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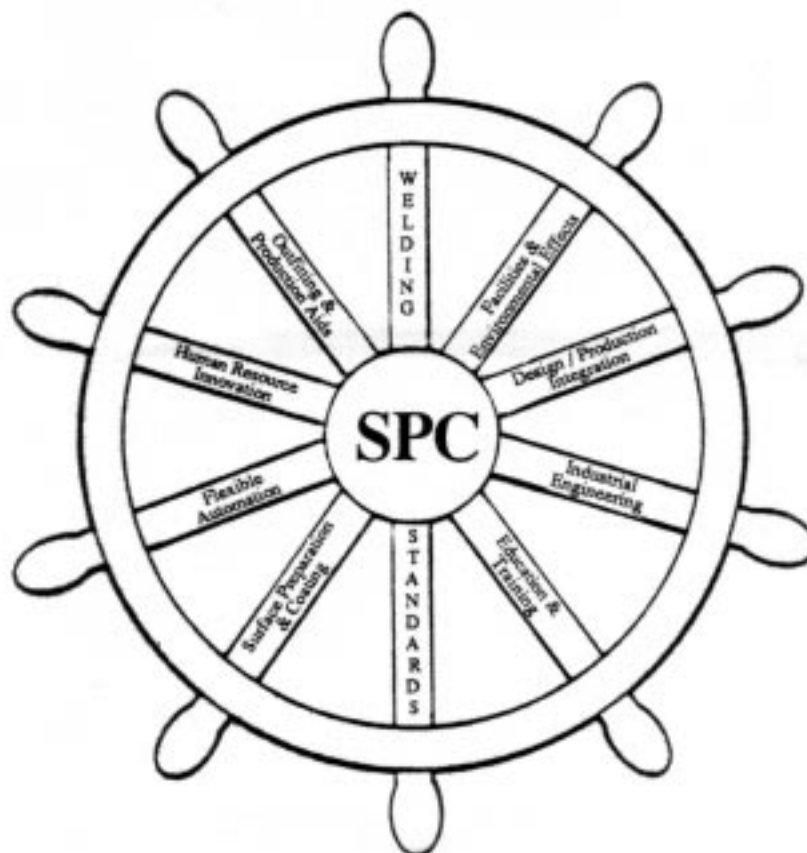
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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM'S 1990 SHIP PRODUCTION SYMPOSIUM

**Preparing for the 21st Century:
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**August 22-24, 1990
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An Assessment of Opinions on Producibility within the Naval Sea Systems Command (NAVSEA)

8B-1

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An Assessment of Opinions on Producibility within the Naval Sea Systems Command (NAVSEA)

by Richard Byrnes and Henry S. Marcus

Introduction

After years of studies, reports, formal and informal discussions, Naval ship producibility is becoming accepted as a necessary ingredient in any recipe for affordable, effective warships. However, within both the Navy ship design and private ship construction communities, the word "producibility" has come to evoke a wide variety of reactions. While there is general agreement that producibility has to do with lowering ship costs, there is not yet a consensus on how those costs are to be attacked, what factors are the most important, and what the roles of the various participants should be.

In order to answer these and other questions, and to form a consensus within the Navy design community that will be compatible with external as well as internal relationships, the Naval Sea Systems Command (NAVSEA) has sponsored a series of steering committee meetings and a workshop on producibility as part of its ongoing research. The purpose of these meetings and workshop is to clarify the meaning of producibility, the needs of the design and construction communities, and to determine critical actions which will enable NAVSEA to integrate producibility more thoroughly into the Naval ship design process.

In support of this consensus building effort, a survey was conducted to help understand the opinions of the NAVSEA community on producibility. Producibility is a multifaceted consideration which is influenced by several disciplines and which is often the subject of debate. Tabulating the survey results would allow members of the community to view the overall range of ideas and opinions which are held by individuals. Subsequently, understanding the current thinking on this topic within NAVSEA can help establish a baseline from which the formulation of producibility goals and plans of action to achieve those goals can be set. Identifying areas where there is agreement, disagreement, and indifference can help design policy makers and designers to better realize where strengths lay, and where changes need to be made. This paper describes the survey methodology and results.

Survey Methodology

Surveys are an efficient and widely accepted means of gathering information to assess group opinion, support decision making, and conduct research. The survey methodology is composed of three steps: survey design, data collection, and data analysis. The first step, survey design, consists of establishing the purpose and targeted sample of the survey, determining the appropriate methods of data collection and analysis to be used, and defining informational needs.

The sample of respondents was a purposeful, non-probability choice, in that it was not chosen to exactly reflect the general NAVSEA population. Respondents were selected because they were deemed to be experts who are critically influential in the NAVSEA ship design and acquisition process and/or on the role that any NAVSEA producibility efforts would play in that process. In other words, it was sought to assess the thinking on producibility of those NAVSEA professionals who may be in a position to do something about it. We do not claim to have surveyed every influential person in NAVSEA, but submit that the sample consists of sufficient diversity and size to represent the range of responses and ideas that may exist regarding producibility opinion.

Of the applicable data collection techniques, which include interviews, questionnaires, observation, and sample content analysis, the producibility survey consisted entirely of questionnaires. This was determined in the interests of both economic efficiency, and the fact that desired respondents were very busy and worked in many locations, such that other techniques would be prohibitively difficult to implement.

The substance of the survey is the informational needs, and these were determined and formulated into three components: administrative information, opinion areas of interest, and respondent comments. These components were then formulated to fit the questionnaire format, and the result was pilot tested in the hope of correcting any ambiguities or other implementation problems.

With the first component of the questionnaire, administrative information, we sought to compile data on the sample make-up, including determining the amount of experience in Naval activities and in producibility that respondents had. The producibility survey was conducted on a sample that was limited to NAVSEA personnel, but within this sample, a wide variety of professional disciplines was represented.¹ Anonymity was guaranteed.

For the second area of informational needs, five key decision making areas were determined and were formulated into a series of thirty-four hypothetical statements, plus two sections requesting respondents to quantify design priority tradeoffs between selected design factors. These five areas of interest are:

- Assess perceptions of the definition and role of producibility for NAVSEA.
- Assess perception of resource availability and needs.
- Assess perception of needs for shipyard activity in the NAVSEA design process.
- Determine perceived design priorities.
- Assess opinions on selected policy options.

The third component was to collect respondents' comments to aid in making a qualitative assessment of perceptions on producibility.

Each of the thirty-four statements was designed to address an individual issue within one of the five areas of interest. The response was measured as a preference on a five point interval scale: (strongly disagree, disagree, neutral, agree, strongly agree). The data from these were compiled and resulted in numerical totals for each of the five possible responses, along with the statistical measures of mean and standard deviation (s). From these measures, the degree to which the respondents agreed or disagreed with the statement can be determined, as well as the extent to which the respondents agreed with each other, indicated in the "spread" of answers.

¹ Some non-NAVSEA personnel participated in the survey during pilot testing, providing valuable insight into the survey content. However, in the interest of clarity, this paper describes only results of NAVSEA respondents.

The design priority sections were included to establish the range of opinion concerning which design considerations were the most important. Examining the results can help to determine areas of agreement and disagreement with established design policy, and this in turn can help decision makers clarify to the community as a whole where the emphasis in design should be.

One design priority section was a round robin series of six "one-on-one" trade-offs between the macroscopic design priorities of acquisition cost, lifecycle cost, ship mission performance, and construction time. Each tradeoff was to allocate 100 points between two alternatives (e.g. 'lifecycle cost' vs. 'construction time'). In the other design priority section, respondents were requested to rank thirteen common design considerations (plus any other considerations the respondent may have wanted to list) according to an ordinal scale (1 for best, 2 for second, etc.). A ratio scale was then used as the respondent was asked to allocate 100 points among the same considerations.

After initial pilot testing, the survey was introduced in April 1989, and fifty-five responses were collected between then and November 1989. One respondent commented that the questionnaire required about an hour to finish, thus these results represent a considerable investment into the knowledge base on producibility.

For all three components of the questionnaire, data analysis consisted of numerical and statistical analysis for quantifiable variables, and identification of common factors, qualities, or comments for qualitative aspects of the sample responses.

Discussion of Survey Results: Administrative

The survey results are comprised of the responses of fifty-five professionals involved in the Naval ship design and acquisition process. The reader can see from Table 1 that the sample was a well educated and well experienced one, and which had a diversity of responsibilities in the process. The range of respondents' occupations included design engineer; ship design manager; program manager (PM) and assistant PM; project and division directors; research and development; and executive directors at the highest levels in NAVSEA directorates. Their active projects include submarine, surface warship and auxiliary

ship design, with specialties in hull, mechanical, and electrical (H, M & E), weapon systems, and financial/accounting practices.

PRODUCIBILITY SURVEY SAMPLE	
NO. OF RESPONDENTS:	55
MILITARY:	4 (7%)
CIVILIAN:	51 (93%)
HAD PREVIOUS PRODUCIBILITY EXPERIENCE	32 (58%)
YEARS AT NAVSEA AVG:	18.0
TOTAL YEARS IN NAVAL ACTIVITIES AVG:	21.4
HAD EXPERIENCE IN:	
ACCOUNTING/BUDGETING/SCHEDULING	27%
DESIGN ENGINEERING	89%
EXECUTIVE MANAGEMENT	31%
MID-LEVEL MANAGEMENT	80%
MATERIAL CONTROL/DOCUMENTATION	7%
PRODUCTION PLANNING	18%
PRODUCTION WORK	9%
EDUCATION:	
HIGHSCHOOL	100%
ASSOCIATE'S DEGREE/TECHNICAL SCHOOL	
BACHELORS DEGREE	96%
MASTERS DEGREE	56%
DOCTORATE	
LAW DEGREE	0%

Table 1

An interesting note on the sample was that 58% of the respondents had been involved with producibility efforts in the past. The range of these efforts included the DDGX producibility feasibility studies, as well as studies for CVNX and CVN71, FFG-7, CG47, DDG963, T-AGOS 19 and 23, SWATH T-AGOS, AOE-6, T-A0 Twin Skeg Concept, the Ships Systems Engineering Standards (SSES), TRIDENT, SSN688, and SEAWOLF.

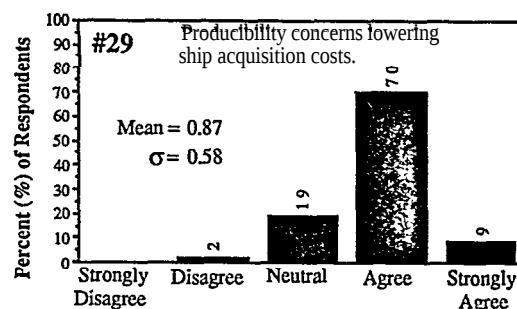
A perhaps more interesting statistic is that less than a tenth of those responding indicated having any production work experience, and less than a fifth had experience in production planning. By contrast, the group had extensive engineering, design, and management experience.

Discussion of Survey Results: Opinion Areas of Interest

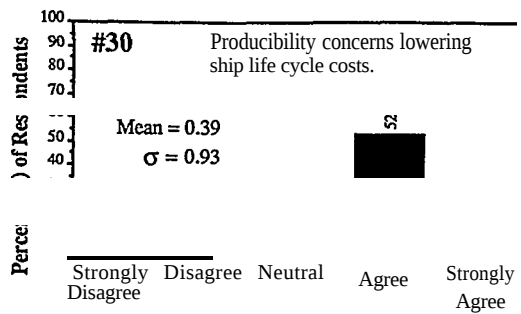
Regarding the thirty-four opinion statements and design priority sections, we have tried to group them in a logical

arrangement that will help identify areas of strong group agreement, disagreement, consistency and inconsistency. The quantitative measures of mean and standard deviation (s) are based on a numerical value assignment of (-2, -1, 0, +1, +2) to the categories: (SD, D, N, A, SA). When looking at these graphical results, we suggest that, though the statements and their response analysis are subjective, criteria for strong group consensus may include a mean value significantly far from zero, a relatively low standard deviation (indicating a smaller spread of opinions), or if the sum of the 'agree' and strongly agree' categories (or disagree and strongly disagree) represents a significant majority or very small minority.² (Where appropriate, pertinent respondent comments will be included in this section, with general comments reserved for a later section.)

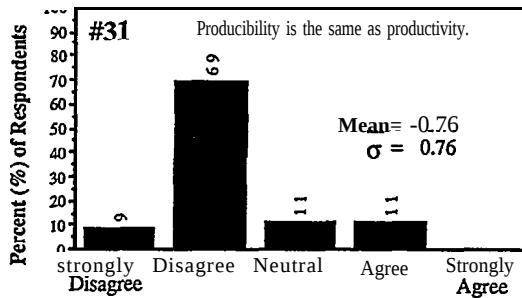
Beginning with the ideas of the definition and role of producibility, statements 29, 30, and 31 along with statements 9 and 10 give some idea as to the general perception of what producibility is. Within NAVSEA, the definition that producibility concerns lowering ship acquisition costs is widely accepted, and this is reaffirmed by the response to statement 29. However, statement 30 shows that although most respondents felt that producibility concerns reducing lifecycle costs, there is some disagreement on this matter.



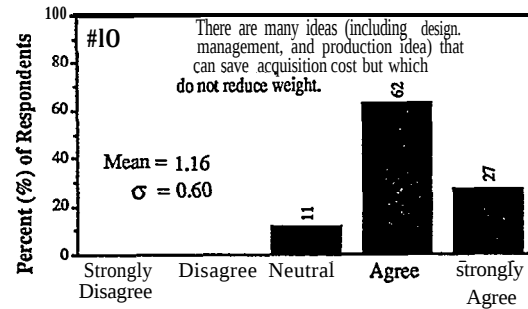
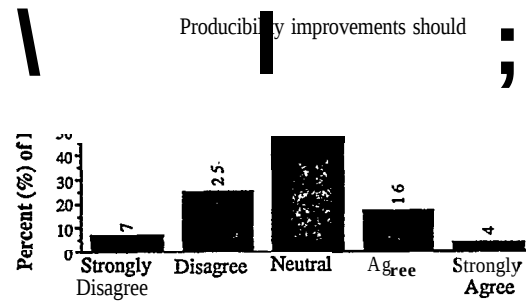
² In the interest of conciseness and to avoid possible confusion, the illustrations for the 34 opinion statements will be identified by their statement number in the upper lefthand corner, and not the conventional Figure 1, Figure 2, etc., scheme.



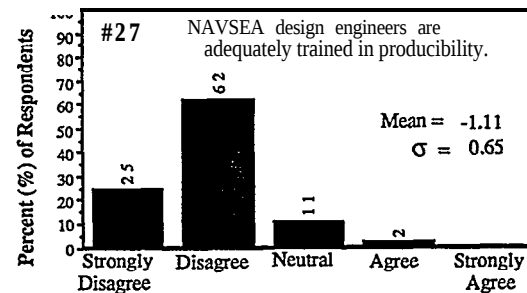
Statement 31 affirms the difference between producibility and productivity. The former deals with inherent properties of a design and the process of producing the designed product. The latter deals with the relative ability of a workforce to manifest those properties.

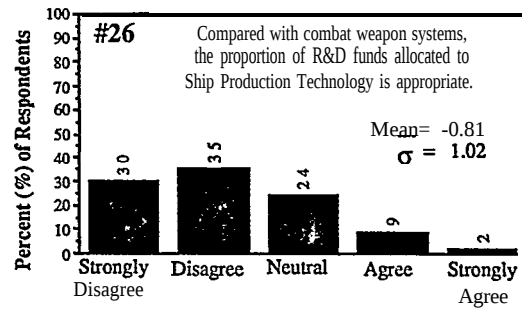
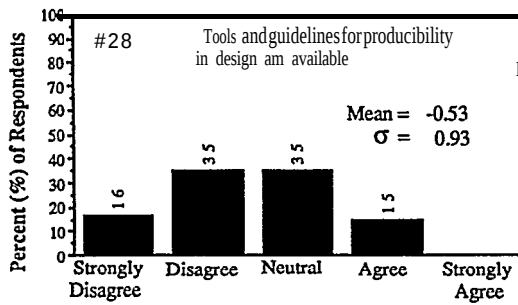


Traditional cost models, which are highly weight dependent, may lead one to believe that if producibility concerns lowering acquisition costs, then one should focus on reducing the ship weight. This traditional logic is refuted by the dispersed reaction to a correlation of an emphasis on weight reduction with producibility improvement in statement 9, and the strong agreement to statement 10 that there are many concepts that can save costs but that do not save weight. This suggests that traditional costs models may need to be reviewed for ways of incorporating producibility dependent parameters.

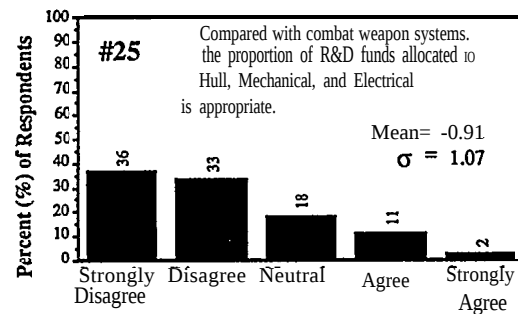
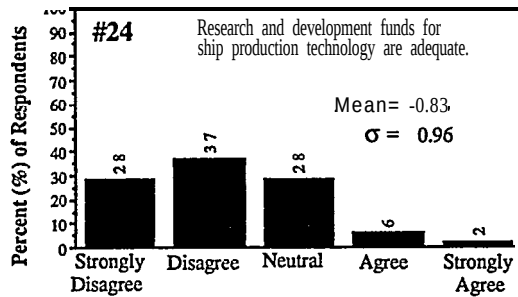


In order to assess the perception of resource availability and resource need, including training needs, we presented statements numbered 24-28 for opinions. Statements 27 and 28 show that there is very strong opinion that NAVSEA engineers are not trained well in producibility, and that there is probably a need for more and/or better tools and other guidelines to train engineers with.

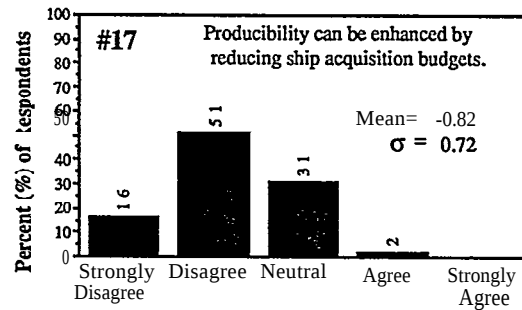


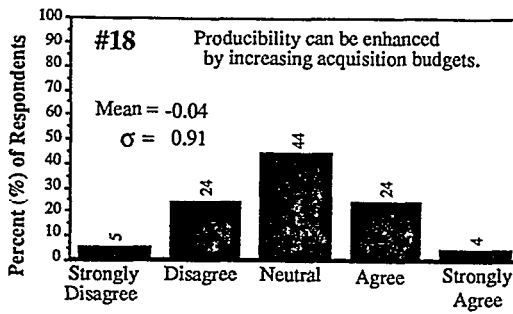


Statements 24, 25, and 26 indicate strong opinion to the effect that the dominant share of research funds available is directed toward weapon systems vis a vis ship production technology and H, M & E.

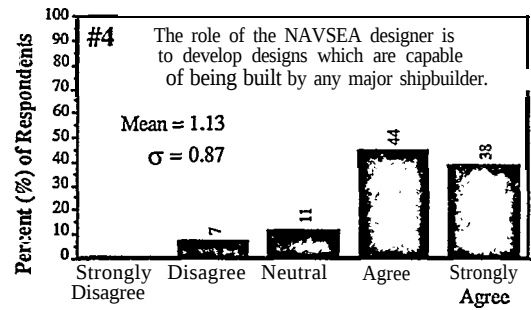


The conclusion that ship designers would like to have more money to devote toward research and development may be foregone. A strong disagreement with statement 17 that producibility can be enhanced by spending less on acquisition reinforces this attitude that a smaller acquisition budget will not enhance producibility. But the near-normally distributed response to statement 18, which queried the need for increased funds for acquisition, possibly indicates that producibility may not be a "money problem" after all. Perhaps the answer lies in how the money is spent.

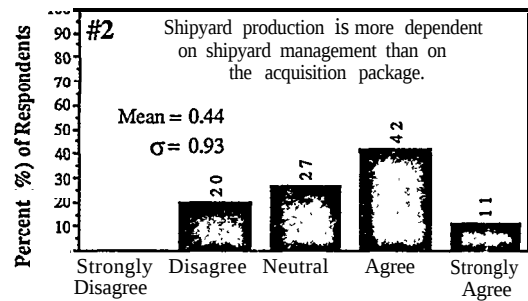
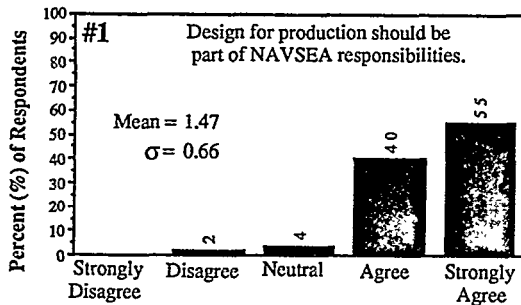


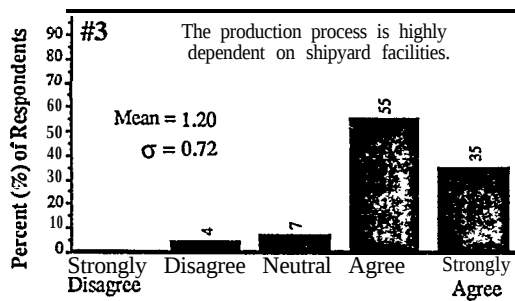


This leads to the question of how the NAVSEA designers and other personnel should treat producibility in the design and acquisition process, or what the role of producibility should be. Statement 1 brought strong agreement that design for production is a NAVSEA responsibility. The goal of design for production is an easily produced product. The results of statement 1 are, however, contrasted by those of statement 4, which show equally strong agreement that a NAVSEA design must be independent of the capabilities of any particular shipbuilder.

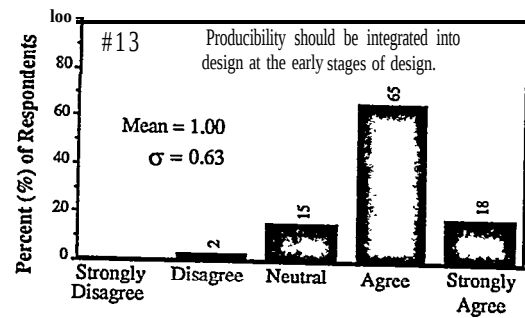
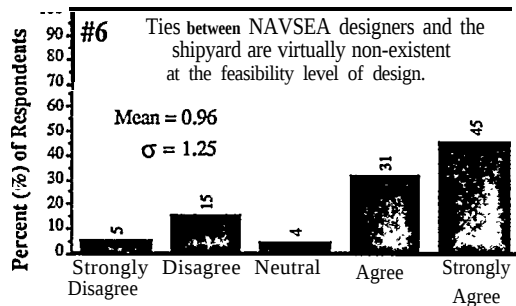


There is a difficult inconsistency in that one cannot design for production without knowing the production process and facilities to be used. This is reaffirmed by statement 3, in which 90% of NAVSEA respondents agreed that production is highly dependent on the yard facilities. Further disagreement as to whether it is the acquisition package or the shipyard management which affect production most is indicated in the dispersed response to statement 2. It appears that clarification regarding the input of shipyards would be helpful.

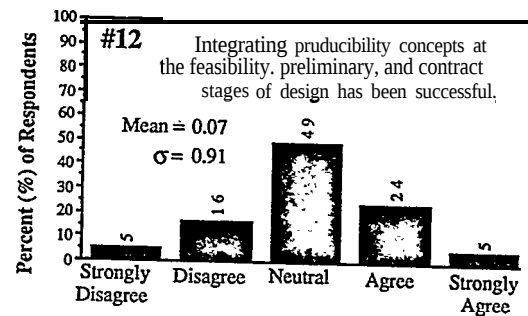


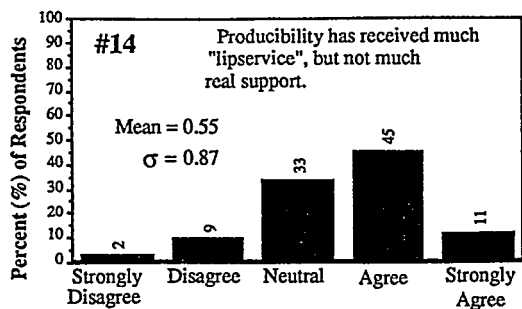


If the shipyards have a significant amount of influence on the outcome of the ship acquisition costs, then a couple of questions might be: 'How do NAVSEA and shipbuilders communicate?', and 'What can be done to assist interaction between NAVSEA and shipbuilders?'. Several statements attempt to address these issues. The bi-modal response of statement 6 indicates that, while there is strong agreement (over 70%) that there is little interaction between NAVSEA and the yards at feasibility studies, there is a significant portion of respondents that think there is interaction. Further analysis of this data showed no significant correlation with these latter respondents and their working groups or occupations. It is possible that either these respondents may have worked together at some previous point and thus formed their opinions based on that experience, or that NAVSEA-shipbuilder involvement occurs on an individual case basis.

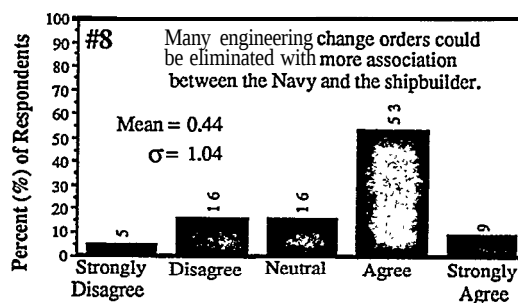
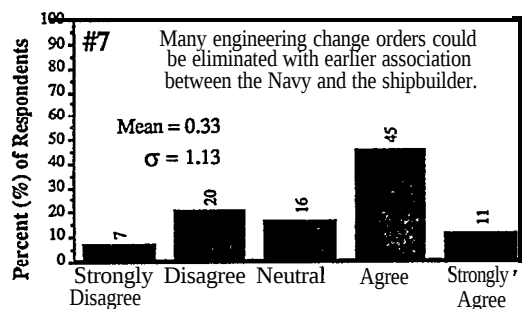


Statement 13 showed strong agreement that producibility should be considered early in design. This could perhaps be assisted by earlier interaction with shipyards. By comparison, the reaction to statement 12, that early producibility consideration has been successful, was mixed. This somewhat neutral response may be explained by the broad nature of the statement. However, after realizing that 56% of respondents agreed with statement 14, that producibility has not received much real support, indifference toward stating success may be better understood.

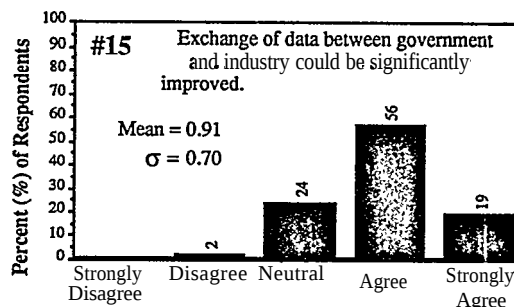
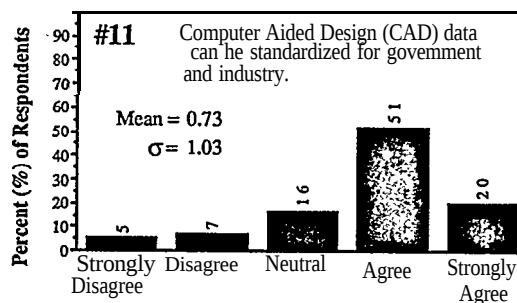




Most respondents agreed that earlier or more NAVSEA-shipbuilder association would result in less change orders. That less change orders will be an indicator of a more producible design is a premise that can be debated. However, the dissent indicated by the bi-modal and nearly bi-modal responses to these statements means it would be helpful to clarify these issues, including the relationships among change orders, shipbuilder involvement, and producibility.



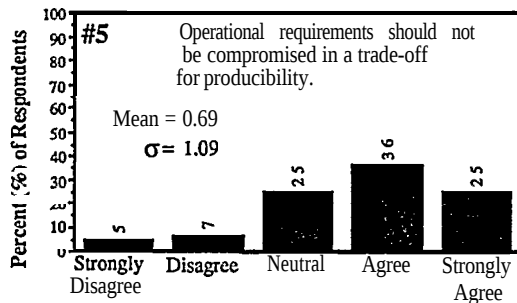
Statements 11 and 15 further indicated a perception that communication between NAVSEA and shipbuilders can be improved.



If NAVSEA-shipbuilder relationships play an important role in realizing producibility benefits and improvements, and if the barriers to improvement lay more in the nature of

the design methods, organizational structure, communication lines and cost accounting methods rather than availability of funds, then perhaps further work to identify these barriers to improvement and implement changes needs to be done. Several statements posed some general policy options regarding the design and acquisition process. Other policy options can be inferred from statements previously noted, such as the cost modeling implications of statements 9 and 10, or the explicit call for producibility effort by NAVSEA as seen in the response to statement 1.

Particular policy options are addressed in statements 5, 16-23, and 33-34. The first of these addressed the question of whether mission capabilities should be compromised in a trade-off for producibility. The majority (61%) agreed that capability should not be compromised, yet a full one-fourth of the respondents were neutral to the statement, and a significant one-eighth disagreed. This issue is a vital one which deserves further explanation, and a few respondent comments can clarify the diversity of opinions. One respondent remarked that "if the ship doesn't meet requirements, [then] why build it?" Another respondent presented a converse view. "if the ship never gets built [because it is too expensive], what good would it be?"

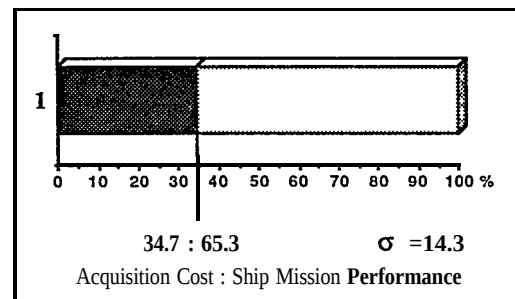


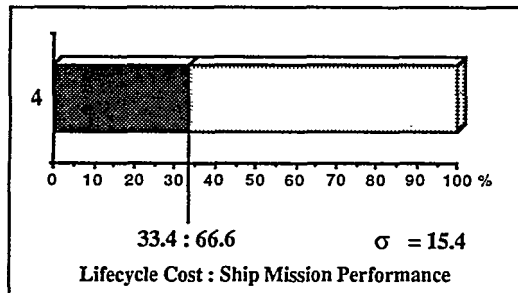
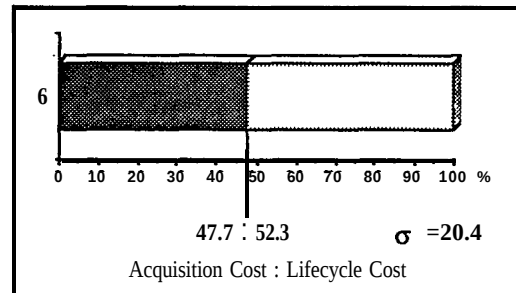
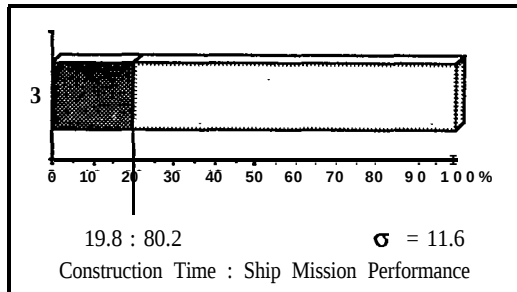
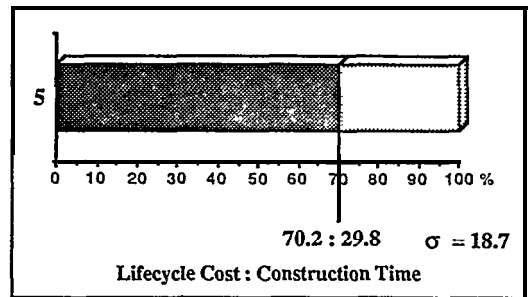
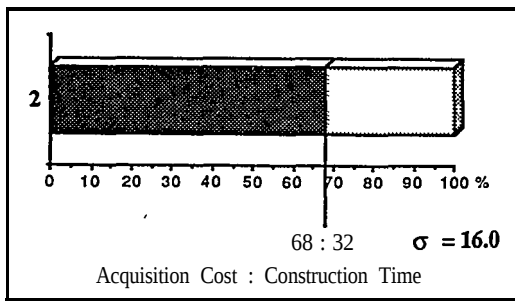
Under the assumption that there are reasonable trade-offs among cost, capability and other factors, an attempt was made to quantify at least some of the major ones. For this purpose we investigated and present here results of the two design priority sections. The first concerns macroscopic design trade-offs among factors of Ship Mission Performance, Acquisition Cost, Lifecycle Cost, and Construction Time. Each of these factors was compared in a

"one-on-one" basis with the other three, with the respondent allocating 100 points between the two, resulting in the six bar-charts below. Interesting results include the degree of favoritism of the various factors, represented as the numerical ratio averages, as well as the degree to which individual opinions were consistent with the group average, represented by the standard deviation.

Consistent with the results of statement five is the fact that Ship Mission Performance is "weighted" more heavily in comparison with each of the other factors. Perhaps not surprising is the fact that Construction Time was weighted lightly compared to the other factors given the existing peacetime environment.

An interesting development among the tradeoff results was a flip-flop of preference concerning the Acquisition Cost and Lifecycle Costs factors. Individual comparisons of both of these costs against Ship Mission Performance resulted in about a two to one preference favoring Ship Mission Performance. However, in these two comparisons, Acquisition Costs received slightly more points versus Ship Mission Performance (a 34.7 share out of 100) than did Lifecycle Cost (a 33.4 share). The flip-flop occurs when looking at the direct comparison of Acquisition and Lifecycle Costs, where Lifecycle Costs received more preference (a 52.3 share).





A similar analysis in comparing the two costs with Construction Time results in Lifecycle Costs having a slight preference, a 70.2 share versus a 68 share for Acquisition Cost, which affirms the direct comparison with no flip-flop. The sort of flip-flop, or non-transitivity in preferences, can be attributed to the complexity of assessing group preference, and is similar to the Arrow Paradox in which group preferences of the sort (A over B, B over C, and C over A) result from mixed individual choices.³

Perhaps one important point is that, regardless of which is actually weighted more, from a ship design point of view the preferences of priority for Acquisition Costs and Lifecycle Cost are very close. (It is acknowledged that other factors, including contractual constraints and

³ This paradox was named for Kenneth Arrow, Nobel laureate in economics with work in utility theory.

appropriations methods, influence the priority scheme in practice.)

Several other design factors were investigated at a somewhat deeper level of detail and the results of these are listed in Table 2. The Arrow Paradox is a case in hand to illustrate that the complexity of assessing multivariate group preferences can often result in paradoxical or shaded results. When the “one-on-one” comparison of variables is expanded to many simultaneous comparisons, this complexity is increased by the fact that variables can be somehow interdependent and can be interpreted differently by each respondent. For example, combat capability and survivability, though different, do have a high degree of dependence, as do habitability and manning, or mobility and availability. After seeing that Ship Mission Performance was the most strongly preferred factor of the previous example, the assessment of “combat capability having an average weight of “only” 22.7 points out of 100 may therefore be misleading.

A better indicator of priorities is to look at ratios of preference for the various factors. For example, combat capability was, on average, preferred over construction time by a 22.7 to 2.8 ratio, which is higher than the one-on-one preference ratio of roughly 4:1. Thus, when many considerations are made simultaneously, though the numbers may be diluted, one can see the dominant priorities and their relative preferences emerge within that given context.

DESIGN PRIORITIES BREAKDOWN		
FACTOR	AVG %	STD DEV
ACQUISITION COST	15.1	13.0
AVAILABILITY	7.3	6.9
COMBAT CAPABILITY	22.7	11.4
CONSTRUCTION TIME	2.8	2.8
DISPLACEMENT WEIGHT	3.3	3.7
ENERGY USAGE	2.7	2.7
GROWTH MARGINS	3.8	3.3
HABITABILITY	2.6	2.4
LIFECYCLE COSTS	10.0	8.4
MANNING	4.1	3.5
RISK MINIMIZATION	4.5	4.1
STANDARDIZATION	3.9	4.3
SURVIVABILITY	11.0	7.9
OTHER:	6.2	5.8
“OTHER” includes Signatures, Seakeeping, Mobility, Endurance, CAD designability, Modular Construction, Follow Ship Cost, and Environmental Protection factors.		

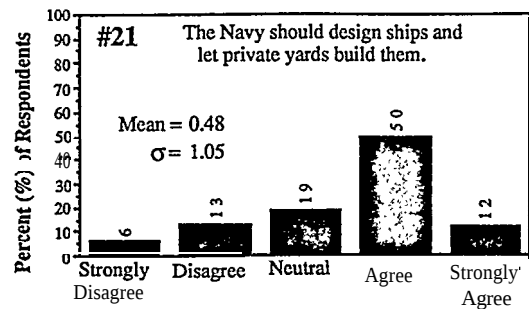
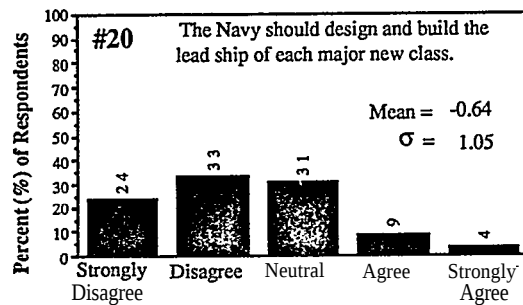
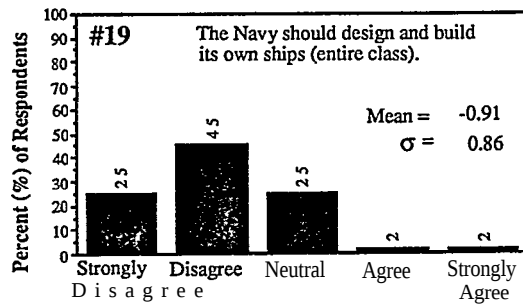
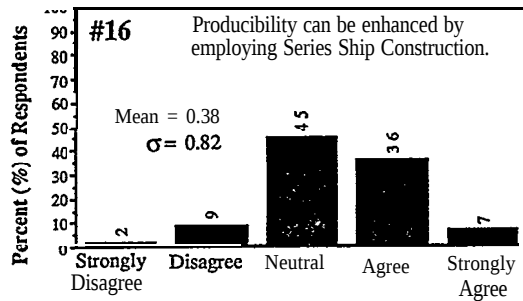
Table 2

In this survey, these dominant priorities seem to be Combat Capability, Acquisition Cost, Survivability, and Lifecycle cost. Availability and Risk Minimization are also noticeably important to NAVSEA designers. The remainder are, though not the most important, still significant, as are the respondent-suggested factors. “OTHER” includes Signatures, Seakeeping, Mobility, Endurance, which were suggested as possibilities on the questionnaire, plus respondents’ suggestions which included CAD applicability, Modular Construction allowances, Follow Ship Cost, and Environmental Protection factors. The ‘costs paradox’ arises again with this assessment results giving a 3:2 ratio for Acquisition Costs over Lifecycle costs.

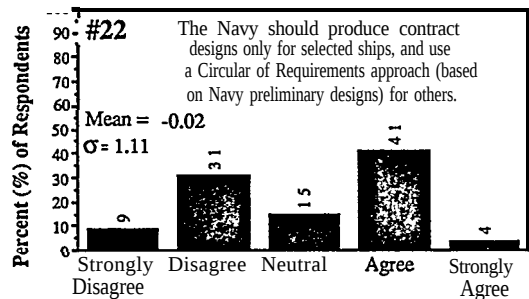
More general policy options were presented in statements 16 through 23. The response to the effect of acquisition budgets was given in statements 17 and 18 previously, with a reduced acquisition budget bringing a negative response, but increased budgets bringing an inconclusive response.

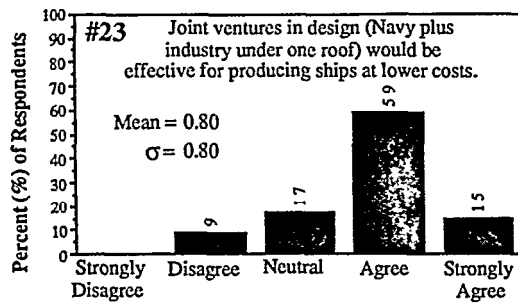
Other statements address general NAVSEA build and contract strategies. Statement 16 shows a large segment of neutral response (45%) to the premise that Series Ship Construction will help ship producibility. Of the

remainder, most (43%) agree that it will. The large neutral response may reflect uncertainty involved with pinning down the responsible factors of a successful shipbuilding program, while the agreement among the remainder may reflect a belief that construction learning curves and associated benefits do enhance ship producibility.

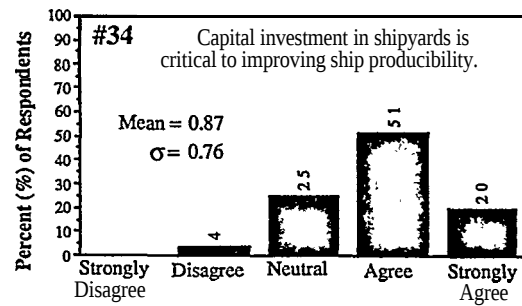
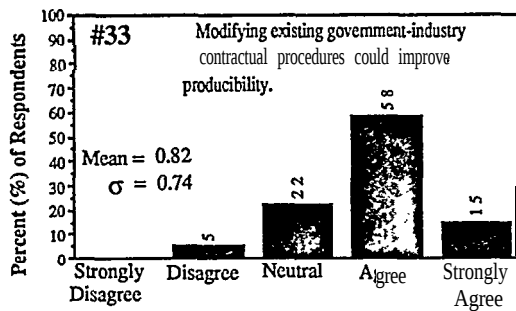


Statements 19, 20, and 21 reflect the conventional ship acquisition strategy, where NAVSEA designs a ship up to a point, the 'contract design', and then a winning bid shipyard continues the detail design and construction. An interesting alternative is the Circular of Requirements (COR) approach, which drew a bi-modal response in statement 22. Whether the COR approach becomes commonly accepted for any type of ship remains to be seen, but the response shows that it deserves investigation. The very strong agreement (74%) to the statement 23 that joint ventures between the Navy and industry would help lower ship costs supports the need to seriously consider alternatives to conventional acquisition strategy and NAVSEA-shipyard relationships.

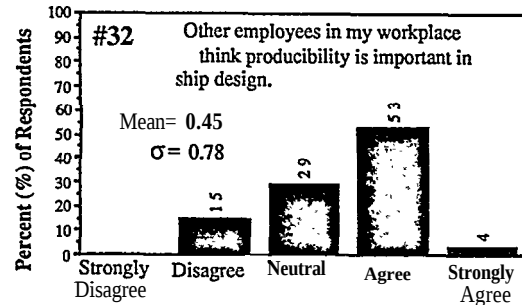




If joint ventures prove to be infeasible in the economic-political environment, some change in operating procedures that help to enhance ship producibility may still be possible. Strong support of modifying existing procedures is shown in statement 33. Addressing another aspect of the economic environment, statement 34 reflects the necessity of U.S. shipyards to update construction methods to utilize modular construction techniques. The 'capital investment' discussed reflects the dependence of ship production on facilities. Whether the Naval ship market is freely competitive or monopsonistic, it is not in the realm of this paper to discuss investment strategy, responsibility, or possible sources of the investment funds. Of the few comments received, one did say that it should be "private money".



A final policy option is whether producibility awareness and training should be encouraged. Feedback for assessing a general attitude regarding the importance of producibility was sought by statement 32. A reasonably strong agreement that respondents felt that other employees also thought producibility is important is tempered by a significant segment (15%) that sees room for improvement regarding employee attitudes. The policy implication is that communication is necessary to bring all employees into a common consensus regarding producibility because even if it is unintentional, a small dissenting segment can undermine an otherwise coherent force.



Conclusions

The Producibility Survey has helped to identify several areas of agreement and disagreement within the NAVSEA community. There is general agreement that design for production should be part of NAVSEA responsibility, and

that it is important to achieve lower costs. But when specific methods of procedure are approached, disagreement or inconsistency arises. For a team to be successful, its strengths should be used to the maximum extent possible, but also weaknesses should be identified and built up with concentrated effort. In **this light, it** appears that several differences of opinion have been noted.

Areas deserving attention include NAVSEA-shipbuilder relationships, training procedures and producibility design tools, cost models with regard for producibility sensitive parameters, acquisition strategy and a general guidance leading to stronger consensus and communication. The results of the statements on the definition of producibility and the outcome of the design priorities sections, especially the paradox regarding the relative importance of acquisition costs and lifecycle costs, may indicate that a clear policy statement would be useful to give direction to the many NAVSEA employees so that the entire NAVSEA ship design body can work assured it will be making a concerted effort towards a well defined, and consequently better, product.

Several of the opinion statements had bi-modal responses, which represent differences of opinion. Because there is such a diversity of experience within each individual NAVSEA career, each person's opinion may be appropriate from his own perspective. From a management perspective, however, these differences give rise to questions, such as in the case of statement 6, 'Why did some respondents feel there is no contact between NAVSEA designers at early stages of design, **while others** felt there was? What should the consensus response actually be? In statements 7 and 8, effects of shipbuilder involvement on change orders were questioned. Change orders have a significant effect on ship costs, and while many are well justified due to the dynamic nature of design evolution and concurrent development, many may in fact be cost drivers which are not as strongly justified. If any of these can be eliminated by modified NAVSEA-shipbuilder relationships, or by revised acquisition strategies or management policies, these alternatives should be pursued.

Regarding the percentage of high level managers that have had previous producibility experience, is 58% too high or too low? What should it be if this survey is to be taken on a similar group in ten years? If producibility is genuinely important, a higher figure would be desirable.

Acquisition strategy has a high degree of influence on ship producibility. It provides constraints around the design process which may be too restrictive for effective design for production. The COR approach had a mixed acceptance, and the concept of joint ventures between the Navy and the shipbuilders was strongly agreed with. Much of this survey has suggested that a high degree of designer-producer interaction is preferable to result in a lower cost product. Because of the relatively low number of shipbuilders available, particularly for sophisticated combatants, a high degree of designer-producer interaction is possible. As technological barriers to producibility are eliminated, the organizational and political ones may be the bigger challenge.

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