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REPORT OF THE PANEL

ON

WEAPON-SYSTEM SIMPLIFICATION

1970 Summer Study

Defense Science Board

San Diego, California

2-15 August 1970

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Office of the Director of Defense Research and Engineering
Washington, D. C.

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88 11 28 062

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704 0188
Exp Date Jun 30 1986

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS NONE
2a SECURITY CLASSIFICATION AUTHORITY N/A	3 DISTRIBUTION/AVAILABILITY OF REPORT Distribution Statement A. Approved fo Public Release. Distribution is unlimited
2b DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) N/A	5 MONITORING ORGANIZATION REPORT NUMBER(S) N/A
6a NAME OF PERFORMING ORGANIZATION Defense Science Board, Ofc of the Under Secy of Def (A) 6b OFFICE SYMBOL (If applicable) DSB/OUSD(A)	7a NAME OF MONITORING ORGANIZATION N/A
6c ADDRESS (City, State, and ZIP Code) The Pentagon, Room 3D1020 Washington, D.C. 20301-3140	7b ADDRESS (City, State, and ZIP Code) N/A
8a NAME OF FUNDING/SPONSORING ORGANIZATION Defense Science Board/OUSD(A) 8b OFFICE SYMBOL (If applicable) DSB/OUSD(A)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N/A
8c ADDRESS (City, State, and ZIP Code) The Pentagon, Room 3D1020 Washington, D.C. 20301-3140	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO: N/A PROJECT NO: N/A TASK NO: N/A WORK UNIT ACCESSION NO: N/A

11. TITLE (Include Security Classification)
Defense Science Board 1970 Summer Study on Weapon-System Simplification, UNCLASSIFIED

12 PERSONAL AUTHOR(S)
N/A

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final	FROM N/A TO N/A	70/08/02-15	11

16. SUPPLEMENTARY NOTATION
N/A

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL Diane L.H. Evans	22b. TELEPHONE (Include Area Code) (202) 695-4158/6463 22c. OFFICE SYMBOL DSB/OUSD(A)

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

FOREWORD

The primary task of the Defense Science Board Summer Study on Weapon-System Simplification was to recommend ways of producing simpler and less costly weapon systems.

There is growing feeling today that this nation is not obtaining needed weapon systems at appropriate costs, despite a significant effort to improve the effectiveness of the acquisition process.

The paradox is that most people in government, industry, and the military services who work in this area honestly desire that this trend be otherwise--and, indeed, for the most part evidence a personal frustration that improved results are not forthcoming in spite of the redoubling of their individual efforts.

The panel is aware that the present period is one of significant transition. The Deputy Secretary of Defense's Policy Guidance Memorandum of 28 May 1970 delineates a policy of weapon-systems acquisition emphasizing phased milestone procurement, continuous system tradeoffs, and contracting tailored to the appropriate phase of the system procurement. This is in sharp contrast to the fixed-price, total-package procurement of prior Defense Department policy.

The panel's report recognizes the deficiencies of the acquisition process of the immediate past, and evidences a concern that:

(1) The new policies may not be far-reaching enough, and

(2) The rate of their implementation throughout the massive Defense Department may be too slow.

The panel identified environmental factors which must be dealt with forcefully and immediately if success through the new approach is to be realized. Foremost among these are:

(1) The entire weapon-acquisition process has become so bureaucratically burdened that individual responsibility and

creativity have been subverted by a morass of checks and balances, audits, reviews, paper work, and numbers of superfluous people who block the logic and progression of acquiring a weapon system.

(2) In this period of declining budgets, there exists an overcapacity of defense industrial base to accomplish the needed defense work.

Radical change of these factors is in order if we are to truly realign and harness personal motivation and individual creativity to produce simpler and less costly weapon systems.

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Panel on Weapon-System Simplification

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Dr. Robert O. Burns	Director, Technical Analysis and Advisory Group Office of the Chief of Naval Operations
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REPORT STRUCTURE

This report contains a series of findings. Each finding is discussed, and recommendations are made. Several pertinent points should be kept in mind when reading the findings, discussions and recommendations.

(1) The focus of this study and report was on weapon-system simplification rather than the general features of the total acquisition process.

(2) Considerations centered around entry into, and the early stages of, the full-scale development phase of a weapon system's life cycle; system production was not examined in detail.

(3) Recommendations made are intended for application mainly to programs of substantial size and national importance, although other lesser programs may also benefit from the adoption of similar procedures and actions.

(4) Many of the recommendations offered have been previously made in contexts other than weapon-system simplification. However, the panel felt it necessary to include certain already partially accepted recommendations both to ensure completeness and because of their significance to weapon-system simplification.

THE PROBLEM

The attempt to satisfy qualitative requirements for weapon systems without due regard to the total dollars available for the development project results in new weapon systems that are not only complex but also more costly than they need to be. Under the present system there is often little motivation for the user to state requirements for anything less than technology will permit. As these stated requirements progress upward through the approval chain, the question of weapon system costs become more significant. As yet, however, we have not been sufficiently astute to develop means by which performance can be credibly traded for cost for new complicated weapon systems. Also, our method of establishing priorities among the various performance characteristics of a weapon system is imperfect; therefore, when a weapon system procurement is undertaken, it is often the trend on the part of industry to emphasize meeting the desired performance rather than making cost/performance trade-offs. Consequently, the resulting weapon system has little chance to be the best compromise between available money and desired performance.[1]

[1] From memorandum of John S. Foster, Jr., Director of Defense Research and Engineering, for the Chairman, Defense Science Board, 12 May 1970.

FINDINGS, DISCUSSIONS AND RECOMMENDATIONS

1. The Requirements Process

Finding

The requirements process does not foster minimum adequate solutions to the military portions of national security problems.

Discussion--Requirements at National Policy Level

The requirements process is the mechanism through which broad objectives and policies are translated into funded weapon-system programs. It is not merely a vehicle by which the operating forces express their preferences for future equipments, nor is it a phase wherein problems are developed for decision by the Secretary of Defense. Rather, through the requirements process, the DoD identifies and initiates the research, development and production activities that are necessary to fulfill the military aspects of national security objectives.

Weapon-system simplification can best be achieved when sufficient attention is given to examining the fundamental capability that is to be provided at a program's completion and the value of that capability to the nation. An appropriate perspective must be employed early in the conceptual stages of a new weapon system. The lack of such a perspective is a major weakness in current DoD practices. The DoD has concentrated too much attention on arguing the details of specific solutions to service-generated requirements and given too little time to considering minimum adequate programs within "best" approaches, selected from a set of reasonable alternatives.

Recommendation

Establish an effective mechanism for treating major defense requirements at the Secretary of Defense level through a series of iterations of cost versus alternative solutions that begin with establishment of life-cycle cost thresholds against the capability sought and progress to definitize weapon-system development programs against specific cost goals. The Secretary of Defense should express some of his guidance in terms of major national military problems and resources reserved outside program packages, leaving the departments to generate alternate solutions to the requirements thus posed.

Discussion--Requirements at Military Department Level

The requirements process has failed to foster minimum adequate characteristics of specific major weapon systems for somewhat different reasons.

Over the past 25 years or more, too great an importance has been attached to relatively detailed statements of materiel or weapon-system requirements, with the result that excessive weight is given to attaining performance approaching technological limits and earliest possible operational availability.

Careful analysis and test against the experience of the last 25 years fails to substantiate the correctness of policies that have accorded preeminent importance to military requirements based on either (a) user statements of current "deficiencies" or (b) statements made by, or on behalf of, user organizations regarding the character and quality of force needed to successfully oppose a projected future enemy force. The former statements have led, and almost certainly would continue to lead, to weapon systems that inadequately project the growth of opponents' capabilities and therefore are deficient in important technical aspects. Today major weapon-system requirements are not developed from this base. However, if all derived requirements of quality and quantity were satisfied, the latter statement would lead, with equal certainty, to a U. S. military capability that very greatly exceeded the capabilities of potential opponents in almost all respects.

This derives from our acknowledging considerable flexibility in the future allocation of resources by potential opponents and developing U. S. requirements to meet each of the possible resource allocations. To the extent to which total enemy future resources can be correctly estimated, this situation would be avoided by correctly estimating the single allocation that will be made. To develop this allocation estimate with high precision would require an understanding of current and future enemy intent that is quite implausible. It may therefore be concluded that military requirements derived from projections of future capabilities of potential opponents should be treated as maximum requirements rather than essential requirements.

There will, of course, be specific characteristics of weapon systems that are essential to the intended purpose, but almost without exception these truly essential characteristics can be easily recognized. The high probability is that, except for these readily identifiable essential characteristics, the military requirements will express a

need for characteristics that later knowledge will disclose to be excessive.

It appears that the best way to approach a compromise with fund availability would be through a series of iterations of design and changes of requirements compared with projected costs. For this process, the valuable intuitions of the user can be introduced both by means of priority ordering of preferred characteristics and by criticism of the design iterations.

Recommendations

(1) Recognize that military requirements derived from projected enemy capabilities will, in general, call for operating characteristics in excess of those that will actually be needed to successfully oppose potential adversaries.

(2) Revise DoD and departmental directives and procedures to encourage the identification of those few performance characteristics that must be held inviolate, as contrasted with those for which lesser plateaus of performance can be accepted to allow for meaningful cost tradeoffs.

2. Continuity of Tradeoffs

Finding

The panel strongly supports the guidance of the Deputy Secretary of Defense in his memorandum of 28 May 1970 on "Improvement in Weapons Systems Acquisition" as follows:

> Since program risk and cost are dependent on practical trade-offs between stated operating requirements and engineering design, trade-offs must be considered not only at the beginning of the program but continually throughout the development stage.

Nevertheless, in practical application, even when such tradeoffs have been made, there has not been adequate emphasis on achieving simplicity in system design. Current practices encourage commitment to the latest in evolving technology in spite of the fact that the ultimate in every technological discipline may not be necessary to achieve adequate system performance, and may, in fact, result in degrading operational simplicity and reliability.

Discussion

In the system definition and design phase, the tempting challenge of new technology leads to a characteristic tendency to use the most advanced state of the art available. The tendency is understandable, because engineers like to work in the forefront of knowledge. However, a new development program stands the best chance of success if the state of the art is pushed only for those components or subsystems for which the application of new technology is necessary to achieve adequate system performance. Each proven component or subsystem that can be used is one less potential source of unexpected problems.

Although it is clear that adequate advances in system performance will frequently demand the selective application of an advanced state of the art if new developments are worth doing at all, an important lesson, hard learned over years of development programs, is that each advance in technology (e.g., from tubes to transistors to microcircuitry in electronics) has been accompanied by infancy problems that were not envisioned when the devices were selected for initial application. Novelty without utility is wasteful. We need to motivate our system-acquisition teams to settle for an adequately balanced capability instead of the ultimate by taking maximum advantage of the experienced judgment of designers and managers. They must be encouraged to use proven component or device technology whenever appropriate.

Nevertheless, a weapon-system development can be successful in the eyes of the user only if, in a timely manner, the end product attains the performance that the user believes necessary. Also, to survive as a program, the system must be cost-effective, that is, must provide the desired defense capability at a life-cycle cost that is balanced with respect to other defense systems in the total force structure. Total system effectiveness is then a combination of many factors, including a spectrum of performance parameters that may include allowance for growth with later advances. Deployment availability, reliability and simplicity of operation, ease of maintenance, requirements for support equipment, and acquisition cost must be considered.

It follows, then, that the government manager, working with the contractor or contractors, as appropriate, must make performance/cost/schedule tradeoffs throughout the development cycle. Major

performance characteristics should be established early in the conceptual period and refined as the program progresses and more detailed performance and cost data are available. In a well-ordered program, this process should culminate in detailed design tradeoffs during the early stages of the engineering development phase of the program. Subsequent changes of any significance should be minimal if these procedures are followed.

Guidance for these continuing tradeoffs should include weighted priorities. The weighted priorities and any essential minimums then form a framework within which the government manager and the contractor can make tradeoff analyses that will yield the simplest and most effective weapon-system configuration for the least cost.

In current experience, in an era of declining ceiling budgets, program cost savings achieved by the individual military departments have too often been deleted from the total departmental budget originally designated by the Secretary of Defense. This constitutes a reverse motivation on the part of each department to make the necessary effort to achieve major cost savings on individual programs, since the net effect tends to lower performance capability while, at the same time, lowering the total dollars available for that department's programs.

Recommendations

(1) In new system acquisition, within flexible requirements guidance, the government manager should work with the contractor to make tradeoffs over the full cycle of the development program among performance, cost and schedule, with a view to achieving the right balance between system performance and cost.

(2) System designers must be encouraged to minimize risk by using proven components and subsystems when feasible, and committing to the ultimate in a technological discipline only when necessary to achieve adequate system performance.

(3) In order to motivate cost savings through simplification or other tradeoffs, departmental secretaries should be granted the authority to reprogram such cost savings to meet other needs of the same department.

3. Competitive Procedures and Policy

Finding

Cost, performance, schedule and management results versus expectations for those programs that have gone through formal concept formulation, followed by paper contract definition, generally have not shown improvement over prior experience. In response to the Deputy Secretary of Defense's policy memorandum of 28 May 1970, new procedures must be developed to enhance simplification in the competitive environment.

Discussion--Concept Formulation and Contract Definition

In the past decade, the weapons acquisition process has gravitated toward complete program definitization, to be achieved largely through paper-work planning and extended paper-work competition.

The approach was embodied in an acquisition cycle composed of concept formulation, which included activities to prepare the program for competition, followed by contract definition, which contained activities of extended paper-work competition and source selection, followed by the actual development and production of the system.

The utilization of the contract-definition cycle on major programs has on occasion cost upward of $100 million and taken as long as two years. This effort has resulted in paper proposals weighing a ton or more, for whose preparation and review the efforts of thousands of people were employed. There is little evidence to indicate that efforts and expenditures of this magnitude yield results commensurate with the time and money expended. The contract-definition phase has been used in the past to reduce risk, plan the program, and select the winning contractor. The preponderance of evidence indicates that it has not done any of these jobs very efficiently.

There has been a tendency to depend on paper contract definition to reduce technical risk before entering full-scale development, instead of using test data derived from advanced development hardware to accomplish that function. Thus, both military department and contractor have allowed themselves to be deluded into thinking technical risks have been reduced when subsequent events have often proved otherwise.

Paper contract-definition competition and accompanying source selection have also allowed industry to promise too much and to take

undue risks in its ability to perform with regard to system performance, schedule and cost. On many occasions, this has led to inflexible commitments between government and industry wherein they are locked together by an overoptimistic contractual work statement.

Recommendations

(1) Rescind DoD Directive 3200.9, and eliminate all procedures regarding paper contract-definition competition.

(2) Conduct sufficient advanced development during concept formulation to reduce risk to an acceptable level before entering full-scale development.

(3) Conduct the functions of (a) risk reduction, (b) planning, and (c) source selection separately, and simplify source-selection procedures by dedicating them to the sole purpose of selecting the engineering development contractor.

Discussion--Small, Competent Design/Development Teams

The panel was furnished information showing that the cost of developing most recent major U.S. weapon systems has been far greater than the costs of a number of comparable foreign systems and certain commercial and classified systems in the United States.

These case studies indicate that the best weapons have generally been developed at minimum cost when the following conditions obtain:

(1) Design/development teams are small and made up of competent personnel in both government and industry.

(2) Members of teams in both government and industry have worked closely together, preferably with similar uninterrupted experience on previous programs, so that the lessons learned on one program are most likely to be applied to subsequent programs.

(3) A close relationship exists among all those concerned with making project decisions, serving to minimize problems of communication and documentation and promote mutual confidence.

The acquisition cycle, in these cases, has been characterized by constant communication and face-to-face discussion rather than a voluminous flow of paper between government elements, between the system/project officer (SPO) and industry, and between designer and producer within industry. There was minimum documentation

but rigid control of the documentation used. The number of briefings and other distractions to the design/development team was also kept to a minimum. The program manager was given considerable responsibility, authority and contracting flexibility.

This complete set of conditions will be difficult to achieve and maintain in the intensively competitive environment of the United States. Such skilled teams take time to build. Conversely, overcapacity in the defense industrial base will require a significant reduction in the number of development contractors. Since continuity of effort on the part of design teams in any given area is a major factor in simplifying weapon systems, the Office of the Secretary of Defense (OSD) and the military departments should give this factor the fullest consideration in making future decisions and source selections. More recognition should be given to the benefits of such things as a design team's creativity, their availability, past related performance, and other real but less quantifiable criteria.

Recommendations

(1) Use, wherever possible, small design/development teams of proven competence under conditions that allow them to operate efficiently.

(2) Have available at least two such teams in each major weapon-system area.

Discussion--Competitive Prototype Procurement

From its review of procurement practices, the panel concluded that paper competitions were not conducive to weapon-system simplification during the competitive phase. Conversely, it appears that competitive hardware-prototype procurements at the system or major subsystem level have a significant potential for reducing risks and motivating weapon-system simplification.

Recommendation

DoD policy on weapon-system acquisition should require that competitive hardware prototypes be procured, except where fiscal or other restraints make this form of procurement impractical.

4. Decision Making

Finding

A significant cause of the increased cost of, and slippage in, the weapon system acquisition process has been the sluggishness of the DoD structure and process in decision making.

Discussion

A considerable body of philosophy has been published which encourages the placing of decision making and commensurate authority at the lowest possible level in the Defense Department's structure. The project manager (or SPO) has been appropriately identified as the principal maker of decisions, excepting only those relating to the few important milestone events reserved for levels above him up to and including the Secretary of Defense. A concomitant philosophy would limit the collection and flow of management information above the project manager to the minimum essential for visibility at the highest level where the reserved decisions are made.

The truth of the matter is that all levels of the organizational structure, from contractor and project manager up through the departmental and OSD levels to the Congress, appear to have lost confidence in the managerial capability, judgment and even integrity of the levels below. The visible reaction to this loss of confidence has been the flow and accumulation of vast amounts of detailed information throughout the structure in the form of formal reports, ad hoc reviews, multilevel briefings, and the detailed files of each organizational level and technical support organizations.

The work load of preparing and furnishing this volume of data, as well as correlating, explaining and updating it, has diverted a considerable amount of the project manager's time and effort from the technical responsibilities of his job. But, more important, the sheer volume of the data has inundated the decision-making structure above the project manager, seriously diluted his decision-making effectiveness, and provided a commensurate rationale for delaying decisions until (1) the volume of data provided can be thoroughly analyzed, (2) the data already furnished are clarified, or (3) additional data can be furnished.

Generally, in the past, budgets and program schedules have not anticipated these data-induced delays; hence, program funds have

not been provided to finance their cost. The inevitable results have been cost increases over the target and schedule slippages.

Since a fundamental cause of this condition is psychological, i.e., the system's loss of confidence in itself, the correction will require a change of attitude on the part of many people. Unless sponsored and encouraged by the highest authorities, this change in attitude may take a long time.

Recommendations

(1) As improvements are made in the acquisition process, the Secretary of Defense should enunciate and personally sponsor a concurrent confidence-building program.

(2) A program to reduce the volume of data relative to the weapon-systems acquisition process and unencumber the project manager/contractor team should be directed by the Secretary of Defense for immediate execution at all levels.

5. Specialized Requirements and Administration Systems

Finding

A proliferation of special staff offices at all levels that originate, enforce and monitor specialized management control systems for weapon systems design and development has evolved over the past decade and these offices are still in place. They have continued to demand an inordinate amount of attention from the government/contractor development teams at a time in the early design stages when the superimposition of special administration is clearly inappropriate and diverts management attention from design tradeoffs that could lead to simplification.

Discussion

In systems definition and subsequent development, the project manager/industry/user team must ensure that the hardware produced is reliable, easily maintained and in a controlled configuration. Concurrently with the attainment of these necessary objectives during the definition/development cycle, both the project manager and industry must have mutual visibility on the attainment of quality and the meeting of agreed-upon cost, performance and production milestones. Depending on the size and complexity of the design or development job, varying administrative control systems can and have been used to

achieve these considerations. Some of these relate to requirements, as reliability, maintainability, standardization or value engineering, and others relate to management, as PERT, C/SCSC, MIS, etc. To the extent that the requirements are important, they must be fundamental considerations in basic design. To the extent needed, management control systems must be incorporated. However, excessive documentation, unnecessary administrative review, and misuse of the time of critically important design engineers must be avoided.

Indeed, administrative procedures for assuring the proper consideration and attainment of these objectives must, of necessity, have different time-phased checkpoints. For instance, the ultimate test of maintainability may come at a time when the hardware is being serviced in the field and the maintenance sergeant finds he does not have access to the component to be replaced. If this is the first time his chore has been considered, it obviously is too late. Similarly, if a development contract running several years is not determined to be 100-percent overrun until after three years of effort, then a mutually beneficial financial management system did not exist between industry and the project manager. Failures in system design and program control like these have actually happened. Efforts to eliminate these poor management practices have resulted in specialized systems, requirements, and procedures for "ilities"and "controls" at all levels. The preponderance of administration and controls has been added at levels above the project manager/industry/user team in spite of the fact that they are the only people who can assure proper performance in these areas.

With the growth and structuring of staff offices to direct and monitor these functions have come inflexibility, bureaucratic reporting, and less than efficient utilization of personnel in staff versus line functions. These centralized controls are self-defeating in that staff organizations cannot assure proper considerations in the detailed day-to-day work, but conversely, by virtue of their existence, will cause distraction of the project manager/industry/ user team with reporting and inspections which add little--and, indeed, can induce an inflexibility that inhibits the attainment of workable management systems.

Recommendations

(1) Special staff offices that exist solely for administering value engineering, quality assurance, cost reduction, configuration control, contract performance evaluation, data management, standardization, zero defects, human engineering, reliability, maintainability, safety, C/SCSC, etc., should be eliminated.

(2) These functional support considerations should be incorporated into the program by the project manager/industry/user team during the design/development evolution.

(3) Project managers and their industry counterparts should be required to have mutually agreed-upon financial management and technical milestone systems, structured for the given job in conformance with broad management system requirements in lieu of standardized military specification systems.

Supplement

to

REPORT OF THE PANEL

ON

WEAPON-SYSTEM SIMPLIFICATION

The Technical Requirements Process

1970 Summer Study

Defense Science Board

San Diego, California

2-15 August 1970

Office of the Director of Defense Research and Engineering
Washington, D. C.

INTRODUCTION

This finding, along with the associated discussion and recommendations, was submitted to me after the final summer study session was held in San Diego. It addresses the specification problem, an important aspect of simplification that is not otherwise addressed in the Panel's report. Although this material has not been reviewed and approved by all of the members of the Panel, I feel that it is sufficiently important to be published as a supplement to the basic report.

Thomas L. Phillips
Chairman

The Technical Requirements Process

Finding

Technical "design-to" specifications are being elaborately expanded and excessively detailed by highly specialized personnel of government laboratories.

Discussion

A close relationship exists between the upper level of broad mission operating requirements and technology addressed in the Panel Report under "Continuity of Tradeoffs" (page 3) and the lower level of detailed technical requirements that are firmly established in the subsystem- and component-oriented military specifications such as HIAD, MIL-F-8785 and MIL-STD-461, to name but a few. Once a conceptual design is established, rigid military specifications circumscribe the detail design and dictate the complexity of each subsystem and therefore, indirectly, the vehicle as a whole. Thus, following along with the concept of small design development teams (page 7), a corresponding reduction should be effected in the technical staffing of governmental laboratories, since it is there, in a technical sense, that the expanding and more explicit requirements originate.

Within the theme of simplification, the exquisite detail that has crept into technical requirements documents can and does significantly escalate the cost of weapon systems. As a specific example, MIL-F-8785, "Flying Qualities of Airplanes," has essentially tripled in size and detail in a span of approximately four years. While a good portion of the requirements are valid (i.e., a better knowledge of what constitutes good flying qualities, especially in dynamic responses), a far larger portion of the expansion imposes extra redundancy, unnecessarily complex fail-safe performance capabilities, and excessive demonstration requirements. This results in such features as extra hydraulic systems and oversophisticated electronic actuation and monitoring devices, all of which cause the increasing expenditure of critical engineering effort without substantially improving the system or the mission's accomplishment.

In the area of electromagnetic interference (EMI) control, a great proliferation of specifications, guidelines and handbooks has been generated, ranging from the basic MIL-STD-461, "EMI Characteristics, Requirements for Equipment," to the AFSC Design Handbook DH 1-4 on "Electromagnetic Compatibility." There are at least seven other military specifications on this same subject, and it is a fact that the cost of a system procured under one standard can be significantly different from the cost based on another standard.

Even the transportability specification, MIL-STD-794B, covering the requirements for development, control and reporting of preservation and packaging techniques, has essentially doubled in size in the past several years. There are numerous other examples in the fields of propulsion, electronics, tactical missiles and naval ship systems.

If the size of the laboratories were reduced by the elimination of functions that exist *solely* to upgrade and nurture these detailed specifications, then it is believed that the laboratories could more efficiently focus their available resources on generic technology and the projection of future needs. This is not intended to imply that specifications should be eliminated, but rather to highlight the fact that technical cultists contribute to higher program costs, as do cultists of "ilities." *Requirements should be realistic, achievable and cost-effective.*

As an outgrowth of the smaller professional staffing of the government laboratories, rapport between industrial and government technical personnel could be substantially enhanced, directly minimizing the extensive documentation and justification that are required at present.

Recommendations

(1) Within the various government technical laboratories, those operations whose function and output have been allowed to devolve into the generation and promulgation of excessively and unnecessarily detailed technical specifications should be reduced significantly and realigned toward more creative technical pursuits.

(2) A vigorous program should be initiated to purge existing detailed specifications of excessive requirements and demonstration criteria.

(3) Project managers and their industrial counterparts should be charged with the responsibility of structuring the detailed technical specification requirements to match the needs of a *given* program.