1.87	.97	33.3	33.3	15.9	8.7	0	8.7
21. Hardware and software reliability*	1.91	1.76	.94	37.7	33.3	14.5	7.2	0	7.2
22. Storage requiremts.*	1.88	1.34	1.24	55.1	11.6	13.0	8.7	4.3	7.2
23. Mgmt. Support of system	1.87	1.41	1.17	49.3	17.4	11.6	8.7	2.9	10.1
24. Lack of user interest in system	1.86	1.58	1.06	44.9	29.0	11.6	5.8	2.9	5.8

It is of interest to determine if management issues are more important than technical issues. This would serve as a guide in efforts to improve the maintenance procedures and tools. Statistical tests indicate that management problems are more significant. To carry out the tests the average rating was computed for technical and management areas for each respondent. The Mann Whitney-Wilcoxan and sign tests were selected to test the hypothesis that the distribution of the average response of each category was the same. These tests do not depend on actual scores but relative ratings. For the Mann Whitney-Wilcoxan test the hypothesis was rejected at the $\alpha = .10$ level. For the sign tests it was rejected at the $\alpha = .01$ level. Both results indicated higher values for the management areas.

A second hypothesis is that the response to the problem of user demands for enhancement and extension is significantly larger than average for all problem areas. The same nonparametric tests were applied and the hypothesis of the same distribution was rejected at the $\alpha = .10$ level. This indicates user demands are more of a problem than other areas.

The respondents were asked to contrast the relative importance of maintenance with new system development within their organizations. The relative frequency appears in Table II. It indicates most view maintenance as more important than new development. More strikingly, few view new system development as more important.

TABLE II

IMPORTANCE OF MAINTENANCE COMPARED
TO NEW SYSTEM DEVELOPMENT

Maintenance and Enhancement	Percentage
By far more important	33.3%
Somewhat more important	21.7
Equal importance	34.8
Somewhat less important	5.8
By far less important	4.3

Other findings are presented in [8]. The conclusions based on the limited sample are:

- Maintenance and enhancement consume much of the total resources of systems and programming groups.
- Maintenance and enhancement tend to be viewed by management as at least somewhat more important than new application software development.
- In maintenance and enhancement, problems of a management orientation tend to be more significant than those of a technical orientation.
- User demands for enhancements and extensions constitute the most important management problem area.
- The use of productivity aids in application software development remains limited. However, maintenance programmer productivity is not considered by management to be a major problem.

Overall more attention should be given to management problems associated with maintenance. In practice, maintenance work should be categorized to permit the gathering of more detailed management information. Project reporting systems should be detailed with respect to the type and tasks of maintenance and enhancement. This is being done with several organizations as a follow-up activity.

A second major area of effort has been directed toward management trade-offs in the design and evaluation of computer networks. In this area the activities include 1) working with Mr. Frank Miller of the Naval Electronics Laboratory Center in San Diego to perform trade-off analyses, 2) developing criteria for evaluating network services, and 3) considering security and auditing of computer networks. In the first case, the network model [10] is anticipated to be installed soon at NELC. Trade-off analysis will be continued for several Naval networks. Several papers were prepared in the area of network evaluation ([2], [6]). These methods are based on analyses of network cost and performance data using stochastic processes. In the third case, an assessment of the auditing and security problems was developed in [6] and [7]. The detailed results are presented in the cited paper references and will not be described here.

The work in the next period will continue the maintenance and network research. In the maintenance area the attention will be focused on 1) examining problem areas in maintenance, 2) developing techniques for organizations to measure maintenance work, and 3) developing methods for

cost-performance trade-offs in handling enhancement requests. In the network area work with NELC will be continued along with efforts to assess network services and to address pricing and supply issues of network services.

The people supported under the contract were Professor Bennet P. Lientz, Principal investigator, Professor E. Burton Swanson, and the following graduate students: Mary Culnan, Kweku Ewusi-Mensah, James Schenck, Ira Weiss, Steven Kwan and Gerry Tompkins.

Dr. Weiss graduated with honors in 1976 and joined the faculty of New York University. Mr. Tompkins is expected to graduate in June, 1977 and enter university teaching. Mssrs. Ewusi-Mensah, Schenck, and Kwan will be advanced to Ph.D. candidacy by May, 1977. Mr. Kwan's area of interest is computer network performance measurement; Mr. Schenck's is minicomputer networks; Mr. Ewusi-Mensah's is network service pricing. Ms. Mary Culnan is a Ph.D. student whose interests lie in data management and computer networks.

Professor Swanson served on the School of Management Staffing Committee as well as several curriculum committees. He published two papers including "Computer Application System Development: Some Implications for Programming Practice" (Data Management, May, 1976) and "Information System Approaches: Directions for Research and Practice"(Management Datamatics, 1976). He also presented the paper "The Dimensions of Maintenance" at the Second International Conference on Software Engineering in October 1976. He served as a reviewer for the National Science Foundation.

Professor Lientz was advanced to Step II Associate Professor. He continued as Chairman of Computers and Information Systems and Coordinator for

Information Systems for the School. During the year he gave invited talks at the Computer Performance Symposium, EDP Auditors Annual Meeting, and the Annual Meeting of the ACM. He presented seminars on computer networks and security to the partners of Peat, Marwick, and Mitchell. He conducted a seminar on distributed processing in Rio de Janeiro, Brazil. He has been listed in Who's Who in the West. A book on the systems approach is being completed for Prentice-Hall, Inc. A previous book entitled Computer Applications in Operations Analysis (Prentice-Hall, Inc.) is in its third printing.

He continued as Associate Editor, Computer Networks and as a reviewer for the IEEE Transactions, Management Science, and Journal of American Statistical Association.

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This paper summarizes the progress under contract N00014-75-C-0266 for the period January 1, 1976 through March 31, 1977.

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