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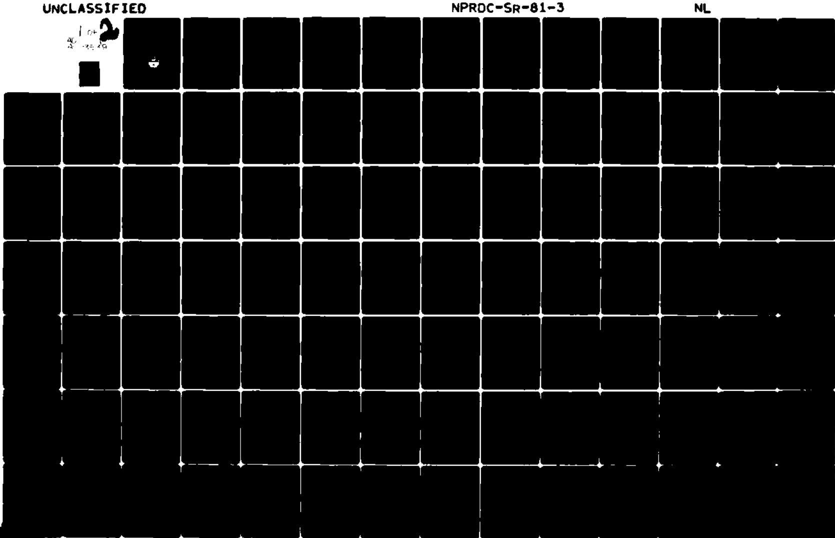

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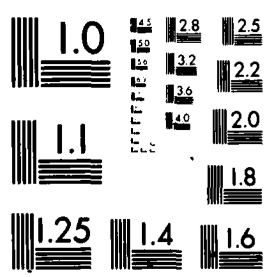

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ENGINEER'S GUIDE TO THE USE OF HUMAN RESOURCES IN ELECTRONIC SYSTEM DESIGN: AN EVALUATION

NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO, CALIFORNIA

NAVY PERSONNEL RESEARCH
AND
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San Diego, California 92152

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ENGINEER'S GUIDE TO THE USE OF HUMAN RESOURCES IN ELECTRONIC SYSTEM DESIGN: AN EVALUATION

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Approved by
James F. Kelly, Jr.
Commanding Officer

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San Diego, California 92152

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FOREWORD

This development effort was conducted under Contract N00123-79-C-1335 with Anacapa Sciences, Inc. in support of Navy Decision Coordinating Paper Z1170-PN, subproject Z1170-PN.05, Reducing Manpower Costs Through Better System Design. It was sponsored by the Deputy Chief of Naval Operations (Manpower, Personnel, and Training, OP-01).

The objective of the subproject is to develop techniques for analysis of hardware/software/personnel trade-offs at all stages of system design. The objective of this effort was to conduct an evaluation of "An Engineer's Guide to the Use of Human Resources in Electronic Systems Design," which has been developed to assist hardware developers to reduce the number and skills of operators and maintainers required by Navy surface ship electronic systems.

Many talented, dedicated people within the Navy Department and contractor design and development companies contributed to the evaluation. Particular appreciation is extended to individuals from the following organizations, who provided substantive comments and guidance during the project.

- Chief of Naval Education and Training
- Naval Electronics Systems Command
- Naval Sea Systems Command
- Naval Weapons Engineering Support Activity
- Naval Electronics Systems Security Engineering Center
- Naval Ocean Systems Center
- Chief of Naval Operations
- Bendix, Electrodynamics Division
- FMC, Northern Ordnance Division
- General Electric, Electronics Systems Division
- Goodyear, Aerospace-Defense Systems Division
- Gould, Chesapeake Instrument Division
- Hughes Aircraft, Ground Systems Group
- ITT-Gilfillan
- Litton, Datalog Division
- Lockheed Electronics, Systems Division
- Lockheed, Aircraft-Missiles and Space Division
- Radio Corporation of America, Missiles and Surface Radar Division
- Singer, Librascope Division
- Sperry, Microwave Electronics

JAMES F. KELLY, JR.
Commanding Officer

JAMES J. REGAN
Technical Director

SUMMARY

Problem

The Navy cannot provide sufficient numbers of adequately skilled operators and maintainers for sophisticated shipboard electronic systems. One of the steps that can be taken toward the solution of this problem is to reduce the human resource requirements of new system acquisitions. In a previous project, An Engineer's Guide to the Use of Human Resources in Electronics Systems Design was developed to help control the system acquisition and design process. The guide provided both data and direction to reduce manning requirements, starting with design decisions made at the earliest stages of conceptual development.

Objective

The objective of this effort was to evaluate the Engineer's Guide to determine the validity of its methodology, the adequacy of its data, and the degree to which it can be implemented. A preliminary objective was to identify specific users who would apply the Engineer's Guide in the systems design process.

Approach

A survey was administered to members of the Navy systems acquisition and development communities and to a representative sample of the senior engineering design and management community within contractor facilities. Respondents were asked to evaluate the usefulness of each major section of the guide.

Rating data were gathered and analyzed on several utility and adequacy factors. Also, comments were gathered and analyzed, and important themes were extracted.

Results

The guide's overall potential utility was clearly evident from the results. However, many specific suggestions were received for improving specific sections of the guide and for refining its overall format.

Conclusions

- The guide will have a positive effect on future Navy electronic systems by making human resources a specific design consideration and by providing necessary technical data.

- The guide must be issued in the form of a military instruction, handbook, or standard if it is to be implemented effectively.

- The guide needs to be reorganized to facilitate access to data. Additional information should be added to several sections.

- Specifications must be developed to direct implementation of the guide by the Navy systems acquisition and development community and application by the contractor design and development community.

Recommendations

- Revision of the guide should include direct inputs from technical experts in the Navy acquisition and contractor design communities.

- The process of making the guide an official military document (instruction, handbook, or standard) should begin.

- The guide must be issued in a format (hardbound copy, three-ring notebook, computer data bank, etc.) that will allow cost-effective updating, because much of the most useful material is time-sensitive. Alternative media should be explored.

CONTENTS

LIST OF FIGURES

INTRODUCTION

Problem and Background

For several years, the Navy has been unable to provide sufficient numbers of adequately skilled operators and maintainers for sophisticated shipboard electronic systems. Manpower problems in operating and maintaining these systems are widely recognized in the Navy and in the Office of the Secretary of Defense. To deal with these problems, the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics) has outlined new constraining requirements for dealing with manning support problems before final decisions are made to acquire new major systems.[1] Also, the Navy has begun a program to document and, eventually, monitor and control the problems in matching manpower resources with new system hardware requirements. The intent of this program, which was called the HARDMAN Program, was to develop a regulatory structure to ensure that manpower requirements would become a major factor in making system acquisition and design decisions.[2]

To support ASD requirements and complement the HARDMAN regulatory structure, the Navy Personnel Research and Development Center began development of the Engineer's Guide to the Use of Human Resources in Electronics System Design.[3] The purpose of the guide was to provide a data base that would help the Navy acquisition and development community and the contractor design community to develop electronic systems that require fewer human resources--in terms of both numbers and skill levels. It was a first attempt at assembling existing data, gathering new pertinent data, and packaging the data in a document that could be called out by system acquisition and development organizations and implemented by design engineers.

The guide was limited in scope, covering five types of electronic systems aboard surface combatants: sonar, radar, fire control, communications, and data processing. It included an introductory chapter, a chapter on designing in relation to human resources, and pertinent data under the following sections:

1. Definition and Impact of Design Concepts. This section included a list of 21 design concepts (e.g., built-in test equipment, standard hardware components, automatic decision making).

2. Interaction of Design Concept Impacts on Different System Design Criteria. This section included a list of 14 system design criteria (e.g., total number of operators required, initial system acquisition costs, shipboard maintenance man-hours required), and results obtained when a group of Navy experts in engineering, acquisition, and maintenance rated each of the 21 design concepts against each of the 14 system design criteria.[4]

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[1] ASD Memo of 17 August 1978.

[2] Military Manpower vs. Hardware Procurement Study (HARDMAN), (Final Report). Washington, DC: Chief of Naval Operations, October 1977.

[3] An Engineer's Guide to the Use of Human Resources in Electronic Systems Design (NPRDC Tech. Note 79-8). San Diego: Navy Personnel Research and Development Center, December 1978.

[4] See Tables 1 and 2 in the following section (pp. 20 and 36) for complete listings of the design concepts and criteria.

3. Types of Technicians Assigned to Surface Ship Electronic Systems. This section identified the types of technicians assigned to, and their responsibilities for, operation and maintenance of the five types of electronic systems addressed in the guide.

4. Projected Supply of Technical Ratings at Different Experience Levels. There is a projected shortfall of experienced technicians of virtually every type associated with surface ship electronic systems. Specific shortages were presented in this section.

5. Evaluation of Alternatives. This section provided aids which the designers could use to conduct tradeoff analyses involving manning, skills, and other design criteria for alternative hardware systems.

6. Taxonomies of Tasks and Associated Skill Levels. This section presented data on the capabilities of first-, second-, and third-class petty officers in performing operational and maintenance tasks required by the five types of electronics systems covered in the guide. These data were intended to help designers avoid tasks that were too difficult or time-consuming for technicians at lower skill levels.

7. Different and Time-consuming Tasks. This was a listing of tasks, selected from 6 above, that were either difficult to perform (skill intensive) or required excessive time to accomplish (manpower intensive).

8. Training Requirements and Navy Enlisted Classifications (NECs). This was a listing of the job specialties and training requirements for the technicians listed in Section 3.

9. Billet Life Cycle Costs for Required Personnel. This section included data for estimating personnel life cycle costs for selected system life cycles (1, 5, 10, 15, and 20 years).[5]

10. References.

Objective

The objective of this effort was to evaluate the technical data and methods included in the guide before implementing them in the acquisition and design communities. Specifically, answers were sought to the following questions:

1. Does the guide provide a reasonable and feasible concept for reducing the current and projected manning problems with the Navy's shipboard electronic systems?

2. What specific user communities can apply the guide effectively during system design and acquisition?

3. Is the specific approach taken in the guide viable?

4. Are the specific data and procedures presented in the guide accurate, complete, understandable, and usable?

5. What revisions are required in the guide to assure its successful implementation?

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[5]See Koehler, E. A. Manpower Availability--Navy Enlisted Projections--FY78-84 (NPRDC Spec. Rep. 79-1). San Diego: Navy Personnel Research and Development Center, 1979.

METHOD

User Identification

Acquisition/Development Community

The guide was distributed by the Chief of Naval Materiel (Assistant Deputy Chief (Technology and Laboratories)) to a variety of naval commands and organizations within the Department of Defense (DoD) as well as to individuals who had provided assistance in developing the guide or had expressed an interest in using it.

To obtain preliminary reactions and to solicit aid in identifying potential users, approximately 100 people within DoD were contacted by telephone about 6 weeks after the guide had been distributed. In the majority of cases, persons contacted either had not received the guide or had not had an opportunity to review it. For those who had not received the guide, arrangements were made to deliver another copy, along with an Information Feedback Sheet, which was intended to obtain information on the recipient's own qualifications, experience with system development programs, knowledge of programs under development that could benefit from the guide, specific individuals who might be users of the guide, and reactions to a series of questions concerning the feasibility of implementing the guide and the completeness of its content. For those who had received and reviewed the guide, telephone interviewers solicited preliminary reactions and suggestions as to potential users. These potential users were contacted and arrangements made to provide a copy of the guide and the Information Feedback Sheet to them.

To obtain a detailed critique of the guide, detailed comments on the best users and likely utility of the guide, and specific suggestions regarding its introduction and implementation in the acquisition community, group interviews were conducted at The Naval Sea Systems Command (NAVSEA) (Codes SEA-05L1C, SEA-3134, and PMS-30612), the Naval Electronics Systems Command (NAVELEX) (Codes ELEX-4701 and 5203), the Naval Electronics Systems Security Engineering Center, and Naval Ocean Systems Command (NOSC) (Codes 924 and 921). A semistructured interview technique was used, in which a standard set of questions and topics was used to guide the discussion and ensure that all pertinent topics were covered. However, interviewees were allowed to digress from specific topics or expand the coverage of a topic to explore areas that were not anticipated during development of the structured questions. An Evaluation Debriefing Form, which included the questions and topics, as well as space for recording interviewee's comments, was used for these interviews.

Originally, plans had been to conduct the evaluation entirely within the Navy acquisition community. After the telephone interviews and the group interviews were completed, the guide was to be presented to a sample of acquisition groups that had Navy electronic systems under development. Members of these groups were to evaluate the guide's applicability over a period of 2 to 3 months and then participate in group debriefings. The Evaluation Debriefing Form was to be used again in these sessions.

However, results obtained from the Information Feedback Sheets and the first round of group interviews showed that it was not feasible to test the guide using only members of the acquisition community. The guide's technical application to system design was seen as almost totally the responsibility of the contractor design community. Further, it was felt that the guide would have to be suitably reformatted, as a military instruction, handbook, or standard, before it could be implemented through contractual specification. For these reasons, it was decided to shift primary emphasis of the evaluation to the contractor design community.

Contractor Design Community

Lockheed's DIALOG search system was used to search the Frost and Sullivan Defense Market Measure System (DM^2) data base to identify contractors with then-current design and development programs in the five areas covered by the guide. The search parameters specified: Navy contracts, electronic systems, stage of work to be either R&D or production, and a minimum program size of $5 million or more for R&D or $20 million or more for production. The cost criteria were included to ensure that the programs were major contracts within, at least, Acquisition Category (ACAT) III, and represented the full Weapons System Acquisition Process.[6]

Approximately 20 development programs in sonar, radar, fire control, communications, or data processing were identified that met the above criteria. For each program, the computer search provided descriptive summaries, which included the sponsoring agency, contracting office, and contract number. Contract numbers were used to identify the technical point of contact within each sponsoring agency, through assistance from the contracting offices. These contacts were then telephoned and briefed on the guide's purpose and scope and the need to survey high-level designers and design managers in the contractor community. In almost all cases, the technical point of contact for each program identified several individuals in the contractor's facility who would be qualified to review and comment on the guide.

Next, the chief contact at each contractor facility was contacted by a letter, which briefly explained the purpose and scope of the guide, the history of problems in operating and maintaining sophisticated electronic equipment in the Navy, the regulatory structure being created under the HARDMAN program, the procedures for the survey, and the required qualifications of participants. Because it was believed that most participants would review the guide and fill out the survey instrument on their own time, the letter stated that a $100 honorarium would be given to each respondent.

Follow-up phone calls were made to identify those chief contacts that wanted their groups to participate in the survey and to identify qualified individuals within each group. Respondents had to have substantial design experience in one or more of the five areas of electronics systems covered by the guide and had to be a program manager, project engineer, or a senior member of the design staff. Because of the close relationship between fire control systems and launcher and gun mount systems, designers with experience in the latter were also included. Initially, 52 qualified respondents from 13 contractor facilities agreed to participate in the survey. Of these, 10 dropped out due to work schedule conflicts.

Survey Instruments

Two survey instruments were developed--Evaluation Package C, for the contractor community, and Evaluation Package G, for the DoD acquisition community. The two instruments were identical, except that Evaluation Package G did not mention the $100 honorarium, which could not be offered to DoD personnel, and addressed the respondents in the context of acquisition instead of design.

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[6]Many ACAT III programs are made up of multiple contracts, all of which may be smaller than specified in the cost criteria. Thus, the cost criteria served to exclude these programs.

Respondents were asked to evaluate the usefulness of the information in the guide's introductory chapters and major sections by responding to six questions, using a five-point response scale, where 1 = the most positive, and 5 = the most negative. These questions, along with their anchor scales, are listed below:

1. Considering my present job as a designer, the information in _________ is (Very useful---Completely useless).

2. If DoD were to seriously impose design constraints based on manpower considerations, the information in _________ would be (Very useful---Completely useless).

3. The information in _________ appears to be (Very accurate---Very questionable).

4. The information in _________ is (Thorough and complete---Full of gaps and omissions).

5. The format (tables, charts, text, etc.) for presenting the key information in _________ is (Appropriate: Easy to understand---Inappropriate: Hard to understand).

6. In order to provide helpful guidance to designers like me, _________ should be (Kept exactly as is---Changed drastically (or omitted).

Respondents who rated parts of the guide as either 4 or 5 were asked to provide comments as to the reasons for their negative ratings. If they were not familiar with the information in a particular part of the guide, they were asked to check a "Don't know" box provided.

Also, respondents were asked (1) to indicate whether they understood the 21 design concepts (Section 1) and the 14 system design criteria (Section 2) and whether they felt they were useful as is, useful if modified, or useless, (2) to explain why they felt concepts or criteria should be modified or dropped, and (3) to describe any concepts or criteria that they felt should be added to the list.

Finally, respondents were asked to provide information as to their job title, type of job, experience with specific systems, and amount of time spent in examining the guide and filling out the survey form.

Evaluation Package C was sent to the 42 respondents from contractor facilities who agreed to participate in the survey; and Evaluation Package G, to members of the Navy acquisition community who had provided unusually detailed critiques of the guide earlier. Appendix A provides a copy of Evaluation Package C.

All of the Evaluation Package C instruments and three of the Evaluation Package G instruments were returned. Since there were no systematic differences in the data from the two packages, the 45 sets of data were pooled for statistical analysis.

Data Analysis

Rating Data from Evaluation Packages

A frequency analysis was performed on the rating data from the 45 respondents to Evaluation Packages C and G. Histograms were generated to show the distribution of responses to the six questions asked concerning the usefulness of the guide's preliminary chapters and major sections. Also, percentages of responses as to the understandability and usefulness of the 21 design concepts and the 14 system design criteria were derived.

Comments from All Evaluators

Comments on the guide were recorded in a variety of forms. This included notes made in Evaluation Packages C and G, telephone interviews, group interviews, Information Feedback Sheets, letters, and memos. All comments were analyzed to identify and extract every "complete comment" (i.e., a comment that stood by itself as a complete, intelligible utterance concerning a topic related to the guide). From this analysis, 1,084 complete comments were identified, and each was transcribed onto a separate card along with several lines of identifying code (see Figure 1). In transcribing, comments were categorized according to their nature and content. Usually categories were the titles of major sections of the guide. Within categories, specific topics were identified. Topics were usually one of the scales, or structured questions, within a survey instrument.

An analyst then synthesized all of the comments within each topic in an attempt to remove some of the redundancy among comments and to recast comments so that thoughts flowed in a logical and comprehensible fashion.

Appendix B lists DoD and contractor personnel who made substantive contributions to the evaluation of the Engineer's Guide.

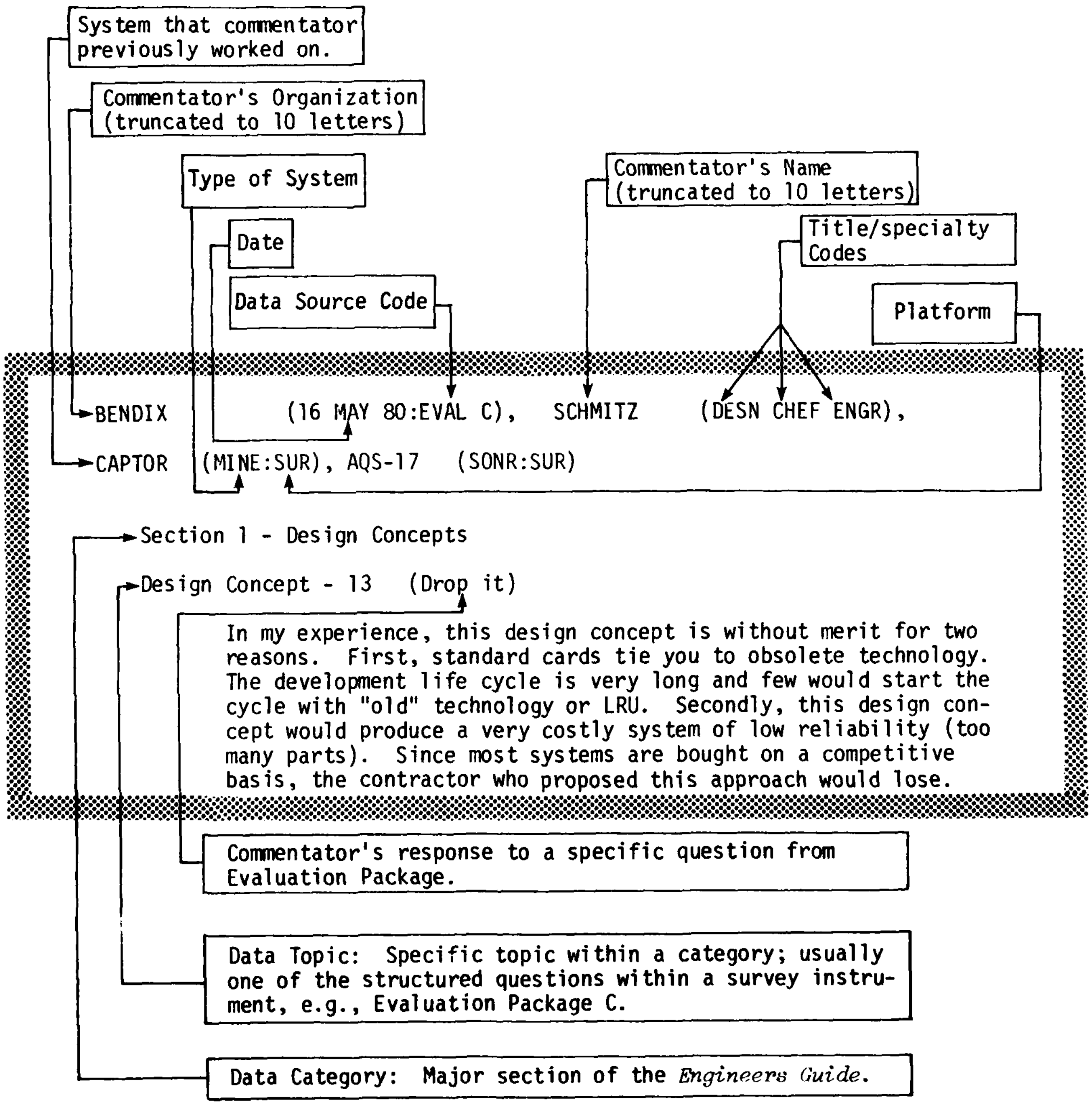

Figure 1. Example comment card with key to identifiers.

RESULTS

Respondents to Evaluation Packages C and G spent an average of 5.5 hours in reviewing the guide, with a standard deviation of 3.4 hours; and an average of 3.3 hours in filling out the evaluation packages, with a standard deviation of 2.0 hours. Since these respondents provided the majority of comments included in this section, many remarks are critical, because respondents were specifically requested to explain why they gave negative ratings. However, the overall majority of respondents generally reacted favorably to the guide, as is evident from the summarized rating data.

In reorganizing many of the comments to follow the sequence of topics in the guide, it was necessary to lift short sections of longer comments out of context. To reestablish a commentator's context and meaning, it was often necessary to add or delete a few words or to restructure some phrases. Because the synthesis of comments from many sources into a reasonably coherent set of statements on a given topic in the guide did not usually preserve the exact original wording of each commentator, quotation marks are not generally used in the following material. Also, it should be noted that:

1. A colon is used to indicate the end of prefatory remarks by the analyst.

2. A paragraph generally contains closely related notions.

3. Where several respondents' statements are contained in a paragraph, all of the comments by a single respondent are in a single sentence, concluded by a period. Semicolons and dashes are used to punctuate complete thoughts within each respondent's sentence.

4. Where a single respondent's statements constitute a paragraph, several sentences may be used to express several thoughts. The context unambiguously distinguishes between single-respondent and multiple-respondent paragraphs.

5. The number in parentheses behind each question/topic indicates how many of the 45 respondents answered or addressed that particular question/topic.

Chapters I and II: Introductory Material

There was little enthusiasm for the material presented in Chapters I and II of the guide. Although most respondents considered that the information was of some use, it apparently did not provide an effective introduction. The problem was not so much the accuracy of what was presented, but certain gaps and omissions. Suggested changes and additions included the following primary themes: rewrite the existing material, demonstrate application of data from the guide to the design process, and add certain technical issues (such as equating system performance requirements to maintenance/operator requirements, other system design tradeoffs, and a weighting system for concept evaluation).

Data from Six Questions in Evaluation Packages

Figure 2 shows how respondents answered questions regarding the information in the first two chapters of the guide. Comments relative to these questions are provided below.

1. Useful for Present Job? (15)

Those who believed that the introductory material was useful said: It could provide information to people who were unfamiliar with the topic. Describes an area that few design engineers have considered. Provides general awareness.

Those who believed that it was not useful said: Training, manpower costs, availability, and Navy-imposed constraints are beyond the scope of the designer. Information was much too complicated and detailed for any program manager or designer to take seriously. No direct practical application.

Other comments included: The information might provide a nice background and awareness of the problem but only a shallow treatment of its symptoms and possible causes. The subject is well known to a depth much greater than this elementary overview. It provides essential information on background and objectives, but it provides no operational direction--does not tell the designer what to DO.

2. Useful for Serious Manpower Constraints? (14)

Here the comments focused more on the realities of trying to apply the data in the introduction. On the positive side, statements included: Programs will initially be more expensive, though life cycle costs would probably be reduced. Material needs to be expanded--what facilities are involved, how does the Navy system work, what are the details of organizational versus depot repair, etc.?

On the negative side, comments included: The information is of little use because it is generalized and may not be correct or appropriate for a specific system. The data are basically motherhood and do not fully address the total system design problem; minimizing the manpower requirement, taken to its ultimate, will result in a completely unaffordable system in terms of hardware cost and development cost.

Other comments were: The material provides interesting questions and insights but misdirects attention from the real problem. The information is instructive, but is not definitive nor provided in a manner that could make it obligatory to the designer.

On the latter theme, others observed: Specific requirements and cost goals would need to be defined. Navy constraints need to be identified. In general, a statement of goals like that provided in these chapters does not tell the designer what to DO.

One commentator stated: Designers are always under the gun in the following order: function, schedule, and cost.

3. Accurate? (6)

Comments included: Information is true and accurate, but only to awaken the uninitiated, not the experienced systems engineer. The data are general and nonspecific. The information should be expanded.

One commentator observed: I never experienced a DoD customer that was serious about maintainability.

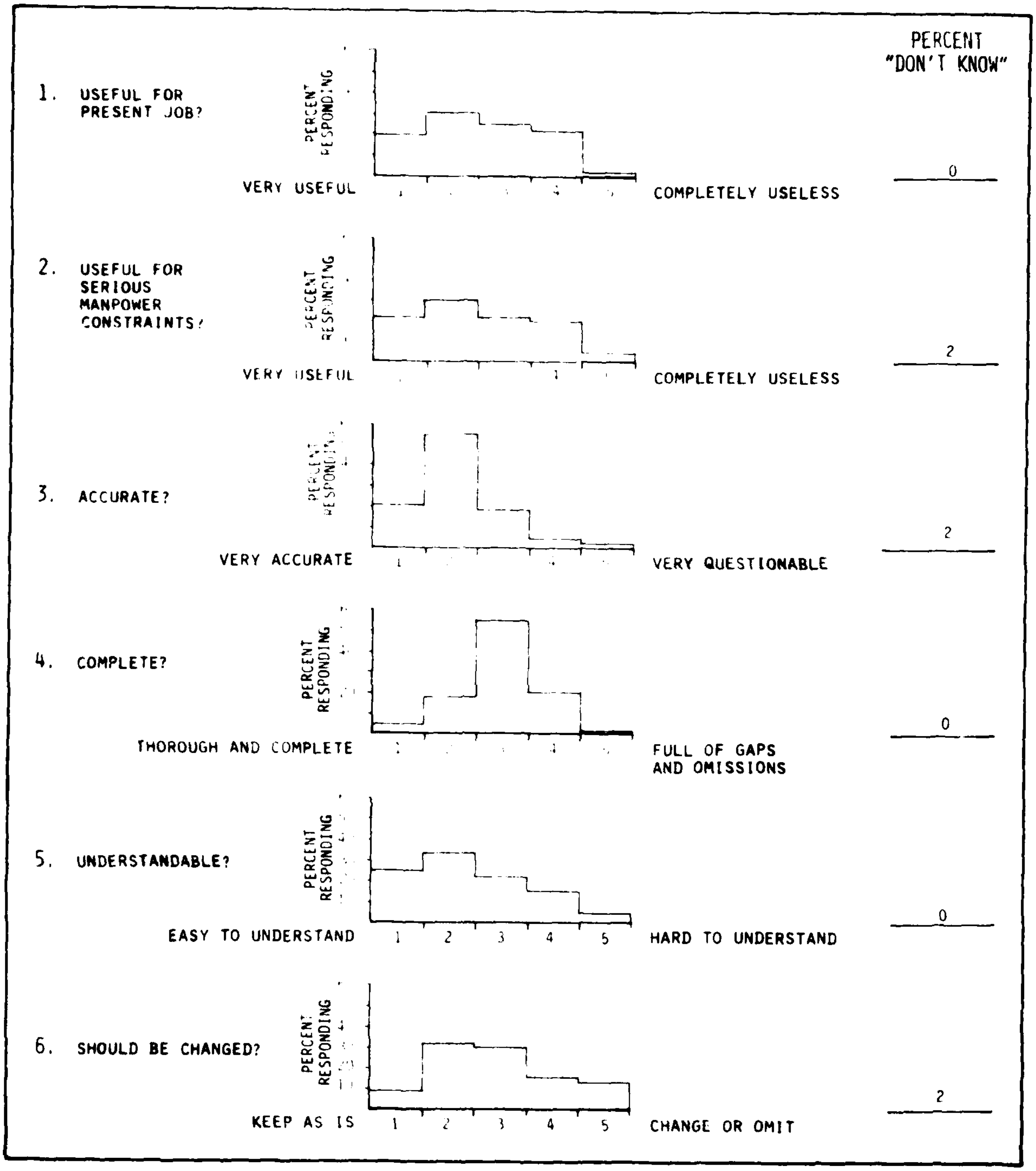

Figure 2. Ratings of information in Chapters I and II: Introductory Material.

4. <u>Complete</u>? (14)

On the positive side, comments included: The information is informative and interesting. Information is general and not exhaustive, but probably adequate for introducing the concept of the guide.

On the negative side, statements included: Doesn't make sense until the remainder of the book is read. Difficult to extract the true intent of this document. Full of redundancy, especially in the four factors driving manpower tasks; nowhere was expressed the basic concept that all systems have two major elements, performance and cost, and that the intent of this document is to cut operating and life cycle costs without sacrificing performance. Very general. Does not address the complete system design problem and would result in a biased design.

Other respondents observed: The maintenance philosophy varies widely with the system type and end use (e.g., aircraft versus submarine). Need better definitions; acronyms need to be spelled out.

One commentator suggested that it would really help the designer if insight were provided into the shipboard organizational problem and the difficulties associated with maintenance task execution.

5. <u>Understandable</u>? (12)

All the comments indicated that the material in Chapters I and II is difficult to understand. Typical comments were: Terms are undefined and the figures too complex--it is very difficult to understand what points are being made. Too much detail in graphics without supporting text. Too many words in boxes--too hard to read; not familiar with all terms used. Print too small; too much information; too complicated to be readily understood; designers simply won't bother with this kind of material. Charts could be presented/discussed more clearly.

Comments on specific figures include: Figure 2 requires more explanation. Figure 2 not needed. Figure 1--explain the acronyms for the uninitiated, e.g., MPT&S, DSARC, etc. Figure 3 is too complicated to be readable.

One respondent suggested that the charts be subdivided according to the user--charts for Navy management should be separate from those charts which are directed to the design engineer.

One commentator observed that in large programs, objectives for human resources are stated much earlier than indicated in Figure 2: Waiting to apply "Navy-imposed criteria" until after Step 5 of Figure 3 is too late.

6. <u>Should be Changed</u>? (21)

Comments indicate that this material should be changed and improved rather than eliminated. One commentator remarked that the orientation provided by this material is important and should be expanded so that the remainder of the book is not used by rote. Suggestions for changing the manner in which the information is presented included: Rewrite completely; I had to read most sentences three or four times before I could understand them. Define acronyms for those not familiar with them; a table of definitions would be useful.

A large number of comments focused on the need to demonstrate the application of this information to the design process: The information is of such a general nature that the imposition of these data, by contract, on the designer will not really result in specific design action. Does not provide guidance, only information. Expand and show examples; provide design review guidelines. Provide more concrete information on the symptoms/impacts of the manpower resources being mismatched with systems; the concepts and milestones in Figure 1 are not explained fully enough to be useful. I could not find a smooth transitional flow from the premise to conclusion; the beginning must be extremely clear and describe precisely the intent of the document, the problems, the approach and the benefits. Need more information on how this would be implemented and how the design will be constrained.

A number of comments focused on specific technical issues: Expand information to equate system performance requirements to maintenance/operator training requirements. Expand to at least address other areas of system design tradeoffs; indicate a weighting system to help in concept evaluation. Rewrite in one cohesive form (basic ideas are good) and add information that different systems will have different responses to the questions rather than leave this an implied point.

One respondent noted an apparent lack of direction to a specific user audience for the guide. He stated that Chapters I and II seem to be a rationale for a book written for Navy personnel rather than design engineers.

Another commentator pointed out that consideration must be given to include data on the Standard Electronic Module Program (SEMP) and Navy Standard Processors (e.g., AN/UYK-7/20, AN/UYQ-21, etc.), which are often specified as required equipments and which have significant impact on designers.

One commentator pinpointed the real issues behind the guide. He stated: The last 20 years of DoD and NASA history are replete with attempts to impose expensive, complicated solutions to similar problems; designers and program managers are usually constrained by "design to cost" or similar features, and if human resources are to be considered, a simpler, more direct index must be provided.

Comments from Other Sources

The following general comments came from sources other than Evaluation Packages C and G. To a certain extent, these comments are similar to comments covered under the various questions listed above.

Several commentators stated: The flow chart in Figure 3 was useful; however, the top and bottom halves of the flow chart should be connected because the arrow didn't seem to go anywhere. Also, the connection between the flow chart and the boxes that precede each of the following sections in the guide should be highlighted to help the reader make the connection between the master flow chart in Figure 3 and the remainder of the guide.

There were several comments to the effect that the introductory material was confusing at first but understandable after a reading of the guide. This would indicate that the introductory material was counterproductive.

One respondent wrote: The material was too academic; the design engineer does not think in those terms. The questions posed in the introductory material could be retained in the form of a checklist, but they should be made simpler. A different general observation was: The introductory material should be beefed up to include more about the methodology and potential application of the report. Another commentator wrote: The title and introductory material give an impression of promising to solve more problems than the guide actually does; the guide claims it provides a more rigorous, objective and tight methodology than is, in fact, presented.

Several commentators stated that the best audience and users of the guide would be manpower and training analysts within the Navy. These commentators stated: Personnel skill level and availability information already exists (contrary to a statement in the introductory material in the guide), but it is not used by designers. The manual could be best used as a "monitoring" tool to review contractor proposals. Contractor designers need to be influenced in order to impact human resources requirements through system design, but this would be best accomplished by using the guide to monitor contractors rather than by developing a procedure for having contractors implement the guide themselves.

One evaluator included a general comment about the graphics used in the guide. He believed that most of the figures needed redesign to increase eye appeal and to highlight the central point illustrated by each figure.

Finally, one evaluator seemed to want to absolve designers of responsibility in addressing Navy human resources problems. He stated: The responsibility must be placed on the individual maintenance man to maintain a certain level of proficiency in order to advance.

Section 1: Definition and Impact of Design Concepts

Section 1 was rated as being both useful and understandable. Respondents commented that the section would have been even more useful had greater detail been provided, particularly on the impact of design concepts on system cost. Also, there was concern about the difficulty in applying information of this type to the design of future systems.

As shown in Figure 3, the accuracy of the data were questioned. Concerns included the judgmental nature of the data, the relatively small sample of judges, the qualifications of the judges, the lack of validation, and the lack of information on response variability.

Twenty-six respondents recommended that this section be changed in some manner. Principal recommendations were to: reorganize and reformat the material for easier application, improve the measurement scale, and expand the number of judges and the scope of their experience.

Data from Six Questions in Evaluation Packages

Figure 3 shows how respondents answered questions regarding the information in Section 1. Comments relative to these questions are provided below.

1. Useful for Present Job? (16)

Several positive comments included: This is an excellent presentation. Table 1 and the definition of the 21 design concepts are useful. Useful in creating awareness of operator/maintainer tradeoff philosophy. Principal payoff is in large systems (e.g., AEGIS, DD 963, FFG, DDGX).

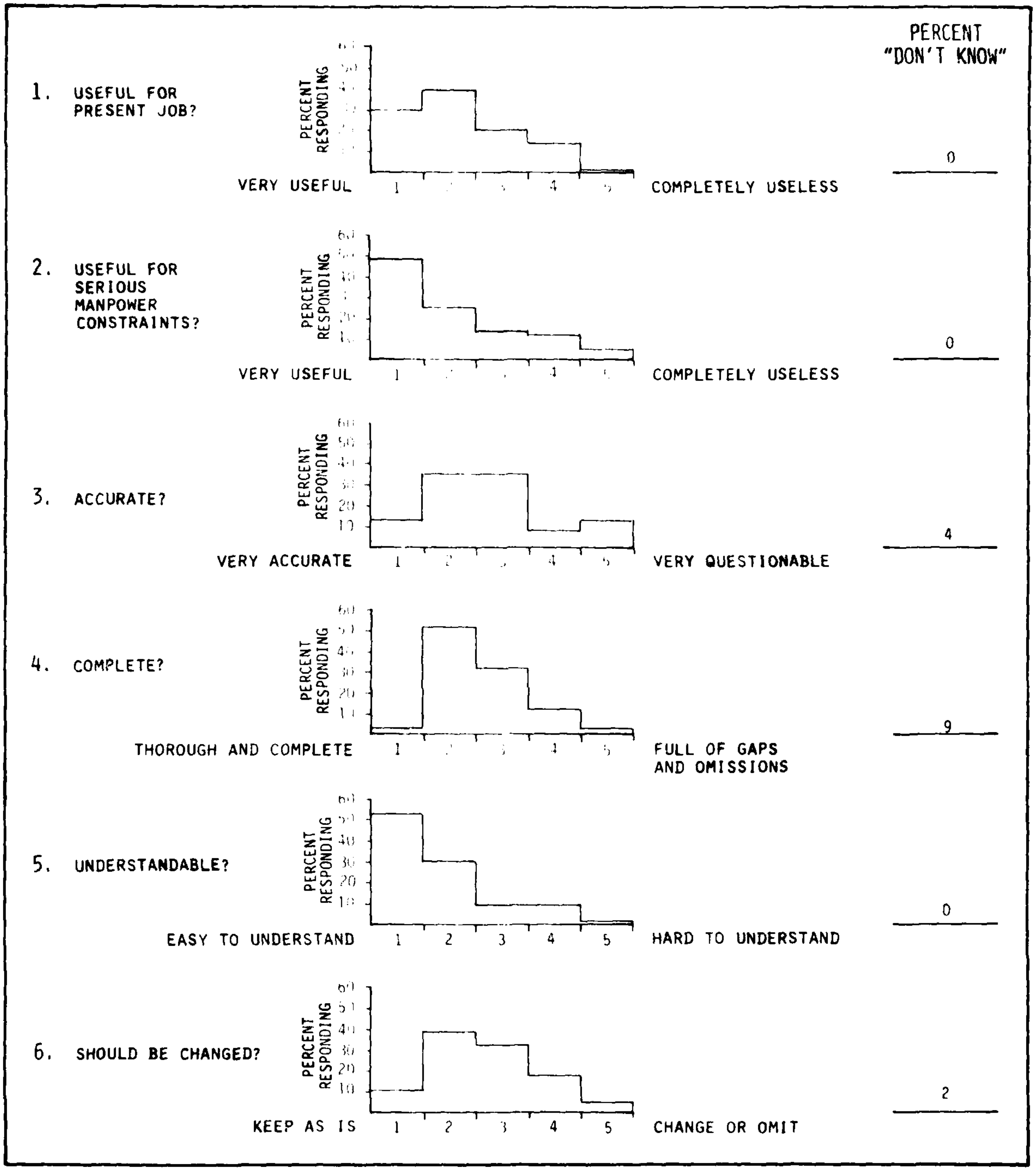

Figure 3. Ratings of information in Section 1: Definition and Impact of Design Concepts.

Two commentators saw the usefulness of the data and made the following suggestions for improvements: A more detailed discussion of the significant elements of Table 1 would be helpful; why, for example, does "automatic decision-making" have such a negative impact on maintenance? The information presented is quite informative, but is difficult to assimilate; the data shown in the charts would be more effective if some summary and cross-correlation were provided.

Several respondents expressed difficulty in accepting judgment data: Provide the data point for consideration, but the measurable utility is questionable; the 21 questions are not really all pertinent and the data used to measure them are opinions, not hard facts. Don't really know what the percent beneficial/adverse impact means or what it is based on; evidently it is totally subjective. As stated, the data are subjective. A larger data base may provide different results and would be desirable.

Several comments demonstrated concern for relating the data to cost considerations: It's hard to determine the value of the data; how does one use this in terms of dollar tradeoffs in the system design process; what is the appropriate algorithm? I could not relate the data to system costs. The buying activity should indicate the importance of these things prior to proposal evaluation and negotiation, not use this approach as a fudge factor after the fact to justify a decision; the cost impact of this approach would be serious. Two commentators indicated the information misses the mark in system design: For a system design concept, much of the information is irrelevant. All programs, regardless of concept, already specify use of good equipment layout, standard hardware, operational simplicity, use of LRUs, etc. Considering the magnitude of the problem, I do not feel that many of the design concepts are viable, particularly if an effort is made to categorize hardware (e.g., simple/complex, electronic/mechanical, onshore/shipboard, etc.).

One respondent had a series of objections to the approach: The whole concept and the basic premise of quantifiable design concepts for tradeoff studies are faulty. The areas which are listed in Section 1 are not congruent (e.g., automatic decision-aid is much more complex and dependent upon implementation than are the four approaches concerning LRUs). The designer does not have flexibility in all of these areas. There are many more areas that have not been considered--use of standard building blocks, backfit vs. forwardfit interfaces, and modularity, reaction time, performance vs. cost, etc. The data used to quantify the concepts are based on a limited set of opinions. Several concepts are too general to be useful, while others are misrepresented. In many cases, the utility and impact will vary between systems and specific implementations.

2. Useful for Serious Manpower Constraints? (13)

Several comments echoed those that were made under the topic above and will not be repeated. Two comments suggested that the approach would be useful: The information is useful for trends. The approach would be useful with realistic, quantitative data.

Two commentators indicated that the approach was not new: DoD is already imposing restrictions on certain new ship and systems development (e.g., AEGIS, CG 47); requirements have been established since the contract start in 1970. This approach has little use; there is nothing really new here.

One respondent said that manpower should be responsive to design, not the reverse: This is a cart-before-the-horse approach based on a single constraint--manpower. It's like squeezing a balloon--manpower can be brought down, but other items, like system cost, will go up. It's not practical.

One comment implied difficulty in implementing the approach via contract: The data are not presented in a manner than can be quantified and dictated by specification parameters.

One commentator suggested that the information could be updated to get a perspective on the design concepts from the operator/maintainer viewpoint.

Two comments indicated that the data are complicated and cumbersome: There seem to be too many choices; this serves to complicate the design process. There is no handy way to find the required data; it would be better to relate it to a specific design under consideration.

Another comment concerns additional difficulties in applying the approach: The 21 design concepts are not all under designer control and many address issues that are greater than the single system, e.g., platform/force maintenance problems and concepts.

3. Accurate? (16)

One respondent stated: In most cases, the data agree with my intuition and experience. Another commentator took the opposite view: I have considerable disagreement with the conclusions drawn on the effect of the design concepts on the A through N System Design Criteria.

A large number of comments focused on the accuracy of the data base: Accuracy of all tables in all sections is questionable; variance is not given, but it is stated that there are wide ranges. There was no presentation of any data to validate the impacts. There was not enough information on the way the data were obtained or the qualifications of the respondents; also, the number of respondents seems low. I have to be a little skeptical of the limited number of raters; were they balanced with regard to their respective backgrounds and professional specialties? There is not enough information on the 32 judges to trust their judgment over my personal experience and that of the people who work for me. The attempt to quantify the impacts of these design concepts is dangerous, since it is based on a small set of opinions; in some cases, the concept appears to have been misrepresented or misunderstood; in others, the impact is so dependent on specific implementation that a generalization is ridiculous (e.g., automated support of operations and maintenance). The sample size is small and biased in favor of the procuring agency's viewpoint; increase the sample size by using industrial equipment designers (not prime contractors); comparing a "design concept" to a "baseline concept" may give a perceived advantage or disadvantage but little accurate quantitative data.

Some commentators disputed the accuracy of data presented for specific design concepts: When system complexity is increased, MTBF is increased, not decreased as stated in the guide. Data are at least debatable; for example, LRU concepts are dependent on the size of the LRU; a limit of five lowest replaceable units, as compared to 20 makes a major difference in the weights. I had trouble with the view on embedded computers and with some of the analyses on initial acquisition cost; also, the analysis of supply and support costs appear to support the Navy myth rather than actual experience costs.

One respondent described how the accuracy of the data could be improved by using a different system for categorizing the design concepts: Design concepts cover too broad a range. They could be better categorized into small systems or units, subsystems, large systems, unmanned vs. manned vs. multimanned systems, etc.

4. Complete? (10)

Two respondents said that the material was too generalized and should be more specific. One said: Surely this is not purported to be a complete list of design concepts which impact maintainability and operability?

Two respondents reiterated questions concerning the data base: It would be good to get a bigger data base of opinions. We are forced to assume that this work is valid; the information in the technical report covering the development of the guide would be crucial to determining if the data really are valid.

Commen*s on specific topics in Section 1 included: Expand definition of the term "technical fea bility" and add an explanation of "technical and practical risks." The calibration of the asurement scale (e.g., plus or minus 30 percent) is not explained satisfactorily. On uld review standard hardware versus system complexity and mean time to repair.

Two comments suggested that the data were presented in something of a vacuum: The effect of combinations of design concepts should be considered; this is usually the case in actual maintenance design concepts. The technical aspects of the system should be tied in to this discussion; design concepts that might help manpower should be considered in the context of maintaining the required level of technical performance of the system.

Two comments suggested that the information was not complete unless it considered several additional design concepts; these design concepts are presented in a later section.

5. Understandable? (10)

One commentator said: I like this type of presentation as it is easy to spot trends.

Four comments suggested problems with the data: Formats bothered me at first. It is not organized in a useful form. It took a few minutes to figure out these charts; a specific point of confusion is the fact that the "0" on the charts is equivalent to the "baseline" design concept; this was not explained or I missed it. The charted data are hard for the designer to translate into hardware requirements.

Two comments suggested difficulty in understanding Table 1 and suggested that a good explanation is needed.

Figure 4 was also a problem: Figure 4 (and other initial figures in each section) should be set apart from the text more clearly, perhaps with a solid line across the page. This would also highlight the purpose of the figure. I like the use of cross-reference tables in Sections 1 and 2.

One respondent stated: Format is okay but the content is misleading. A better approach would be to show sigma bars around responses.

6. Should be Changed? (26)

Several comments under this question echoed sentiments and suggestions expressed earlier and will not be repeated here. A large number of comments were made under this section; they are grouped below according to the main focus of each comment.

Three commentators did not like the basic approach and/or the content of the data in the guide: As presented, it is an attempt to quantify and legitimatize some subjective data and is not useful. The generality of the operational design concept is too great; what does "operational simplicity" really mean to the rater?--minimizing options in an inherently complex system may still leave the operator with difficult tasks to master. Curves 2 through 5 on Pages 1-1 through 1-17 do not all appear to be logical or consistent.

Several commentators indicated that the material should be reorganized and reformatted: Information would be useful if it included a good index. Information should be reviewed and reorganized. Simplify it by changing and improving some concepts that are obviously not applicable. Should be revised and streamlined to include only those items that actually affect a system design criterion. Drop profile write-ups from the description section on the concepts; the discussion of the profile detracts from the presentation; the reader can get the same information by examining the chart himself. I believe it would be more convenient if the graphs were presented as numerical data in a single table.

Several respondents remarked that the material, as presented in Section 1, was inordinately difficult to understand: Text material, Pages 1-1 through 1-5, is very difficult to understand without rereading it several times. Eliminate "taxonomy" as its meaning is not clear; use normal words! Provide more complete explanations. Explain the system design criteria in Section 1; although these definitions do appear in Section 2, they don't help the reader very much when he is still in Section 1 and needs to know the information.

A couple of commentators had difficulty finding the definition of "technical feasibility": No definition of "technical feasibility" was found in the publication although it is presumably a measure of the probability that the system design concept could be implemented; perhaps a brief definition of the term and how it was derived could be included. Show technical feasibility in Table 1.

Several respondents expressed a desire for improvements in the measurement scale: The percent values of each criterion are not necessarily comparable units (e.g., how does a 20 percent increase in acquisition costs compare to a 10 percent decrease in MTBF?). Presentation technique is good but it would be helpful to have some guides on the importance of 10, 20, 30 percent impact; how much is necessary in order to cause a design modification? Need a way of showing the relationship (weighting) between items.

Two commentators focused on the size of the group of the judges and problems with consensus: Try to get more than 32 opinions for consensus. The data base should be expanded and upgraded with fewer indecision marks.

One senior program manager suggested: Some changes need to be made in this data base. The way "Technical feasibility" is defined in the guide doesn't tell me anything. The profile evaluation could be more specific; at this point it's not too useful for deciding between controversial items. I don't know what the percentages mean.

Another senior program manager suggested: A methodology should be developed to relate types of equipment and missions to specifications for the appropriate BITE penetration, spares planning, etc. How about including a designer's consolidated and comprehensive checklist?

Data on Specific Design Concepts

Table 1 shows how respondents rated the understandability and utility of each of the 21 design concepts. The number of responses upon which the percentages are based varied from 38 to 44, depending on the design concept and the type of question. In some cases, respondents markings were illegible; in others, respondents chose not to mark a category for a number of reasons: problems in understanding the design concept, disagreement with a specific design concept, or disagreement with the general approach taken in the guide. These comments were included in the comment data base. The "Utility" percentages are based on 38 to 43 responses; and the "Understandable" percentages, on 41 to 44 responses. Since responses indicated a high level of understanding of all 21 design concepts, the following paragraphs will focus on their utility.

1. Equipment Layout to Facilitate Maintenance. (3)

Comments included: This is the most important design concept in my opinion. This design concept needs categorizing relative to systems size--1-box, 10-box, possible compartment locations, submarine or surface ship? This design concept also impacts MTBF via special flex cables, smaller partitioning with worse cooling, etc.

2. LRUs--No Spares. (21)

Almost half of the respondents indicated that this design concept should be dropped: Drop it; this is impractical from a realistic, real life standpoint; it is not cost-effective. This philosophy would apply only to a small number of systems since integrated circuits are so prevalent and these are essentially not repairable. Should be dropped because of its adverse effect on overall operational capability. It would be a logistics nightmare to supply each ship with "piece parts"; also, the distribution and inventory costs would be significant. Requires an extremely knowledgeable person to repair the equipment. Only useful in nonessential equipment. There is no guarantee that a defective LRU can be repaired--this puts the equipment completely out of service. No design work is done to this concept any more; thus, including it in the guide is a waste. This is just a space filler for the guide; there is a 33-percent disagreement on its impact, and there are no practical differences in any event. I can't conceive of a no-spares situation for a primary combat system unless the design employs a great deal of redundancy; you just can't wait for LRU repair in many cases. Too much risk that complete capability could be lost for long periods. The rate of technological advance is such that the use of this holdover concept would produce proportionately greater acquisition costs with time. Components would have to be spared and more sophisticated test equipment and skills training would be required. Should be dropped since we do not consider personnel to be capable of onboard repairs; the no-spares concept for most Navy electronics equipment is never considered. For a complex system of high value, this is not a viable concept.

Three commentators indicated that the concept should be modified. One said that the definition of LRU was wrong, that it could include any type of assembly. One pointed out the questionable value of having all technicians trained to handle repair of PC boards. The third commentator suggested that Design Concepts 2 through 5 should be combined in some fashion to achieve a better logical categorization; he said that Design Concepts 2, 3, and 4 require maintenance at some level, whereas Design Concept 5 requires no additional maintenance.

Another commentator suggested that Design Concepts 2 through 5 were all viable and worth keeping; however, he presented the following insight on problems with sparing: Decisions regarding LRU spares are too often made at a provisioning conference

Table 1

Reactions of Commentators to Specific Design Concepts

DESIGN CONCEPT	Understandable (% Responding)		Utility (% Responding)		
	I Understand it	I Don't Understand it	USEFUL: Keep it	USEFUL: Modify it	USELESS: Drop it
1. Equipment layout to facilitate maintenance	100	0	87	8	5
2. LRUs--No spares	100	0	42	12	46
3. LRUs—Spares with onboard repair	100	0	68	20	12
4. LRUs—Spares with remote repair	100	0	83	10	7
5 LRUs—Spares with throwaway maintenance	100	0	71	17	12
6. "Overdesign" for reliability and maintenance	100	0	65	28	7
7. Embedded computers	95	5	35	51	14
8. Automatic performance monitoring	98	2	64	31	5
9. Built-in test equipment	100	0	74	21	5
10. Built-in troubleshooting logic aids	98	2	69	26	5
11. Automatic fault localization	98	2	65	28	7
12. Standard hardware components	100	0	67	21	12
13. Standard hardware--Cards/LRUs	100	0	66	19	15
14. Standard hardware--Functional units	100	0	55	21	24
15. Standard hardware--Subsystems	100	0	73	17	10
16. Operational simplicity	100	0	81	12	7
17. Built-in operator performance aids	100	0	78	10	12
18. Automatic decision making	100	0	62	30	8
19. Automatic information transmit and display	98	2	71	19	10
20. Built-in training capability	100	0	72	15	13
21. Combined operator/maintainer functions	100	0	61	18	21

Note. 31 percent of the respondents indicated that additional design concepts should be included.

and are made on the basis of funds that the Navy has at a particular point in time rather than on the basis of the designer's concepts. As a result, the system is supported in accordance with a later logistic concept rather than the original design concept. This results in a mismatch between sparing support and system design. To correct this, a firm decision should be made at the time that the specification is issued on what the LRU sparing philosophy will be as well as the point-of-repair.

3. LRUs--Spares With Onboard Repair. (7)

Most of the seven comments suggested that this design concept be dropped or modified. Those who said it should be dropped stated: This would keep the system off the air during maintenance. This has all the disadvantages of Design Concept No. 2, with the added cost of a set of spares. Since most electronics is now mounted on printed circuit boards, which require a high degree of skill to repair, this option was never considered other than in an emergency; I consider any shipboard repair to be very detrimental to system reliability later on.

Those who said that the concept should be modified stated: In many cases onboard repair will not be cost-effective, since it is likely that more test equipment and training will be required. Limit the types of onboard repair. Minimize onboard repair.

One commentator introduced a wider perspective in considering this design concept, along with Design Concepts 4 and 5: How about adding the concept of onboard-repair/remote-repair/throwaway philosophy based on proper logistic support analysis and life cycle cost considerations? This is current reality.

4. LRUs--Spares With Remote Repair. (5)

One commentator said to drop this concept: This system has the same limitations as Design Concepts 2 and 3 but utilizes an unworkable supply concept.

Two respondents said that the concept should be modified: A compromise between Design Concepts 2 and 4 could be worked out; however, I am not sure how you would select which spares to carry. In Design Concept 4, the concept needs a standard Navy circuit board size in order for the concept to work; a combination of Design Concepts 4 and 5 would work even better where you would have throwaway for a given dollar-value board and remote repair for the remainder.

Two commentators endorsed this concept: With proper planning and support, this concept can result in adequate support at moderate costs, either with depot or contractor repair. Although this concept has merit, I feel that "remote repairs" simply means "at a contractor facility."

5. LRUs--Spares With Throwaway Maintenance. (6)

Three of the six comments indicated that this design concept should be dropped: It has the same limitations as Design Concepts 2, 3, and 4. It's possibly workable, but at a high price, probably too high in view of the trend to pack a lot of hardware/software onto a single board. It costs too much.

Three comments suggested that the concept be modified: No system can afford complete spares or throwaway maintenance; this should be modified to read "partially spares with remote repair and partially spares with throwaway maintenance." Throwaways should be determined by cost. In deciding on a throwaway, one must also consider the cost of repair (e.g., paperwork, test, evaluation, actual repair, etc).

6. "Overdesign" for Reliability and Maintenance. (10)

Two comments noted the current status of this concept: Some current system specifications already require that you consider overdesign. Overdesign has proven useful on submarines, especially stable circuits. High reliability JAN parts and components are already required in the general and equipment specifications; this concept would be valid for redundant circuits and backup mode equipment.

Several comments reflected different emphases in discussions of this concept: Redundancy is mentioned but I suggest that a little more emphasis be given to redundancy in circuit design. In the explanation, I would emphasize redundancy much more than component ratings; we are now required to use very high-rated components, but failure is more likely to occur in the board, solder joints, connectors, etc.; so redundancy is the main design tool. I believe we consider hydraulic/mechanical interlocks in lieu of additional electronics. Provide an example of the use of each design concept and, if several methods are used to achieve a particular design concept, provide as many examples as methods (e.g., higher-rated components, system redundancy, ultrareliable components).

Three comments focused on possible difficulties with this design concept: If a circuit seldom fails, the sailors will have little practice in repairing it; they will have forgotten their training and must be very competent to fix it. Difficult to implement effectively. The timely availability of higher quality parts is a real problem in implementing this design concept; in considering this concept, you should include the effects of likely scheduling difficulties.

7. Embedded Computers. (25)

The large number of commentators on this topic almost universally criticized the guide's treatment of this design concept. One commentator stated: Your concept is naive; you have erroneously made the baseline to be 1950 technology. Page 1-21 indicates a definite "cultural lag" in accepting microprocessor technology. Don't confuse microprocessors, which are part of a technology, with "distributed processing," which may become a system requirement in complex multifunction, multicomputer systems. Also, embedded computers seem to be out of place with the other design concepts. There are other more system-relevant computer configurations decisions that impact maintenance and maintenance philosophy; these include redundancy and reconfiguration.

Other commentators found fault with the presentation on embedded computers in the guide: This is not the same type of concept as the others; maintenance people can learn about troubleshooting embedded computers as easily as any other logic circuit. I question whether the new microprocessors are as unreliable as the profile indicates. Embedded computers can be treated like any other LRU at a remote repair depot; they can be tested as a total "black box" with a sophisticated card analyzer. The description of embedded computers does not have to be true; the data shows a great misunderstanding of the technique. Consideration of embedded computers as LRUs with remote or throwaway maintenance would alleviate the shipboard maintenance requirements for such units. I disagree with the definition as stated and the group that provided the judgmental analysis; this is an extremely immature technical attitude; I could see constraints on the use of microprocessors, but not as stated in the guide. The degree of difficulty in maintaining embedded computers is dependent on the maintenance philosophy that is employed. Embedded computers can be readily checked by automatic test equipment, which nullifies the adverse impacts under System Design Criteria A, B, C, E, and F.

A large number of comments focused on the actual benefits of embedded computers: Embedded computers are useful for implementing Design Concepts 8, 9, and 10 and may be cost-saving. Embedded computers may lead to better fault isolation. With adequate BITE, embedded computers can be effective in permitting maintenance by lower skill levels. Consideration should be given to the diagnostic capability embedded computers can provide. Totally disagree; I think most people miss the point; embedded processors do not require standard computer-type maintenance but should be treated as any other logic card with some built-in test capability; embedded processors are, in fact, the best means of accomplishing reduced manpower for complex systems. If embedded computers were combined with automatic performance monitoring and built-in trouble-shooting aids, then the negatives on the data charts should become positives. Disagree--embedded computers and implanted test points provide fault detection/isolation capabilities; this evaluation is completely in error. Suitable application of limited embedded processing can save centralized processors, which create their own problems of programs and control. If properly implemented, embedded computers can enhance maintenance.

Three comments focused on the widespread and growing use of embedded computers: It would be hard to stop or even slow down the use of microprocessors; very large-scale integration is the "wave of the future." This concept will get greater emphasis as large-scale integration and very-large-scale integration matures and the military better learn to handle proper maintenance training. I believe this is a more common practice than the text implies; the descriptive text seems obviously biased against the concept. The profile is accurate for now, but by the time this is published, it will have drifted to the right about 10 percent; this is the most dynamic design concept right now, and the results in each case are highly dependent on the quality and type of implementation.

8. Automatic Performance Monitoring. (5)

The five comments on this topic were quite varied. They included: Automatic performance monitoring is okay if it is coupled with attempts to automatically restore degradation. You should include PMFL (Performance Monitoring and Fault Localization); this would increase initial design costs but greatly reduce training, MTTR, and required experience for personnel. Do you mean performance or operational readiness monitoring?--true performance monitoring by automatic means would be far more adverse than shown. Because the chart shows that 33 percent of the system design concepts were marked "Substantial disagreement on impact," this concept should be modified or possibly deleted. One commentator offered the following observations about automated performance monitoring: The impact on MTBF will not be adverse if the interfaces are fail-safe.

One commentator believed that Design Concepts 8, 9, 10, and 11 should be combined into one or two design approaches.

9. Built-in Test Equipment. (2)

One commentator said: This design concept has the greatest potential for reducing maintenance manpower; the "high initial acquisition cost" is really a good investment.

The second commentator said: I don't believe the chart reflects a true picture for the impact on System Design Criteria D, G, and N.

10. Built-in Troubleshooting Logic Aids. (4)

One commentator stated that the design concept needed a better definition and specific examples. A second said that this concept should be used in conjunction with separate test equipment and documentation as a transition strategy between the baseline and fully built-in troubleshooting logic aids.

One respondent stated: Too much sophistication in troubleshooting aids can drive the maintainer away from getting a "feel" for the equipment. The maintainer must have a functional understanding of the equipment.

Two commentators were concerned about software costs for implementing this design concept: Software costs are underestimated. This design concept has a great potential for reducing maintenance manpower, but the software aspects could drive costs up.

11. Automatic Fault Localization. (8)

Two commentators indicated difficulty with the definition of this design concept. One commentator wanted it expanded and examples provided. The other stated that the definition of automatic fault localization to three printed circuit cards is unrealistic, that such a low number of cards would drive the costs, the computer programming, and the size up too far. A third commentator said that if the amount of circuitry required to provide automatic fault localization is substantial, the maintenance of such circuitry must be considered.

Several respondents saw the virtues in automatic fault localization: This concept will grow with the use of very-large-scale integration; it has great long-range potential for manpower savings. Fault localization pays for itself, particularly in MTTR; however, the tendency is to go overboard with fault localization--better to concentrate on the most common failures.

Two commentators disagreed concerning the negative impact on MTBF. One stated that: MTBF is not negative because MTTR is the overriding factor.

Another commentator indicated that MTBF would not be affected negatively, as shown in the charts, especially if fail-safe interfaces existed between the test system and tactical functions. However, he cautioned, while automatic fault localization does significantly improve a portion of the MTTR, it won't do it to the extent shown in the chart if you take into account all the steps and procedures involved in mean logistics downtime (MLDT).

12. Standard Hardware Components. (7)

One commentator heartily endorsed this design concept: Your improvement percentages for System Design Criteria A, B, C, E, F, H, and J are conservative. Printed card board design may vary across contractors, but other system specification requirements can make further improvements through standardization--standardized cabinets, standard printed card board nests, access, replace without adjustment, etc.

One senior member of the design community said: If the desired system capabilities are to be met, the Navy supply system should be improved to use this concept. Alternatively, the Navy could help with vendor component availability. The utility of the concept depends on how it is managed.

Another commentator pointed out a practical problem in implementing this concept: Somewhere or somehow, a designer must be made aware of where data on standard Navy hardware is available for his use. One commentator stated that standard hardware should be used where practicable but not across the board.

Two commentators rejected use of this concept: Since I see very little repair at the component level aboard ship, standardizing at the transistor, resistor, etc., level would not accomplish much; I would drop this. The designer cannot keep up with technology and new requirements if he uses this concept.

13. Standard Hardware-Cards/LRUs. (10)

One comment supported this design concept: Very effective in reducing acquisition cost and improving MTBF via higher production. Four comments indicated rejection of the concept: Not compatible with current techniques; this is really 1960's stuff that did not work. Strongly disagree that this is a useful concept. Standard cards tie you to obsolete technology; since the development cycle is very long, very few people would want to start the cycle with old technology; also, this design concept would produce a very costly system of low reliability (too many parts). Today's systems are so complex and the goals are so precisely defined that such standards would be awkward to use. For example, the digital function cards, which were general purpose, that were offered by numerous companies in the 1960's are practically nonexistent today.

Other problems in using this design concept were mentioned: This is generally specified in the individual equipment specification and is not optional to the designer. This concept is feasible but it is limited by performance requirement.

One respondent expressed disbelief that standard cards exist.

14. Standard Hardware-Functional Units. (10)

Three commentators believed that this concept should be included with No. 13. One of these suggested it should also be combined with No. 15.

Several commentators saw problems in implementing this concept: Not practical, every system has its own requirements. Difficult to accomplish. Most hardware systems have unique requirements; unless standard units were very cheap, this would be a very expensive way to design. Complex functional units are rarely exchangeable between systems. With the advent of very-large-scale integration, functional-unit packaging for large signal and data processing systems becomes less technically feasible and would increase manufacturing costs; production technology for very-large-scale integration and discrete components to be put on the same board may be difficult.

15. Standard Hardware-Subsystems. (6)

One comment suggested that the beneficial-impact percentages for System Design Criteria A, B, C, and F were conservative.

Three respondents related this design concept to computer systems: Think this only applies to the computer world; it doesn't mean much to other designers. I am not aware of any standard hardware subsystems unless this is addressing items such as the UYK-20, UYA-4, etc.; if this is the case, it should be made clear. This design concept must be modified to reflect that the approach results in the use of outdated, inappropriate hardware (e.g., UYK-7 and UYK-7 watercooled computers).

Two comments suggested problems in implementing this design concept: Standard hardware subsystems cannot provide acquisition-cost advantages unless the equipment and documentation are available early in the design process; also, the standard subsystems cannot be too elaborate (i.e., provide everything for everybody). Standard hardware at the subsystem level is impractical because it requires too much designer research to implement.

16. Operational Simplicity. (5)

Two of the five comments indicated problems in the definition of this design concept: Need better definition of simplicity (e.g., does it mean many simple modes are easier than fewer complex modes?). Also, need guidance on MMI criteria. The choices for operational simplicity need to be made more specific; also, you must consider the cost of this simplicity in terms of a reduction of total mission performance capability.

Two comments indicated the problems in implementing this concept: The problem is that no two areas of discipline agree on what controls they need and what they can do without. Where electronics is used to control complex mechanical equipment, like missile launchers and gun mounts, the mechanical maintenance requirements limit the degree of operational simplification.

17. Built-in Operator Performance Aids. (2)

Of the two comments made under this topic, one could not be interpreted. The other stated: Maybe there should be two categories of design concepts; one would be General Concepts and the other Special Concepts. Design Concept 17 would be in the Special category. It would only be of value in a system where the operating sequences were so weird that cueing was necessary.

18. Automatic Decision-Making. (6)

Three comments indicated a need to clarify the definition of the concept: Needs clarification about the nature and level of decisions to be made. Complicates matters and can be misleading. Does operational capability and effectiveness diminish when the automatic decision is unacceptable? Needs to deal with the case where an operator may override the automatic decision.

One commentator stated that the design concept may reduce required operator skills but greatly increase maintainer skills.

One commentator offered the following to explain the trend toward automatic decision-making: Tactical threats, reaction time requirements, complexity of processing, multiple target AAW handling, etc. are driving some systems in this direction. The slower moving scenarios of ASW can be approached differently, as can surface warfare in a limited number of cases.

19. Automatic Information Transmit and Display. (5)

Two comments indicated problems in implementing this design concept in certain cases: You can't do this with individual systems; it is only possible when dealing with a whole ship. Requires total integration into ship routine.

Two commentators said that there was no alternative to using the design concept: This is basic to most modern systems; who would design without it? In my opinion, today's technology has made the alternative trivial, particularly when trying to conserve personnel.

One commentator offered the following to explain why alternatives to the design concept may still be viable for Navy systems: In the case of this design concept, technology is competing with traditional Navy schools of thought concerning "ship driving" and "ship fighting." Improvements may be accepted in selected pieces of equipment, but the OOD will not let a technically bright contractor take over the entire operation of his bridge. In casualty conditions, when computer-aided displays have failed, the runners, talkers, etc., may still be used. In considering the limiting cases of survival, safety of the ship, navigation with casualty damage, responsible officers will revert to basic, no-frills information communication; a contractor will not be allowed to "design it out of the system."

20. Built-in Trainer Capability. (6)

One of the comments could not be interpreted. Three comments expressed disagreement: This area is such a plus as to be almost mandatory; I do not agree with the .76 for technical feasibility—it should be more like .96. I don't believe that an adverse impact of -10 percent is true for System Design Criterion A; training equipment will be common to system equipment, certainly no more complex if the human factors engineer does a good job. Hardware costs are underestimated.

Two respondents suggested that the design concept was unnecessary: OJT onboard ship should be done with actual operator consoles; there is no need to make new hardware. It is not utilized enough in the operational environment to warrant costs.

21. Combined Operator/Maintainer Functions. (6)

One comment endorsed the combined function: You must know how to operate it if you maintain it; have a common person.

Two comments criticized the combined function: The complexity of modern systems requires full-time maintenance personnel to maintain a system. Combining the functions would require a highly-trained technician to stand long watches when he could be gainfully employed in maintenance.

One comment showed disagreement with one of the statements in the guide: I don't agree that "commonly" two separate sets of personnel operate and maintain.

One commentator said: To my knowledge, gunners' mates must operate and maintain their own equipment and, therefore, there is no tradeoff here for our equipment design (launchers and gun mounts).

One commentator saw the following trend: The 1980s will see a significant departure from the baseline. Smaller ships, like the FFG and DDG, will invest in combined operator/maintainer rates and training to minimize crew size.

Suggested Additional Design Concepts.

Seventeen respondents made comments regarding additional design concepts to be covered in the guide.

Two suggestions concerned training concepts: How about shipboard self-paced maintenance training as a concept directed toward upgrading technical capability? I suggest cross-training of maintainers and operators on different types of systems as a design concept.

One commentator suggested adding the complement to Design Concept 1: Design Concept 1, design for maintenance, is half of human engineering; design for operability is the other half. Design for operability should be added to the list of design concepts to round out human engineering.

Three comments focused on functional partitioning as a design concept: Functional partitioning to one LRU, or a few LRUs, could greatly benefit MTTR. A system partitioned into "small black-box" functions would be a good design approach; each box would be an LRU (e.g., power supply, logic module, A/D or D/A converters, display, keyboard, etc.).

One commentator seemed to combine the concept of functional partitioning with standardization: Standard modules (PC cards) and other standard entities (cabinets, power supplies, etc.) are used in AEGIS. Perhaps this concept would be useful whenever a new system is designed.

One commentator suggested standardization for operator displays: Operator presentations or displays should be standardized (e.g, signal-processing displays like GRAM, WATERFALL, PPI, etc.).

One commentator suggested standardization for software: Operation and maintenance would be impacted by standard software modules, software debug aids, automatic documentation, etc.

One commentator addressed the problems concerning Design Concept 7: Design Concept 7, the embedded computer or microprocessor, is a fact of life. I think some additional design concepts should be developed which make the embedded computer acceptable. For example, one design concept could utilize a microprocessor where the complete unit is an LRU so that no troubleshooting is required within the microprocessor. A second concept would be to specify that maintenance by a computer specialist is required in certain cases where you can anticipate that the traditional rating assigned to the equipment is not qualified. A third concept would be use of redundant embedded processors.

Three commentators alluded to redundant processing, as well as other new trends in hardware/software design: Consider multiple redundancy systems with majority voting and/or self-healing. You should design for redundancy, channelization, and graceful degradation to minimize the impact of failure; also, better maintenance and training documentation should be functionally oriented. Consider distributed computation similar to Design Concept 7 but with greater emphasis on reducing mainframe CPU; this will reduce long-range costs.

Two commentators focused on concepts to reduce maintenance onboard ship through a change in repair philosophy: Deferred maintenance is a major design concept; as an example, in the DD 963, 25 percent of organizational maintenance will be deferred to in-port periods where it is done by roving teams. A concept is zero maintenance (from the crew's viewpoint) control systems with sufficient redundancy that they operate for one or more years; at the end of this period, a team of experts comes aboard, tests and stores full redundancy, and buttons up the system for at least one more year.

One commentator suggested the following maintenance concept: Another concept, not liked by the Navy but practical in the fleet, is cannibalism; controlled cannibalism should be evaluated as a design concept.

Another commentator suggested: Shipboard layout to facilitate maintenance would be a valuable design concept. This would include centralization of control, spares access, information storage and retrieval, tools and test equipment, readiness assessment, etc.

Two commentators suggested the following approaches to troubleshooting: Use of interactive computer-aided troubleshooting and maintenance, using an off-line computer. Use of fault trees, visual fault indicators, and discrete LEDs on printed circuit boards.

One commentator suggested the design concept of minimizing power and cooling requirements in system design.

General Comments on Design Concepts

Several comments could only be categorized as generally applicable to the entire discussion of design concepts.

One commentator stated: All these concepts have some value, but must be applied with discretion. The designer should give tradeoff consideration in each case.

For new system development (1970-1980), Design Concepts 3, 4, 5, 6, 8, 9, 11, 13, 15, 17, 18, 20, and 21 will most likely be addressed as an integrated system approach. Evaluating them as they would interact together would be different from evaluating them as individual concepts.

One commentator said: Any systems designer with any degree of experience is aware of all of the concepts listed in the guide. There are no blacks and whites. Different aspects of the problem require different tradeoff considerations; any new system is made up of standard and nonstandard parts, LRUs which are repairable onboard, LRUs which are repairable at the intermediate and depot levels, built-in test equipment, etc.

Another commentator echoed the admonition to make design decisions tailored to specific cases: The more automatic aids that you add to gear, the less system reliability you can expect. Very careful tradeoffs are required in each specific case.

One evaluator said: Design Concepts 16, 17, 19, 20, and 21, along with Concepts 8, 9, 10, and 11, are the wave of the future. Design Concept 18 will be overtaken by embedded computers and distributed computation.

Comments from Other Sources

Specific Design Concepts. The majority of comments from other sources echoed thoughts and suggestions that were evident in those made by respondents to Evaluation Packages C and G. To repeat these comments would be to add a great deal of redundancy to this section. We will only present comments that provide new perspective and insights. The following paragraphs contain the comments without introductory remarks and are ordered by the order of the design concepts; the last few paragraphs contain general comments pertinent to all or most of the design concepts.

1. Design Concept 1 lumps together several design approaches that should be separated because different systems are more or less amenable to them. These

approaches include modularization by function, easy access for maintenance, extensive/easily understood coding, and test point accessibility/design.

2. Design Concepts 2 through 5, on LRUs, should be combined. They should treat the general problem of accessibility of spare parts via intrasystem communality, built-in spares, spare kits, lifetime spares purchased at time of acquisition, etc. Accessibility of spares is an important element that can facilitate "Easter-egging" and minimized downtime. (Easter-egging denotes the practice of sequentially removing parts of a system and replacing each one with a known good spare until a system begins working.) Accessible spares is the key in Design Concepts 2 through 5, not standardization per se. Standardization has little effect on manpower utilization even though it may greatly affect system downtime. Also, modularization has no real impact unless combined with accessibility/replaceability concepts or with modularity by function concepts.

The judges have failed in their assessment of Design Concepts 2 through 5 concerning LRUs. They have not fully taken into account the full inventory and distribution costs, nor the talent level of technicians required, when onboard repair is considered. The cost of training people and providing facilities for organizational level repair is inconceivable. Throwaway is much more cost-effective. As an example of how difficult it is to repair complicated boards, IBM has had trouble repairing some of their own UYF-1 cards; if IBM can barely do it, the Navy can't possibly do it.

3. Design Concept 6 misses the point; overdesign to achieve high reliability and maintainability is not an issue in manpower savings per se. "High inherent availability" is a proper design concept. This concept allows reliability/maintainability tradeoffs within the perspectives of operational constraints.

4. The view on Design Concept 7, Embedded Computers, is wrong. An across-the-board statement that microprocessors have a negative impact is akin to someone 20 years ago saying we should not use transistors. Maybe there should be a limitation on the use of microprocessors in systems that are maintained by unsophisticated personnel, but do not make blatant, blanket statements about them. Microprocessors are not always associated with embedded computers, the latter being 16-, or 32-bit machines. Some micros, like the 2901 Series, can be used in 2- or 4-bit slices. It is not necessarily harder to troubleshoot them than other digital logic devices.

Embedded computers has a different meaning than that given in the guide, which seems to distinguish between embedded computers and other digital devices. A better distinction would be between analog and digital devices. The guide distinction between microprocessors and nonmicroprocessors is an illogical way of partitioning the world of digital devices.

Embedded computers are beneficial or adverse, depending on the nature of the system and the implementation. A preferred implementation is "modularity-isolated, off-line, used for automatic performance monitoring or built-in test and automatic fault localization, and fail-safe."

5. Design Concepts 12 through 14 have missed the point. Standardization per se has no impact on manpower. This set of design concepts can be replaced by consideration of spares availability.

6. Design Concept 15, Standard Hardware-Subsystems, is the only standardization decision that has effects on human resources because it reduces the need for training. But this is a Navy decision, not a contractor decision. In this case, the acquisition

manager needs to do more work up front to make these decisions properly before he lets out the specification. In order to do this, the acquisition manager needs technical assistance which he doesn't usually have.

7. Design Concept 17, Built-in Operator Performance Aids, may give you a marginal gain in operator performance but it is bought at the expense of needing a high-level maintainer skill. Thus, the overall design concept is not all that desirable unless it is required for safety.

8. Historically, Design Concept 18, Automated Decision-making, is only implemented in a halfhearted way. Unless fully automated (eliminating the need for operators), this concept should be implemented only to enhance operator display information, not make decisions for him.

9. There should be a constraint on Design Concept 20, Built-in Training Capability, to use it only when no additional hardware is required.

10. Design Concept 21, Combined Operator/Maintainer Functions, is okay under several circumstances where either the operator or the maintainer functions are so simplified that they can be assumed by the other.

Additional Design Concepts. An additional design concept is the tradeoff between digital and analog implementation of a function. Digital functions usually require fewer, often no adjustments; digital functions are easier to BITE and performance-monitor; and digital hardware is easier to standardize. On the other hand, analog functions are traditionally less complex in parts count and are simpler to teach and understand; however, these advantages are rapidly disappearing. The primary advantage of analog is the ease of interfacing to the external world, which is normally also analog. Because digital functions are complex to properly implement in hardware, software, and firmware, they suffer certain disadvantages.

An additional design concept would be to consider the tradeoff between number of cards and costs. This probably has a manpower implication. This is one of the practical problems that faces the engineer--how big should the cards be and how many of them should there be?

General Comments. The guide could help us by telling us what makes a system complex to an operator or a maintainer. As engineers, we act on intuition and common sense. The guide could help us.

Section 1 is particularly well done and understandable. However, I strongly suggest that you add at least one example under each definition.

The judges' group should have a broader experience base and not use their unsubstantiated feelings as a basis of judgment. The group might be expanded prior to publication.

I would like to see the judges' credentials, perhaps in an appendix.

Because the evaluative profiles in this section could have substantial impact on the design of new systems, it is imperative that the projected impacts be quantitatively verified.

The treatment of the design concepts as all-or-nothing or go/no-go factors is unrealistic. For example, there are degrees of "operational simplicity."

The design concepts presented in the guide are extremely heterogeneous in complexity. It would be helpful to break the design concepts down into logical units that are more equivalent in their scope and complexity.

You must state the constraints for all the design concepts. Tell under which circumstances a design concept is beneficial; tell under which circumstances it should not be used. Without such constraints, somebody who is writing the specifications could call for the design concepts in the guide willy/nilly and the contractor would be stuck with complying with something that could be inappropriate and even silly.

Section 2: Interaction of Design Concept Impacts on Different System Design Criteria

The content of Section 2 was understandable and relatively useful to most respondents. No consistent themes were revealed by supporting comments.

Accuracy and completeness of this section was considered to be adequate, but was not highly rated. Typically, evaluation of accuracy and completeness was rated as 2 or 3 on the 5-category scales, with very few 1 or 5 ratings. Of the few comments made, most questioned the qualifications and representativeness of the sample of judges, or disagreed with the judges on specific issues.

Although the distribution of ratings indicated that many respondents would like to see changes made in this section, there was no consensus regarding these changes. A wide variety of specific problems were identified and suggestions presented.

Data from Six Questions in Evaluation Packages

Figure 4 shows how respondents answered questions regarding the information in Section 2. Comments relative to these questions are provided below.

1. Useful for Present Job? (7)

A positive comment stated: The information provided a good summary of the problems that have to be considered and covered in the design.

Three negative statements included: Section 2 is a repeat of Section 1 and as such is of little value. Would not know how to use. There is not an obvious way to relate this information to other design criteria.

Two commentators suggested: Needs to be valid. Another input should be made to quantify the variables; I don't feel the spread is adequate and the answers would be different for different types of equipment.

One comment stated: I take exception to the adverse effects of microcomputers on new systems. If I followed the information presented here, I would have to design around it.

2. Useful for Serious Manpower Constraints? (11)

Many of the comments echoed those made on the previous question.

Comments included: Useful as information only. More positive, explicit data would be more convincing. More of a hindrance than a help; it would be the basis of many meaningless meetings. Tradeoffs should be made by the offerer relative to DTUPC goals.

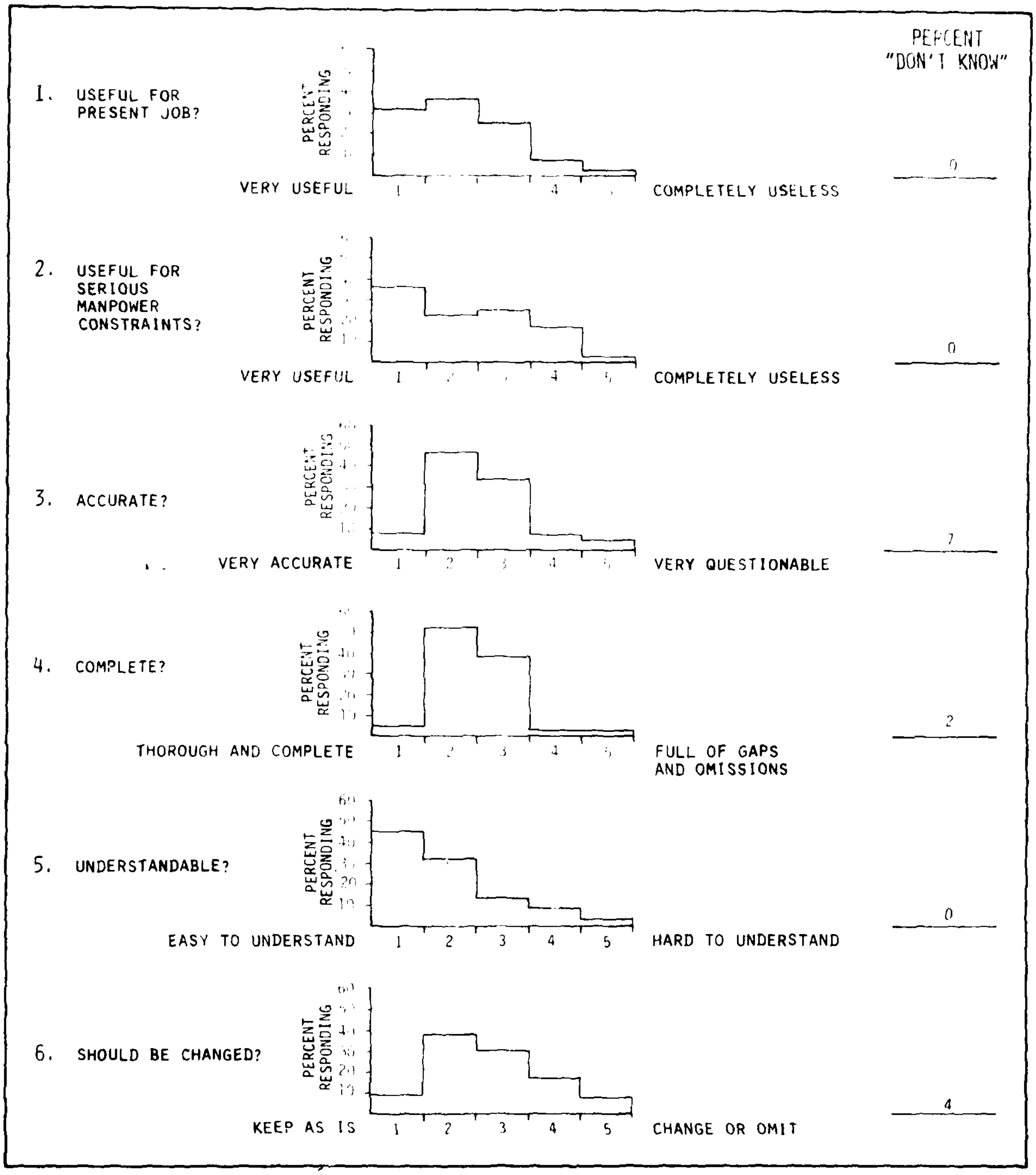

Figure 4. Ratings of information in Section 2: Interaction of Design Concepts on Different System Design Criteria.

The data provided are difficult for the designer to quantify; there is a good chance the designer will be confused as to which items have priority. Perhaps it should be arranged in order of Navy equipment operators, then ranked in order of Navy equipment maintainers.

One respondent made the following tongue-in-cheek comment: There are no tradeoffs. Just follow the yellow brick road as dictated by manpower constraints. As an example, a shipboard system can be designed that requires "0" shipboard maintainers, but the costs, space, and weight may well be impractical.

3. Accurate? (12)

Many of the comments reflected those that were made under the question of accuracy in Section 1. These comments focused on the qualifications of the judges, their number, and a desire to see the data base validated. Some of the comments simply expressed disagreement with the judges on several issues.

One respondent found the information to be accurate, with the exception of "embedded computers." He suggested that new data be acquired from operators and maintainers that have systems that contain embedded computers.

One respondent stated: The profile for Criterion M warps the emphasis on "initial" as opposed to life cycle costs, which is the purpose of the manual. You should interchange Profiles M and N.

4. Complete? (4)

Comments included: Criteria should be more definitive. Information is very generalized; possibly too complex for small systems. Is it, in fact, personal observation? Design Concepts 8, 9, 10, and 11 presuppose that embedded computers will not be used for these concepts, or else there is a built-in conflict.

5. Understandable? (8)

Three comments concerned the relationship between Sections 1 and 2. A bit misleading at first; this chapter should be described as a simple cost-indexing of Section 1, not as "complementary" to Section 1, implying new information. Should reference back to Figure 3; a heavier black outline around the second box in Figure 5 would help; establish a clear relationship to Section 1. Your technique of interchanging the ordinate and abscissa between Sections 1 and 2 is poor; I was prepared to follow the structure of Section 1 into Section 2.

Two comments concerned definition of the system design criteria: I believe that the explanations of the evaluation criteria could be improved; for example, I don't understand the meaning of the last sentence on Page 2-4. The criteria in Section 2 were, in general, not clearly stated.

Two comments indicated insufficient direction on how to use the information in Section 2: The charts are subjective and, although they provide interesting data, leave the designer with questions as to which design direction should be followed. There is not enough instruction given to indicate how to use the information.

One commentator thought that Section 2 was "very pictorial."

6. Should be Changed? (14)

Several comments restated comments made earlier and will not be repeated. Short comments included: Should be quantified and backed up. Omit criteria not considered human resources (e.g., costs, MTBF). Provide a single table showing numerical values.

Two comments focused on applying the information: There need to be examples of how to use the information; need a roadmap through the material. Clarify definitions of the criteria and give one or more examples of the application of each criterion.

Two comments focused on the interaction among the criteria: It is difficult to balance all the factors involved in order to decide which set of criteria should be emphasized. More specifics are needed on the interaction of the criteria.

Two comments focused on questions of specific equipment: It would appear that the section would have to be tailored to meet the equipment type and mission as the Navy sees it; summarize Section 2 with a designer's checklist. Information must be specifically related to system size/complexity and unit levels.

One commentator opined: It seems that at this point you were more interested in presenting "variations on a theme" for academic interest and statistical analysis than you were in developing a good solid rationale which can build a basis for Sections 5 and 6.

Data on Specific System Design Criteria

Table 2 shows how respondents rated the understandability and utility of the system design criteria. As with the design concepts, the percentages are based upon the number who responded under each category. Forty to 43 respondents rated the understandability of the design criterion; and 36 to 42, their utility. As reflected in the table, respondents had no problem in understanding the criteria, and few proposed dropping any of them. Five system design criteria--A, B, D, G, and J--were rated as useful but in need of modification by 25 percent or more of the respondents.

Comments relative to the specific design criteria are provided in the following paragraphs.

1. A--Maintainer Skill and Experience Level Required. (12)

Five comments concerned the definition and scope of the criterion: The text assumes that every designer understands the skill level of "first enlistment" and "second enlistment" personnel; a summary of skill levels could be added. Don't understand meaning of last sentence in definition. Guidance is needed in associating maintainer's skill with rating/training, e.g., what are the percentages of faults in representative hardware which can be repaired by various types of personnel; can the proficiency profiles from Section 6 be made more quantitative? I don't think the skill levels should be limited to just "long timers," but should also indicate new enlistee capabilities. It would be useful to know the feelings about the percentage change of those needed beyond the first enlistment; these charts only consider about one-half the problem.

Two comments focused on embedded computers: I don't agree with the judges on embedded computers. New designs will definitely contain microprocessors; therefore, a maintainer will master this "new" device such that it will eventually be nothing more than a "logic board" of future systems.

Table 2

Reactions of Commentators to Specific System Design Criteria

DESIGN CONCEPT	Understandable (% Responding)		Utility (% Responding)		
	I Understand it	I Don't Understand it	USEFUL: Keep it	USEFUL: Modify it	USELESS: Drop it
A. Maintainer skill and experience level required	98	2	69	29	2
B. System-specific maintenance training required	98	2	70	28	2
C. Shipboard maintenance man-hours required	100	0	82	15	3
D. MTBF	100	0	70	25	5
E. MTTR	100	0	72	23	5
F. Tools, test equipment, facilities costs	100	0	80	15	5
G. Supply and support costs	100	0	64	31	5
H. Operator skill and experience level required	100	0	82	15	3
I. System-specific operator training required	100	0	85	12	3
J. Total number of operators required	100	0	72	25	3
K. System operability	98	2	78	19	3
L. Overall operational capability and effectiveness	95	5	68	24	8
M. Initial system acquisition costs	100	0	81	14	5
N. Operational lifetime costs	100	0	72	22	6

Note. 20 percent of the respondents indicated that additional system design criteria should be considered.

A variety of critical comments included: Don't agree with 7, 18, 19, and 20; these are beneficial, not adverse. Design Concepts 2 and 3 should be more negative; 5 should be more positive; 7 should be much more positive. Design Criteria A and B should be combined. The criteria and the topic need to be reexamined.

2. B--System-Specific Maintenance Training Required. (9)

A variety of short comments offered: What is the magnitude of system complexity (e.g., hardware, software, firmware)? If you are using current NECs to maintain new systems, then the entire reference moves toward adverse. The designer probably will not know the training time requirements. Recognize the advent of LSI, VLSI, and distributed computation on future training requirements. Criteria are not clearly stated. Agree on embedded computers; these should be as easy to maintain as any other logic elements. Combine this criterion with Criterion A.

Two comments focused on standard hardware: Standard hardware components would have a positive impact on system specific maintenance training only if onboard repair is required. Do you consider standard building hardware (e.g., UYK-20 and UYQ-21) system specific? Generally, there does not seem to be enough emphasis on this design feature.

3. C--Shipboard Maintenance Man-hours Required. (3)

Two comments concerned embedded computers: Disagree on embedded computers. The maintenance of embedded computers is dependent on the maintenance philosophy employed and may not necessarily be as negative as shown.

One commentator suggested that the criterion be split into preventive maintenance and corrective maintenance.

4. D--MTBF. (8)

One comment indicated that the presentation of data confused cause and effect: MTBF is a result of the design concept and not the cause of any adverse or beneficial effect.

Two comments discussed dropping or modifying the criterion: Combine MTBF and MTTR which then become "corrective maintenance"; also, MTBF is too pure a concept to be practically applied here as it is. Drop MTBF and MTTR because they are adequately covered already by reliability and maintainability specifications and organizations.

A variety of disagreements with the data included: The profile is not reasonable for built-in test equipment, which should be desensitized to MTBF; it should not cause system failure; also, need to define MTBF more specifically. I question the results for Design Concept 6. I do not believe that performance monitoring, fault detection, and fault localization equipment should degrade system performance (MTBF) as indicated; better approaches are available. As an LSI circuit itself, embedded computers have a very high MTBF and will not degrade a system (as suggested by the guide): MTBF may actually improve when you consider the amount of hardware an embedded computer replaces!

One commentator offered the following analysis: I disagree with the relationship between MTBF and Design Concept 7, 8, 11, and 19. Do you distinguish between MTBF and MTBE? With good design, a test system will not impact MTBF, but may contribute to MTBE; E stands for "events," which are not impacts on performance.

5. E--MTTR. (6)

One comment indicated confusion of cause and effect in System Design Criterion D: MTBF is a result of the design concept and not the cause of any adverse or beneficial effect.

Two commentators disagreed on the results for Design Concept 6: Overdesign will result in potentially fewer provisioned spares; in the event of failure, MTTR may actually be adverse rather than "0." Disagree on Item 6; it takes longer to repair items that you are not familiar with (have had no practice on).

A variety of other disagreements with the data included: embedded computers reduce MTTR. LRUs—No Spares must have an adverse effect! Since the concept of using standard hardware is that circuit cards utilize throwaway maintenance, one might expect that Concept 13 on the graph would be nearly as positive as Concept 5.

6. F--Tools, Test Equipment, Facilities Cost. (5)

One comment indicated confusion with respect to the presentation of information: Built-in Test Equipment was not to be included, according to the definition, but it was estimated to have a 15 percent beneficial effect.

One commentator suggested that this design criterion, along with G, M, and N, be dropped because they are "adequately covered by cost specifications and organizations." Another commentator believed that System Design Criterion F should be combined under a single heading concerned with nonrecurring costs.

One commentator disagreed with the data on Design Concept 6: With overdesign, test equipment may not be available. This would adversely affect MTTR.

One comment suggested a need for additional data: As a designer, I would have a difficult job in making an estimate for the tender and depot costs for test equipment and facilities. Either some additional data should be provided, or the tender and depot aspects of this criterion should be dropped.

7. G--Supply and Support Costs. (10)

One of the comments could not be interpreted. Suggestions included: This is very difficult to quantify but it should be pursued; these secondary effects are of a most serious magnitude. You should split depot, tender, and shipboard costs into separate items. As a designer, I would have a difficult job in estimating costs for cataloging, receipt, storage, transfer, issue, etc.; some additional guides have to be provided. If life cycle cost studies were a condition of the contract, the Navy should supply a set of standard values to establish a common baseline.

Disagreements with the data included: Design Concept 7 should be more positive; Design Concept 20 should be more negative. This curve is misleading; benefits are indicated from standard hardware, but that is an oversimplification when considering overall costs.

Three disagreements focused on repair: I believe contributors to the study were truly off base on Design Concept 5; were they knowledgeable in costs of repair versus throwaway? It is my understanding that the decision to use throwaway maintenance is based on a unit price cost where it is cheaper to buy a new unit than to repair it;

therefore, I do not understand why throwaway maintenance had such a negative impact on supply and support costs. I believe the judges did not account for the inventory and distribution costs for onboard repair.

8. H--Operator Skill and Experience Level Required. (4)

Three of the comments suggested that there was a problem in understanding this design criterion. Part of the confusion focused on the meaning of the term "number of people beyond their first enlistment required to ensure a high degree of system operational effectiveness." One comment suggested that this criterion be combined with Criteria I and K and presented on one graph.

9. I--System-specific Operator Training Required. (2)

One of the comments suggested difficulty in understanding the criterion. The other comment suggested that it be combined with Criterion H, because the judges' data showed that there was little difference in the judges' perception of the two criteria.

10. J--Total Number of Operators Required. (8)

Several of the comments indicated that there was confusion about the definition and scope of Design Criterion J. Some of these comments indicated that the criterion should be modified to be more clear.

One respondent stated that embedded computers and automatic performance monitoring should have a beneficial impact on the number of operators.

One commentator stated: This analysis doesn't address the changing demands on Operational Readiness Operators (e.g., the assessment of workload).

Two comments suggested additional design criteria, which will be treated in a later section.

11. K--System Operability. (4)

Two of the comments addressed quantification problems: Operator error rates will depend on each individual operator and thus are very difficult to estimate. It's very difficult to quantify this criterion but it should be pursued; these secondary effects of system design are of most serious magnitude.

Two of the comments focused on the definition of the criterion: I think ease of operation, error rate, and reaction time should be independent criteria. Consider adding system flexibility and degraded mode operation to the definition of system operability.

12. L--Overall Operational Capability and Effectiveness. (8)

Four comments focused on problems with the definition and scope of the criterion: I think more specificity is required; several broad operational requirements (e.g., system reaction time) should be cited and rated separately. The definition is too all-encompassing; there is nothing specific to grasp as a reference for what you mean. It's too judgmental; you need more specific criteria to be useful. A measure of equipment effectiveness would have to be tailored to the specified mission requirements; it is not clear what parameters were used for this measurement. One commentator said: the concept of technical performance should be tied to operational performance in some manner; there are tradeoffs between these two which could be addressed.

One commentator repeated his earlier comment: It would be very difficult to quantify but it should be pursued; these secondary effects of system design are most serious in magnitude.

One commentator said: This is confusing; I do not understand why all are judged beneficial.

One commentator suggested the criterion be dropped: This is probably adequately covered by system performance specifications and acceptance testing.

13. M--Initial System Acquisition Costs. (3)

One commentator stated: As a designer, I would have trouble determining the increase or decrease of these costs. I would need some backup data.

Another stated: The perceptions of your sample group are biased due to their backgrounds. From the designer's standpoint, several items do not increase initial costs if they are incorporated early and if the designer is accustomed to the concept (e.g., 1, 2, 9, and 10). Other concepts will increase costs due to the rapid movement of technology (e.g., 12, 13, 14, and 15).

One commentator suggested that the overall presentation would be improved if Profiles M and N were exchanged in order of presentation. He also stated: The profile for Criterion M is misleading--benefits are indicated from standard hardware, but this is an oversimplification when considering overall costs.

14. N--Operational Lifetime Costs. (5)

Three of the comments were reiterations of remarks concerning other criteria. They were: Very difficult to quantify but should be pursued; the secondary effects are of a most serious magnitude. As a designer, I would have trouble determining the increase or decrease of these costs; I would need some backup data. The perceptions of your sample group are biased due to their backgrounds; from the designer's viewpoint, several items do not increase initial costs when incorporated early and when the designer is accustomed to the concept (e.g., Concepts 1, 7, 9, and 10), other concepts will increase costs due to the rapid movement of technology (e.g., 12, 13, 14, and 15).

New thoughts include: Would prefer some relationships to provide hard tradeoff decisions between life cycle costs and acquisition costs to make an intelligent and proper decision. I do not agree with judges on the adverse impact of Design Concepts 4 and 5 versus the "0" impact of Concepts 2 and 3.

Suggested Additional System Design Criteria

Fourteen additional system design criteria were suggested by the commentators. One was uninterpretable; one was actually an additional design concept, which was treated earlier.

One commentator suggested that Design Criterion J, total number of operators required, actually depended on the system mission requirements. He suggested that a better criterion would be: Total number of operator interfaces, which would relate to operator station complexity.

Another commentator suggested that the minimum number of required operators would be a good criterion in that it would be independent of any baseline.

One commentator said that watch station requirements under Conditions 1 and 3 would be a good design criterion.

One respondent wrote that Mean Time Between Removals (MTBR) would be an important criterion for maintainability, particularly where fault isolation or BITE is incorporated. Another commentator believed that Mean Logistics Down Time (MLDT) is the criterion that really drives system availability.

One commentator wanted to lump several classic criteria under one heading: The topic of Operational Availability or Dependability might provide a more effective measurement of the interface between MTBF, MTTR, Spares Availability, Spares Repair Time, etc.

One commentator suggested that the ability to modify and upgrade a system is one important design criterion.

One commentator believed that the requirements for documentation (e.g., training manuals, drawings, etc.) is an important design criterion.

One commentator appeared to want to refine some aspect of System Design Criterion N, Operational Lifetime Costs: How about life cycle costs? Logistic elements seem too vaguely employed.

Two commentators focused on support maintenance. One stated: Total maintenance impact involves shore maintenance; I believe some reference should be made to IMA effort; shipboard *maintenance* goes to "0" if you weld the thing closed. The other stated: How much non-Navy support is required, e.g., how much support from NAVSEACENLANT, NAVSEACENPAC, Contractor, and ISEA?

General Comments on System Design Criteria

The following paragraphs contain comments without introductory preamble.

I understand what you are driving at but I don't know how to achieve a proper balance in my own mind. Different customers react in different fashions and many people tend to emphasize their own pet prejudices. As an example, operational lifetime costs would be important over a long haul, but the initial buyer is interested in the initial system acquisition costs. I don't think your guide, or anybody else's, can resolve the dilemma.

Given the definition of embedded computers, I do not agree with the judges' evaluation. Their collective judgments are political and lacking in understanding of what can be done.

This is merely another permutation of the bad data contained in Section 1 and the quantification is therefore questionable. The categories are valid, but the use of them is not. For instance, opinion cannot tell if use of embedded processors will drastically affect lifetime cost; it will vary between systems.

Basic areas and concepts are valid, but they are not applied correctly. Most of these areas require a good deal of ILS analysis and should be addressed that way for varying implementations.

This section presents interesting information, but how does a design engineer use it?

In general, I feel that all of the descriptions could be beefed up and expanded.

Comments from Other Sources

All of the comments from other sources reiterated, in one way or another, comments from the Evaluation Packages C and G. They will not be repeated here.

Section 3: Types of Technicians Assigned to Surface Ship Electronic Systems

Although respondents had little trouble in understanding the information in Section 3, many of them questioned its accuracy and completeness. As a consequence, respondents varied greatly in how useful they considered Section 3 to be for their present job or for the imposition of design constraints on manpower considerations. Nearly all the suggestions for change were to expand the information contained in Section 3. The following specific additions were recommended: more complete profile of operators and maintainers, and procedures for better relating technician information to future trends in equipment design.

Data from Six Questions in Evaluation Packages

Figure 5 shows how respondents answered questions regarding the information in Section 3. Comments relative to these questions are provided below.

1. Useful for Present Job? (13)

Most comments focused on the inadequate amount of material presented on this topic: Just doesn't tell me much. Information is very general and could be expanded upon to be more useful. Not enough information to be very useful; the material is too blah.

There were a number of suggestions for improving this section: A better description of skills and skill levels is appropriate. I could use a list of courses and materials in the courses as well as the general education and skill levels of the various ratings. Would be useful to include a profile of the source of training taken by each of the ratings.

One respondent said: This section deals with a critical point with which designers are perhaps least familiar--the job description approach seems totally inadequate--I feel this aspect of the handbook should be expanded significantly, identifying the training requirements, typical time on job, I.Q. spread, etc.; lay it on the line as to what the problem really is.

One commentator, a member of the acquisition community, said: The engineer/designer doesn't give a jolly damn about the job title of the man who is supposed to fix the gear. The personnel specialist on the project knows more about Rating Descriptions than is offered here.

An engineer said: I assume that the lowest possible level of technician will be available and assigned for equipment service/operation.

One commentator described a future problem: Integrated and all-digital systems will not permit distinctions between certain ratings that have historically assumed different portions of system maintenance. They must now be lumped together.

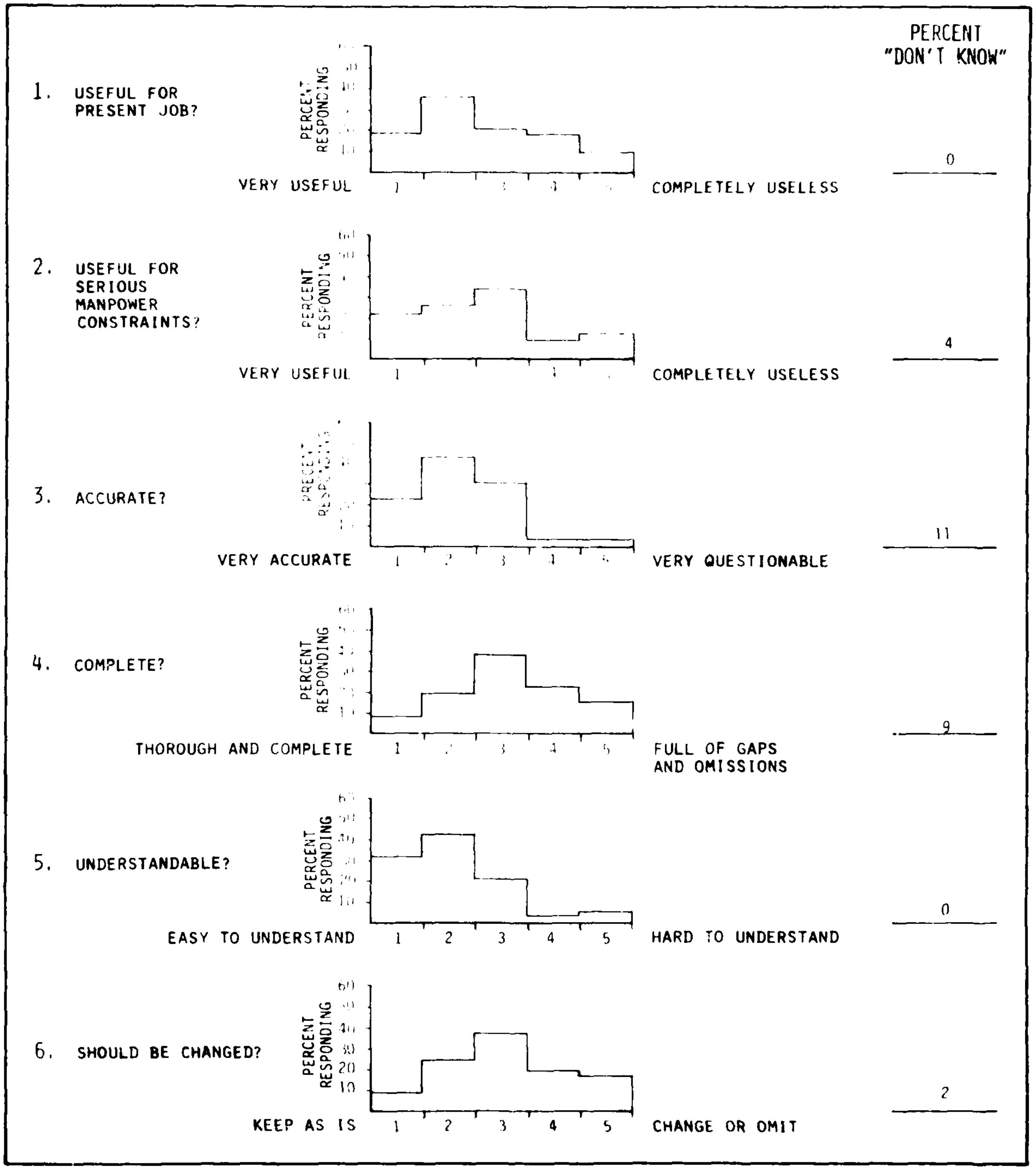

Figure 5. Ratings of information in Section 3: Types of Technicians Assigned to Surface Ship Electronic Systems.

2. Useful for Serious Manpower Constraints? (5)

Many of the comments on this question referred back to those on the previous question. Respondents said that the same drawbacks of the material with regard to usefulness in their present jobs would obtain in future attempts to impose serious manpower constraints. Typical comments were: The information is too superficial to be of any but token value. Not enough information to be very useful.

Echoing an earlier concern regarding the future of the Navy rating structure, one commentator said: The information is useless--the Navy structure is too traditional and directed toward outdated equipment and not the maintenance of modern integrated systems.

3. Accurate? (1)

The comment was: This information may not be accurate for the rating structure planned for ships that are currently under development. The information in this section may be obsolete before the report is even published.

4. Completeness? (14)

Comments on completeness echoed those on usefulness. One commentator summed it up succinctly by saying: A chart that says sonar technicians repair and operate sonars is a bit much--surely a more detailed description of skill levels is available.

Other comments included: Quantities could be presented. Information on training curriculums could be presented. There is not enough meat. Skill levels within the types of skills were glossed over; the levels of skills should be mentioned so that this information will be in perspective when it appears in later sections of the guide.

Two respondents reiterated the concern that the information may be out of date. One said: The information is 20 years out of date. The other added: For those types of systems in which standard displays are shared, a maintenance specialist should be created to take care of the standard hardware, regardless of the traditional rating in which the hardware may fall.

Two commentators noted that the section does not tell how to determine the grade of personnel or the number of personnel required for a system under design nor does it provide a detailed procedure to compare the complexity of a present system with the complexity of a past system so that one could judge the manpower skill required for the present system.

Three commentators suggested that: The guide should have a broader scope, it should cover other types of electronic systems and other types of platforms to be more complete. Elsewise, the title of the guide should be changed to specify the limitations of its applicability.

5. Understandable? (4)

There were no comments on precisely how understandable Section 3 was to readers. One respondent noted that designers can identify required quantities of personnel and tasks that need to be performed and that they probably would not care that the personnel titles might be ET, FT, etc. An opposite view suggested that more rather than less information should be provided; this commentator suggested that rating profiles for each technical rating be provided along with a sample shipboard organization chart showing rating structure.

6. Should be Changed? (19)

One commentator stated that the coverage of personnel types as presented was good. The remaining comments on this question reflected a need for more detail: Two pages can't answer Question 3 as the guide purports. Either drop the section or expand it enormously. Tell me something useful or forget it. Expand it. The information should be expanded or deleted. You don't expect companies with no background to participate in this business; the data supplied imparts no information. It doesn't tell much about skill levels; it is not possible to quantify them, given the individual skill variances.

Suggestions for improvements and changes in this section include: Could use elaboration of equivalent educational levels or extent of training and average years in service. Provide a better profile of the personnel who will actually be performing the work. Need more details to understand the amount of training and requirements for personnel at the various levels. Should add educational level and job descriptions.

Some commentators again noted the problem of relating information about technicians to current design trends. Their comments include: In current system design, the roles of DS and FTM have tended to merge. Multifunction 1980 radar systems, which combine detection, tracking, evaluation, weapon assignment, fire control solution, missile launch, midcourse guidance, and kill evaluation on multiple targets, have equipment and computer configurations which require a "new breed" of technicians. Combat control systems, integrated and all-digital, will not permit distinctions between DS and FTM ratings for maintenance; designers cannot conceptualize certain parts of the design as for DS and other parts FTM.

Other respondents suggested relating information about technicians to an analysis of the equipment complexity: Need a more analytical approach to skill levels by either complexity factor, number of components, or type of components, etc. Relate system complexity to quantity of operators and maintainers.

One commentator suggested combining this section with Section 8, which covers training requirements and Navy Enlisted Classifications (NECs).

Comments from Other Sources

These comments were, to a certain degree, similar to information from Evaluation Packages C and G.

Three commentators from the acquisition community indicated that Section 3 contains information that is useful to designers. The other comments were to the effect that the information was interesting, but not presently useful to designers. One commentator stated: The information is superficial and should have been integrated into Section 4 as part of the definitions of the types of personnel.

Another evaluator, agreeing with sentiments expressed in the Evaluation C and G data, suggested that Section 3 be expanded to include rating profiles, departments of shipboard organization, watch assignments, maintenance tasks, etc. This commentator also suggested that a brief statement of personnel utilization during Condition 1 and Condition 3 would be helpful.

Section 4: Projected Supply of Technical Ratings at Different Experience Levels

There was substantial disagreement among respondents as to how useful Section 4 would be to system designers. Ratings on usefulness tended to be bimodal. Comments made indicated that, on the negative side, the information was not relevant to system designers and their design task. Some went further to state that the supply-of-technicians problem was the Navy's to solve, not the designer's.

Although the accuracy and completeness of the information in Section 4 was rated relatively high by those who completed ratings, relatively large percentages indicated they did not know enough to complete a rating.

The main changes recommended were: drop the information because it is not relevant, and expand the projections to be consistent with 20-year system life cycles.

Data from Six Questions in Evaluation Packages

Figure 6 shows how respondents answered questions regarding the information in Section 4. Comments relative to these questions are provided below.

1. Useful for Present Job? (16)

Positive comments included: Liked the information in the presentation. Useful for trade studies and system design goals.

Another group of comments suggested that the information was not relevant to designers: The information would be of general interest only. Information is nice but only serves to reinforce problem of manning, not help system designer. Personnel availability is of interest to the designer only as a point of emphasis as to why equipment should be designed with the level of skill and manpower established; I don't feel the availability of personnel statistics is important. None of this section tells the designer much. Designer does as good a job as he can within the constraints given him; don't see how this information is going to help him. All systems are already required to be designed for operation and maintenance using personnel of the lowest skill level practicable.

Another group of commentators agreed that the information was irrelevant to designers, but added the opinion that responsibility for addressing the manpower shortage problem lay elsewhere: All this says is that there will be certain shortages; maybe it would be better, cheaper, to generate incentives (within the Navy) to reduce the shortages than to add cost and complexity to the equipment. This is not the designer's problem but the Navy's; why do only one in five sign up for a second hitch (motivation?); why are senior rates in short supply (career-path development is so poor?). The problem here is obvious, but it is with the Navy and not the information; the Navy must broaden electronic technician training.

One commentator echoed the notion that the blurring of distinctions between DS and FTM ratings, as well as others, makes projected supply statistics that are broken down in the traditional fashion irrelevant. Another respondent stated that the information was not specific enough: This doesn't indicate who will be assigned to "my" system--only what the total Navy pool of talent consists of.

A member of the acquisition community drew the following conclusions: The designer sees his system as getting the manpower because of its "importance;" it's the other guy's system that will be short of manpower. The data given must assume one set of

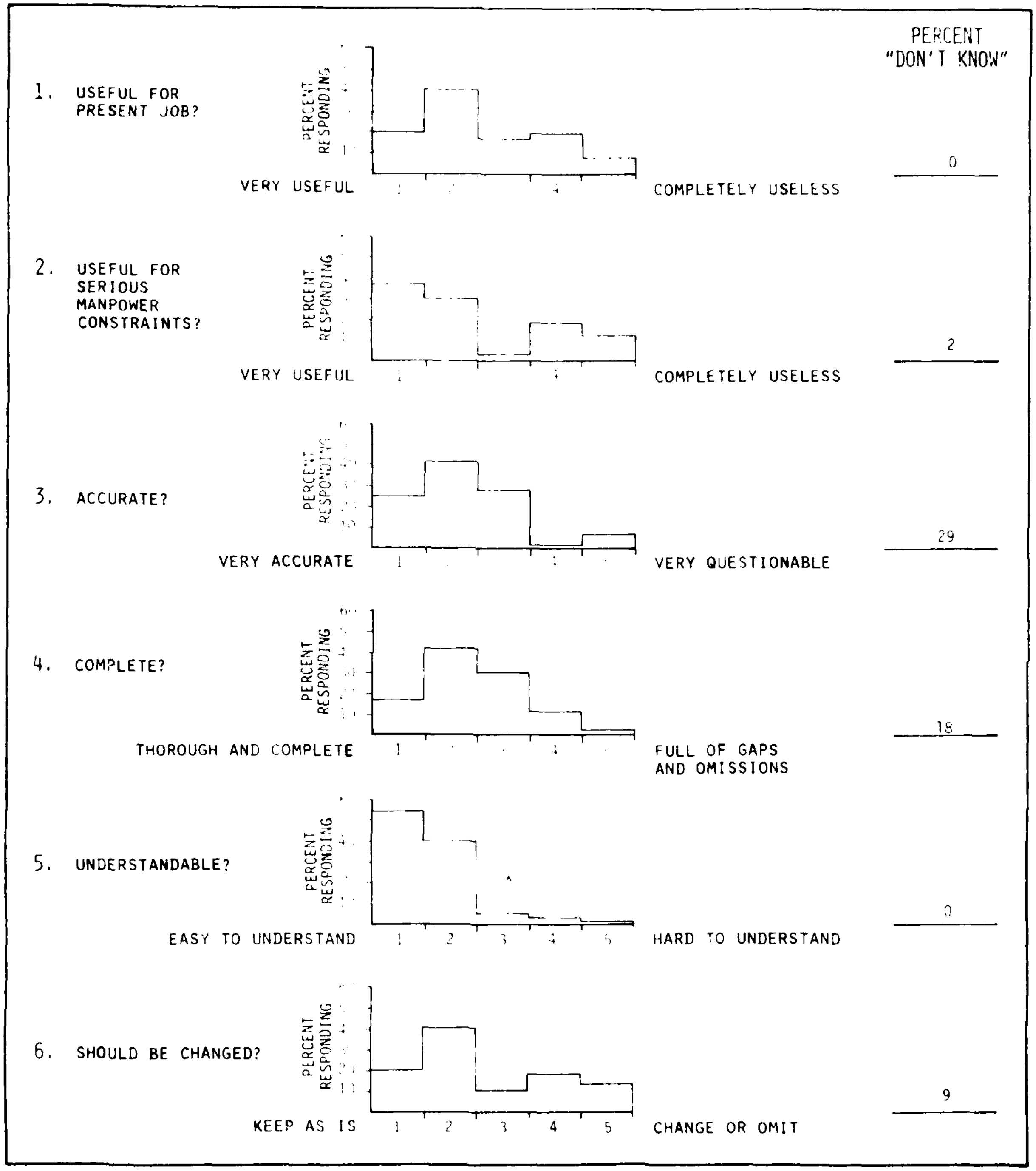

Figure 6. Ratings of information in Section 4: Projected Supply of Technical Ratings at Different Experience Levels.

conditions; if reality changes, the projected data will be useless. (On the other hand, projections through only 1984 aren't much good; a system started now won't be in the water by then.)

One senior, highly-experienced program manager from the design community said: The Navy should place specific manpower requirements as part of the System Performance Specification; I doubt if a full-range manpower study supported by Human Engineering Studies is typically in order.

2. Useful for Serious Manpower Constraints? (9)

Several comments echoed sentiments expressed regarding Useful for Present Job? Negative comments included: Of little value. Basically this section is an overkill; could be simplified.

A number of responses focused once more on the issue of who is responsible for manpower availability: DoD must be responsible for specifying certain design constraints relative to manpower availability. The designer has no control over personnel availability but can design to meet availability; however, he needs to be told via the specification what the technical level is to which he should design; DoD should use this information to determine how many personnel may be assigned to a particular item. DoD should concern itself with better technical utilization and organizational structure of shipboard maintenance personnel.

3. Accurate? (4)

Two comments expressed doubt concerning the accuracy of the data: Too many variables influence manpower availability. Data are based on projections whose veracity changes with assumptions/time. A third comment suggested that although the data looked reasonable, the commentator was somewhat skeptical of long-term forecasts: I would like to see tolerances (limits of uncertainty) on available resources and needed resources.

In counterpoint to the problems inherent in projecting availability, one respondent suggested that the projections did not extend far enough into the future: Since the design process now requires 8 to 10 years from initial development through first shipboard operational system, manpower availability must be projected much further out into time to be of any use during the design.

4. Complete? (6)

One comment on completeness echoed the desire for a longer-range projection: We design systems now for fleet use in 1985-1995.

Two comments suggested that additional data are needed to help with interpretation of the projections: Should delineate contingency variables. This type of information is especially apt to be misunderstood; strongly urge that raw data and interpretation be caveated; interpretation of the meaning of the data can only be properly made if the history of each rating is known; vast differences exist between ratings and, therefore, users should be urged to get additional data from detailers and other sources before they make design decisions.

One commentator cut to the heart of the problem in a particularly insightful interpretation of the availability data: As the quality of personnel decreases, what will happen to the skill requirements? Promotion will continue but what about skill?

5. Understandable? (2)

One commentator liked the graphical data but expressed the following caution: Simplistic thinking must be avoided in using these data--suggest that a set of review criteria for interpreting the data and a list of cautions be applied before data are used in making design decisions.

One respondent identified several faults in the presentation which made it difficult to understand: Format on Figures 8, 11, and 13 show a poor choice in the vertical scale; the broken scale is misleading and not consistent with normal practice. "Numbers of men," besides being overlapping, is misleading. Also, the use of percentages for available and shortfall is in need of normalizing (i.e., using percentages to compare between rates is meaningless, so you must rely on the numbers on the axis in order to understand it and make a comparison).

6. Should be Changed? (12)

Two commentators stated that this section should be omitted. One of these remarked: The projected supply problem is the Navy's responsibility, not the designer's; the Navy must start to be responsible to the needs of the designer.

One commentator said that contingencies such as national emergencies, the draft, etc., should be presented and discussed.

Three respondents commented that the time frame of the projection should be expanded. One said: A 20-year projection should be made in order to be consistent with the expected life of new systems.

In contrast, another evaluator said: The data become obsolete very quickly and are only good for a year or so after they are issued; they should not be used for any hard planning.

One commentator stated that the data should be presented in separate sections, one section for each Navy rating.

Comments from Other Sources

Many of the comments from other sources echoed those that were made in response to Evaluation Packages C and G. Positive comments included: This is very useful material; the format is very clear. Manpower availability projection information is generally useful; however, other sources than the NPRDC report should be given.

One set of commentators from the acquisition community echoed a sentiment expressed by a member of the design community concerning the need for the Navy to exercise some responsibility in this area: Acquisition people normally don't worry about personnel supply--maybe these graphs will bring attention to the problem.

Several commentators expressed concern over the variables that affect supply projections and the possibility that the data are in error now or will soon become obsolete. At the very least, it was suggested, some aid and direction should be provided to help users properly interpret the data.

Section 5: Evaluation of Alternatives

Most respondents indicated that Section 5 was both useful and understandable, with the bulk of the ratings at the higher ends of these scales. However, ratings were distributed widely across the scales for levels of accuracy and completeness. The primary concerns of respondents were that the approach for evaluating alternatives would not work, the approach was not relevant to design requirements, the methodology was too subjective, the data provided were obtained from a sample of judges that was too small and probably biased, and a variety of improvements in the method should be made.

Comments from other sources focused on the utility of the data to the acquisition community. One subset of comments suggested that the information was relevant to system designers but not acquisition people. Another subset stated that the information was more useful to the Personnel and Training Analysis Office (PATAO) within NAVSEA than to the designer community. Several other comments pointed out problems in the approach.

Data from Six Questions in Evaluation Packages

Figure 7 shows how respondents answered questions regarding the information in Section 5. Comments relative to these questions are provided below.

1. Useful for Present Job? (10)

Positive comments included: Interesting approach. Information appears useful in evaluating designs (i.e., comparing one against another, but of less use in performing the design function).

Some negative comments focused on the irrelevancy of this approach to current design requirements: Not related to contract award or requirements. Waste of time; you do not have the degree of latitude (suggested here) but work the tradeoffs only within Navy-defined constraints.

Another set of negative comments focused on concern that the method for evaluating alternatives will not work: Useful only if the impact indexes are real. Impact indices are so subjective and the comparisons of the 21 design concepts so diverse, I don't think that the summation of value has any meaning. Quantitative approach is good, but I have the impression that two people with similar backgrounds would arrive at completely different answers (in making up the judgmental data base). Even after completing all worksheets, it appears unlikely that a clearcut decision would be indicated.

One respondent asked the question that must occur to anyone who would like to proceed to an overall single index for comparing two or more systems (as suggested at the end of Section 5). This commentator asked: How can one arrive at an impact index weighting system?

2. Useful for Serious Manpower Constraints? (12)

Several comments on this question echoed those on the first question regarding usefulness. One commentator stated that it would be useful if imposed like MIL-STD-217 on reliability.

Most comments suggested problems in the approach: Some sort of evaluation/tradeoff would have to be done. It would create more problems than it solved. This

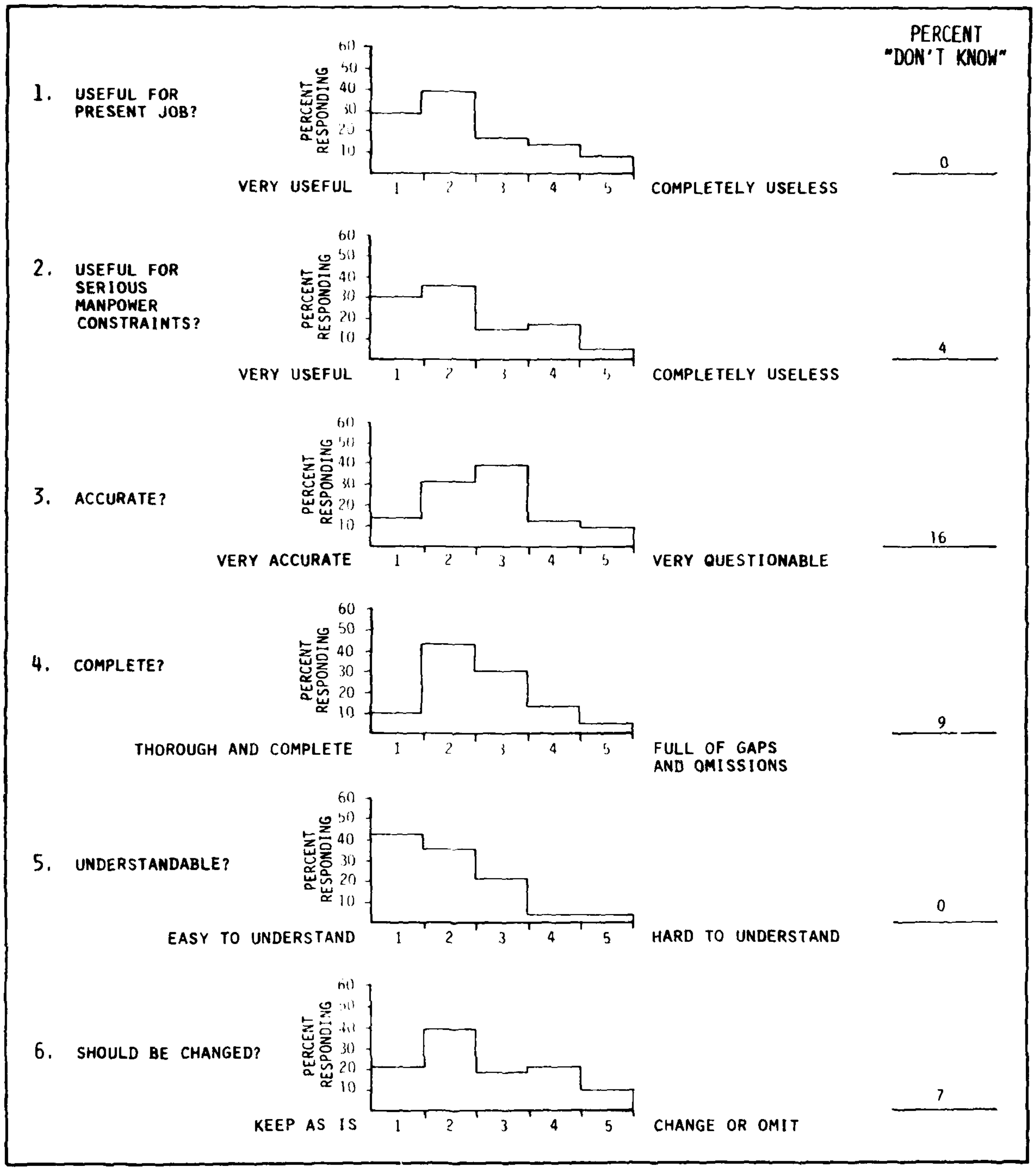

Figure 7. Ratings of information in Section 5: Evaluation of Alternatives.

is a statistically-oriented procedure that does not yield to the design insight and understanding that was achieved in Sections 1 and 2 of the guide. Overall, it seems too easy; when proposals are written, each contractor "solves all the problems;" however, it is difficult to see how it would be implemented and later evaluated.

One commentator said: The approach is based upon invalid assumptions and on an idealistic view of the system design process; many of the areas listed are either dictated or are too undefined for evaluation.

One commentator offered this analysis: The problem with this section is "What do the values and summations mean?" How do you compare a value of +118 units of operational effectiveness against -109 units of initial cost? Values given are some mix of nominal, ordinal, linear, exponential, etc., scales without regard for comparability of units. The process would be fine if it could be shown to have an interpretable, valid meaning; regretfully, it doesn't appear to have these required qualities.

3. Accurate? (8)

Most of the comments under this question focus on the credibility of a methodology based on subjective data: Subject to judgment; not as clear as shown. The weighting factors are subjective.

One group of respondents questioned the use of subjective data and added a caution against using data from a particularly small sample group: If your sample group is small and biased your input data are bad; hence, "garbage-in, garbage-out." I have to be a little skeptical because of the limited number of raters; were they balanced with regard to their respective backgrounds and professional specialties? Information is only as good as the subjective evaluations in Sections 1 and 2; given another group of evaluators providing data for Sections 1 and 2, I doubt that the statistical results would be the same; therefore, all the results of Section 5 would deviate as well. This compounds fuzzy data in Sections 1 and 2 with fuzzy system design.

One comment from a designer included a lengthy discussion and analysis of several problems: Summary score compresses the variance contained in those items which were presented as having substantial disagreement among the judges. Perhaps some 1-sigma or 3-sigma deviations should be factored into the design evaluation summary to reflect the substantial disagreement among judges on certain items. Understanding the role of "substantial disagreement" items, and the variation that they would contribute to the totals in Worksheet 5, may well change the result of the sample system features that were postulated and may well change the iterative process of tradeoff following initial analysis. I would strongly suggest early review of these issues with the Navy Program Manager for a particular system development; his decisions and guidance could narrow down the variances and tailor this tradeoff analysis to his particular needs and requirements.

4. Complete? (7)

Positive comments included: The tools are useful in evaluation, but help is needed in trading off MTBF and MTTR versus system operability and operational capabilities. The idea behind this approach has merit, but it would be helpful to point out explicitly that the numerical results are indicators based on the accuracy of the assigned numbers; if the assigned numbers have a wide spread of values, then the results will have a wide spread; the danger of trying to use the numbers to obtain too-fine results should be addressed.

The need for assigning weights for the system design criteria was stated: Unless values for weighting the 14 criteria are provided, the designer has no objective basis for a choice. More emphasis should be placed on unequal weighting; costs often dominate design decisions, sometimes to the exclusion of almost all other factors.

One commentator stated: Not accurate for a thorough tradeoff analysis. One asked: How do you use the system design and evaluation summary?

One respondent suggested: An example should be given to show how the impact index is obtained from the interaction of 21 design concepts and 14 system design criteria. This would give a better understanding of the total evaluation.

5. Understandable? (2)

Both comments on this question suggested some problems in understanding the procedure: Need examples of two hypothetical or actual systems to show in detail how the impact indices are applied. I think Sheets 5-2 and 5-3 could be written better.

6. Change? (15)

Positive comments included: Keep it like it is but substantiate the numbers. Modify it for considerations such as life-cycle cost and recurring versus nonrecurring cost tradeoffs relative to hardware versus software.

Negative comments generally focused on suspicions about the validity and reliability of the ratings: This assumes demonstrated validity and reliability of the ratings which are at the heart of this technique. I won't argue with the weightings but I would maintain that strictly judgment or intuition can provide a wide range of results. Too broad and open to questions. A larger data base would help establish more confidence in the Impact Indices.

Two comments suggested that the procedure may be irrelevant to system design: This kind of evaluation, as presented, may turn out to be a paperwork exercise that does not really contribute to design decisions. It always seems overly simple when one adds up a number of measures to find an answer to best system design.

Two comments suggested certain improvements: guidelines should be presented which show how to weight and translate the system design and evaluation summary; also, impact index needs further explanation. Weighting factors or guidelines for establishing such factors would be a useful addition.

Comments from Other Sources

One group of comments concern the utility of Section 5 of the guide to the acquisition community. One commentator said: NAVELEX acquisition people would not use this material. Another commentator stated: This stuff is only useful for the actual equipment designer; NAVSEA doesn't do this level of design.

On the other hand, one evaluator stated that the Personnel and Training Analysis Office (PATAO) within NAVSEA would use this information: This is the heart of the report for PATAO analysts. However, you may need to beef up this section to discuss just how the evaluation forms would be applied in the real world. I can see application to the sole source evaluation board process for manpower and training requirements of a new system. System designers or program managers, even if they had the time to try to apply this methodology, could do more harm than good. It should be used by experienced PATAO analysts trained in the full implications of the methodology and could be used at various phases of the system design and development process.

One commentator said: Section 5 purports to provide an objective means to determine "which general design alternative best satisfies not only manpower and training criteria but costs, potential benefit, and technical risk considerations." This is an overstatement of what is actually accomplished by the method described in this section.

One commentator said: Section 5 implies an analysis of two or more systems. A program manager, responsible for the delivery of a military system within restricted resources, has enough trouble designing and analyzing one system. There is not sufficient energy, time, or money to devote to designing and analyzing two or more systems.

One commentator used the guide to compare an old flight deck communication system, the AN/SRC-22, with a new one that is currently under development. While the new one had been demonstrated to be a better system than the old on the majority of criteria applied in a formal review, the analysis using the guide showed that the new system was only better in a small number of areas than the old. The respondent concluded that the impact indices in the guide are not applicable across the board to all systems: For different systems, ships, technology, etc., the indices will be very different. The design concepts in the guide are presented in a vacuum. The total tradeoff problem actually includes a larger number of variables than considered in the guide. For example, the number of systems or units to be produced is one of many variables that are not discussed.

One very senior and highly experienced system designer made the following observation on how the tradeoff analyses in Section 5 may be misleading in the system design and acquisition process: The sections where tradeoffs on human resources are made "have the potential for encouraging contractors to 'bull' each other and the Navy" because everybody is going to make it appear that their proposal solves all problems and meets all requirements. "There hasn't been a system proposed yet that can't be operated and maintained by untrained Neanderthal monkeys."

Section 6: Taxonomies of Tasks and Associated Skill Levels

The pattern of ratings for Section 6 was almost identical to those for Section 5. Although the material was considered to be useful and understandable by most respondents, its application was viewed with a substantial amount of skepticism. Comments emphasized the difficulty of using the task taxonomies and associated skill levels, particularly in making the transition from information based on older systems to the design of new systems. The format for presenting the information was also criticized.

Comments from other sources reiterated those from Evaluation Packages C and G, although a wide variety of additional insights and suggestions was provided. No strong common themes were evident in the additional material.

Data from Six Questions in Evaluation Packages

Figure 8 shows how respondents answered questions regarding the information in Section 6. Comments relative to these questions are provided below.

1. Useful for Present Job? (13)

Several comments focused on the difficulty in using this material: The information appears good but the material is hard to use. If data were broken down by equipment nomenclature, it would be more useful. Unlikely that any of this information would be used during the initial stages of system design. This doesn't help much except to say that the third class petty officer needs close supervision; the percent time consuming data doesn't help because relative times aren't given; not sure how to use this information. Not related to contract award or requirement.

One respondent found the material was too superficial: We developed the Operator Task Analysis and inputs to the ship's manning document; our current experience goes far beyond the material in Section 6. On the other hand, another commentator suggested that the material was too detailed: I cannot realistically see myself designing operator/maintainer functions on a new program which considers the differences between the first class, second class, and third class petty officers; perhaps this might be a fine tuning point for upgrading older systems.

Three comments focused on the difficulty in making the transition from information on older systems to newer systems: Not very useful; for example, my systems have only a few tasks that are common with the SQS-23/26; I would have to spend an inordinate amount of time in examining the 23/26 to find comparable tasks. Tasks that are identified in the guide are too closely related to specific systems; general categories would be more useful. How operators and maintainers are perceived to perform (by what I believe is a poor data sampling method) on old systems is not germane to expected tasks on new systems.

One evaluator suggested that the information is irrelevant to the way some types of design are done: The equipment that I am concerned with does not take into account any specific rating, but assumes a lower class technician will most likely be using and maintaining the equipment.

One commentator drew some conclusions concerning design: An analysis of the data presented in this section clearly shows a lower proficiency in troubleshooting and replacing components (resistors, capacitors, etc.). Newer systems which employ micro-miniature components would create an even greater challenge to skill proficiency in troubleshooting and replacement. These data suggest that we eliminate consideration of onboard repair of LRUs.

2. Useful for Serious Manpower Constraints? (5)

One respondent found the usefulness of the information lay in the fact that it developed insight: Information is useful to the extent that I now know that I need selection and training to the second class petty officer level before I can get enough talent to keep an equipment working. Third class petty officers are obviously only apprentices and second class petty officers are journeymen.

Two comments suggested problems in using this information to constrain manpower: I don't see how these data can be useful as anything except a reference or

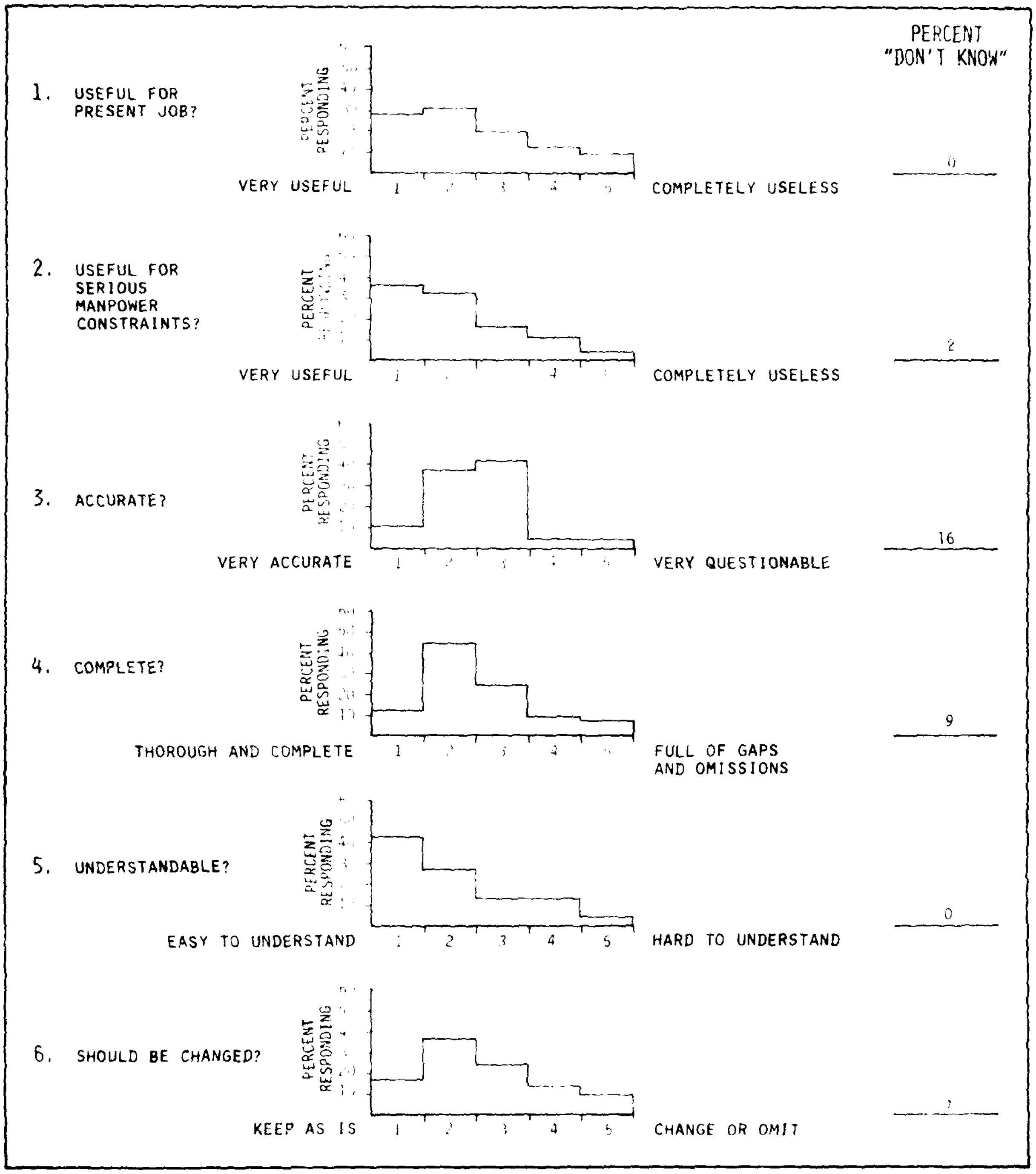

Figure 8. Ratings of information in Section 6: Taxonomies of Tasks and Associated Skill Levels.

checklist; the system specifications should call out the features that are desired. Maintainer/operator tasks are defined, but to come up with a time consuming rating would be hard to specify.

One commentator suggested that the material is unnecessary: Designers with any experience currently design for least skill level.

One commentator deduced that, if this information were imposed as a design criterion, manpower constraints would take first priority and operator functions would be eliminated.

3. Accurate? (8)

Several comments questioned the accuracy of the data: Too many limited opinions to enable a statistically valid acceptance of the illustrated data. I wonder if the senior chief petty officers aren't conditioned to believe that rank and skill level are positively correlated; the separations in assessed capabilities seems too uniform. The reader's confidence is diluted by the caveat and weak language used on Page 6-5 of the guide ("Unanimity of opinion on this point was unlikely...", "...relatively strong agreement that some...").

One commentator who marked the "Don't Know" category asked: Are all tasks defined? Are the time consuming factors accurate as seen from the technician's viewpoint?

4. Complete? (5)

The few comments under this question mostly echoed comments made under the Useful and Accurate categories. One commentator said: Would like to see more detail regarding the actual basic skill level of each rating.

Another comment suggested that the breakdown of material by rating was not going to be viable for very long: For example, DSs are being phased out.

5. Understandable? (6)

One respondent stated: I like your clear definitions of "limited, partial, competent, superior."

Negative comments included: Not easy to understand. The three curves always follow each other--using a shaded band or cross-hatching might be easier to read. I find it difficult to understand and work with the graphical display of the task taxonomies; can this representation be done in a different way entirely (e.g., bar charting, tables, etc.)? The connecting lines seem to throw me off and there is some confusion in my mind as to what the differences among the three petty officer technician levels really are.

Three comments focused on the difficulties in using the material in design: There is no handy way to find the material required and relate it to a design problem. It is difficult for the designer to measure technician effectiveness on a new design released to the fleet; true competency, based on our experience, is not as related to skill/pay grades as it is to personnel motivation and individual skills. Not sure how to use the limited information presented here.

6. Should be Changed? (18)

A wide variety of comments were offered under this question. One comment stated: This appears to be good material but the presentation was awkward.

One commentator suggested that the material does not give the designer any direction: What class petty officer should be used for what task? Does this vary between equipments? What are the minimum requirements by class for certain tasks?

One respondent came up with some answers to the above questions: Consider a summation of the essential task difficulty differences for each petty officer level at the end of Section 6; it would be useful to profile the differences according to the following generally understood technical levels--apprentice (PO3), journeyman (PO2), and fully qualified technician (PO1).

Numerous comments focused on the difficulty of using information regarding old equipments to make design decisions on new equipments: This section's value depends on a new system having tasks which are similar to existing Navy systems: At best, this section would serve as a general guide for estimating operation and maintenance tasks. Only applicable to existing systems; new designs will be significantly different. Obsolete equipment; this approach does not consider the new trends in integration; would like to see analysis on new equipment (e.g., UYK-43 and 44 replaces UYK-47 and 20). The problem is the new type of integrated system, not isolated equipments or chassis. Requires definitions of example equipments; also, I could not understand the function performed by many of the tasks that were described.

Several respondents focused on the format of the presentation: I don't like your format, but I don't have a constructive suggestion. Figure 15 needs much heavier outlines around the referenced blocks. Explanations should be made much clearer on the chart headings; they should be as self-explanatory as possible; the current format requires that the reader refer back to Pages 6-4 and 6-5. A different graphical representation of the data would be good here; also the text should be expanded to give the user helpful hints as to how he can use the data on existing systems as points of departure for determining the manpower and training impacts on his new design.

One senior engineer suggested the use of more common language in presenting the information in Section 6: After consulting my secretary's dictionary, I found out what "taxonomy" means! You must remember that most system design engineers are just a little illiterate (even us managers). We tend to like simple, logical communications. Webster's definition of taxonomy as an "orderly classification" isn't too hard to understand. Why don't you use those kinds of words. Try speaking our language if you expect to "sell" this guidebook.

One comment suggested that a better transition at the end of Section 6 would be helpful in leading into Section 7: Suggest your text in Section 6 provide a bridge or forward reference to Section 7.

Comments from Other Sources.

Many comments from the other sources were similar to those of respondents to Evaluation Packages C and G. The following present some additional insights: I didn't like the time-consuming percentages. It was hard to relate this statistic to what the technicians are doing. I would rather have seen the percentage of a technican's total work time that is spent on each activity.

One commentator thought that the guide should explain the reasons for the time-consuming tasks: Why is something time-consuming? Follow this lead and provide the information to the designer; he won't dig it out himself.

One respondent noted the need for additional data in order to properly interpret the time-consuming percentages: We also need data on the frequency of the tasks; are they quarterly, yearly, etc.?

Noting the difficulty in translating information on tasks from old systems to the desgn of new, a group of commentators from NAVELEX said: The tasks which talk about old style maintenance reduce the credibility of this document. Designers don't design systems that way anymore. It might help if you noted that some of the tasks which are extreme examples of the above are not currently accepted philosophy. These commentators also admonished: Reorganize this information by systems, not by ratings.

One individual made several detailed comments on the material in Section 6: In order for the engineer to design a new system that avoids tasks which involve difficulty, he will need to find out what features produced problems in the old system. It is not the general mode of operation for the engineer to spend a great deal of time examining old systems; one doesn't seem to make much forward progress if you keep looking backward. Also, instead of utilizing questionnaire data, as in the guide, there should be more objective 3M data (with all its shortcomings) that could be used to support analyses of "time to repair." Finally, the manpower and training analysis community may be able to use the difficulty data to modify existing training courses, even if the data do not turn out to be used by the design community.

Section 7: Difficult and Time-consuming Tasks

The material in Section 7 is essentially the same as that in Section 6, only organized in a different manner. Therefore, it was not surprising that the ratings and comments were quite similar to those obtained for Section 6. One difference, however, is the greater regard by respondents for the accuracy of Section 7. Almost twice as many rated the accuracy of Section 7 in the top two positions on the scale than rated Section 6 in the top two positions. Also, fewer indicated that they didn't know about the accuracy. Perhaps Section 7 was organized in a more credible format.

Data from Six Questions in Evaluation Packages

Figure 9 shows how respondents answered questions regarding the information in Section 7. Comments relative to these questions are provided below.

1. Useful for Present Job? (9)

A number of these comments echoed those from Section 6 and will not be repeated here. One comment by a designer was very positive: This is an excellent concept--why not expand it to include most probable tasks as well as most difficult? Reliability analysis should be able to predict the most probable causes of repair tasks which can then also be addressed in the design.

One commentator observed that the material did not lead to objective conclusions: The task descriptions require the reader's imagination to develop a feel for the complexity of the tasks.

The following comment suggested limits for applying the information to design: I don't think it does much good to point out areas of problem design since you are only

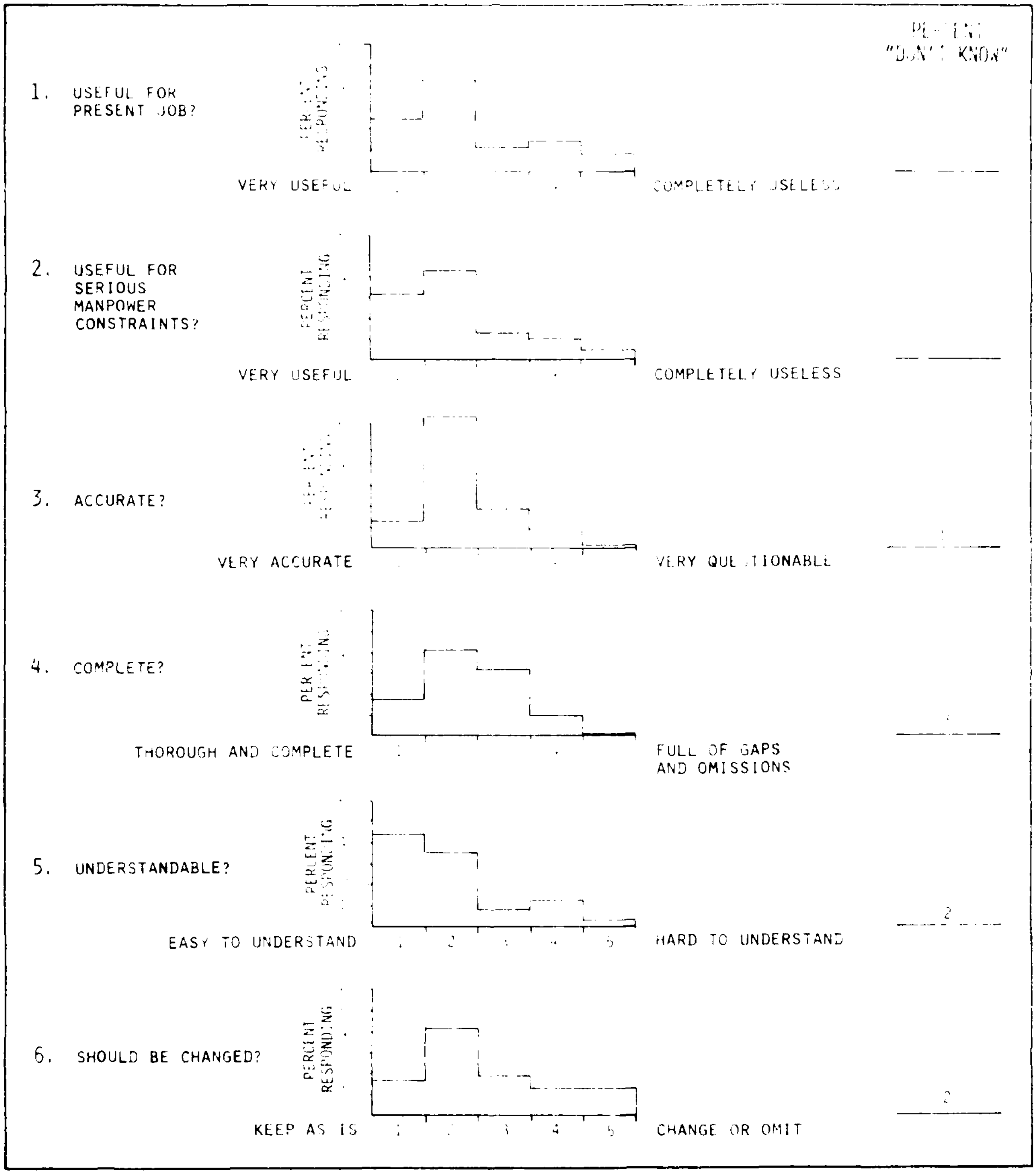

Figure 9. Ratings of information in Section 7: Difficult and Time-Consuming Tasks.

itemizing a few problems from among an almost infinite number of problem designs. The data here would be most valuable in the refit of equipment or for the next generation of the same equipment.

Two remarks indicated that the difficult tasks may be intractable: Can't really eliminate any of these generic tasks. The information is interesting, but many, if not most, of the difficult tasks could not easily be eliminated from digital system design, i.e., adjusting a magnetic tape transport.

One commentator appeared to discount the data in Section 7: I disagree; the difficult tasks are localization and isolation of faults. The number of "glitches" rises exponentially as a function of integration and modular design.

2. Useful for Serious Manpower Constraints? (4)

Most comments reiterated previous comments. New thoughts included: The data would be difficult to specify, difficult to establish definitive design criteria. The data might help equipment designers but would be useless to the system designer.

3. Accurate? (5)

The comments mainly reflected an uneasiness about the validity of the judgmental data base: I wonder if the senior chief petty officers aren't conditioned to believe that rank and skill level are positively correlated. All the data in the manual need to be backed up in order to be accepted. I assume that the judgmental data are based on experience.

One commentator noted: Some of the tasks defined do not appear to be operator or maintainer tasks (e.g., rewriting/writing programs, analyze test data).

4. Complete? (1)

The comment here was by a respondent who marked the "Don't Know" response box. He said: Are all of the tasks identified? How well are time-consuming factors established?

5. Understandable? (4)

One commentator said: Color-coded pages were excellent. Other comments echoed those made on Section 6 regarding the complexity of the format, the confusing graphics, and a problem in the organization of the material. The latter sentiment was stated: The problem is in the organization and in being able to find if the desired information exists, where it is, and whether there are other applicable data elsewhere in the document.

6. Should be Changed? (10)

Several suggestions for improvement were made: I have the impression that the data are significant, but I am unsure about the format. Reorganize and provide good indexes. If data were broken down by equipment nomenclature, it would be more useful. Fix minor typographical errors, Page 9-4, Paragraph 1. Need to add more information and better guidelines on how to assign the weighting factors in Table 3. I think that some indication of what specific types of tasks can be performed by the different ratings would be better than the currently presented data for suggesting to designers how to design the equipment for maintenance.

One commentator stated: The information should be useful as a comparison guide; however, I do not understand the exact requirements of many of the tasks that were presented in this section. Therefore, the difficulty and time requirement data are meaningless to me as far as making design improvements.

Another respondent said: Section 7 is difficult for a designer to quantify. I understand the intent of the document but getting there is another thing. How meaningful are the subjective measurements?

One comment stated simply: Omit it.

Comments from Other Sources

Once again, many of the comments from other sources were similar to comments elicited by Evaluation Packages C and G; these are not repeated here. A group of commentators from the acquisition community (NAVSEA) stated: This is great material. Perhaps the main list of tasks (Section 6 of the guide) could be put in an appendix or second volume and just put the list of difficult and time-consuming tasks in the main report or the first volume.

Another member of the acquisition community said: The data on difficult tasks in Section 7 purports to answer the question "What skill levels and number of operators and maintenance personnel are required to perform these tasks?" This has been historically a very critical question in system manning analysis; this section of the guide contributes virtually nothing to more precisely answering the question. There is little promise of objectively determining the skills and manning level of the system from the data presented in this section. A commentator who is at once a member of the acquisition community and the Navy design community remarked: Sections 6 and 7 are interesting and useful, but they do not drive the designer toward a goal.

Section 8: Training Requirements and NECs

Section 8 was not positively regarded by the sample of respondents. Most respondents considered that the information was of marginal utility, accuracy, and completeness. Also, some respondents had difficulty in understanding this section, and others felt they did not know enough to respond.

Additional data were suggested for the section to make it more useful for designers on their present job and to permit a satisfactory response to imposed manpower constraints. However, many said the material was of little or no value to them.

Data from Six Questions in Evaluation Packages

Figure 10 shows how respondents answered questions relative to the information in Section 8. Comments relative to these questions are provided below.

1. Useful for Present Job? (17)

Positive comments included: Good reference data; I will look forward to future updates. In 25 years, I never saw a list of courses before.

A large number of comments indicated that the material was of little or no value: It does have some value, although very little. Not related to contract award or requirements. Cannot correlate training requirements with the list of ratings included in

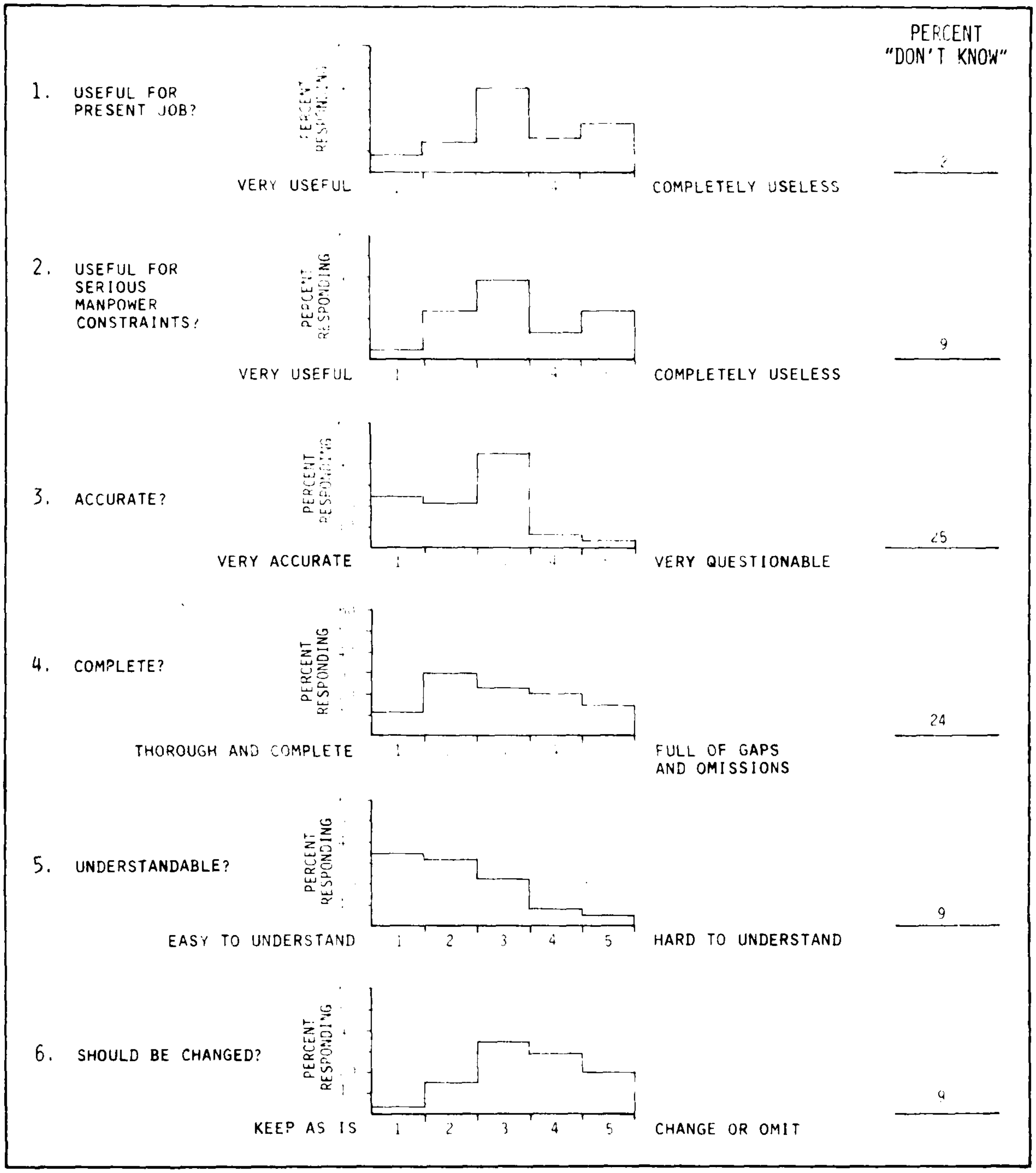

Figure 10. Ratings of information in Section 8: Training Requirements and NECs.

this section. Don't see how information can help me design a system; how do I use the information? Knowing what has been given without a feel for the complexity of the material covered in the training and the resulting proficiency of the students gives no useful information for design tradeoffs. Courses are equipment-specific; how do I know the courses apply to my system? Data are too limited in detail to be useful. Knowing titles of NECs provides no useful information to system designers. Information in Section 8 is incomplete.

Several respondents suggested what is needed to make Section 8 useful: Need the additional detail which was mentioned to be under development and not yet available; a description of how to access a computerized data bank might be useful. List of NECs could impact design if detailed descriptions of the training for each of the ratings were included. Reference to the NEC Manual would contribute as much or more than the information in its present form.

One commentator reiterated his remarks concerning the whole approach to design in response to manpower requirements: This is the-cart-before-the-horse "bull." Training requirements and NECs should be driven by design requirements, not the reverse.

2. Useful for Serious Manpower Constraints? (11)

Some commentators pointed out the need for additional data in order to make this information useful in responding to serious manpower constraints: Information on NEC costs for various technical ratings is vitally needed. If this information were available, it would be of great assistance to any manpower and training support analyst. The section is missing some key data which are under development; at the present it would not be of much use. Need facts--how much does training cost? How long does it have to be? How successful is it? Availability of courses and content, devices and facilities should be summarized here.

Two respondents saw problems in the data: Implicit in these data are the assumption that new equipment can or should be designed to utilize existing NECs; this is a fallacious assumption! There doesn't seem to be a significant correlation between manpower and available courses.

Two commentators rejected the use of this type of data: This is a DoD problem. This would become another requirement to be contended with by the designers; it would add little to system design.

3. Accurate? (3)

These comments again pointed out that the section is missing key data which are under development. One comment brought to light a new thought concerning the accuracy of these data: Courses like TALOS are listed, but the school closed 2 years ago.

4. Complete? (10)

Many comments on this question echoed points that have already been made; these will not be repeated. One commentator noted the lack of specific information that should have been included: the MK-86 FSC NEC should be included; this training course has existed since 1971-72. One commentator noted the need to make the material up to date: Doesn't list courses that are about to be made available.

Two comments indicated that the data were too general: The data are in terms of relative factors: need better, exact guidance to be able to tradeoff nonrelative factors. Needs amplification of actual skills and knowledge possessed by each NEC.

5. Understandable? (4)

Most of the commentators echoed earlier thoughts. One new idea was proposed: Listing is raw data; a cross-reference to task types would be better.

6. Should be Changed? (19)

Many of the comments on this question reiterated previous sentiments. The following are general suggestions: Either drop it or expand it. It needs to be more complete; it is currently of little practical use to the designer; it is general information only. This section doesn't say anything; the references are nice, though. Data needs to be expanded and reformatted. Does not have data that are of value to the designer--except in a general, informative manner. Omit section until data which are referred to on Page 8-2 become available. This would probably best be presented in an appendix since it does not add to the process of determining training requirements.

The following are some more specific suggestions for improving the material: A tie-in to training would be useful; present the number and the duration of classes to relate to the level of required experience. Provide some means to evaluate the level of training received and the average proficiency of students at the end of formal training. There is too much redundancy among the many courses presented; the entire list could be condensed by skill category. Expand the section and give a basic outline of material covered in each course. The section should be expanded to give the designer more insight into the problems, availability, and cost of training. The data for life cycle costs involved in developing new NECs should be presented. Provide an outline for a typical NEC and the cost factors involved in developing a new NEC.

Comments from Other Sources

One group of commentators from the acquisition communitity (NAVELEX) stated: This is very good and useful information. Another group of commentators from the acquisition community (NAVSEA) stated: This is not useful; the designer will rely on the training plans conference for this kind of input.

Comments on the inadequacy of the material presented in Section 8 included: It is only a pretense to think that this information answers the question that it claims to address. It is inadequate just to present the number and title of the NEC; why not also provide the NEC descriptions from the NEC Manual?

A manpower and training analysis expert from the acquisition community suggested: This section needs further expansion to be of maximum use. The list of NECs is woefully out of date. Give a few examples of system NECs under each rating and delete the complete lists which are currently provided in the guide and which can be more readily obtained from a current NEC Manual. Provide more discussions of NEC development to show the role that NECs play in manpower and training analysis and, consequently, how that may affect the selection of design alternatives. The NEC life cycle cost data, which is apparently under development, is vital to making this section useful.

Section 9: Billet Life Cycle Costs for Required Personnel

Respondents had little difficulty understanding the information in Section 9, and most indicated by their ratings that the information on billet life cycle costs was useful. Both accuracy and completeness of the information were questioned, however, by a significant proportion of respondents. In addition, many felt they did not know enough to assess accuracy and completeness. Part of the credibility of the section was lost because of two inconsistencies between dollar amounts in the tables and the text. Many comments pointed out these errors, using the error to justify low ratings. In addition to suggestions for correcting these errors, suggestions were made to expand the information to make it more useful.

Data from Six Questions in Evaluation Packages

Figure 11 shows how respondents answered questions relative to the information in Section 9. Comments relative to these questions are provided below.

1. Useful for Present Job? (8)

Several commentators stated that the information was not useful to a designer's current job: This information is not particularly useful to a designer. A typical designer hasn't got time for this; it may be appropriate for a specialized analyst. If I am doing life cycle costs, this is of general interest; otherwise, it is of little value in designing systems. Life cycle cost is only a secondary requirement for my present job in systems engineering. The first time I ever saw such a table; these numbers have been quoted by others though.

One respondent suggested that the Navy would not appreciate design inputs based on this type of information: Navy not receptive to life cycle costs from a designer's standpoint.

One commentator made the following suggestion: Data on specific life cycle costs by rate are not useful. However, a rule of thumb for a technician at the E-4 or E-5 paygrade would be more useful. The variation between ratings (job specialties) is small enough that a rule of thumb would be adequate. These numbers are also small compared to system acquisition costs and system support costs (other than manning).

2. Useful for Serious Manpower Constraints? (5)

One comment indicated that this information would not be useful to the designer. Another comment reiterated the earlier sentiment that this was not the designer's concern: Tell the Navy to work more efficiently with less manpower and reduced payroll.

A member of the acquisition community foresaw the following problem: If DoD constrained a system to be built with a low budget for manning, they might constrain the system right out of existence.

The following suggestions were made to make the material relevant for serious manpower constraint: Should be updated for each contract to reflect current economic factors. The information must be in current fiscal year dollars.

3. Accurate? (10)

A large number of comments pointed to two errors in this section. One error appears on Page 9-4 in the third paragraph, where the dollar amount at the end of the

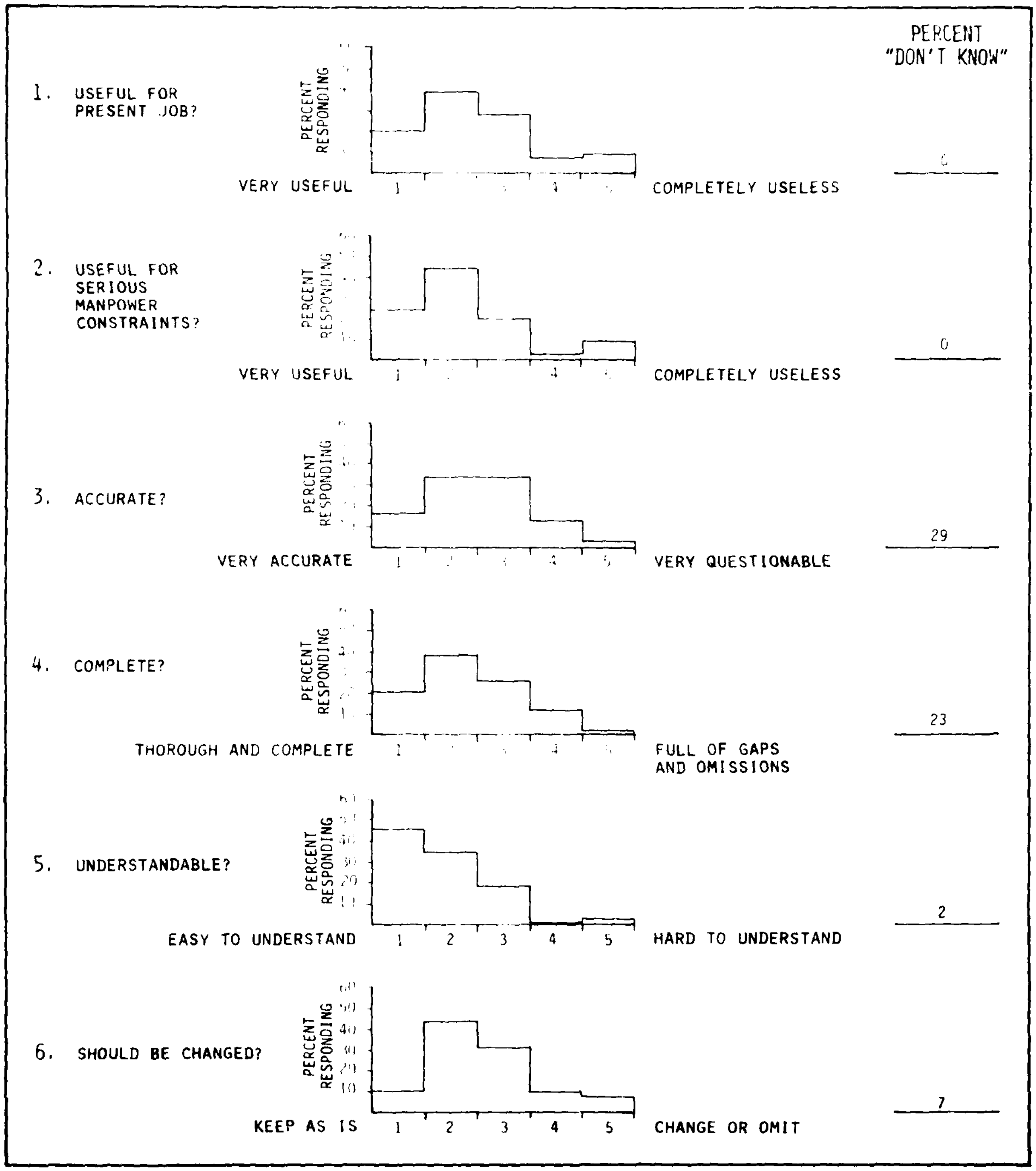

Figure 11. Ratings of information in Section 9: Billet Life Cycle Costs for Required Personnel.

paragraph is for a 10-year life cycle cost instead of the 15-year life cycle cost called for. The other error occurs in the last table on Page 9-6, where dollar amounts in the example problem are for 10-year life cycle costs instead of 15-year life cycle costs called for.

Two comments expressed concern over the basis for computing life cycle costs. One said: Do these costs include allowances for leave, sickness, or other time off? A manpower and training analyst stated: Various cost models and data exist within the Navy; this is just one of them; input factors are always open to debate and are questioned; why not mention advantages and limitations of this model and point out other models which can be used for budget, funding, and program justification?

4. Completeness? (4)

One commentator noted that a large cost factor group, operational specialists, were missing from the data.

Two comments suggested the need for more information on technical matters: Need a more detailed discussion of the 10 percent discount rate. What about escalation, cost growth, forward pricing?

5. Understandable? (1)

The comment was in reference to the errors in the text.

6. Should be Changed? (8)

Several of the suggestions concerned fixing the errors in the text and tables. Two commentators stated that the material was irrelevant to design: Omit the material; it is a Navy problem. Section 9 could be eliminated; it is of no real interest to design criteria.

Several respondents suggested changes that would expand the information to make it useful: Text could be expanded to discuss other cost factors which have not been included in this presentation. Delete Table 4 and provide more examples. More backup information is necessary in order to modify the current situation. Modify this material with specific historical examples of Navy manning topics--watch standing, preventive maintenance, etc., for each type of operator or maintainer.

Comments from Other Sources

On the positive side: The billet life cycle cost data presented in Section 9 is a clear, straightforward presentation and is valuable reference material. The cost data are very desirable; however, they must be updated yearly.

The following suggested some questions as to the relevance of the material to design: This is useful information to higher level people, not to designers. Useful but not indispensable information; how is it used in the work sheets?

One commentator discussed the problems of using life cycle costing considerations in system design: Section 9 contains the central elements required to drive design if, and only if, total life cycle costing can be imposed in the acquisition. Often life cycle costing cannot be imposed because it conflicts with constraints in the R&D budget. In the near term, other specifications constraints must be imposed to drive design in the right direction until life cycle costing finally (if ever) comes of age.

Section 10: References

The references were not considered to be very useful or relevant by the sample of respondents. Interestingly, many comments indicated that the references could only become relevant if they were made part of a contractual document. Relatively large percentages claimed they were not sufficiently knowledgeable to assess the references. For example, nearly half did not feel qualified to rate the completeness of Section 10. Many suggestions were made to expand, annotate, categorize, and index the references to make them more useful.

Data from Six Questions in Evaluation Packages

Figure 12 shows how respondents answered questions regarding the information in Section 10. Comments relative to these questions are provided below.

1. Useful for Present Job? (10)

Most of the comments on this question suggested that the references weren't useful or relevant: In the normal work environment, there is not time to do much library work. Why should the designer have to read all those references? Reference utility would be primarily in evaluating this Manual. Not very helpful unless one wishes to specialize in the subject. The material extracted from the references is useful, but the references themselves are of no value unless I am tasked with reading, analyzing, and criticizing them. If this guide is to be the authority, it doesn't need references. They are not required for current contracts.

Two comments treated the problem in accessing the material if the designer wished to: References not available to the typical designer. These references are from a wide variety of sources; if I needed one of them, our librarian might have a tough time finding a copy; I recommend that these references be kept as a single library somewhere that all users can access.

2. Useful for Serious Manpower Constraints? (8)

Some remarks echoed the sentiments expressed on the first question. Three comments related the utility of the references to contractual requirements: References are not very useful unless one wishes to specialize in this subject; of course, if this concept were to be imposed contractually, the references would be of value. References might be of value in the event of a serious DoD push to do something constructive. No definitive requirements are stated.

One of the commentators believed that the references were irrelevant: None of the references truly addresses the problem.

Two comments indicated that the references should be indexed or annotated: This list of references is useful as a beginning but needs to be greatly expanded; also, the various types of references should be categorized with annotations as to their intended or suggested use. I would not know what documents provided a particular set of data.

3. Accurate? (4)

Two of the four comments on this question stated that the commentators could not assess the accuracy of the references.

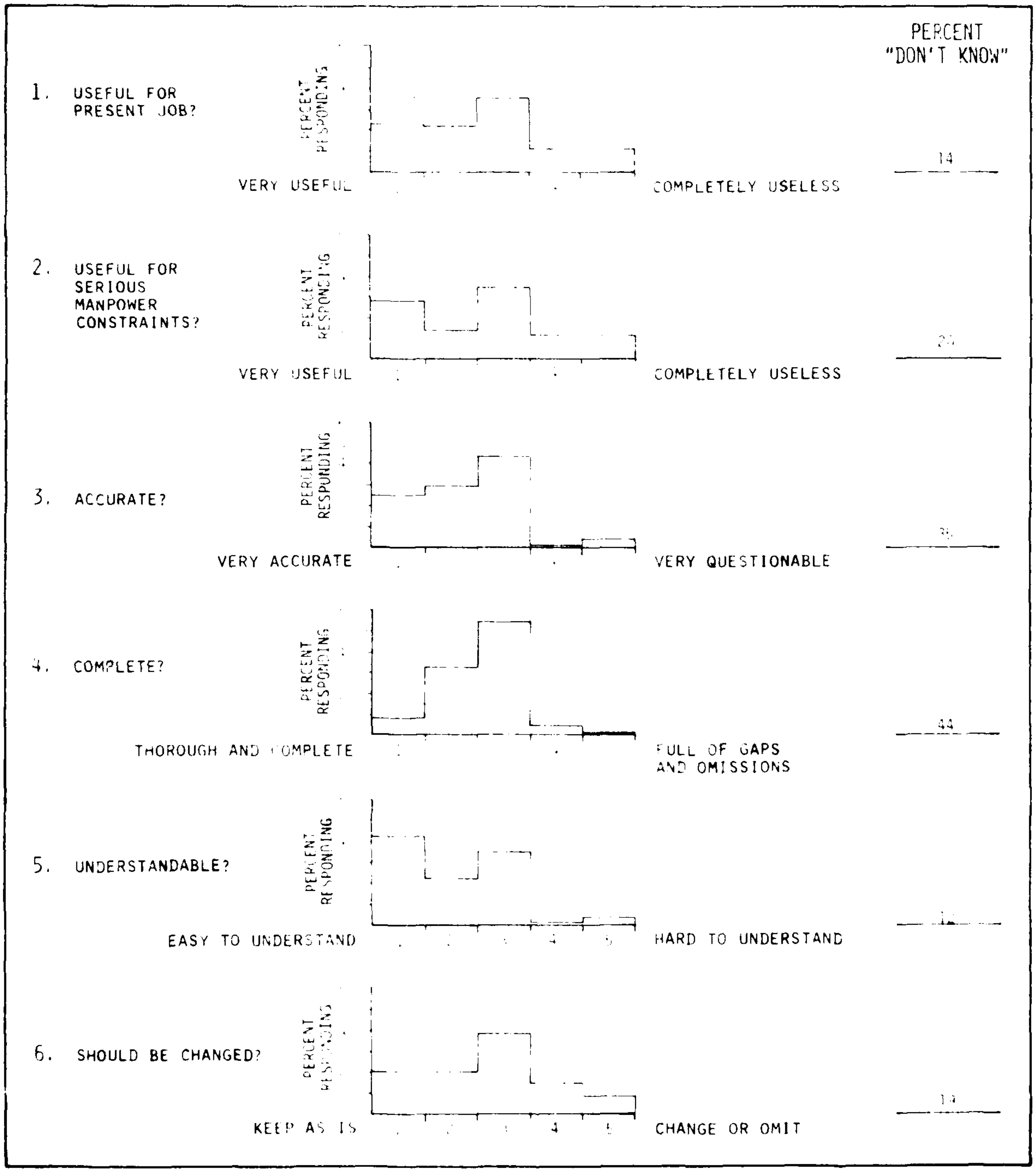

Figure 12. Ratings of information in Section 10: References.

Two comments suggest that the particular references in the guide miss the mark: I have read most of the references and I really don't feel that the subject in question is addressed from the system designer's point of view. Suggest you look for more industrial contractor references, like the last one on Page 1-2.

4. Complete? (1)

The one comment under this question said that the commentator had no idea about the completeness of the list of references.

5. Understandable? (0)

6. Should be Changed? (11)

Two of the comments on this question indicated that the section should be dropped: To be useful, the guide should stand alone. A bibliography is of no particular value to the program or system engineers.

The larger proportion of comments suggested that the reference material be increased: Expand it. Expand it and index it. Change to an annotated bibliography. Could use some abstracts. Provide short extract of what each report covers and contains and the validity base of the reported data. Updating of new information/references should be a follow-on project.

One commentator suggested the following: Present some kind of tabular representation that categorizes the reference materials and shows, under each category, what kind of assistance it will provide in relating manpower and training requirements to systems design. Also, provide a contact list of DoD and Navy organizations which can be a source of information and counsel.

Comments from Other Sources

A commentator from the acquisition community suggested: This section is totally inadequate. Should be revised and greatly expanded. Don't merely give a list of references, provide several pages of text discussion to explain different types of references, their potential uses, and other sources of help within Navy organizations; the latter could be categorized by codes and functions.

A group of respondents from the design community suggested: The guide should include a list of military specifications. What does each specification cover? Include specifications, standards, Data Item Descriptions, etc. Requisition people don't study these specifications, they just include them in the contract package and nobody knows which ones are really relevant.

The commentator from the acquisition community suggested the following documents should be referenced in the guide: New Development Human Factors Program Guide, BUPERS, 18659A; Human Factors Technique Employed in Deriving Personnel Requirements in Weapons Systems Development, October 1967, Report No. PRR68-3; Personnel and Training Research in Support of Advance Ship Programs (Rev), Volumes I and II, March 1971, PTB71-2; Guide for Conducting Personnel Training Research in Support of Advance Ship Programs, May 1970, PTB-70-7.

Comments on the Guide as a Whole

Many comments could not be categorized and treated under the specific sections within the guide. These comments, which represented evaluators' reactions to the guide, its purpose, approach, and content, as a complete entity, provided some of the most insightful critiques and useful suggestions regarding the guide. For facility in preparation, these general comments have been grouped into seven themes: general critique, the need for a document like the guide, utility of the guide, suggested users of the guide, implementing the guide, suggestions about the content of the guide, and suggestions on the format of the guide. In the following paragraphs, we have identified the approximate level and type of person who made each comment to provide some perspective for interpretation. Also, it should be noted that a given comment under one theme may also pertain to another.

General Critique

1. Contractor (Senior Systems Engineer). Personally, I found the book informative and plan to retain it. Certainly a book of this type is needed and long overdue.

2. NAVELEX (Technical Director of a Directorate). The guide lucidly and correctly pinpoints the issues involved and the clear responsibility of the systems designer to consider the human resources factor as an element of system design. Adequate generic coverage is provided of the tradeoffs that can and should be made between skill levels of human resources versus complexity of electronic systems in the concept of life cycle costs. The guide can be a useful tool for systems designers, particularly our hardware contractor engineers who in many cases have little, if any, appreciation of the personnel resource and skill level conditions in the Navy.

3. Contractor (Program Manager). Some of the sections were very good. Some were just so much paper. Section 7 on Difficult and Time-Consuming Tasks and Section 6 on All Tasks had a lot of detail that was very good and very useful. Those are the kinds of things that you really have questions on. I am impressed with the amount of work that went into putting the guide together. This kind of data are very important to us. It's not that bad that the first cut at making a guide like this should have some inaccuracies. I want to encourage the continuation of the development of these data. If the data were tuned up, the guide would have an overall beneficial impact on the design process.

4. Contractor (Senior Systems Engineer). My comments were brief due to my basic disagreement with the whole approach to the book and some of its underlying assumptions.

5. Contractor (Publications Manager). I think the design guide is a fine idea.

The Need for a Document Like the Guide

1. NAVELEX (Technical Director of a Directorate). Those of us experienced in the ship design discipline have long realized that the human being is the most resource-consumptive item (from a life cycle cost standpoint) that must be put aboard ship. As we put more and more complex systems aboard ship to improve and expand the ship's capability, the controlling factor is not so much the skill level of each individual per se as it is the numbers of personnel required at any given skill level to operate the ship. Thus, the incentive for automation, high reliability, ease of maintenance, and self-diagnosis, are tied directly to reducing manpower that must be put aboard and increasing the productivity and motivation of that manpower, while at the same time increasing the combat capability of the ship. It is considered that the widespread circulation and use of this guidebook will promote this objective.

2. NOSC (Division Head). While responsibility for consideration of human resources (in fact, all support elements) as an element of design rests with system designers, there is not now any method of contractually requiring this action. The majority of all system design work is done in industry; therefore, no requirement is ever translated to the designer. Furthermore, support requirements in general are not established in conceptual phases except in a most cursory manner; therefore, review points (NSARC, DSARC, etc.) have no criteria on which to judge the proposed development.

Manpower, personnel and training system concepts are not routinely required. No restraints on manpower utilization or skill levels are imposed. Follow-on ILS planning is driven by design with no attempt to reduce ILS requirements.

Acquisition process decisions are driven by the sponsoring source of funding (i.e., R&D, not LCC considerations). LCC guidelines are not established for developmental systems.

Utility of the Guide

1. Contractor (Engineering Program Manager). I enjoyed the evaluation and learned a great deal. We could have used this manual in Trident and Captor. We could have used it to design the ground support system for Captor; we ended up with embedded computers that have since turned out to be a big pain. It's difficult to obtain and train people to maintain the sophisticated electronics. Would like to keep the book. Would like to see data base expanded. Would like to see the data base updated regularly. If possible, please keep us advised as to when it may become a document that we can use in our work.

2. OPNAV (?). The guide may be more useful in comparison of candidate systems in order to determine which is the more cost-effective for purposes of awarding a contract.

3. Contractor (Chief Electronics Engineer). We are very aware of the maintenance problem. I understand exactly what you are trying to do with the guide. It's the Navy customer that makes life tough for us; we tell him that if he wants all the fancy features on the system, it's going to take a large amount of training; however, if he can live without certain features and requirements, then training can be cut down accordingly. The guide will be a useful document to prove this point. In the past, we have been saying that you can eliminate a maintenance man and save a certain number of dollars, but there has never been any compelling proof for this argument. Now we can use the guide to prove the argument and show, additionally, that the Navy can't provide the manpower any more to maintain all the fancy features.

4. NOSC (Division Head). The data are an average that doesn't mean much. Different ships and different implementations would lead to different results. You could not plug this information into a formula and trust the result. It is very good if you take it with a grain of salt and think about it, but not as a cookbook. If the guide were reformatted, it could be useful in conjunction with our Project Manager's Guide.

5. Contractor (Electronics Engineering Manager). I liked the guide and think it is quite useful in many systems. I would like a copy of the final report.

6. NESSEC (RDT&E, Staff). COMSEC Limited Maintenance (board substitution) can only be done by technical personnel who have attended a specific course for each equipment. Therefore, each ship must have a maintenance man qualified for each equipment. The 21 design concepts in Section I will be useful in developing future COMSEC repair and maintenance concepts.

7. NOSC (Program Manager). The guide helps by providing information on manpower availability and explaining what the design concepts do and how they interact.

Suggested Users of the Guide

1. NAVELEX (Deputy Commander for a Directorate). The guide has been reviewed by several codes within NAVELEX. Those who have reviewed the study carefully have agreed that it would be useful to hardware design contractors. At present it is not in a form that can be imposed on contractors as a specification, military standard, etc. However, it can be furnished as information to the design contractors. The study would not be useful to contractors that are working to a clearly defined production specification. Only those in the design phase would find it helpful.

2. NAVSEA (ILS Engineer in a PM Office). It seems like the kind of stuff that an ILS person like myself could use. Program manager might use it; APM would not.

3. Contractor (Engineering Program Manager). I found the work very useful to system designers and managers. The surveys in Sections 1, 2, 6, and 7 were particularly good.

4. NAVELEX (Branch Head). The users of the guide might be the program manager, technical director, and project engineer. People who work on advanced development models (ADM) should also use the guide; thus, the breadboard models would be a lot closer to what the production models should be.

We could have used the guide in redesign of the SPN-42 when we were deciding on the type of display system to be used. The guide would have advised of the troubles of using equipments which require chilled water systems.

The guide would also be very useful for new contractors who don't know much about the operating Navy.

5. Contractor (Systems Discipline Engineer). Perhaps the document, with some revisions, could be useful as a management evaluation tool. However, I think the entire document is of little use as a design guide. Most of the information presented is well known to any system designer with any degree of experience. The information that is "new" may be okay but it is of little use in evolving a design.

6. NAVSEA (Assistant Program Manager, Manpower and Training Analysis). I feel that this report can be immensely useful to a great many people like myself who participate in system acquisition. It is a great relief for once to read a report where the methodology does not depend on complicated formulas and which can be understood by a wide variety of potential users. The potential application of the guide to the Navy's Source Selection Evaluation Process, especially during the Source Selection Evaluation Board (SSEB) proceedings, alone would almost justify its development.

7. NAVSEA (Manpower and Training Analyst). In my opinion, the document is an excellent tool and roadmap for hardware acquisition managers and senior system designers. It should be of valuable assistance to them in assessing their manpower requirements and the cost implications of alternative electronic system configurations. The approach and methodology reflected in the guide appear to be sound and sufficiently broad enough in scope to measure all major design/cost elements. A few points for consideration are:

If the document is programmed to be the engineer's guide or bible, some thought ought to be given to the maintenance of the data bases (e.g., questions of validity, methodology, projections of personnel availability, billet costs, etc). I see a maintenance requirement relative to the content of the data in the guide, updating procedures, and responsibility for doing all of this. Also, loose leaf binders might be more advantageous from an updating standpoint, rather than a permanently bound document.

Projections of manpower availability might be expanded to include other ratings (e.g., OTs, PMs, CTMs, DPs, etc.), since design considerations may include complex operator requirements and the operator availability of appropriate junior/senior pay grades may not support the implementation of the design configuration.

8. NAVSEA (Human Engineering and Manpower and Training Analyst). The question of who will apply this guide is paramount. Given a program office which is organized and functioning to produce a system, the engineers, managers, and administrators are committed to the hardware design and production. Application of the guide will require additional workload and, hence, labor and funding. Application of the objective of the guide may make an important contribution to the system; however, given the engineering orientation and technical specialty, someone with a background in personnel, manning, training, and engineering will need to be added to the program office to implement the objectives of the guide.

The guide, in itself, does not lend itself to application by an engineer. The guide falls short of a cookbook; hence, the application must be performed by someone competent in the manpower field to implement its objectives. It could almost be said that were such a person within the project office, the guide would not be necessary. It is concluded that an engineer cannot use this guide to more effectively design a system for optimum use of human resources, nor is the guide sufficient to determine personnel and training requirements more effectively than is currently being done. The value of the information in this document, if recast, may be to convey a sharp awareness to program managers of the importance, complexity, and costs of system manpower. The type of data in Sections 1 and 2, dealing with the impact of design concepts on manning, offers a potential to have a very worthy impact on design. Were these data carefully validated and well-refined, a set of principles and rules for an engineer to follow for effective use of personnel could be formulated. While the document currently falls short of providing guidance to engineers concerning use of human resources in system design, identification of the factors involved and the clustering of some data into a single document would be of use to manning specialists in assisting engineers in system design.

Implementing the Guide

1. NOSC (Program Manager). Industry is the place that the guide would be used. The guide has to become a requirement in the contract. If OPNAV implements the guide, NAVMAT will have to follow suit. Just making it a NAVELEX Standard won't give it the coverage that it would get if it were an instruction from OPNAV or NAVMAT.

2. Contractor (Senior Staff Engineer). It is encouraging to see serious consideration given to this important area, and I am appreciative of the opportunity to contribute to this effort. I hope that any comments and evaluation are viewed as constructive criticism of the content or procedures and not seen as opposition to the intent of the guide.

Although the guide is interesting and inforn... ive, its present format would not be expected to produce any appreciable change in the human resources requirements of a system design developed and procured under today's environment and practices. Some specific suggestions are: After thorough quantitative validation of the evaluation criteria profiles (in Section 2) by appropriate organizations, incorporate the applicable ones in a new military handbook on human resource predictions. Also, validate and include Sections 6 and 7 in the new military handbook.

Develop minimum human resource requirements for inclusion in contract specifications and for award evaluation criteria. General requirements would have to be quantified specifically for each system under procurement. By this procedure, human resources are included in design criteria, first as incentivised by contract award, and second by quantitative contract requirements.

3. NAVSEA (Branch Head, Manpower and Training Analysis). The guide should be imposed on the Program Manager and Acquisition Manager, in both government and in the contractor structure. This guide should be Source Selection Board GFI. Also, it should be a base document for determining contractor capability during preaward surveys. Navy briefing teams should provide contractors with a good understanding of the guide and its application.

The guide should be a military handbook that must be referenced; there must be an "audit trail" to ensure that the guide was used by whomever.

4. Contractor (Senior Systems Engineer). The unanimous feeling was that effective implementation of the book will be very difficult due to the problem of establishing precise, unambiguous, measurable tests of these factors. Once such tests are developed, they should be funded separately to ensure the task receives its due.

5. NAVELEX (Branch Head). The guide could be tied in to logistics support analysis: Supply support and maintenance manning. The guide is more applicable to the contractor than to offices in NAVELEX. The acquisition engineer should pull out parts of the guide relevant to a specific system and include it in the contract specification. If the guide is published as a military handbook, it can be invoked as either a guide or a requirement in the contract specification. The guide should carry a military handbook number.

6. Contractor (Project Leader). All of the complicated weighting factors could be put forth by the customer for the engineering manager at the contractor's facility; but for a designer, the data were not readily accessible. There is no index to guide me to find particular data. It was too much like an academic report.

I would like to know what the tradeoff weights are between manpower, performance, size, weight, etc. The latter three are what drives engineering design; that's what we are trained to look at. If you want to establish new criteria (manpower criteria), you must provide weights or some basis for establishing the priorities of the new criteria over the old ones that we are used to.

I would be more receptive to rules of thumb and straight guidelines than pseudo-engineering tradeoff formulas.

7. NOSC (Division Head). The guide will only work if the guy who is writing the specifications puts it in the requirements. Unfortunately, the average guy writing the specifications can't respond to the guide. Also, no one pays any attention to the

requirements and instructions; the Navy doesn't check up to see if they are followed. We need a method that is an economic incentive to industry to follow the guide. However, cost-incentive programs are not that method, they just don't work.

In order to implement the guide, you must train acquisition managers in the use of the guide so that they will make it a requirement to contractors. Subsequently, you must measure the contractor's implementation of the requirement. Thus, you need a deliverable within the contract that is related to the guide.

8. Contractor (Staff Engineer). The underlying USN problem is real and appreciated; however, I do not believe your draft guide will solve it. If the Navy intends to make consideration of human resources a requirement in the design process, then it must mandate this and support it with appropriate resources.

Suggestions About Guide Content

1. Contractor (Systems Engineer, Adequacy). The material in the sections following Chapter II can make a positive contribution to electronics system design. The first two chapters, however, should be reissued to reflect more emphatically and more accurately what the proposed technique purports to accomplish. I found the introductory portions weak.

The example of the system design analysis is good, but it seems to come to a screeching halt with the statement that the consequent design improvement would then come about by iteration. This a key part of the guide and ought to be elaborated and emphasized by example. What follows is anticlimactic and fits more appropriately into appendix section.

2. Contractor (Staff Engineer). If designers are to meet a new mandatory requirement, then they must be provided with a "handbook" which is simpler, clearer, and less pedantic than the guide. The guide's logic is too complicated (e.g., Figure 3) and no beginning-to-end example is presented for guidance purposes. The guide strikes me as too academic and "researchy" to be of real use to designers. For application in the real world, data must be available in a more concise, straightforward form. At this point, it is more suited for program managers.

3. Contractor (Project Leader). The academic stuff was okay for an introduction, but it did not facilitate use of the data when it permeated through the whole book. As a designer I would be looking more for a handbook rather than for a justification as to why the handbook was necessary.

4. Contractor (Senior Systems Engineer). Write with more commonly used English, even if more words are required. The biggest example seems to be "taxonomy" although "evaluative criteria" received some votes. You cannot write above a tenth grade level if you expect systems engineers to read it.

5. NAVSEA (Human Engineering, Manpower, and Training Analyst). It is recommended that the guide be retailored to identify those features which contribute to the single best design (i.e., a set of rules to follow to optimize the design). For example, from the profiles of Section 1, only good can come from a design that includes equipment layout to facilitate maintenance, uses standard hardware components, and "designs for operational simplicity"; but nothing good can be said about "combined operator/maintainer functions." Don't tell the engineer to "compare" and "tradeoff"; instead, tell him how to build the best system from a manning and training standpoint and how he should go about it.

6. Contractor (Readiness Design Manager). I would rather have seen a handbook called "Guide to Concept Selection in Electronic Systems for Shipboard Use," which contained individual sections based on design concepts. This would put forth a detailed description of a particular design concept followed by the related data. For example, program development considerations, design requirements, manning impact, training impact, fleet/ship operations impact, and examples/experience reference data.

This approach would have two major advantages: It would provide a guide for the selection of the basic concept, applicable to both Navy and contractor use. It would be easily expandable to include the introduction of new concepts in new sections. Additional data could easily be added under each concept section in terms of options, improvements, and experience gained in the future.

7. Contractor (Program Manager and staff). The guide did not describe the problem and the exact purpose of the guide very clearly. Suggest you list problems of prior systems. Discuss generation to generation problems; use tech-eval and op-eval data. Don't quantify it, just highlight the important points.

Update the guide yearly; for example, the Navy Safety Center publishes the Navy Reactor Reports for Nuclear Operations. These reports describe very succinctly the problems that happen from time to time. They describe personnel actions or design flaws that may have caused problems.

The guide should be in the form of a notebook which is updated yearly, as discussed above. These updates would also tell what design concepts were tried, on which systems, and how the design concepts worked out. This would provide a corporate memory for the acquisition and design community.

There is a 35-year gap between the baseline systems that were used for the design concepts and the systems that are being designed today for the 1985-1995 time frame. Because of this gap, the data in the guide don't relate at all. The guide needs current projections on technical trends, manning trends, and Navy planning. Use systems that are currently under design, being tested just prior to fleet introduction, or were recently introduced. Don't use systems that have been operationally deployed for a long period of time, because they were designed in the '50s and '60s.

Hit logistics and training. Answer the question, "What happens when the system hits the fleet during the introduction period?"

Checklists and rules of thumb are very useful. Would prefer rules of thumb to be presented in the guide instead of tradeoff formulas. Prefer ballpark estimates on costs (e.g., cost billet information should not be down to exact dollars). It should provide information like, "A sailor costs $200,000 for 20 years." Then the designer and acquisition people can tradeoff number of cards, modules, etc., to answer the question, "Does saving one man really save that much money?"

Suggestions on Guide Format

1. NAVSEA (Branch Head and staff). The guide is too cumbersome. The good material in the guide is too spread out. It should be streamlined for engineers. It could be broken into two volumes: The first volume should give the "quick and dirty" answers to the problem. The second volume should provide backup information to instill confidence in the guide. It might be best to publish Volume I and Volume II in a single document, so that they do not get separated from one another; however, the Volume I material should be on colored paper in the front, Volume II on white paper.

Organize the whole thing by functions or systems, not by ratings. Preface each section with manpower availability charts for that particular type of equipment. Within each section, devote two to three pages per example system, no more.

A sample application of the guide could be provided in an appendix to Volume I.

The guide must be more directive; currently it does not tell the engineer exactly what to do with the information.

Get rid of the word "taxonomy." Keep terminology in designers' language, not in terms of manning of ILS.

Tab or index the material. Use a three-ring binder or screwpost type binder in order to allow updating for new material as it becomes available. At the very least, drill the paper for a three-ring binder and send it out stapled, so that users can put it in whatever binder format they want.

2. Contractor (Senior Systems Engineer). Divide the book into two parts: One being a small part with the conceptual information, and the second part being the data section. The object would be to increase the likelihood of the book being read.

3. NAVELEX (Branch Head and staff). This material needs a roadmap to help people get through the information in the guide. Do not like page after page of words; want good stuff to jump out. Improve the format and layout. It needs to be human-factored!

4. NAVSEA (Branch Head, Manpower and Training Analysis). The guide is excellent, an innovative format. The graphics could be an important and refreshing input to the PM-AM fiscal-statistical analysis supporting program presentation before DoD, OMB, Senate and House Conferences. But an addition is needed. A radical, simple, usable, attactive, eye-catching device. Perhaps this could be a large slide rule format, which would be graduated to scale the events along the critical path. Include: stage of development, projected personnel supply, tasks and skill levels, difficult and time consuming tasks, training requirements and NECs, and billet life cycle costs.

CONCLUSIONS

General

1. Most respondents from the Navy system acquisition and development community believed that the information in the Engineer's guide would benefit the system design and acquisition process by making human resources a specific design consideration and by providing necessary technical data.

2. In general, senior, high-level engineering managers from the contractor design community endorsed applying the information in the guide to the system design and acquisition process; however, mid-level designers often had difficulty relating the guide to their immediate design problems.

3. A subset of the contractor design community rejected the idea of designing in response to manpower requirements; these designers believed that the Navy personnel and training system should solve manpower problems, and be responsive to design, not the reverse. Another subset of designers, however, endorsed the concept of addressing

manpower problems at the system definition and design stage. The second group endorsed the guide and/or wanted to see it improved.

4. The current form of the guide is inappropriate; it does not allow specification of the guide, in whole or part, as a requirement in contracts. A military instruction, handbook, or standard would be a much more appropriate form.

5. The information in the guide is too fragmented. The current format of the guide does not allow efficient and appealing access to important data. To apply information in the guide to the design of a particular system, a user would have to gather bits and pieces of information from a variety of places in the guide. The guide should be reorganized by type of system.

6. The guide confounds the two major types of users. Navy program managers and system acquisition personnel will use it differently than contractor managers and designers. The guide must be explicit on how each group will apply the information. The organization of material in the guide must facilitate the two different types of use.

7. Titles, headings, and introductory comments should not purport to cover a larger scope than the guide actually does. For example, many of the sections in the guide do not cover the topics as completely as implied by the introductions. Also, the title of the guide should delimit the scope of the document, that it is restricted to five types of systems aboard surface ships.

8. The varied backgrounds of the guide's users require that a glossary be added to ensure universal understanding of technical terms in the guide.

9. A corollary to the conclusion above is that, as much as possible, technical terms and jargon be reduced to their common-language equivalents. The biggest offender was "taxonomy," although the detailed comments suggested other problem terms.

10. An index is needed for efficient access and retrieval of information. Re-organization of the guide will reduce but not eliminate the need for an index.

Specific Sections

1. The two introductory chapters are inadequate; they do not introduce the remainder of the guide very well nor do they provide accurate direction on specific requirements, and goals to be achieved as a result of using the guide.

2. The second introductory chapter is naive. The premise underlying system design, exemplified in Figure 3, is an ideal that does not relate well to the real design world: The notion of iterative solutions to design, with feedback loops from later points in the overall design process to earlier ones is not realistic. Except for certain large system acquisitions, integrated ship designs, and, perhaps, some laboratory development efforts, conceptual design is a one-step process where contractor designers take their "best shot" at design proposal and preproposal stages. To introduce the guide in the context of a grand, tradeoff-based, iterative process will jeopardize the guide's credibility with many experienced designers.

3. The data on design concepts are potentially useful for designing systems to require fewer human resources. However, the current presentation and data base have problems that need to be solved. Specific conclusions regarding the design concept data base in Section 1 include:

a. Design concepts must take into account types of equipment and types of missions. This is very critical for considering built-in test equipment, and the group of design concepts related to sparing strategy.

b. Definitions of design concepts need to be improved; they should be illustrated with more detail and examples.

c. The judgmental data base needs to be improved. Data need to be gathered from a larger group of judges. Judges must have specific credentials qualifying them to relate the impact of design concepts on specific system design criteria. The numerous indecision marks in the current data base must be resolved; they seriously jeopardize the credibility of the data.

d. The measurement scale relating impact of design concepts on system design criteria must be improved to make this information applicable during design. A translation of this scale into terms of cost would be one welcomed solution.

e. The set of design concepts concerning LRUs, spares, and location of repair should be reorganized and consolidated to better reflect basic tradeoffs in this area. LRUs-No spares should probably be dropped entirely.

f. The treatment of embedded computers must be entirely revised to better reflect the true nature of this technical area and the current trends in large scale integration (LSI) and very large scale integration (VLSI).

g. The design concepts concerning various levels of standard hardware need to be examined and possibly reorganized and consolidated to better reflect viable alternatives in this area.

h. All of the definitions of design concepts should be examined, rewritten, and edited with the assistance of engineering design experts.

i. The additional design concepts suggested by commentators need to be examined and screened for inclusion in a revised guide, again with the assistance of engineering design experts.

4. The reorganization of Section 1 information and the presentation of it in Section 2 was confusing to some evaluators. At the least, definitions of system design criteria should be presented along with the definitions of design concepts; the present separation of these definitions makes Section 1 and Section 2 incomplete and hard to understand by themselves. Further, consolidation of the data represented in the profiles may be very helpful (e.g., eliminating variables on a profile that have a negligible impact, presenting the data in discrete categories in tabular form). Other specific conclusions regarding system design criteria in Section 2 include:

a. Each system design criterion should be examined, rewritten, and edited with the assistance of engineering design experts.

b. The guide must carefully distinguish between MTTR (Mean Time To Repair) and MLDT (Mean Logistics Down Time) and, possibly, use the latter as a more appropriate criterion for trading off the overall effects of the design concepts.

c. Suggested additional system design criteria should be examined and screened for possible inclusion in the guide, with the assistance of engineering design experts.

d. The judges' expertise and subjective data were especially suspect regarding the intricacies of supply and support costs. All of the impacts of hardware standardization concepts and level of repair concepts on supply and support costs were questionable. This aspect of the data base especially needs improvement.

5. The material in Section 3 on types of technicians assigned to surface ship electronic systems was completely inadequate. The large number of comments that suggested additional types of information to be included in this section indicate that designers need, and are interested in, descriptive information on Navy technicians. More complete descriptions of each type of technician should be developed for the revised guide.

6. If the information in Section 4 on projected supply of technical ratings is included in the revised guide, the specific users must be identified and provided with instructions for applying the information to either system acquisition or design. In its current form, the information is not perceived to be relevant or useful to designers.

7. A small but articulate group of commentators have argued against the utility of the evaluation of alternatives approach in Section 5. The approach has been called "pseudo-engineering," an attempt to derive a superficially refined comparison index based upon relatively crude judgmental data. The underlying data have not been validated and there is very likely a wide variability in the applicability of the data to different types of systems, for different types of missions, etc. Further, the notion of comparing alternative system designs has been called unrealistic (see conclusions regarding introductory material in Chapter II); several commentators stated that a designer hardly has sufficient time and resources to adequately design one system, let alone several for comparison. A sizable number of comments suggested using a checklist to present straightforward guidelines for system design.

8. The applicability and utility of data in Sections 6 and 7 for improving design will be dependent upon two things. One is a detailed specification of how the designer is to apply information about old systems to the design of new ones. The other is a need to base the historical data on systems under development or very recently deployed to the fleet; many commentators believed that the systems included in Sections 6 and 7 were too old to be relevant to future design efforts. Other conclusions regarding Sections 6 and 7 include:

a. Brief descriptions of example systems should be provided as a technical context for the task data.

b. It may be unnecessary to break down proficiency profiles by first, second, and third class petty officers, because the crux of design improvement will be the elimination or improvement of problem tasks, which will improve proficiency of all paygrades of technicians. However, commentators who expressed this opinion also wanted a summary of the general differences between the paygrades and a statement of the probable mix of paygrades that would be assigned to a given type of system. This would help them envision the level of maintenance and operation typically available for their system.

9. The information in Section 8 on training requirements and NECs is inadequate. If this type of material is to be retained in the guide, additional data should be included to make it useful.

10. The information in Section 9 on billet life cycle costs is useful to designers, although additional data would be helpful. The level of precision in the current data tables is not necessary.

11. Reference material should be expanded and annotated.

RECOMMENDATIONS

1. The specific shortcomings noted in the current guide, which are indicated in the previous section, should be corrected.

2. The guide should be reorganized and reformatted. Although this point is subsumed by the recommendation to correct specific shortcomings, it is so important that it should be made a major recommendation. The recommended preliminary outline will accommodate the majority of comments regarding organization and format.

3. Revision of the guide should include inputs from Navy acquisition organizations and contractor designers. As will be evident in the recommended preliminary outline, many topics require intimate familiarity with current acquisition procedures or design technology. Collaboration with experts in acquisition and design will be necessary to ensure the guide's utility and eventual acceptance and implementation by members of the user communities. In addition to providing guidance and technical input to draft revisions of the guide, experts from the acquisition and design communities should help edit and check portions of the revised guide that treat their areas of technical expertise. For example, one or two senior contractor designers with extensive experience in radar systems should edit the section on radar. One or two experienced directors or branch heads from appropriate SYSCOMs should edit material that specifies how the guide is to be used by the acquisition community.

4. The revised guide must be a military instruction, handbook, or standard. This point is subsumed by the recommendation to correct shortcomings in the guide; however, it is so important that it must be made a major recommendation. In its current form as a report, the guide cannot be implemented as a requirement by the acquisition community, and it would be unrealistic to think that the design community would apply it voluntarily. The revised guide should be in a form that can be called out as a contractual specification or, at the very least, as one of the weighted factors in proposal evaluation or in the sole source selection process.

5. Alternative mediums for the guide (e.g., three-ring notebook, computer-accessed data base) should be examined. The medium for the revised guide must allow convenient and cost-effective updating, because much of the most useful material is time-sensitive.

A preliminary outline for the revised guide, which is based upon consideration and interpretation of all of the data that were gathered during the evaluation, is presented in Appendix C. This outline meets the letter and spirit of the bulk of conscientious suggestions that were received during this evaluation.

APPENDIX A

EVALUATION PACKAGE C

EVALUATION PACKAGE C FOR:

AN ENGINEERS GUIDE TO THE USE OF HUMAN RESOURCES IN ELECTRONIC SYSTEMS DESIGN

Produced for:

NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER
San Diego, California 92152

Produced by:

ANACAPA SCIENCES, INC.
Santa Barbara, California 93102

February 1980

A MESSAGE TO EVALUATORS

Greetings! You have received a copy of this evaluation package through a long and intricate selection process that started months ago in San Diego, California. Hopefully you are a systems-level designer who has had prior experience in the design and development of electronic systems for the U.S. Navy. If you have worked in the areas of radar, sonar, fire control, communications, or data processing, that is even better.

If you have had none of the above experience, then someone made a mistake in giving this package to you. Please return it without further obligation.

If you are one of the people that we are interested in, please read on. As previously arranged, a $100 honorarium will be given to qualified evaluators who complete this package.

THE PROBLEM

(IN AN OVERSIMPLIFIED NUTSHELL)

The Navy does not have enough men to operate and maintain all of its electronic systems; a shockingly large proportion of the men that are available don't have the skill and experience to do the job (especially maintenance) correctly. We have studied this problem to death and most of the conclusions suggest that system designers could help us solve it.

Certain cases have shown that systems *can* be designed to be operated and maintained by fewer and lower skilled men. But we don't know enough about how to coordinate the Navy acquisition process with the contractor design process to achieve this reliably with every new system.

THE ENGINEERS GUIDE

Development of the "Engineers Guide to the Use of Human Resources in Electronic Systems Design" was an initial attempt to provide the kinds of data that Navy acquisition management teams and contractor designers could use to cope with manpower problems. Some sections of the report pinpoint manpower shortages and skill deficiencies for specific types of electronic systems. Other sections present data and procedures for evaluating manpower and cost implications of alternative system designs during early stages of concept development.

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ENGINEER'S GUIDE TO THE USE OF HUMAN RESOURCES IN ELECTRONIC SY--ETC(U)
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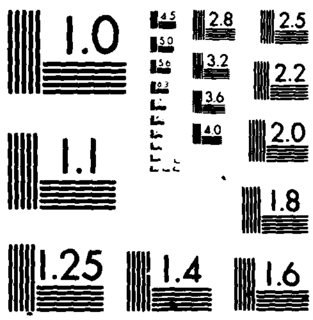

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

REVIEWING THE GUIDE

Your first task is to read through the Guide at least once to grasp the overall concept and to learn how to use the data tables and charts. As you read through the Guide, please ask yourself the following questions:

- "Could I have applied this information to the last Navy electronic system that I worked on?"
- "Could I use this information to reduce the numbers and skill levels of operators and maintainers of future systems."

EVALUATING THE GUIDE

Your second task is to go through the Guide section by section as you work through the yellow evaluation forms. The evaluation forms ask for two kinds of information: the rating scales and checksheets on the left-hand pages ask for structured responses which can be analyzed statistically. The right-hand pages ask for your suggestions for modifying the Guide and the explanations of your views.

The statistical data from the left-hand pages will be used to pinpoint problem areas in the Guide. The explanation data from the right-hand pages will be used for making modifications to the problem areas.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT OUR COMPUTER CAN ANALYZE STATISTICALLY

Chapter I: Introduction and Chapter II: Designing in Relation to Human Resources

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

C-1. Considering my present job as a designer, the information in Chapters I & II is:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

C-2. If DOD were to *seriously* impose design constraints based on manpower considerations, the information in Chapters I & II would be:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

C-3. The information in Chapters I & II appears to be:

1	2	3	4	5	[ ]
Very Accurate				Very Questionable	Don't Know

C-4. The information in Chapters I & II is:

1	2	3	4	5	[ ]
Thorough & Complete				Full of Gaps and Omissions	Don't Know

C-5. The format (tables, charts, text, etc.) for presenting the key information in Chapters I & II is:

1	2	3	4	5	[ ]
Appropriate; Easy to Understand				Inappropriate; Hard to Understand	Don't Know

C-6. In order to provide helpful guidance to designers like me, Chapters I & II should be:

1	2	3	4	5	[ ]
Kept exactly as is				Changed Drastically (or Omitted)	Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Chapter I: Introduction and Chapter II: Designing in Relation to Human Resources

Explain your reasons for circling a "4" or "5" on any item on the opposite gage.

C-1. ______________________________

C-2. ______________________________

C-3. ______________________________

C-4. ______________________________

C-5. ______________________________

C-6. ______________________________

Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 1: Definition and Impact of Design Concepts

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

1-1. Considering my present job as a designer, the information in Section 1 is:

1 — 2 — 3 — 4 — 5 [ ]

Very Useful (1) ... Completely Useless (5) — Don't Know

1-2 If DOD were to *seriously* impose design constraints based on manpower considerations, the information in Section 1 would be:

1 — 2 — 3 — 4 — 5 [ ]

Very Useful (1) ... Completely Useless (5) — Don't Know

1-3. The information in Section 1 appears to be:

1 — 2 — 3 — 4 — 5 [ ]

Very Accurate (1) ... Very Questionable (5) — Don't Know

1-4. The information in Section 1 is:

1 — 2 — 3 — 4 — 5 [ ]

Thorough & Complete (1) ... Full of Gaps and Omissions (5) — Don't Know

1-5. The format (tables, charts, text, etc.) for presenting the key information in Section 1 is:

1 — 2 — 3 — 4 — 5 [ ]

Appropriate; Easy to Understand (1) ... Inappropriate; Hard to Understand (5) — Don't Know

1-6. In order to provide helpful guidance to designers like me, Section 1 should be:

1 — 2 — 3 — 4 — 5 [ ]

Kept exactly as is (1) ... Changed Drastically (or Omitted) (5) — Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 1: Definition and Impact of Design Concepts

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

1-1. ______________________________

1-2. ______________________________

1-3. ______________________________

1-4. ______________________________

1-5. ______________________________

1-6. ______________________________

Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT
OUR COMPUTER CAN ANALYZE STATISTICALLY

Design Concepts: Place an "X" in one of the two columns under A and an "X" in one of the three columns under B to express your opinion of each Design Concept discussed in Section 1 of the Guide.

	A		B		
	I Understand it	I Don't Understand it	USEFUL: Keep it as is	USEFUL: Modify it	USELESS: Drop it
1. Equipment layout to facilitate maintenance					
2. LRUs--No spares					
3. LRUs--Spares with onboard repair					
4. LRUs--Spares with remote repair					
5. LRUs--Spares with throwaway maintenance					
6. "Overdesign" for reliability & maintenance					
7. Embedded computers					
8. Automatic performance monitoring					
9. Built-in test equipment					
10. Built-in troubleshooting logic aids					
11. Automatic fault localization					
12. Standard hardware components					
13. Standard hardware--Cards/LRUs					
14. Standard hardware--Functional units					
15. Standard hardware--Subsystems					
16. Operational simplicity					
17. Built-in operator performance aids					
18. Automatic decision making					
19. Automatic information transmit & display					
20. Built-in training capability					
21. Combined operator/maintainer functions					

☐ Additional Design Concepts: Place an "X" in the box at the left if you believe that Design Concepts which could significantly impact manpower have been left out of Section 1 of the Guide.

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Design Concepts: Explain your thoughts on the 5 Design Concepts on the opposite page which you most strongly believe should be modified, or should be dropped. Please write the Design Concept number before each explanation.

Design Concept Number

_____ ______________________________

_____ ______________________________

_____ ______________________________

_____ ______________________________

_____ ______________________________

Explain any Design Concepts that should be added to the list.

Use additional sheets for long explanations. Remember to indicate the Design Concept number. (Use X-1, X-2, etc., for new ones.)

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 2. Interaction of Design Concept Impacts on Different System Design Criteria

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

2-1. Considering my present job as a designer, the information in Section 2 is:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

2-2. If DOD were to *seriously* impose design constraints based on manpower considerations, the information in Section 2 would be:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

2-3. The information in Section 2 appears to be:

1	2	3	4	5	[ ]
Very Accurate				Very Questionable	Don't Know

2-4. The information in Section 2 is:

1	2	3	4	5	[ ]
Thorough & Complete				Full of Gaps and Omissions	Don't Know

2-5. The format (tables, charts, text, etc.) for presenting the key information in Section 2 is:

1	2	3	4	5	[ ]
Appropriate; Easy to Understand				Inappropriate; Hard to Understand	Don't Know

2-6. In order to provide helpful guidance to designers like me, Section 2 should be:

1	2	3	4	5	[ ]
Kept exactly as is				Changed Drastically (or Omitted)	Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 2: Interaction of Design Concept Impacts on Different System Design Criteria

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

2-1. ______________________________

2-2. ______________________________

2-3. ______________________________

2-4. ______________________________

2-5. ______________________________

2-6. ______________________________

Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT
OUR COMPUTER CAN ANALYZE STATISTICALLY

System Design Criteria: Place an "X" in one of the two columns under A and an "X" in one of the three columns under B to express your opinion of each System Design Criterion discussed in Section 2 of the Guide.

	A		B		
	I Understand it	I Don't Understand it	USEFUL: Keep it as is	USEFUL: Modify it	USELESS: Drop it
A. Maintainer skill and experience level required					
B. System-specific maintenance training required					
C. Shipboard maintenance man-hours required					
D. MTBF					
E. MTTR					
F. Tools, test equipment, facilities costs					
G. Supply & support costs					
H. Operator skill & experience level required					
I. System-specific operator training required					
J. Total number of operators required					
K. System operability					
L. Overall operational capability & effectiveness					
M. Initial system acquisition costs					
N. Operational lifetime costs					

☐ Additional System Design Criteria: Place an "X" in the box at the left if you believe that important System Design Criteria have been left out of Section 2 of the Guide.

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

System Design Criteria: Explain your thoughts on the 5 System Design Criteria on the opposite page which you most strongly believe should be modified, or should be dropped. Please write the System Design Criterion letter before each explanation.

System Design Criterion Letter

______ ____

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______ ____

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Explain any System Design Criteria that should be added to the list.

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Use additional sheets for long explanations. Remember to indicate the System Design Criterion letter. (Use X-A, X-B, etc., for new ones.)

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 3: Types of Technicians Assigned to Surface Ship Electronic Systems

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

3-1. Considering my present job as a designer, the information in Section 3 is:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

3-2. If DOD were to *seriously* impose design constraints based on manpower considerations, the information in Section 3 would be:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

3-3. The information in Section 3 appears to be:

1	2	3	4	5	[ ]
Very Accurate				Very Questionable	Don't Know

3-4. The information in Section 3 is:

1	2	3	4	5	[ ]
Thorough & Complete				Full of Gaps and Omissions	Don't Know

3-5. The format (tables, charts, text, etc.) for presenting the key information in Section 3 is:

1	2	3	4	5	[ ]
Appropriate; Easy to Understand				Inappropriate; Hard to Understand	Don't Know

3-6. In order to provide helpful guidance to designers like me, Section 3 should be:

1	2	3	4	5	[ ]
Kept exactly as is				Changed Drastically (or Omitted)	Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 3. Types of Technicians Assigned to Surface Ship Electronic Systems

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

3-1. ______________________________

3-2. ______________________________

3-3. ______________________________

3-4. ______________________________

3-5. ______________________________

3-6. ______________________________

Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 4: Projected Supply of Technical Ratings at Different Experience Levels

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

4-1. Considering my present job as a designer, the information in Section 4 is:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

4-2. If DOD were to *seriously* impose design constraints based on manpower considerations, the information in Section 4 would be:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

4-3. The information in Section 4 appears to be:

1	2	3	4	5	[ ]
Very Accurate				Very Questionable	Don't Know

4-4. The information in Section 4 is:

1	2	3	4	5	[ ]
Thorough & Complete				Full of Gaps and Omissions	Don't Know

4-5. The format (tables, charts, text, etc.) for presenting the key information in Section 4 is:

1	2	3	4	5	[ ]
Appropriate; Easy to Understand				Inappropriate; Hard to Understand	Don't Know

4-6. In order to provide helpful guidance to designers like me, Section 4 should be:

1	2	3	4	5	[ ]
Kept exactly as is				Changed Drastically (or Omitted)	Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 4. Projected Supply of Technical Ratings at Different Experience Levels

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

4-1. ____________________

4-2. ____________________

4-3. ____________________

4-4. ____________________

4-5. ____________________

4-6. ____________________

Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT
OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 5. Evaluation of Alternatives

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

5-1. Considering my present job as a designer, the information in Section 5 is:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

5-2. If DOD were to *seriously* impose design constraints based on manpower considerations, the information in Section 5 would be:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

5-3. The information in Section 5 appears to be:

1	2	3	4	5	[ ]
Very Accurate				Very Questionable	Don't Know

5-4. The information in Section 5 is:

1	2	3	4	5	[ ]
Thorough & Complete				Full of Gaps and Omissions	Don't Know

5-5. The format (tables, charts, text, etc.) for presenting the key information in Section 5 is:

1	2	3	4	5	[ ]
Appropriate; Easy to Understand				Inappropriate; Hard to Understand	Don't Know

5-6. In order to provide helpful guidance to designers like me, Section 5 should be:

1	2	3	4	5	[ ]
Kept exactly as is				Changed Drastically (or Omitted)	Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 5. Evaluation of Alternatives

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

5-1. ______________________________

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5-2. ______________________________

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5-3. ______________________________

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5-4. ______________________________

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5-5. ______________________________

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5-6. ______________________________

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Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT
OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 6. Taxonomies of Tasks and Associated Skill Levels

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

6-1. Considering my present job as a designer, the information in Section 6 is:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

6-2. If DOD were to *seriously* impose design constraints based on manpower considerations, the information in Section 6 would be:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

6-3. The information in Section 6 appears to be:

1	2	3	4	5	[ ]
Very Accurate				Very Questionable	Don't Know

6-4. The information in Section 6 is:

1	2	3	4	5	[ ]
Thorough & Complete				Full of Gaps and Omissions	Don't Know

6-5. The format (tables, charts, text, etc.) for presenting the key information in Section 6 is:

1	2	3	4	5	[ ]
Appropriate; Easy to Understand				Inappropriate; Hard to Understand	Don't Know

6-6. In order to provide helpful guidance to designers like me, Section 6 should be:

1	2	3	4	5	[ ]
Kept exactly as is				Changed Drastically (or Omitted)	Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 6. Taxonomies of Tasks and Associated Skill Levels

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

6-1. ______________________________

6-2. ______________________________

6-3. ______________________________

6-4. ______________________________

6-5. ______________________________

6-6. ______________________________

Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT
OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 7. Difficult and Time-Consuming Tasks

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

7-1. Considering my present job as a designer, the information in Section 7 is:

1 — 2 — 3 — 4 — 5 [ ]

Very Useful ... Completely Useless — Don't Know

7-2. If DOD were to *seriously* impose design constraints based on manpower considerations, the information in Section 7 would be:

1 — 2 — 3 — 4 — 5 [ ]

Very Useful ... Completely Useless — Don't Know

7-3. The information in Section 7 appears to be:

1 — 2 — 3 — 4 — 5 [ ]

Very Accurate ... Very Questionable — Don't Know

7-4. The information in Section 7 is:

1 — 2 — 3 — 4 — 5 [ ]

Thorough & Complete ... Full of Gaps and Omissions — Don't Know

7-5. The format (tables, charts, text, etc.) for presenting the key information in Section 7 is:

1 — 2 — 3 — 4 — 5 [ ]

Appropriate; Easy to Understand ... Inappropriate; Hard to Understand — Don't Know

7-6. In order to provide helpful guidance to designers like me, Section 7 should be:

1 — 2 — 3 — 4 — 5 [ ]

Kept exactly as is ... Changed Drastically (or Omitted) — Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 7. Difficult and Time-Consuming Tasks

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

7-1. ______________________________

7-2. ______________________________

7-3. ______________________________

7-4. ______________________________

7-5. ______________________________

7-6. ______________________________

Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT
OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 8. Training Requirements and NECs

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

8-1. Considering my present job as a designer, the information in Section 8 is:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

8-2. If DOD were to seriously impose design constraints based on manpower considerations, the information in Section 8 would be:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

8-3. The information in Section 8 appears to be:

1	2	3	4	5	[ ]
Very Accurate				Very Questionable	Don't Know

8-4. The information in Section 8 is:

1	2	3	4	5	[ ]
Thorough & Complete				Full of Gaps and Omissions	Don't Know

8-5. The format (tables, charts, text, etc.) for presenting the key information in Section 8 is:

1	2	3	4	5	[ ]
Appropriate; Easy to Understand				Inappropriate; Hard to Understand	Don't Know

8-6. In order to provide helpful guidance to designers like me, Section 8 should be:

1	2	3	4	5	[ ]
Kept exactly as is				Changed Drastically (or Omitted)	Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 8. Training Requirements and NECs

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

8-1. ______

8-2. ______

8-3. ______

8-4. ______

8-5. ______

8-6. ______

Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT
OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 9. Billet Lifecycle Costs for Required Personnel

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

9-1. Considering my present job as a designer, the information in Section 9 is:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

9-2. If DOD were to seriously impose design constraints based on manpower considerations, the information in Section 9 would be:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

9-3. The information in Section 9 appears to be:

1	2	3	4	5	[ ]
Very Accurate				Very Questionable	Don't Know

9-4. The information in Section 9 is:

1	2	3	4	5	[ ]
Thorough & Complete				Full of Gaps and Omissions	Don't Know

9-5. The format (tables, charts, text, etc.) for presenting the key information in Section 9 is:

1	2	3	4	5	[ ]
Appropriate; Easy to Understand				Inappropriate; Hard to Understand	Don't Know

9-6. In order to provide helpful guidance to designers like me, Section 9 should be:

1	2	3	4	5	[ ]
Kept exactly as is				Changed Drastically (or Omitted)	Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 9. Billet Lifecycle Costs for Required Personnel

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

9-1. ______________________________

9-2. ______________________________

9-3. ______________________________

9-4. ______________________________

9-5. ______________________________

9-6. ______________________________

Use additional sheets for long explanations. Remember to indicate the item number.

USE THIS PAGE TO PROVIDE STRUCTURED RESPONSES THAT
OUR COMPUTER CAN ANALYZE STATISTICALLY

Section 10. References

Circle the scale number that best indicates your degree of response to each item. Put an "X" in the "Don't Know" box for items to which you cannot respond.

10-1. Considering my present job as a designer, the information in Section 10 is:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

10-2. If DOD were to *seriously* impose design constraints based on manpower considerations, the information in Section 10 would be:

1	2	3	4	5	[ ]
Very Useful				Completely Useless	Don't Know

10-3. The information in Section 10 appears to be:

1	2	3	4	5	[ ]
Very Accurate				Very Questionable	Don't Know

10-4. The information in Section 10 is:

1	2	3	4	5	[ ]
Thorough & Complete				Full of Gaps and Omissions	Don't Know

10-5. The format (tables, charts, text, etc.) for presenting the key information in Section 10 is:

1	2	3	4	5	[ ]
Appropriate; Easy to Understand				Inappropriate; Hard to Understand	Don't Know

10-6. In order to provide helpful guidance to designers like me, Section 10 should be:

1	2	3	4	5	[ ]
Kept exactly as is				Changed Drastically (or Omitted)	Don't Know

USE THIS PAGE TO PROVIDE EXPLANATIONS THAT OUR HUMAN ANALYST CAN USE TO MODIFY AND IMPROVE THE GUIDE

Section 10. References

Explain your reasons for circling a "4" or "5" on any item on the opposite page.

10-1. ______________________________

10-2. ______________________________

10-3. ______________________________

10-4. ______________________________

10-5. ______________________________

10-6. ______________________________

Use additional sheets for long explanations. Remember to indicate the item number.

PLEASE FILL IN THE BACKGROUND INFORMATION REQUESTED BELOW. PLEASE PRINT CAREFULLY A FULL MAILING ADDRESS TO ENSURE RECEIPT OF THE HONORARIUM.

NAME ______________________________ PHONE (   ) ________

COMPANY ______________________________

DIVISION ______________________________

JOB TITLE ______________________________

BRIEF JOB DESCRIPTION ______________________________

____

____

1. What system development programs have you worked with in the last 5 years?

System Designator	Type of System	Your Major Responsibilities

2. Approximately how much time did you spend in examining the Guide?

   ________hours ________minutes

3. Approximately how much time did you spend in filling out this evaluation package?

   ________hours ________minutes

4. Honorarium mailing address ______________________________

   ____

   ____

5. Thank you for spending your valuable time and energy in helping us.

APPENDIX B

PERSONS WHO MADE SUBSTANTIVE CONTRIBUTIONS TO THE EVALUATION

Persons Who Made Substantial Contributions to the Evaluation

DoD Personnel

CNET - McCluskey (Program Analyst) - Code N315. (9 July 1980, Evaluation Package G)

NAVELEX - Brooks (Branch Head), Golden, and Blankenheim - ELEX 4701 - System Effectiveness Engineering Division - Maintainability and Human Engineering Branch. Privateer (Director) - ELEX 460 - Maintenance and Material Support Division

NAVELEX - Hobart (Technical Director) - ELEX 05A - Materiel Acquisition Directorate. (9 April 1980, Memo)

NAVELEX - Holmes (Director) - ELEX 310 - Research and Technology Directorate - Telecommunications Division. (28 November 1979, Memo)

NAVELEX - Miller (Branch Head) - ELEX 5203 - Air Traffic Control and Navigation Systems Division - Ships System Applications Branch. Bell Aerospace - Junke (Project Manager) and Femiano (Technical Director): SPN-42 Surface ship radar. (22 January 1980, Group Interview)

NAVELEX - Spangler (Technical Director) - ELEX 501A - Material Acquisition Directorate -Ship Programs and Systems Integration Division. (November 1979, Telephone Interview)

NAVELEX - Von Perbandt (Deputy Commander) - ELEX 04 - Logistics Directorate. (24 April 1980, Memo)

NAVSEA - Lee (Branch Head) - SEA 05L1C11 - PATAO - Strike Warfare Program - Combat Systems Branch. (2 January 1980, Information Feedback Sheet; 23 April 1980, Telephone Interview)

NAVSEA - Lewis (Logistics Management Specialist) - PMS 300C - Combatant Craft/Service Craft/Amphib Acquisition Projects - Program Management. (11 December 1979, Telephone Interview; 18 April 1980, Telephone Interview)

NAVSEA - Mellis (Analyst) - SEA 313 - Ships Concept and Development Group Systems Engineering Division - Manning and Controls Integration Branch. (20 November 1979, Telephone Interview)

NAVSEA - Plato (Branch Head), Luce, Mellis, Stein, Carlson, and Judge - SEA 313 - Ships Concepts and Development Group - Systems Engineering Division - Manning and Controls Integration Branch. (21 January 1980, Group Interview)

NAVSEA - Vroom (Engineering Research Psychologist) - SEA 05L1C1 -PATAO - Strike Warfare Program - Strike Warfare. (January 1980, Personal Notes; 29 April 1980, Telephone Interview; 27 May 1980, Evaluation Package G and Letter)

NAVSEA - Walker (Engineering Psychologist) - SEA 05L1C31 - PATAO - ASW/Ship Support Program. (15 January 1980, Memo; June 1980, Evaluation Package G)

NAVSEA - Young (Manpower and Training Analyst) - SEA 05L1C41 - PATAO - Special Systems Program. (January 1980, Memo)

NWESA - Casey (Analyst) - ESA 834. (November 1979, Information Feedback Sheet)

NESSEC - Dwinelle (Analyst) - Code 2102. (16 January 1980, Information Feedback Sheet)

NOSC - Nunn (Division Head) - Code 921 - Test Technology Office. (13 February 1980, Interview)

NOSC - Ward (Division Head) and Townsend - Code 924 - Electronic Engineering and Services Department - Design Engineering Division. (January 1980, Memo; 13 February 1980, Group Interview)

OPNAV - Beggs - OP 321D - Surface Warfare - Surface Combatants/Modernization/ Readiness Ship Maintenance/Modernization. (January 1980, Information Feedback Sheet)

Contractor Personnel

Bendix - Chief Engineer, Design: CAPTOR, air or surface implanted mine system; AQS-17, airborne mine relocating sonar. (16 May 1980, Evaluation Package C)

Bendix - Chief Engineer, Program Manager: AQS-13E, airborne sonar signal processor; AQS-18, helicopter dipping sonar. (12 May 1980, Letter; 16 May 1980, Evaluation Package C)

Bendix - Program Manager: SEAGUARD, deep water acoustic system; AQS-13, airborne sonar; F-14, airplane, primary hydraulic system. (16 May 1980, Evaluation Package C)

FMC - Project Engineer, Design: GMLS MK 13/4, TARTAR missile launcher for FFG-7; GMLS MK 26, TARTAR/AEGIS missile launcher for CGN-38, DD-993, and CG-47; EX 72, interface simulator for AEGIS GMLS. (6 June 1980, Evaluation Package C)

FMC - Senior Project Engineer: MIU (Message Interface Unit), missile setting interface; digital data bus, surface shipboard interior communications; gunmount and missile launcher components; microprocessor-based test equipment. (6 June 1980, Evaluation Package C)

FMC - Project Leader, Design: MK 71/0 surface ship 8" gunmount; MK 45/0, surface ship 5" gunmount; MK 42/11, surface ship 5" gunmount; GMLS MK 13/4, TARTAR missile launching system. (6 June 1980, Evaluation Package C)

FMC - Design Assurance Manager: GMLS MK 26, missile launching system; GMLS MK13/4, missile launching system. (6 June 1980, Evaluation Package C)

FMC - Chief Engineer, Electrical: GMLS MK 26, missile launching system; GMLS MK 13/4, missile launching system; MK 45, 5" surface ship gunmount; MK 42/11, surface ship 5" gunmount upgrade; GMLS MK 10, missile launching system. (5 May 1980, Telephone Interview; 6 June 1980, Evaluation Package C; 6 June 1980, Letter)

GE - Systems Engineer: SQR-19 (TACTAS), surface ship tactical sonar system; SURTAS, surface ship towed array surveillance sonar. (16 June 1980, Evaluation Package C)

GE - Program Manager: SQS-26, surface ship sonar; SQS-53, surface ship sonar; SQQ-89, sonar display; SQR-19, surface ship sonar; ASWCSI control system. (13 June 1980, Telephone Interview; 16 June 1980, Evaluation Package C; 16 June 1980, Letter)

GE - Manager, Systems Engineering and Implementation: SQR-19, surface ship towed array sonar; SQS-53, surface ship sonar; COBRA JUDY; site defense radar. (16 June 1980, Evaluation Package C)

GE - Manager, Design Review: SQS-53 PEC, surface ship sonar. (16 June 1980, Evaluation Package C)

GE - Manager, Systems Engineering: SQR-19, surface ship towed array sonar. (16 June 1980, Evaluation Package C).

Goodyear - Program Manager, Engineering: MK 48, wire guided torpedo, surface or submarine; TRIDENT submarine, ground support; CAPTOR, implanted mine, air or surface. (12 June 1980, Evaluation Package C)

Goodyear - Manager, Product Engineering: PERSHING II, terminal guidance, army missile; SUBROC, submarine fire control and guidance system. (12 June 1980, Evaluation Package C)

Goodyear - Manager, Product Engineering: F15 simulator; P 2, guidance system. (12 June 1980, Evaluation Package C)

Gould - Manager, Electrical Engineering: TTUMS, towed array measurement system; DDCS, seismic data collection system. (25 June 1980, Evaluation Package C)

Gould - Lead Engineer: DDCS, seismic data collection system; Vickers, remote control system. (16 June 1980, Evaluation Package C)

Hughes - Senior Systems Engineer: NP/CSD, large screen display, air system; SSN display suite; MK 113/10, submarine fire control system; BQQ-5, submarine sonar system. (23 June 1980, Evaluation Package C)

Hughes - Program Manager; Senior Design Engineer; Senior Engineer; and Design Engineer: SURTAS, surface ship sonar; BQQ-5, submarine sonar; MK 112, submarine fire control system; SQS-53, surface ship sonar; SQR-19, surface ship sonar. (11 June 1980, Group Interview)

ITT - Gilfillan - Project Engineer, Design: SPS-48C, surface ship 3-D radar. (1 May 1980, Evaluation Package C)

ITT - Gilfillan - Manager, Product Engineering: SPS-48, surface ship 3-D radar; TPN-22, approach control radar, Marine Corps; TPN-18, air traffic control radar, Marine Corps; FPN-40, air traffic control radar, Marine Corps. (1 May 1980, Evaluation Package C)

ITT - Gilfillan - Logistics System Specialist Engineer: SPS-48C, surface ship 3-D radar; SPS-48 NTU, New Threat Update. (1 May 1980, Evaluation Package C)

ITT - Gilfillan - Logistics Project Engineer: SPS-48C, surface ship 3-D radar. (1 May 1980, Evaluation Package C)

ITT - Gilfillan - Senior Systems Engineer. (1 May 1980, Letter)

Litton - Program Manager: UXC-4, tactical/digital facsimile transceiver; CSTOT, combat system team operational trainer, surface/helicopter; CAORF, ships bridge simulator; AXR-15, low light level TV for S-3 Aircraft. (29 May 1980, Evaluation Package C)

Litton - Manager, Advanced Systems: UXC-4, tactical digital facsimile transceiver; FAST FAX 6000, high speed secure facsimile network; Overlay Generator, multicolor transparency facsimile printer; MASS TAPE, 1 trillion bit memory system. (29 May 1980, Evaluation Package C)

Lockheed - Project Leader: HIGH BOY, real time sensor control and readout; OUTLAW HAWK, command and control. (27 June 1980, Evaluation Package C)

Lockheed - Staff Engineer: USQ-81, command and control tactical data display. (27 June 1980, Evaluation Package C)

Lockheed - Project Engineer, R&D and ORDALTS: MK 86, gunfire control system. (20 May 1980, Evaluation Package C)

Lockheed - Chief Engineer: MK 86, gunfire control system. (20 May 1980, Evaluation Package C)

Lockheed - Systems Engineer: SSURDS/DDGX, sensor/weapons system, surface ships; SEAFIRE, electro-optical sensor system, surface fire control system; SIRCS, intermediate range combat system. (20 May 1980, Evaluation Package C)

RCA - Systems Engineer, Adequacy: AEGIS, combat system. (30 May 1980, Evaluation Package C)

RCA - Manager, Systems Support Engineering: AEGIS combat system and weapon system. (30 May 1980, Evaluation Package C)

RCA - Human Factors Engineer: AEGIS combat system; IRR, Trident communications trainer; NOSS, ocean satellite system. (30 May 1980, Evaluation Package C)

RCA - Senior Systems Engineer: AEGIS, computer controlled phased array radar. (30 May 1980, Evaluation Package C)

RCA - Manager, Readiness Engineering: AEGIS, total ship, combat system, weapon system. (30 May 1980, Evaluation Package C)

RCA - Manager, Combat System Readiness: AEGIS, weapons/combat system, CG-47 class ships. (30 May 1980, Evaluation Package C)

RCA - Systems Discipline Engineer: SP1-A, radar. (30 May 1980, Evaluation Package C)

Singer - Systems Design Engineer: FCS MK 117, submarine fire control system; FCS MK 118, Trident submarine fire control system. (28 May 1980, Evaluation Package C)

Singer - Manager, Product Design Department: MK 116/1, surface ship ASW fire control system; SFCS MK 1/0, submarine fire control system, Australia; MK 377/0; power drive amplifier, ASROC launcher. (28 May 1980, Evaluation Package C)

Singer - Publications Manager: FCS MK 113, submarine fire control system; FCS MK 116, surface fire control system. (28 May 1980, Evaluation Package C)

Sperry - Senior Engineer: S-3(), ASW aircraft update; Life Cycle Software Support Facility, large scale avionics software maintenance facility; VSM-247, automatic test equipment system. (9 June 1980, Evaluation Package C)

Sperry - Manager, Test Equipment and Systems Engineering: MK 68, surface ship gunfire control system; TALOS, surface ship fire control system. (9 June 1980, Evaluation Package C)

APPENDIX C

RECOMMENDED PRELIMINARY OUTLINE FOR REVISED GUIDE

The guide should be published in separate volumes for each type of system. The following outline is for the volume on surface ship sonar, and exemplifies the topics to be covered for each type of system.

DESIGN GUIDE TO OPERATOR AND TECHNICIAN REQUIREMENTS

I. INTRODUCTION TO USING THIS GUIDE

Background
Using This Guide

II. OPERATORS AND TECHNICIANS FOR SURFACE SHIP SONAR

General Description of STGs
STG Training
STGs Aboard Ship
Trends in the STG Rating

III. SYSTEM DESIGN FEATURES THAT IMPACT OPERATOR AND TECHNICIANS REQUIREMENTS

Overview
Category 1: Equipment Layout for Operation
Category 2: Operator Job Performance Aids
Category 3: Number of Operational Modes/Choices
Category 4: Operator Software Aids
Category 5: Built-in Operator Training Capabilities
Category 6: Shipboard Information Transmission and Display
Category 7: Equipment Layout for Maintenance
Category 8: Technician Job Performance Aids
Category 9: Technician Hardware/Software Aids
Category 10: Built-in Technician Training Capability
Category 11: Hardware Standardization
Category 12: Standardized Information Display and Management
Category 13: Standardized Software Modules
Category 14: Grades of Components and Fabrication
Category 15: Miniaturization/Integration
Category 16: Functional Partitioning
Category 17: Processing Architecture
Category 18: Redundancy/Reconfiguration
Category 19: Location of Repair
Category 20: Repair Versus Throwaway Maintenance
Category 21: Maintenance Cycle
Category 22: Shipboard Layout for Maintenance

IV. CHECKLIST OF SYSTEM DESIGN FEATURES

Overview
System Design Features Checklist

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