REPORT OF THE DEFENSE SCIENCE BOARD 1981 SUMMER STUDY PANEL ON

OPERATIONAL READINESS WITH HIGH PERFORMANCE SYSTEMS

OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR RESEARCH AND ENGINEERING
WASHINGTON, D.C.

APRIL 1982

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DEFENSE SCIENCE BOARD

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MEMORANDUM FOR THE SECRETARY OF DEFENSE

THROUGH: UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

SUBJECT: Defense Science Board 1981 Summer Study on Operational Readiness with High Performance Systems - ACTION MEMORANDUM

The attached report of the Defense Science Board 1981 Operational Readiness Summer Study was prepared by a Panel chaired by General William E. DePuy, USA (Ret.), which had broad membership of high level personnel from the defense industry, DoD's development, acquisition, training, test and logistics communities, and senior retired military commanders as well as representatives of each of the Military Services.

The study's charter requested that the Defense Science Board investigate how to achieve adequate operational readiness with high performance systems, and to make recommendations concerning the impact of high performance and technology on operational availability of equipment, skill and training requirements of operators, and maintainers, and support.

The major conclusions of the study are:

- High performance is not necessarily incompatible with readiness as long as DoD demands and manages acquisition and readiness to that goal.
- While high technology should be exploited, that objective must be disciplined by a fixed requirement that all systems meet stringent reliability, maintainability, and useability standards before and after entering the force.
- The chief cause of low operational availability is low reliability coupled with the lack of spares at the maintenance work sites. A shortage of spares is a DoD management, not a specific weapon system, shortcoming.
- Under current management practices, readiness aspects of systems development are sacrificed when time and funds run short.

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The most significant recommendations are:

- o Design reliability into systems at the beginning--test-redesign-retest until readiness objectives are adequately met. When test and evaluation indicates that the system meets reliability and readiness requirements, initiate limited production; follow the new system into the field, and fix problems prior to full rate production.
- o Set peacetime standards for operational availability high enough to support training and surge demonstrations. Buy war reserve spares against wartime utilization rates.
- o Program, buy, and distribute spares to achieve a specific quantified (numerical) availability.
- o Increase visibility of system-by-system readiness support requirements at all appropriate management and operating echelons.
- o Establish an advocate for readiness within OSD and the Military Departments for whom readiness is the first priority.

While everyone supports readiness, when budget crunches come, readiness funding has in the past often been decreased. We do not currently have a strong, unambiguous readiness advocate within either OSD or the Services who has adequate control and visibility of acquisition decisions and resources. This applies both to the front-end design and development process, and to the production and deployment phase (i.e., DSARC and PPBS). This has been the case for decades.

The Defense Science Board believes the recommendations of the Task Force will increase readiness if they are implemented. The study recommendations have been forwarded to the Secretaries of the Military Departments and the Chairman of the Joint Chiefs of Staff who have, in general, supported them. Their responses (attached) mention a few reservations which have in general been incorporated into the report. A series of implementation actions need to be taken, which are consistent with, but extend those in the current effort on improving the acquisition process. These are outlined in the attached implementation plan for which your approval is recommended and requested.

In summary, it would be my view--based on a variety of DSB studies--that the next dollar on the margin in DoD should be allocated to the procurement of spares; with even higher priority than new systems procurement or research and development.

Norman R. Augustine
Chairman

COORDINATION:

ASD(MRA&L) - Subject to attached comments.

Implementation Plan: Approve / Disapprove

Copy to:
Chairman, JCS

Caspar W. Weinberger
21 JUN 1982

ASSISTANT SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

MANPOWER,
RESERVE AFFAIRS
AND LOGISTICS

20 MAY 1982

MEMORANDUM FOR The Deputy Secretary of Defense

SUBJECT: Defense Science Board Report on Operational Readiness for High Performance Systems

I fully support the overall thrust of the DSB recommendations and the approaches outlined for their implementation. However, one of the implementing recommendations, namely that "MRA&L assume responsibility for readiness" may not be sufficient in itself to achieve the needed improvements. I am now the readiness advocate in the PPBS process. In the acquisition phase, we have the classic problem that Dick DeLauer controls the funds and program actions which influence the R&M, support and trainer design and procurement, while I am the advocate in the DSARC to improve these areas. Working with Dick, we have had substantial success in reshaping some recent programs late in development. However, the separation of advocacy from responsibility and authority is probably not the most effective long term arrangement particularly at the front end of the weapon programs. Some improvement in definition of responsibilities and authority needs to be sought. This may be even more important in the Services than OSD.

Thus, I would like to interpret the DSB implementing recommendation as a charge from you to work out with Dick DeLauer needed improvement in specific responsibilities, in order that we may both be better advocates in the acquisition phase, and to additionally work with the Services to strengthen our approaches to advocacy for weapon system readiness in the PPBS. If you concur, we will proceed, and report to you on our progress.

Larry Korb

Lawrence J. Korb
Assistant Secretary of Defense
(Manpower, Reserve Affairs & Logistics)

CONCUR ______________________

DISCUSS ______________________

OPERATIONAL READINESS WITH HIGH PERFORMANCE SYSTEMS

Plan to Implement Defense Science Board Recommendations

Action Required

1. Operability, Reliability, Maintainability Standards, Design, and Test

a. Military Departments 1/ to evaluate the incorporation of high technology in pursuit of high performance in new systems and in product improvement to determine that systems will meet high standards of operability, reliability, maintainability (OR&M) before IOC. (1, 1-2) 2/ (USDRE) 3/

b. Military Departments establish high reliability requirements that reflect system utilization with a view towards an acceptable level of mission critical failures, e.g., once per month for a maintainable continously operating system, every 10 missions for maintainable system which is used only several hours per day, etc. (2-1) (USDRE)

c. Military Departments maintain high reliability and maintainability standards in manufacturing as well as in design. Use the Navy R&M program as a model for all the Services. (1-1) (USDRE)

d. Military Departments define maintenance standards for all of the actual maintenance conditions the systems will actually encounter (including environmental conditions the system is subject to) taking into account expected maintenance personnel availability, skill levels, their experience, and available training. (2-2) (USDRE)

e. Military Departments program and fund a specific Operability, Reliability, Maintainability, and Producibility (ORM&P) engineering effort for each system development testing (DT) and before IOC to correct deficiencies known at that time; they are to provide strong R&M incentives to contractors. (2-3) (USDRE)

f. Military Departments increase emphasis in DT on verifying OR&M, in conditions which resemble as close as possible those in which the system will operate and be maintained. (2-7) (USDRE)

g. Military Departments program and provide funds for follow-on OR&M improvements by contractor during early stages of deployment after IOC. (2-4) (USDRE)

h. Military Departments maintain production programs at low rate until redesign actions in 1.e. and 1.g. above have largely resolved ORM&P as well as performance problems. (2-5) (USDRE)

1/ All references in this plan to MIL DEPS include Defense Agencies as applicable.

2/ References are to Summer Study Panel recommendations (see Appendix C of the Report).

3/ Indicates responsibility for implementation action.

2. Software Development and Maintenance

a. Military Departments consider software as a part of the system to be developed, and will manage it as a development item by planning and budgeting for it through the entire program life cycle; will take into account the high cost/performance uncertainities inherent in software; readiness implications are to be included in all software activities. (3-1, 2, 6) (USDRE)

b. USDRE develop and evaluate a plan to institute a DOD funded 2-year training course (for example at community colleges) in the software field, with an accompanying 4-year military commitment, and, if deemed feasible, make recommendations to SecDef. (3-3) (USDRE)

c. USDRE encourage contractors to perform IR&D on software technology. (3-4) (USDRE)

d. USDRE develop and evaluate a plan to qualify software houses before being allowed to bid as small business/SA set asides and, if deemed feasible, make appropriate changes in regulations. (3-5) (USDRE)

3. Readiness Responsibility and Assessment

a. SecDef designate ASD(MRA&L) (with USDRE support prior to IOC) as responsible for system readiness in DoD. MIL DEPS to establish similar designation down through the level of the major acquisition and logistics commands. (4-1) (SecDef)

b. Military Departments establish responsibility and accountability for readiness and review it as vigorously as performance at all acquisition decision milestones and other program reviews. (4-2, 3) (USDRE and ASD(MRA&L))

c. The Military Departments include within operational testing and evaluation (OT&E), readiness assessment as close to combat conditions as possible to verfy C, R &M and operational availability (Ao); utilizing results (in conjunction with field reports) to approve or withhold full rate production. An independent assessment of projected system readiness should go to SecDef along with OT&E assessment. (4-4) (USDRE and ASD(MRA&L))

d. The ASD(C) and ASD(MRA&L) review their current effort on "improved management of weapon support funding - decision 30" and expand it to provide vertical visibility of system-by-system support requirement at each operating and management echelon, thus strengthening the system management (vertical component) of DoD management. (11-1, 2, 3) (SecDef)

4. Man Machine Interface

a. Military Departments establish a joint program to improve the reliability and utility of Built in Test or external diagnostic test equipment with initial emphasis on improving technology and subsequently incorporating/retrofitting in systems. (5-1) (USDRE)

b. Military Departments set specifications for support concepts for new systems to reduce the skill levels required of maintainers. (5-2) (USDRE and ASD(MRA&L))

c. Military Departments establish procedures and responsibilities to involve and incorporate the views of the manpower, human engineering, and personnel training communities more deeply into the front-end process of establishment and evaluation of requirements, specifications, RFPs, source selection, etc. (5-3) (USDPE and ASD(MRA&L))

5. Maintenance

a. Military Departments make increased use of civilian (contractor and government employees) as necessary for intermediate level maintenance during initial deployment. (This should take into account determining what maintenance operations can be done by military personnel with the remainder performed by civilians). (6-1, 2) (ASD(MRA&L))

b. Military Departments provide, where appropriate, contractor maintenance at the depot level on long-term basis, where Service maintenance shortfalls warrant it and where our mobilization and combat capability would be improved. (6-3) (ASD(MRA&L))

c. Military Departments increase the emphasis on part task rather than multi-function trainers; and increase the number of trainers. (7-1) (USDRE and ASD(MRA&L))

d. Military Departments establish a demonstration training program on at least one system per Service, utilizing modern training practices; e.g., emphasize practice rather than knowledge, part task trainers, advanced skill performance aids. (7-2, 4) (ASD(MRA&L))

e. Military Departments provide advanced skill performance aids for both maintenance operations and training. (7-3) (USDR&E)

f. Military Departments initiate a joint study on innovative methods of improving, recruiting and retention of high skill level military maintenance technicians in critical shortage areas (including those methods recommended by the DSB). (8-1, 2, 3, 4) (ASD(MRA&L))

6. Spares

a. Military Departments continue to improve capability to compute spares requirements in support of targeted "Ao" per Defense Guidance. (9-1, 2) (ASD(MRA&L))

b. CJCS, in conjunction with the unified and specified commanders, establish peacetime operational availability, (Ao) standards adequate for training exercises and for surge demonstrations to wartime conditions (for each system, in each deployment, e.g., CONUS vs. NATO). (10-1) (SecDef)

c. After review by ASD(MRA&L) of CJCS recommended availability standards (6b. above), and incorporation in the Defense Guidance, Military Departments procure spares accordingly (even at the expense of number of system buys). (9-1) (SecDef)

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

DEFENSE SCIENCE BOARD

9 April 1982

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Defense Science Board 1981 Summer Study on Operational Readiness with High Performance Systems

I am pleased to transmit the final report of the Defense Science Board 1981 Summer Study on Operational Readiness with High Performance Systems (attached).

The study included examination of the following matters concerning the operational readiness of high performance systems:

- The operational readiness status and the basis of criticism of current and past systems.
- The need for such systems as related to operational requirements and the threat.
- Reliability, maintainability, supportability, logistic delay time, inherent and operational availability and their relationship to design, testing, production decision, spares, test equipment and other support items.
- The relation of systems effectiveness and availability to acquisition and support costs.
- Availability, skills, and training of personnel to operate and maintain systems.
- The ability of the management system to observe and manage readiness.

The primary conclusions of the study are:

- Given the ratios between U.S. and threat forces, DoD must continue to seek qualitative superiority through high performance systems.
- More specifically, systems must be designed to meet demands of both the mission and the threat.
- These requirements call for the exploitation of high technology.
- Notwithstanding its numerical advantage, the USSR is also aggressively pursuing high performance through technology.
- High performance is not incompatible with readiness as long as DoD demands and manages to goal for both.
- While high technology should be exploited, that objective must be tempered and disciplined by a fixed requirement that all systems must meet stringent readiness standards before and after entering the force.
- With but a few exceptions the new systems are providing increases in effectiveness relatively larger than their increases in cost.

- The space program and a number of military systems demonstrate the attainability of high readiness standards (reliability and adequate support).
- Those readiness problems that stem from equipment failure can be reduced to manageable proportions by good engineering - by reliability design.
- Given high inherent availability through good design and quality manufacturing, the chief cause of low operational availability is the lack of spares at the maintenance work site.
- A shortage of spares is a management, not a system failure.
- System complexity at the man machine interface (particularly involving the maintainer) is causing personnel recruitment, training and retention problems in all the services.
- Communication between service personnel managers and system design engineers is poor.
- Under current management practices readiness aspects of system development are the first to be sacrificed when time and funds run short.

Some of the more significant recommendations are: 1/

- Continue to design against the mission and threat.
- Exploit high technology in the pursuit of high performance.
- Require that all systems meet high reliability standards.
- Design reliability into systems at the beginning - test - redesign-retest until standards are met.
- Follow new systems into the field, find and fix (redesign) problem components.
- Set peace-time standards for operational availability (Ao) high enough to support training, surge demonstrations and transition to war.
- Program, buy and distribute spares against availability goals.
- Use contractor maintenance "as necessary" in support of new systems; eliminate the current limitation of such support to 12 months only.
- Mount a DoD-wide attack on the pervasive problems associated with Built in Test equipment (BITE).
- Guarantee the manpower, personnel, training and logistics agencies a strong voice at the front-end of the acquisition process including RFP's, source selection criteria and system design.
- Increase visibility, at all appropriate management and operating echelons, of system-by-system readiness and support requirements.
- Establish DoD and Service advocates for readiness.

These recommendations will increase defense systems readiness significantly in the short term and markedly in the long term, and will not increase costs or delay significant increases in operational capability. I urge their implementation rapidly and with little compromise to parochial interests.

1/ These recommendations are consistent with the ongoing process of "Improving the Acquisition Process - the Carlucci Initiatives" but go beyond them.

William D. DePuy, General, USA (Ret)
Chairman,
Defense Science Board 1981 Summer Study
on Operational Readiness with
High Performance Systems

Attachment

DEFENSE SCIENCE BOARD

1981 SUMMER STUDY ON

OPERATIONAL READINESS WITH HIGH PERFORMANCE SYSTEMS

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

INTRODUCTION

The Panel was asked to analyze whether it would be better to have more simple, less expensive, easier to operate, and easier to maintain systems than to have fewer, more complex and expensive systems. Although the Panel focused its chief attention more directly on the readiness issue, it was, nonetheless, the strong conviction of the members that a policy in favor of developing and procuring larger numbers of simple systems would be a substantial error. This conviction was based generally on the following considerations:

- The Soviets are building a large, high performance force against which a lower performance force would do badly.

- The military manpower situation, including the impact of high-cost military personnel on constrained budgets, precludes the idea of having "twice" as many less-expensive tanks or fighters. Life cycle costs are driven by people costs. Furthermore, every added major combat system pulls along a large tail of support with high indirect costs -- training, force structure and overhead, logistics, management, and infrastructure (housing, dependents, personnel services, etc.). Thus, the support tail is more sensitive to numbers of systems than to the complexity of a single system.

- o Availability for combat is not solely dependent upon system reliability (and some of the newer systems are more available than the older systems), but is also dependent upon the capability of the system to operate at night, in bad weather, and under conditions of pervasive ECM -- conditions which dominate European scenarios. In most cases, the simpler systems do not have these capabilities and are thus not available for combat for much of the time they could otherwise be useful.

However, having said this, the Panel strongly believes that the high-performance systems should in all cases clearly be cost effective in the environment in which they will work and should in every case be required to demonstrate adequate reliability before going into the force.

The primary focus of the Panel was readiness. In examining this issue we found it to be a clarifying concept and a useful management tool to distinguish 'inherent availability' or A_i from 'operational availability' or A_o. The key difference in our distinction (see Section 1.0) i[illegible]hat A_o takes into account the effectiveness of the support establ[illegible]ment (such as field repair times) and the availability of spares.

One of the key methods used by the Panel was to compare successive generations of similar systems (e.g., the M60-A1/M60-A3/M-1 series of tanks) and study the impact of technology on performance, cost and supportability. This approach provided a number of valuable insights.

After an introduction, the report of the Panel is organized into five sections which are listed and then summarized below:

Performance Benefits Versus Support Burdens - A Comparison of Systems

Impact of the System Acquisition Process on Readiness

Software

Manpower, Personnel Training and Readiness

Reliability and Related Factors As They Influence Readiness

Performance Benefits Versus Support Burdens - A Comparison of Systems

Some of the critics of the current DoD system acquisition practices believe that current generation systems are more complex than previous generation systems, and, therefore, more difficult and costly to maintain, less operationally available, and less combat ready. The data studied by the Panel doesn't support the contention that our acquisition practices lead us to unsupportable systems in any general sense, although there have been some conspicuous exceptions. The conclusions which the Panel drew from this analysis include:

1. In general, system performance has been increasing faster from generation to generation then either procurement cost or support cost. It should also be pointed out that in every case the newer generation system has so : unique and operationally important capability which permits it to do something the system it replaces couldn't do.

2. There appears to be no direct relationship between advancing technology, complexity, and readiness. Increasing complexity is not necessarily related to declining readiness.

3. Although availability tends to be lower for more complex aircraft, the data clearly shows that in recent years the initial investment in aircraft spares relative to aircraft cost has generally been lower than for earlier generation aircraft. Additional expenditures of operating and support funds can increase the availability of modern aircraft.

4. For systems of equivalent performance and cost, application of new technology actually increases reliability. Although the cost per repair is increasing as technology advances, the frequency of repair appears to be decreasing -- often with a net benefit (as in avionic computer systems).

Impact of the System Acquisition Process on Readiness

Many different aspects of the acquisition process were examined for their impact on the readiness of our systems. The Panel sees no need for a revolutionary change in the existing acquisition policies. We are very much encouraged by recent DoD initiatives in areas such as readiness objectives, pre-planned product improvement, increased industry incentives for reliability and support, and sparing to availability. The Panel does recommend, however, that certain aspects of the existing acquisition process receive special management attention.

1. Each system must have a much stronger readiness orientation during the entire acquisition process. The program manager who controls the program's content, budget, and schedule must be required to meet readiness goals and standards. The manpower, personnel training, and logistics staffs and agencies must monitor and support his actions from program inception to system retirement. Senior acquisition managers must demand readiness and pay the price in dollars, schedule time, testing, and involvement.

2. Representatives of the manpower, personnel training, logistics community must accept primary responsibility for readiness advocacy at Service and DoD program reviews. Emphasis on readiness should be elevated to a level equal to performance, cost and schedule in these reviews. This can only take place with the interest and active support of the DoD and Service acquisition executives and their staffs.

3. Factors which affect readiness (design, logistics concept, maintenance concept, numbers and skills of personnel, etc.) need to be an integral part of the early concept definition work in a new system. Industry must be incentivized to take a more active role in these matters. Readiness standards must be explicit in RFPs, source selection criteria and design goals.

4. It is difficult to transition a system from development to production and we tend to underestimate that difficulty in time and dollars. To field a system with high readiness we need to provide time and money to improve the producibility of the system and to more clearly match the training, documentation, etc. to the production system.

5. The Panel applauds the DoD initiative on preplanned product improvement (P^3I). We would point out that many of our systems have evolved along those lines in the past. Those that did so most successfully had some extra capacity from the beginning which made performance growth more feasible. We must protect that growth capacity from being cut out on the basis of cost-effectiveness related solely to the needs of the initial system.

6. Every system experiences difficulty when it first becomes operational. From a reliability point of view, a small number of the hardware units tend to cause a large percent of the hardware failures. The Panel recommends that the program manager plan from the beginning to address that problem by funding a government and contractor team which will follow a system into the field, identify the high failure rate units and provide the design changes necessary to reduce the high failure rates. The Panel referred to this as 'Follow-up, Find, and Fix Improvements (F^3I).'

Software

Computers - with their attendant software - are being applied in ever-increasing degrees in our commercial and military systems. They are also beginning to play major roles in our supply systems, training systems and maintenance systems. After Service briefings and discussion, the Panel concluded that:

1. Software costs already dominate for some systems and we can expect a trend in that direction. The magnitude of this trend is not well recognized throughout the DoD and, unless it is, our ability to produce large, sophisticated software systems will become the major limitation in fielding the required mission capabilities.

2. Software is always a development item and must be managed like one. We must recognize the cost/performance uncertainties, manage it in ways analogous to development hardware, prototype early, redesign and recost.

3. We must avoid the temptation to substitute excessive software complications to make up for lack of personnel skills, as we seem to have done in the built-in test area in some cases.

4. The planned Defense Science Board study on Embedded Computer Resources is both timely and critical.

Manpower, Personnel Training and Readiness

Adequate numbers of properly trained personnel are a key ingredient for achieving system readiness. The Panel's study of the personnel situation indicates that the U.S. manpower base is diminishing, that the competition for people in key skill areas is increasing, and that, so far at least, our high performance systems are tending to demand more highly skilled personnel. The Panel also found that there was nothing about any one high performance system which makes it too difficult to be operated and maintained by skilled personnel on a selected basis. The Panel's concern is centered on the cumulative impact of all of the more complex systems now programmed into all the Services. Some of the Panel's recommendations include:

1. We should make better use of the available manpower pool through techniques such as incentives for personnel to improve their skills, designs which accommodate available skills, training which is more effectively geared to the inherent skills and experience of available personnel (management techniques for designing equipment to match available skills are largely undeveloped and/or unused).

2. Job aids need to be an integral part of the system design process, but they should not be so sophisticated that they become development and support problems in their own right.

3. We need to avoid both extremes in the man/machine area -- expecting the people to do too much too fast, or going too far in the smart-machine/dumb-man direction. It is clear that design engineers

have not normally been given a clear, useful description of the capabilities and limitations of the Service members likely to be assigned as operators or maintainers. We do not know how to test and evaluate this dimension of the problem during acquisition.

4. Much more emphasis should be put on repeated performance (practice) as part of the training process. Operators and maintainers need to practice their jobs, not just be educated to the theory.

5. Simulators which replicate entire operational systems are expensive and always few in number and too expensive to maintain and modernize. To provide adequately for the necessary practice, much more use should be made of part task trainers.

Reliability and Related Factors As They Influence Readiness

Although there is some imprecision in the taxonomy, the Panel agreed with the Navy's definition of inherent and operational availability, A_i and A_o. A_i is the designed-in, manufactured-in reliability and maintainability of the hardware. A_o is the composite of the inherent availability and the effectiveness of the support environment found in the operating forces. A_o can never exceed A_i, but can, and often does, fall far short of the inherent availability built into the hardware system. Based on these and other considerations, the Panel makes the following observations:

1. The U.S. Navy program for reliable engineering designs and manufacturing processes should be adopted throughout DoD.

2. The maintenance concepts for high performance systems have been force fit into maintenance and repair structures which often are not well-matched to today's systems. One should design such a structure in the light of the technology and performance of modern systems. It should give due regard to factors such as personnel, training, spares, survivability, transportation, response time, etc.

3. The use of built-in test equipment (BITE) is a good approach to maintaining high performance systems, but to date it has been very poorly implemented in initial deliveries of high performance systems. A concerted DoD effort is required to realize the benefits of BITE.

4. Sparing-to-weapon system availability requirements, rather than sparing on demand, is strongly endorsed by the Panel and we are pleased DoD is moving in this direction.

5. The Defense Guidance should require and the Services program sufficient spares to permit exercising systems in peacetime as required to maintain the proficiency necessary to surge to wartime utilization rates.

6. The supply system should also be designed against availability standards. It is not enough to <u>buy</u> spares against availability, they also must be <u>deployed</u> against availability.

7. More extensive use of contractor maintenance personnel should be made at intermediate and depot repair levels. Contractor maintenance personnel should also be used at operational locations during initial field deployment to assist in early correction of identified reliability and maintainability problems. This is an important near- and mid-term solution to skilled personnel shortfalls.

INTRODUCTION

1. INTRODUCTION

The Charter for the Defense Science Board Summer Study on "Operational Readiness With High Performance Systems" posed a number of critical questions to be examined by the Summer Study Panel on Readiness (see Appendix A). The basic challenge to the Panel was to examine ways in which the DoD could have both the performance needed in our military systems and adequate readiness. In particular, the group was asked to study whether complexity and sophistication are implicit in high performance, whether we can afford to both acquire sufficient numbers of high performance systems and the support that goes with them, and whether as an alternative we could achieve improved military capability through acquisition of large numbers of lower performing systems.

In response to the Charter, a Defense Science Board Summer Study was organized with General William E. DePuy, USA (Retired), as Chairman. Mr. Charles A. Fowler of The MITRE Corporation was Vice-Chairman. The Panel met several times in Washington prior to the meetings which took place in San Diego from 3-14 August 1981. In the Washington meetings, a series of excellent briefings were provided by the Services in which current and planned systems were described. Issues relating to the need for these systems, and to the Services' ability to support them with the requisite personnel and material were discussed openly and in detail.

The Panel also spent several hours listening to two of the key proponents of the thesis that unnecessary sophistication in our military systems is reducing military readiness. Mr. Charles Spinney of PA&E provided the Panel with his analysis of the impact of high technology on the readiness of our tactical air forces. Mr. James Fallows also discussed his observations which grow out of his discussions with people in gathering information for a book on military policy and national defense.

To carry out the work of the Panel, the group was divided into four Subpanels:

Subpanel 1 - Performance Benefits Versus Support
Chairman: Mr. D. R. Heebner

Subpanel 2 - The Requirements Process
Chairman: Mr. L. H. O'Neill

Subpanel 3 - Man/Machine Interface
Chairman: Admiral I. C. Kidd, Jr., USN (Retired)

Subpanel 4 - Impact of Complexity on Readiness
Chairman: General John Pauly, USAF (Retired)

The membership of the Panel and the assignments of the various Panel members in the Subpanel structure are given in Appendix B.

Each Subpanel was asked to examine a series of assertions and questions. The "Performance Benefits Versus Support" Subpanel was asked to review a series of Service systems and to examine in detail the performance benefits available from each system versus the support burden which it placed on the Service. Attempts were to be made to identify those systems which were particularly good or bad in this regard, to isolate causes and to make recommendations, and to see if any trends could be distinguished by examining several generations of systems with similar missions.

Subpanel 2, was tasked to consider the consequences of the "front end" of the acquisition process. Briefly summarized, the subpanel's work was to assess the early stages of acquisition, those in which military requirements are specified and acquisition strategy is planned, in an effort to learn if measures taken in that part of the acquisition process has significant effects on operational readiness in deployed systems. To sharpen the charge placed on the Subpanel, the study chairman specifically asked that the following questions be examined:

- Does the requirements process inevitably lead to high performance systems?
- Are performance specifications often set too high?
- Does planned product improvement provide more reliability and maintainability than new starts?
- Does the acquisition process place an adequate emphasis on readiness?
- Are source selection criteria tilted toward performance?
- Can we and should we go to lower cost, more reliable, lower performance systems even in a fixed manpower environment?

Subpanel 3 focused its activity on the man/machine interface, and in particular on the relationship between system complexity and the performance of operators and maintainers. Among the issues the Panel examined were: (1) Whether the complexity of our systems exceeds our ability to operate and maintain them considering the capabilities of our available manpower. (2) The extent to which readiness problems are aggravated by failures induced by operator and maintenance personnel -- and what can be done through training aids to reduce such failure. (3) The state of development of man/ machine technologies, and the extent to which complexity can be engineered away from the man/machine interface. (4) Whether man-power limitations dictate that we limit the number of high-performance systems we build, and tailor all other systems to fit the residual personnel capabilities. (5) The concern that each system we build demands the very best people -- and, since the distribution of personnel capabilities is pyramidal, the concern is that we cannot support our systems in the aggregate with appropriately capable personnel.

Subpanel 4 examined the impact of complexity of defense resources - the size of the force, support manpower, and dollars. Some of the related concerns which were studied included:

1. The relationship between complexity and cost.
2. The impact of cost on quantity, and, in turn, quantity on force capabilities.
3. The effect of increased system costs on war reserves and the ability of the force to sustain combat.
4. The relationship between spares availability and system availability.
5. The interaction of combat to support ratios (teeth-to-tail) and force structure design.

There was considerable interaction between the Subpanels in the San Diego meetings and some overlap in their recommendations. This report combines the individual Subpanel reports and summarizes the overall Panel conclusions and recommendations. It is organized by subject area rather than Subpanel. The remainder of this section describes the Panel's definitions of high performance, readiness and availability -- and discusses the Panel's thoughts on the difficult choices which must be made to achieve a meaningful military capability within reasonable budget limits.

The several Subpanel recommendations were considered by the entire Panel and a series of recommendations were made to the Defense Science Board at the close of the San Diego meeting. These are given in Appendix C.

Subsequent sections describe the system comparisons made; a variety of comments on the system acquisition process; the Panel's concerns about software, personnel and training; the related areas of reliability, maintainability, built-in test equipment, logistics and maintenance; natural resources; and airlift.

1.1 Definitions

It quickly became apparent that there were many ways to define high performance, high technology, and sophistication. It was also clear that various groups used different measures to evaluate readiness. The Panel's definition includes the following characteristics: a high-performance system must provide a significant additional margin of military capability which is judged to be potentially decisive in battle. It must achieve, at the same time, a measurable increase in reliability, operability, maintainability and all those factors contributing to higher wartime operational availability and readiness. Finally, a system is termed higher performance if its achievements are the result of judicious application of advanced technology.

The difference, then, between new high-performance systems and others might be that, e.g., technology can also be applied not to provide basic new military capability, but to provide lower cost, higher reliability, etc. The debate should not be on high-performance versus simple systems, but on how, in any specific case, a given high performance system accomplishes the above objectives.

The Panel recognized, as described below, that readiness is only one factor in what is referred to as Combat Capability. Although the task assigned to this Panel of the Defense Science Board Summer Study dealt with the operational readiness aspects of high performance systems, it is important to recognize the part which the readiness factor plays in our efforts to provide adequately for the security of the United States. To be sure, the readiness of our forces is of paramount importance and it has been of paramount concern to the Defense Department and the Military Services in recent years; however, there are considerations besides readiness in the national defense equation which must be acknowledged to put readiness in the proper context. All of these considerations are interrelated and each provides its own dimension to the total solution which we seek.

It appears axiomatic at this juncture in history that the most effective means of providing for the security of any country is to create and maintain sufficient military strength to deter potential adversaries and to defeat our enemies if this deterrence should fail. The commodity with which we must deal in measuring our military strength is the overall combat capability of our military forces. If this total combat capability is sufficient to deal with any postulated threat, we have been successful. If it is not sufficient, our nation faces perilous times.

It is generally recognized and accepted that total combat capability is made up of four basic components. The first of these is the size of the force - force structure. This is the quantitative dimension. The second deals with the hardware with which we equip our units. It is the qualitative dimension. Over time, it can be directly measured by the success we attain in our efforts to modernize with the best possible equipment which technology can provide and support. The third component involves the readiness of the force - the ability to deploy effectively and employ all elements without delay. It is an extremely complex factor which takes into account such things as the reliability, operability, and maintainability of our systems as well as the training level of our personnel. The fourth and final component is sustainability, which measures our ability to support the total force over time so that it can fight as long and as hard as is required to prevail. It is the time dimension.

All of these components are interrelated and constantly compete with each other for priority and funding. Further, maintaining the delicate balance between them, with finite funding, is acknowledged as being the most challenging task of defense management today. It is interesting that the interrelationship and the competition between modernization and readiness provides the genesis of the issue which this panel of the DSB Summer Study has been asked to examine. Specifically, the issue involves whether modernization of the Armed Services with more complex equipment forces a reduction in readiness, and then, what steps can be taken to correct or preclude this situation. The following paragraphs briefly review each of the identified components of combat capability to establish a proper framework within which the central issue can be viewed.

1.1.1 Force Structure

The objective force structure is determined by a complicated and continuing process involving the character and size of the perceived threat, the nature of the most probable scenario which we may face, our national objectives, the overall capability of U.S. forces, and our ability to properly support the force with logistics, facilities, training, and manpower. It must be emphasized that force structure pertains not only to major combat units but to essential supporting elements as well. It is imperative that supporting units of all types be provided in proper ratio if the inherent capability of the combat organizations are to be fully exploited.

The level of force structure of the U.S. Armed Forces has fluctuated greatly throughout the 1970s. As a gross measure, in 1970 our total Armed Forces strength stood at 3-1/2 million. Today that figure stands at approximately 2 million, although all Services are programming modest to moderate increases over the next five years. The overall reduction in the '70s was basically caused by lack of real growth in the DoD budget and the need to give higher relative priority to modernization after a virtual hiatus during the Vietnam War.

The programmed changes in force structure are in reaction to the significantly increased threat posed by Soviet forces, as well as certain modifications to our national objectives and strategy. These latter changes give added emphasis to the importance of the Middle East/Southwest Asia. Since the Reagan Administration is supporting a substantial increase across the DoD budget over the next five years, the force expansion is not expected to adversely affect the other components of force capability.

1.1.2 Modernization

Historically, military weaponry has been improved as a result of a compelling need for man to protect himself with weapons that were as capable or better than those possessed by his enemies. Accordingly, we have seen through the years a process wherein every improvement or breakthrough in technology was soon followed by the development of hardware which countered that increase in capability. The prevailing axiom throughout this evolution has been a recognition of the tremendous advantage enjoyed by the side with the better equipment. Today this axiom is still operative and in a time of accelerated technological advances, it has become even more binding and time-sensitive.

Broadly speaking, the requirement to modernize in recent years has been generated by the advancing age of our weapon systems and by the increasing threat posed by the Soviets worldwide. All modern systems are developed and produced under criteria designed to give them a certain reasonable service life; however, the diversion of funds to support Southeast Asia operations between the mid-sixties and the early seventies forced the average age of much of our hardware substantially beyond the planned service life. As a result, until recent modernization programs took effect, our forces were equipped with hardware developed with technologies of the 1950s.

Although the aging factor is certainly a substantial reason, by far the most telling stimulant for recent modernization efforts can be found in quantum improvements which have been noted in the size of the Soviet and Warsaw Pact military forces and the quality of their equipment. Over the past ten years, Soviet armed forces have increased by approximately 25 percent, while our strength has declined some 40 percent. During the same time, Soviet defense spending has grown an average of over five percent per year in real terms, and today they invest almost 15 percent of their Gross National Product on defense. On the other hand, U.S. defense spending has remained relatively constant in real terms - approximately 5 percent of our GNP. It is of great significance that through these years the Soviets have continually dedicated a substantial portion of their military budget to research and development efforts and associated acquisition - outspending the United States in this regard by some 240 billion dollars over the past ten years. As a result, the Soviets have been equipping their forces with systems of increasing quality and sophistication, to a degree which indicates that the technological gap is closing rapidly. At present, they outproduce the U.S. 11 to 1 in armored vehicles, 18 to 1 in surface-to-air missiles, 3 to 1 in helicopters, and 2 to 1 in submarines, naval surface combatants, and tactical fighter aircraft. Similar ratios exist in other military commodities and the production imbalance across-the-board is expected to continue.

Given this situation and the U.S. free economy, we are unlikely to match Soviet outlays in peacetime. It is mandatory that we put equipment of maximum combat capability in the hands of our military forces. These systems must be able to compete favorably with enemy systems they must confront. They must be able to survive in the extremely lethal and hostile environment in which they may be forced to operate. They must be flexible in their ability to operate within various scenarios and in any part of the world. They must be devoid of operational limitations which would prevent them from performing their missions around-the-clock and under any weather conditions. These and other requirements force constant improvement of the systems in the field (through modernization and upgrading) and maximum exploitation of the technology available to us. To do otherwise would only aggravate the imbalance which is developing and consume our defense resources without providing capabilities that would be a factor in the sophisticated battlefield of the late 1900s and beyond.

1.1.3 Readiness

This component of combat capability is the dimension explored in great detail by the DSB Summer Study in addressing whether high performance equipment fosters reduced readiness. In this context, then, overall analysis deals with system readiness as opposed to force readiness in the broader sense. It addresses whether the systems which are produced and fielded, in fact, provide the quality and quantity of combat capability envisioned when their respective production decisions were made. In this regard, such things as system reliability, maintainability, and availability become paramount, along with the training status of both the crews that man the systems and the associated support personnel.

In focusing on system readiness throughout this study, the DSB notes that force readiness in the broader sense - the ability of a large integrated military force to effectively perform the overall combat mission assigned to it - must go well beyond consideration of the readiness of the individual systems that make up that force. It must address such factors as proper force balance, the availability of corollary elements (such as electronic warfare units) to support primary systems, the adequacy of command, control and communications capabilities, and the availability of the necessary lift to move and support the force.

The word readiness has many meanings and connotations. Fundamentally, it is the ability to deter a potential military foe from taking action and, failing to deter, the capability to respond with a military reaction capable of defeating the threat. Such a view demands a specific accounting of the threat to be faced and a professional estimate of our own abilities to meet that threat. This is basically the theater commander's view of his capability to perform his assigned tasks. In the aggregate it is also the Joint Chiefs of Staff view of readiness to execute the national strategy. The major elements of this view of readiness include leadership, combat forces, combat support forces and materiel, mobilization capabilities, and transportation both in-theater and from the U.S. With the exceptions of leadership and mobilization, each of these factors is amenable to some form of measurement.

Two of the force characteristics are now being reported under formal criteria accounting. The first of these is the C rating system for reporting the status of battalion and larger size units in the measured categories of personnel, combat equipment, ability to repair and training. These are reported in four levels: C-1, fully combat ready; C-2, substantially combat ready; C-3, partially combat ready; and, C-4, not combat ready. As noted above, readiness involves more than the factors measured by the C ratings. The C ratings do, however, provide a basis for management decisions on resource allocations and do provide a positive incentive at all levels to achieve the best readiness possible. (Note the C-rating systems vary some among the Services.)

C ratings are derived by comparing numbers of assigned personnel and equipment with that authorized. Hence, one can change the C rating quite dramatically by changing the authorization level without changing the assigned level. In such a case, the C rating would change, but the actual fighting capability would not. It is also important to realize that the squadron/battalion commander is almost always given a little less than the goal at the moment and, therefore, always has the task of bringing his unit up to the desired standards.

Another system to report on theater supply levels against authorized support criteria is now being introduced as a second measure of readiness. A third measure of readiness which is often applied to weapon systems is the ratio of time the equipment is considered combat ready to the total time it is in the hands of an operating unit. For some weapons systems the operationally ready status is recorded as it changes over a 24-hour period. A system could be operationally ready, not operationally ready-supply (NORS), or not operationally ready-maintenance (NORM). The operationally ready rate is then the operationally ready time divided by the sum of the operationally ready time, the NORS and the NORM. This is the supply officer's view of readiness or the view of the program manager. Typical operational ready rates vary from 45% to 60%. The choice of what is an acceptable rate is subject to all sorts of caveats. One must remember that although daily operationally ready rates can pinpoint problems requiring management attention, the important consideration is the number of combat systems which can be brought to combat-ready status within the authorized generation time (usually 72 hours except for alert situations). A measure of this consideration is provided in the C-rating system where the ability-to-repair factor is reported on.

1.1.4 Sustainability

Although not addressed in great detail in this Summer Study, the question of sustainability is an extremely important factor in determining the true combat capability of our military forces. Despite the fact that it is readily accepted that it would be necessary to operate our forces at an intense rate initially to make up for any quantitative or qualitative shortfalls, relatively little attention has been given to how long this surge condition must be continued in order to prevail.

The introduction of the flexible response strategy some years ago not only raised the possibility of fighting a conventional war but also the recognition that it would probably be of longer duration than a nuclear conflict. Although logistics planning factors were modified to provide for the time dimension, several factors have caused great frustration in our efforts to provide this sustainability. First, the large basic cost of accumulating considerable stores of spares and munitions was difficult to accommodate in military budgets that provided little real growth. Second, the Vietnam War not only syphoned off much of the available funding, but also caused a rapid consumption of those expendables which were on-hand. Third, delayed modernization efforts that received priority within all of the Services at the conclusion of the Vietnam episode preempted funds which otherwise could have been committed to improving the sustainability picture. There was a fourth factor at work also. Stockpiles of expendables tend to be viewed by decision makers as a single gigantic entity which consumes large quantities of funds with relatively little tangible or visible manifestations of progress. Accordingly, funds naturally flowed more readily to the primary weapons systems themselves, rather than to the wherewithal to operate them over the required period of time.

As a result of the above, there is a real need for priority action to be taken to rectify the substantial shortfall which exists in sustainability. To this end, the DSB has noted that the most recent Consolidated Guidance has directed the Military Services to commit sufficient funds over the next five years to provide the necessary stockpiles to support sustained operations.
Although a precise quantification of the shortfalls by category is difficult, the total amount as reflected in the most recent Posture Statement approximates 50 billion dollars. This figure includes the upgrading of our war reserve munitions stocks with newer, more effective munitions as well as bringing the overall stock levels up to the total requirements. It also reflects the procurement of war reserve spares for new equipment coming into Service inventories.

1.1.5 System Availability

Another term for which the Panel found a multiplicity of definitions was system availability. Eventually the Panel found it useful to carefully distinguish when we were talking about a system's inherent availability (A_i) or, alternatively, a system's operational availability (A_o). Not only is the definition a clarifying concept, but it also appears to have utility as a management tool.

Inherent availability (A_i) is defined as: designed in, manufactured in, availability manifesting reliability and maintainability. It is measured by mean time between failure (MTBF) and that component of mean time to repair inherent in the hardware ($MTTR_i$). The formula is:

$$A_i = \frac{MTBF}{MTBF + MTTR_i}$$

Operational availability (A_o) is defined as that availability which is achieved by the operating forces. It is the consequence of the mean time to repair actually achieved by the operating forces ($MTTR_o$) and the mean logistic delay time (MLDT) as they relate to the mean time between failure which is inherent to the system. A_o is affected by the general efficiency of system support in all of its aspects -- manpower training, job aids, logistics organization and procedures, quantity and deployment of spares. The formula is:

$$A_o = \frac{MTBF}{MTBF + MTTR_o + MLDT}$$

One should take care in making specific calculations using these definitions so as to properly account for utilization rates.

A_i is the product of the development and production effort; Ao of the support effort. A_o can therefore never exceed A_i. At the level of OSD staff, A_i is the province of the USDRE and A_o of the ASDMRA&L. Within the Services, there are comparable divisons of responsibility.

Defense contractors can and must produce high A_i. It is the task of the weapons system acquisition process to require and enforce the achievement of high A_i levels before systems are introduced into the force. Defense contractors cannot be held primarily responsible for low Ao which is, rather, the province of DoD management. However, contractors may be required to deliver specific support analyses and support products indispensable to the achievement of high A_o.

1.2 Funding Ready Systems

Although there are exceptions, experience to date has shown a direct relationship between complexity and unit cost. At the same time, the size and quality of the Soviet threat has forced us to rely heavily on the full exploitation of technology to stabilize the situation, although constrained by a relatively constant and finite budget. Faced, therefore, with increased unit costs, if we are to modernize, it is necessary to make a choice between compensating courses of action. The first of these is to buy fewer of the required systems so as to stay within the funds available. In effect, this course of action gives up force structure for modernization and the net improvement in overall combat capability could only be achieved if each system has a decisive advantage over the threat force and its comparable or related systems. Additionally, fewer numbers of any one system limits flexibility in worldwide deployment, tends to reduce the amount of spares available to support the system, and causes increased reliance on the air and surface lift available to ensure that the weapon system is available where and when needed throughout the world. Finally, a smaller buy would force the unit price up even higher.

The second alternative available would be to stretch the procurement program out by producing at a slower rate. This is a commonly used procedure which DoD has been forced to utilize in the real world of escalating costs and relatively fixed budgets; however, it creates numerous operational, management, production, and, in the long run, cost problems. The most obvious of these is that the full introduction of the new equipment into the operational inventory is delayed; unit conversion programs are slowed and prove to be less efficient; the reduced flow of personnel through training programs tend to cause waste of resources; production facilities are tied up for excessive periods of time, and fluctuations are induced in the size of the needed work force. Here also, it can be anticipated that unit cost will be even higher in stretched-out programs and other funds will be lost in conversions that are forced to be inefficient. A better way of doing this would be to procure systems and spares in the proper ratios from the inception of the program. This would control production costs, while slightly reducing system buys -- but overall readiness would not suffer.

A third, and even more dangerous, alternative, would be to produce primary hardware in the numbers and on the schedule desired, but to gain economies by cutting back on the buy of spares and other support items which are essential to the system. This practice results in the fielding of systems which cannot be properly supported. As a result, their mission capable rates are forced well below acceptable levels and the system is subjected to severe criticism. At this point it is the tendency of the uninformed to blame complexity for the low availability rate of the system. The fault, in fact, lies in our compromise of the logistic plan. In essence, by failing to buy adequate support, we procure expensive weapons systems but deny ourselves the full combat capability which these systems can offer.

The remaining programmatic actions available to us when faced with high unit costs and a constrained budget involve considering the relative value of new systems. To this end, conscious management decisions must be made after a detailed analysis of the contribution of each system to our overall defense and a review of the national objectives and strategies which they support. Other programs could be slowed down in their production rate as a means of releasing the required funds, or they could be cancelled completely. A decision to cancel should be made as early as possible to recover the maximum amount of funds and, at the same time, to minimize expenditures on systems which will not enter production. As a means toward this end, it is necessary to maintain a constant surveillance of our programs with a view toward identification of capabilities which overlap with competing systems so that the wasteful duplication could be eliminated "early-on."

Associated with the above, there are currently procedures in effect for scrutinizing proposed new programs prior to approval to ensure that the requirement is sound and that they are fully justified. Unfortunately, under this scrutiny, badly needed systems are often denied funding, although the operational capabilities are critically needed. It would be valuable in these cases if another option was available wherein the needed capability could be incorporated in weapon systems already in the field. It would then be necessary to provide for possible growth potential rather than developing systems with close space, power, and weight tolerances. Such a provision would permit some upgrading of our capabilities for a small percentage of the funds that would be required to procure an entirely new system.

PERFORMANCE BENEFITS VERSUS SUPPORT BURDENS -- A COMPARISON OF SYSTEMS

2. PERFORMANCE BENEFITS VERSUS SUPPORT BURDENS -- A COMPARISON OF SYSTEMS

As noted in the Introduction, a key activity of the Panel involved a study of several series of systems which represent, over time, U.S. capability in various areas; e.g., in tanks the M60-A1/M60-A3/M1 series. This approach was used to permit analysis of the relative performance and support burdens as our systems have evolved.

In approaching the problems of assessing the benefits of applying high technology to weapons systems vis-a-vis the concomitant support burdens, we sought to use the best experience data and the best analytic data available. We also selected from the truly massive quantities of these data those portions that were best documented and most clearly displayed the relationships we were examining. This resulted in an emphasis on weapons systems in which high technology was well applied, on systems whose properties as fighting vehicles are strongly dependent on the successful application of particular technologies, and whose performance parameters provide vivid comparisons with predecessor systems. While this procedure effectively illustrates the impact of technology where it is well applied -- it does not deal at all with cases where technology may have been misapplied or with cases where an excessive reach for new technology may have prevented successful completion of a development or excessive costs and delays (Cheyenne, for example) or, for that matter, have led to uneconomical acquisition and/or support program burdens. Nor did we attempt to address those cases where a subsystem may have overreached the available technology and introduced unnecessary costs and support burdens, although undoubtedly many such cases exist.

Lack of treatment of such cases in this report is not intended to constitute a denial of their existence by the Panel. If anything, it reflects the fact that such cases represent failures of the acquisition process to make consistently good judgments of how much technical risk to accept in pursuing weapons systems designs adequate to cope with the threat. There is some evidence that excessive technical risks evolve from certain aspects of the competitive source selection process which on occasion has stimulated contractors to go beyond the limits of sound technical judgment in competitive proposals. A balanced treatment of the subject of performance benefits versus support burdens would deal with these factors more fully than the Panel was able to do in its work reported here.

2.1 Institute for Defense Analyses Study

The Panel was ably assisted in its deliberations by a study by the Institute for Defense Analyses (IDA) and a short summary of that study is presented below. The complete study is documented in a classified IDA report, "The Effects of Increasing Technological Complexity on Operational Readiness of Weapon Systems," (IDA Log No. HQ 81-23839), and an Addendum to that report (IDA Log No. HQ 81-23926).

The IDA study attempted to "seek quantitative relationships describing the variation of reliability and maintainability ... of successive generations of ... systems." The study was to consider the hypothesis that current generation systems are more complex than previous generation systems and, therefore, more difficult and costly to maintain, less operationally available, and less combat ready. The main conclusion of the study is that the available data do not support a test of the main hypothesis, although some indicators suggest it may not be true or may be true only in selected cases.

In looking at the readily available data one finds that the data of interest are usually incomplete, and require extensive research and subsequent integration before detailed questions about reliability and support costs, and related matters, can be answered. The data used was compiled from Service data for operating and support (O&S) costs, procurement and operational status where this information was available. Data from prior studies was also used.

One of the cautions expressed in the IDA study concerned possible indicators of complexity. Among the conventional wisdoms are statements such as "the more complex a system is the more parts it has," "costs go up as complexity increases," "as performance increases so does complexity," "the bigger a system is the more complex it is apt to be," and "our modern systems are more complex than their antecedents." The study aptly points out that a comparison of the old mechanical calculators with modern electronic ones results in contradicting most of these wisdoms. The modern calculator is far more complex functionally but far simpler mechanically, easier to use, cheaper and requires essentially no maintenance. The message to be gained is that measures of complexity need to be very carefully placed in an appropriate context to be very useful as indicators.

The systems which were compared with one another are listed in Figure 1, together with some ground rules used in choosing them. The data collected included system characteristics and performance indicators; unit and force procurement data; various operations, maintenance and support costs; and reliability and maintainability indicators (incomplete). The data was collected mainly from Service sources and compares systems as they exist now -- although, in a few cases, it was possible to get data to compare different generation systems at similar points in their life cycles.

Figure 2 compares availability in percent availability and the ratio of operating and support (O&S) costs to support costs. It is immediately apparent that availability tends to be higher as the ratio of O&S to procurement costs increases. With two exceptions, the trend in going from older to newer generation systems is to lower both availability and the O&S/procurement cost ratio. The two exceptions are the A-10 and the F-16. The data do not explain the F-16 case, but it should be observed that the A-10 is a much simpler aircraft than the A-7D it replaces. The obvious trend raises the question of whether the O&S/procurement cost ratio is generally reduced as a management practice as system costs increase. From a further look at that question, the available data seems to indicate that is indeed what has been happening. For example, data is provided in the IDA report which shows that the O&S costs in millions of dollars per year per aircraft vary only from .8 to 1.71 (A-4E to F-15) for the 9 aircraft types studied. In addition, O&S costs are also quite close to one another for successive generations of ships, with the newer ships having lower or essentially identical O&S costs.

2.2 Aircraft Systems

Some additional interesting data are shown in Figure 3. The F-15 appears to be more reliable and cheaper to maintain at the organization level than the F-4. Note, however, that the cannibalization rate of the F-15 is much higher, while it also has many more remove and replace parts. These two characteristics may not be unrelated -- they may in fact suggest a change in maintenance practice from one aircraft type to the next. However, high cannibalization is a natural response to buying insufficient spares, a common practice in recent years as illustrated in Figure 4.

Figure 4 shows that the USAF allocation of its procurement budget between purchases of new aircraft and acquisition of replenishment spares has oscillated through the years. The expressions of concern about readiness comes at a time when a considerably larger fraction of the budget was spent on new aircraft rather than on spares, and it can be observed that USAF plans have tended to redress this balance.

FIGURE 1

SYSTEMS FOR WHICH SOME COMPARATIVE DATA WERE READILY AVAILABLE

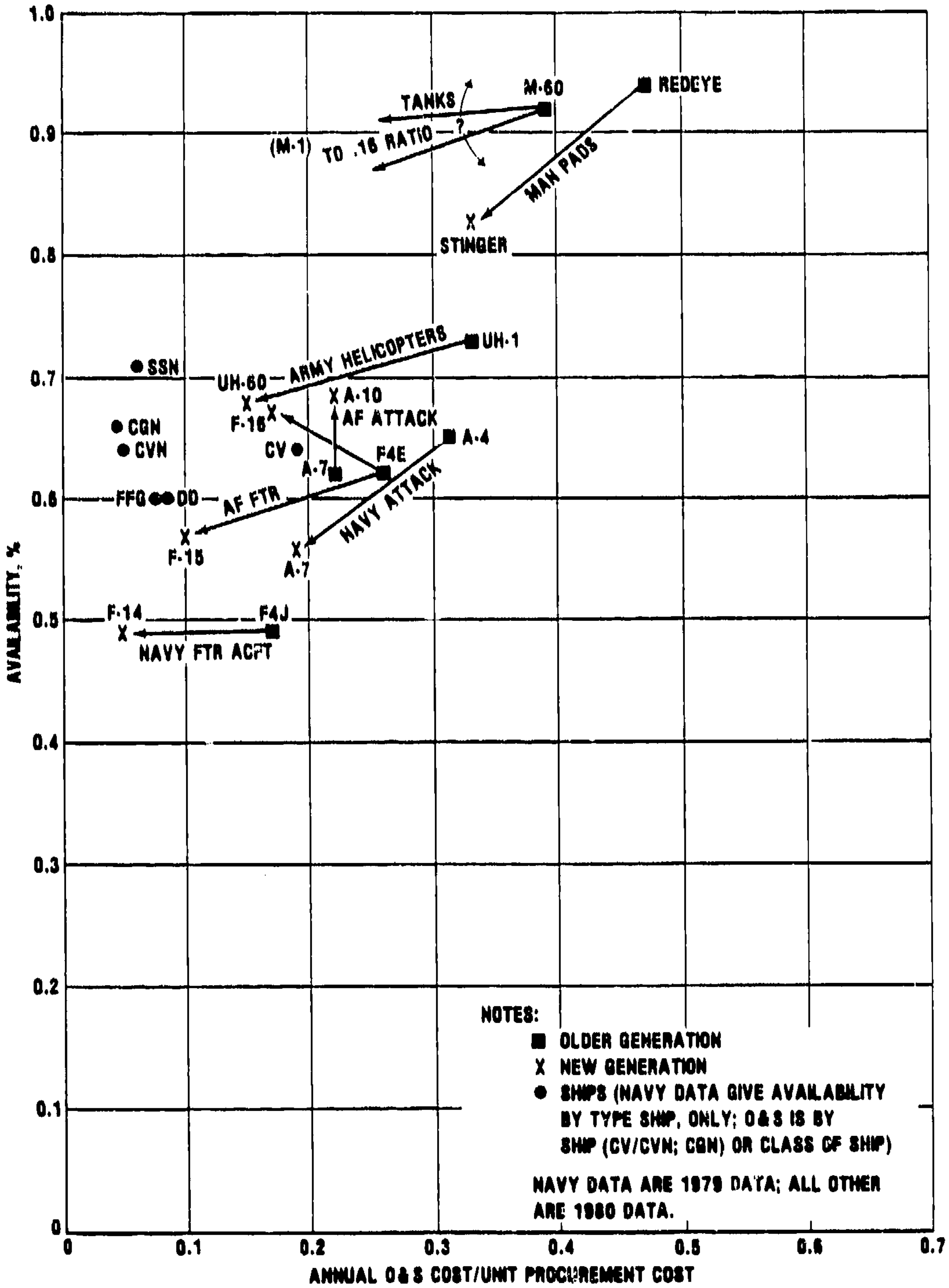
ARMY	NAVY	AIR FORCE
M60-A1/M60-A3/M-1	SSN 637/SSN 688†	A-7D/A-10
REDEYE/STINGER	MIDWAY/RANGER*	F-4E/F-15/F-16
UH-1/UH-60	ENTERPRISE/NIMITZ*	
106 RR/TOW	DD 931/DD 963†	
MPQ-4A/TPQ-37 (CM RADAR) (CB RADAR)	FFG 1/FFG 7†	
	CGN 25-35/CGN 38*	
	F-4J/F-14A	
	A-4E/A-7E	

* INDIVIDUAL SHIPS
† SHIP CLASSES

EXCLUDED:
- SYSTEMS NOT PAST IOC
- SYSTEMS FOR WHICH DATA ARE "BURIED"
- SYSTEMS ONLY REMOTELY COMPARABLE

FIGURE 2

AVAILABILITY AND O&S/PROCUREMENT COST RATIO FOR SYSTEM PAIRS EXAMINED



FIGURES 3 and 4

OTHER INTERESTING DATA

	F-4E	F-15
• MTB ME	1.1	1.5
• MMH/FH (ORG)	7	5
• RECOVERABLE UNITS (e.g. LRU)	1573	3834
• CANNIBALIZATION RATE (PER 100 SORTIES)	9	37

INVESTMENT PATTERN--TOTAL USAF AIRCRAFT

ALLOCATION OF USAF AIRCRAFT PROCUREMENT BUDGET
(3010 MONIES)

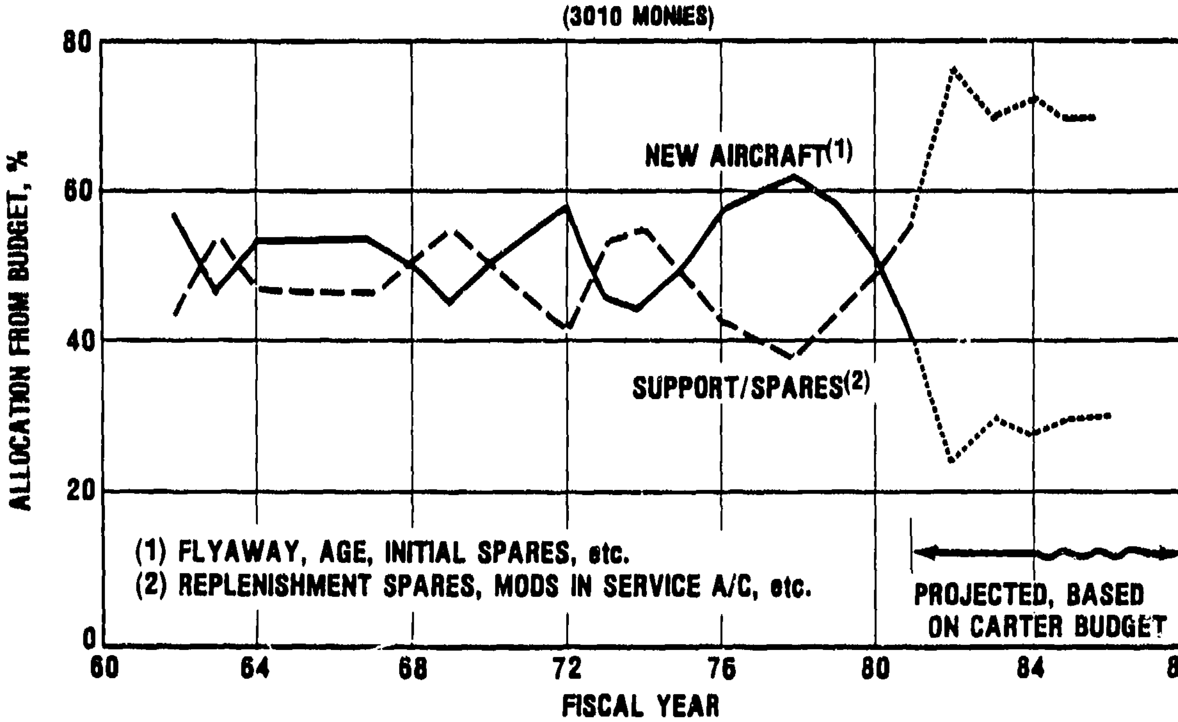


Figure 5 shows a breakdown of O&S cost patterns for the F-4, F-15 and the F-16 aircraft. Essentially, military personnel and O&M costs are the same for the older and the more modern aircraft. The costs for spares are quite different, however. The initial buy of the F-4 included a much larger fraction of spares in the flyaway cost than did the more modern aircraft. The curve for the F-15's acquisition of spares (in the bottom graph) therefore suggests that the needed spares were purchased under the O&S account rather than in the new-aircraft procurement account -- since the spares costs for the F-4 and the F-15 converge rapidly after the initial difference at F-15 IOC. Such a practice may result from the current focus on controlling acquisition costs and the requirement to show cost growth in the system acquisition reviews.

Before proceeding, it is well to explore in some depth what is meant by aircraft 'availability.' The definitions used by the USAF to describe two stages of aircraft availability to fly missions are described here.

<u>Availability, Operational Ready Rate, Mission Capable Rate</u> =

$$1 - \frac{\text{A/C "Out" for Maintenance}}{\text{A/C in Force}}$$

Where

'A/C Out for Maintenance' includes scheduled and unscheduled maintenance and planned modifications. There are variations such as 'fully mission capable,' etc., but the idea is the same.

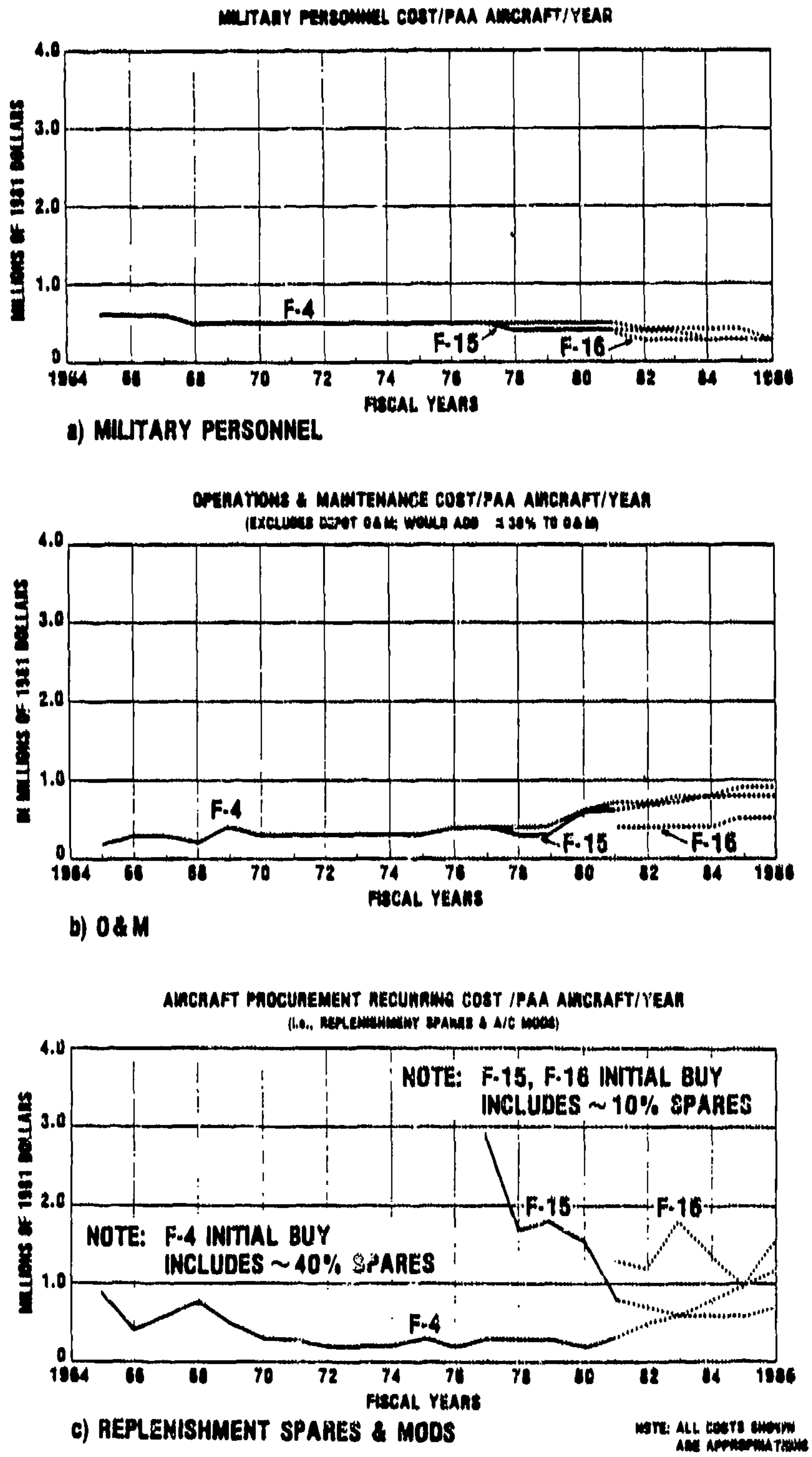
<u>Before Flight Reliability</u> =

Probability A/C on the line will start on Mission

= 1 - (Before-Flight Abort rate).

FIGURE 5

OPERATIONS AND SUPPORT TOA PATTERNS



An attempt was made to relate these definitions to airline practices, through a discussion with a representative of the Air Transport Association. The airlines' analog to 'before flight reliability' is called 'dispatch reliability,' and typical values are the same for the airlines and for the Services. For example, from USAF data the A-7D has a before flight reliability of approximately .97.[1] Dispatch reliability of civilian transport aircraft varies between .95 and .99 with much higher utilization, depending upon the aircraft. The airlines have no analog for operational availability according to the first definition, because (except for major overhaul) maintenance is performed mainly without interrupting the daily flight cycle while the aircraft is at rest (e.g., overnight). Although the airlines do not use their statistical data in the same manner as the Services, it is possible that if operational availability were traced on a daily cycle according to the definition above, the availability of their aircraft might be similar to that of the military.

The airline use of 'dispatch reliability' as a primary measure, and their practice of performing maintenance during the 'off' hours of a daily cycle, suggested examination of data from Southeast Asia operations to explore military comparability further. It was found that no separate availability data were readily accessible to describe aircraft operations associated with Southeast Asia alone, since data for those years have been kept on a fleet-wide, worldwide basis. Further search of the archives might bring more specific data to light. Thus the consideration of 'availability' or its equivalents deal exclusively with peacetime, not wartime, operational factors. The latter may well be both defined and considered differently.

The upper graph in Figure 6 shows some data from an earlier IDA study which indicates that:

- availability varies with the ratio of O&S cost-to-unit procurement costs; and
- this variation displays asymptotic behavior approaching some value between .7 and .8.

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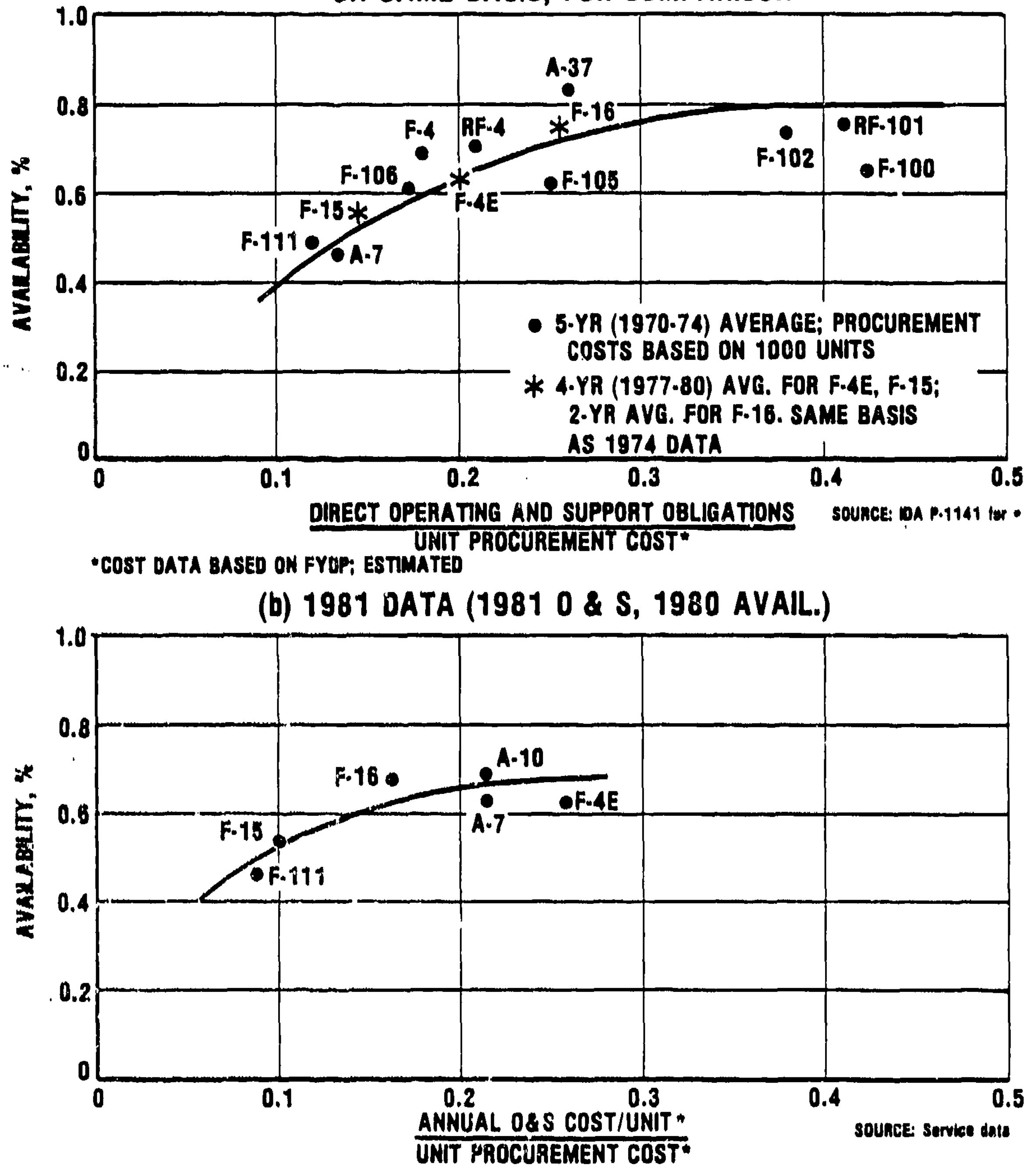
[1] E.g., OC-ALC, "A7D System Effectiveness Report," RCS-LOG-LO(Q)7372, Directorate of Materiel Management, Oklahoma City Air Logistics Center, Tinker AFB, OK, December 1980.

FIGURE 6

AVAILABILITY OF U.S. FIGHTER AIRCRAFT

(a) 1974 DATA; 1981 ESTIMATES FOR 3 A/C, ON SAME BASIS, FOR COMPARISON



*COST DATA BASED ON FYDP; ESTIMATED

(b) 1981 DATA (1981 O & S, 1980 AVAIL.)

*COST DATA FROM USAF COST & PLNG FACTORS AF REG 173-13; UNIT COST CONVERTED TO $1981 FOR OLD AIRCRAFT. AVAILABILITY DATA FROM USAF SUMMARY, COMPTROLLER OF THE A.F.

Recent data for three more modern aircraft, shown by the asterisks, are 'spotted' on this curve, and they affirm the earlier speculation that, if the F-4 and F-15 O&S costs are at about the same absolute level while the F-15 is a much more expensive aircraft, we should expect the F-15's O&S/ procurement cost ratio, and therefore availability, to be lower than that of the F-4.

The lower graph in Figure 6 shows the same variations for many of the same aircraft on a more modern and reliable cost basis. Note how changing the cost basis changes the position on the graph for the different aircraft, although the nature of the overall relationship doesn't change.

In Figure 7, similar availability data for Army and Navy aircraft are compared with the data presented previously for Air Force aircraft. The data suggest that this kind of variation might be the same for the aircraft of all three of the Services. Note:

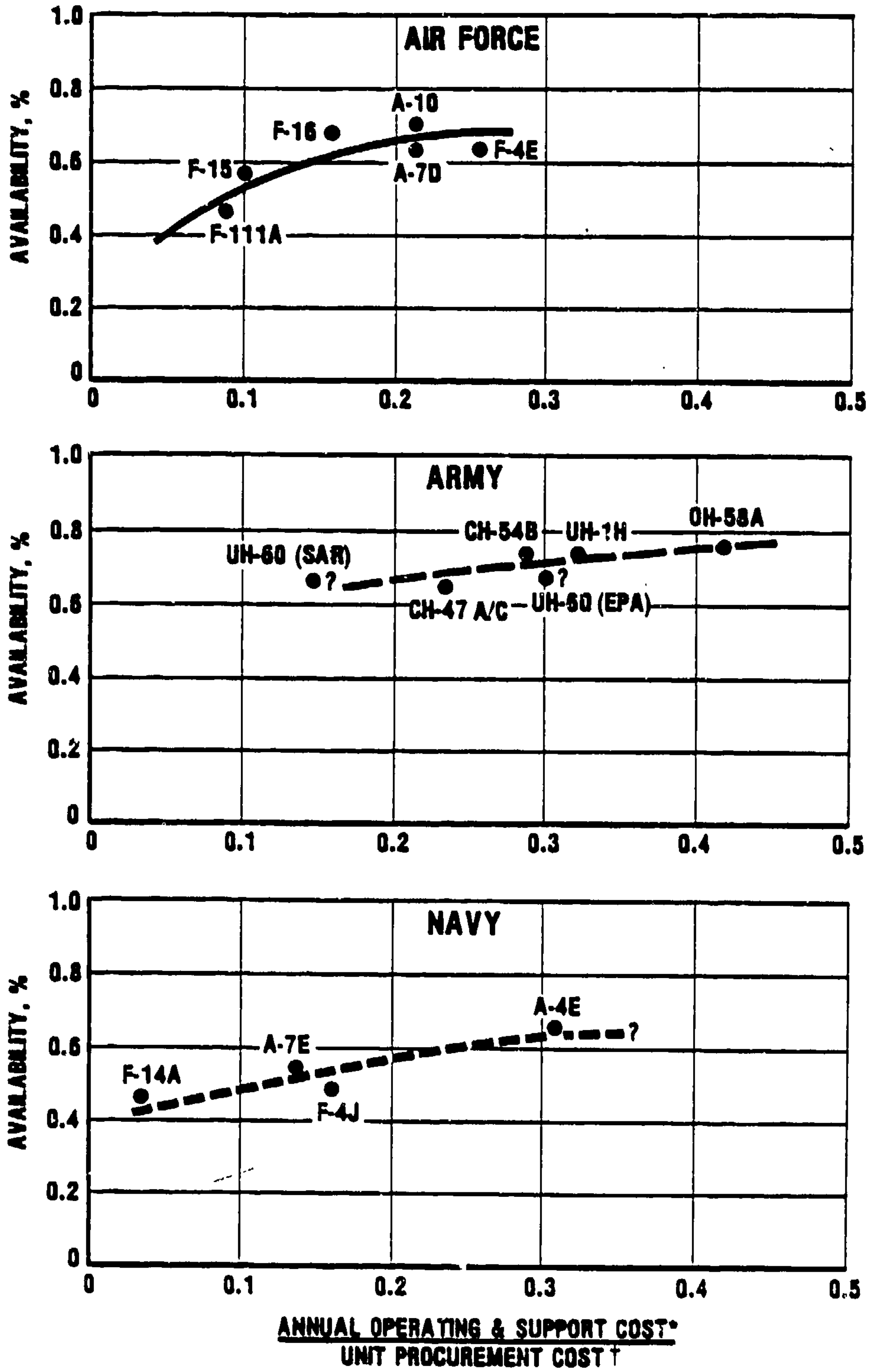
- The position of the F-14, which is an aircraft whose operational readiness has been questioned.

- The difference in the positions of the points for the UH-60 using two different U.S. Army cost sources. The EPA (Extended Planning Annex) data are thought to be more consistent with the data for the other helicopters.

To summarize the data presented above for fighter aircraft, it appears that availability does tend to be lower for more complex aircraft -- but it is also clear that in recent years the initial investment in aircraft spares relative to aircraft cost has been lower than for earlier generation aircraft. The availability of modern aircraft can be increased most quickly by additional expenditures of operating and support funds. Care must be exercised in doing this, however, since the impact of higher O&S expenditures on aircraft availability is nonlinear and has greatest effects when aircraft availability is 60% or less. Some as yet undetected factor may be causing this asymptotic behavior, but it was not discernible from the available data. One should also remember that the analysis is based on peacetime operations and that wartime factors are likely to be different.

FIGURE 7

SOME ADDITIONAL DATA — 1981



* (1981)
† (converted to $1981)

2.3 Helicopter

Figure 8 shows typical variations of helicopter reliability and maintenance cost history. All components of the helicopter appear to follow the same trends, becoming less reliable with time, while maintenance costs increase. However, as will be indicated in the next slide, the interaction of these trends with operational availability is not simple.

The upper graph in Figure 9 shows the operational availability history of several Army helicopters. Note that the availability varies considerably from machine to machine and also from year to year. The data suggest that twin-engine helicopters might have slightly lower average availability than single-engine machines. Although previously (in the pairwise comparison data) it appeared that the UH-60 had lower availability than its older counterpart, the UH-1, it can be seen here that the UH-60's current availability is in the middle of the availability band for all of the machines, so that the implied reduction of availability in comparing the UH-1 and the UH-60 alone may have little real significance.

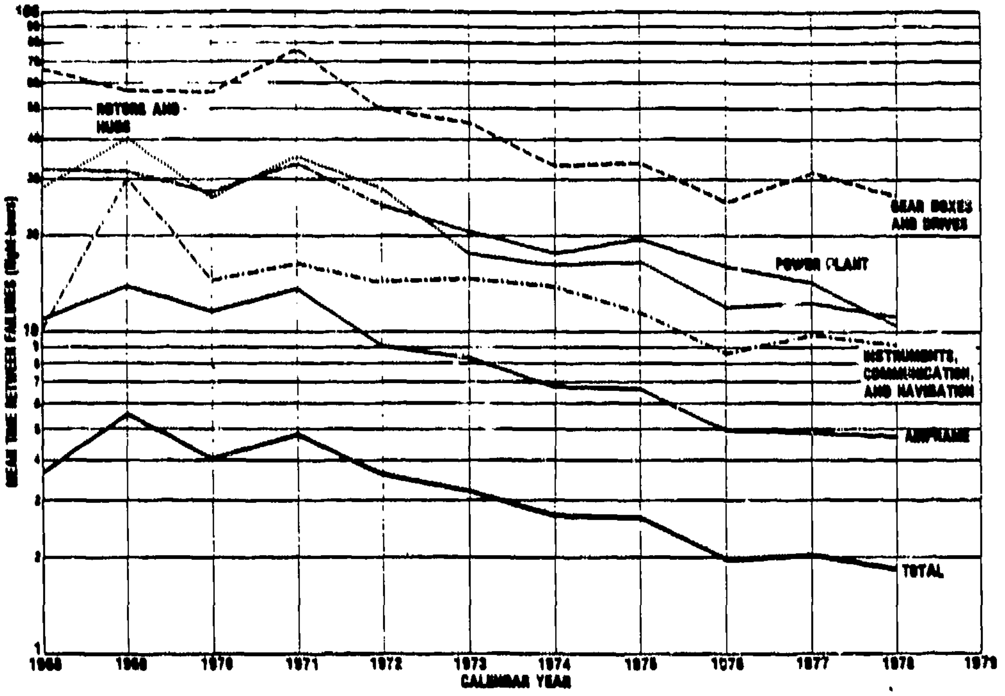
The lower graph examines the question, whether a combat type helicopter might have lower availability than a transport type. The AH-1S, which, although it is a single-engine machine, may be the most complex aircraft of all because it has a gun turret and the TOW missile, also has the highest availability of all the machines in the UH-1 generation.

It appears from these data that the Army has preserved helicopter availability despite the typical reliability and maintenance history displayed earlier. One reason for this is suggested by the data in Figure 10 which show that, much more than the other Services, the Army has drastically reduced flying time per machine in recent years. It was not possible to obtain flying hour data and O&S time histories for the individual helicopters to explore how the Army has balanced operating costs, flying hours, and reliability over time.

As seen above, operational availability varies considerably among helicopter types, and from year to year for a given type. There is no general trend toward lower availability as the helicopter ages, but, characteristically, O&S costs do increase with age. Attack helicopters and the newer generation (UH-60) helicopters do not necessarily show lower availability than the earlier generation utility/transport machines for which there is longer experience.

FIGURE 8

MTBF VERSUS YEAR FOR THE NAVY SINGLE ENGINE UH-1/HH-1/TH-1 SERIES



MMH/FH FOR THE NAVY SINGLE ENGINE UH-1/HH-1/TH-1 SERIES

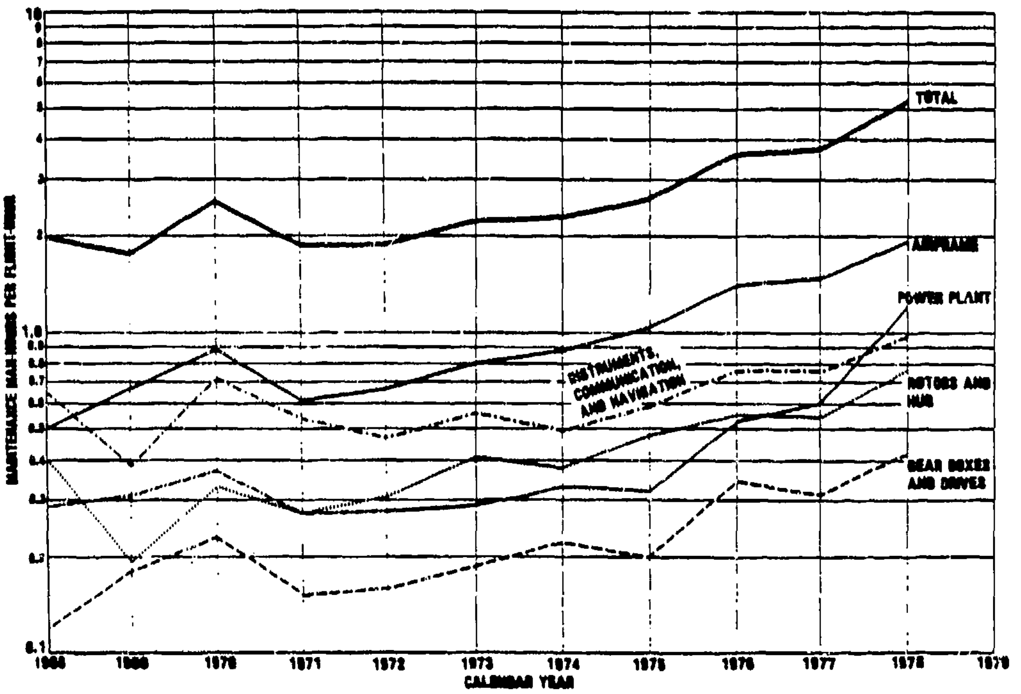
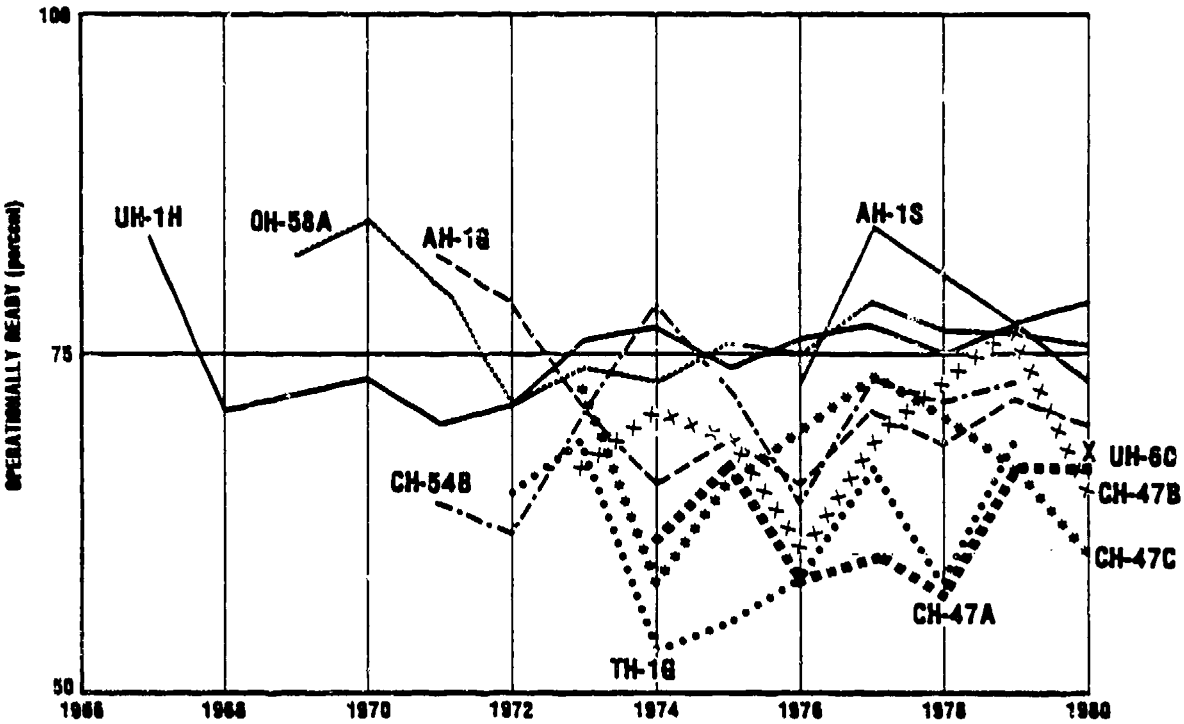
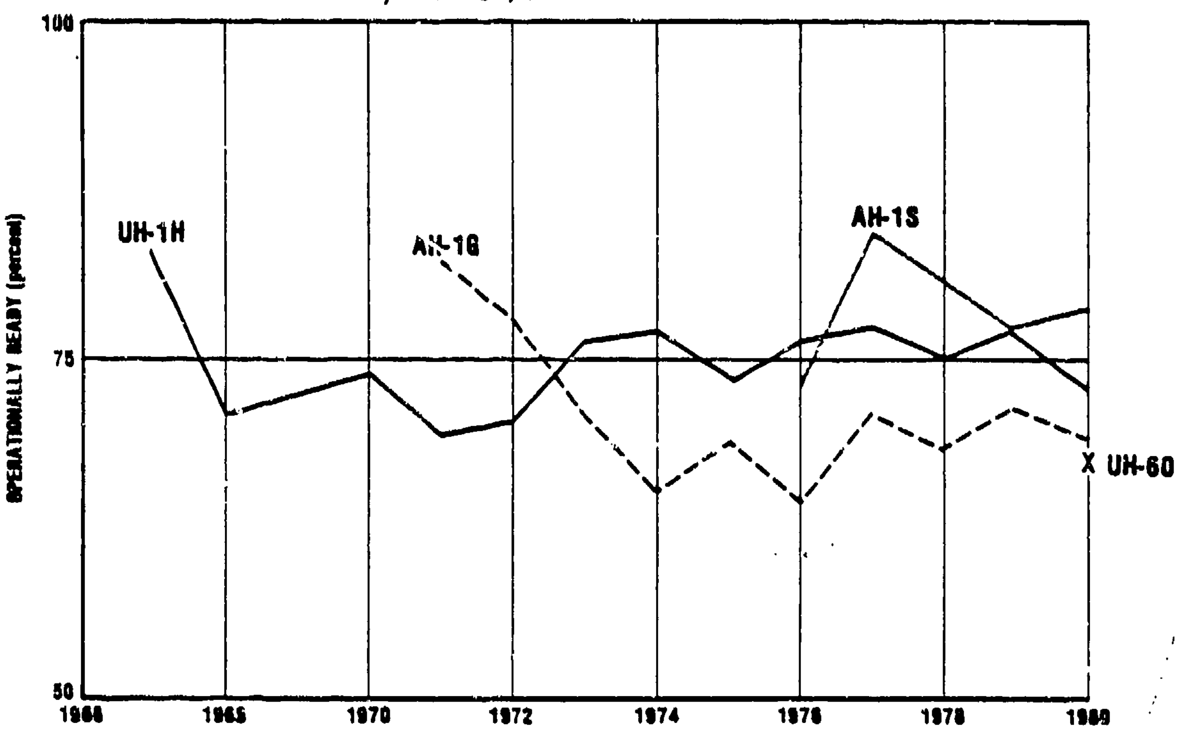


FIGURE 9

AVAILABILITY OF HELICOPTERS



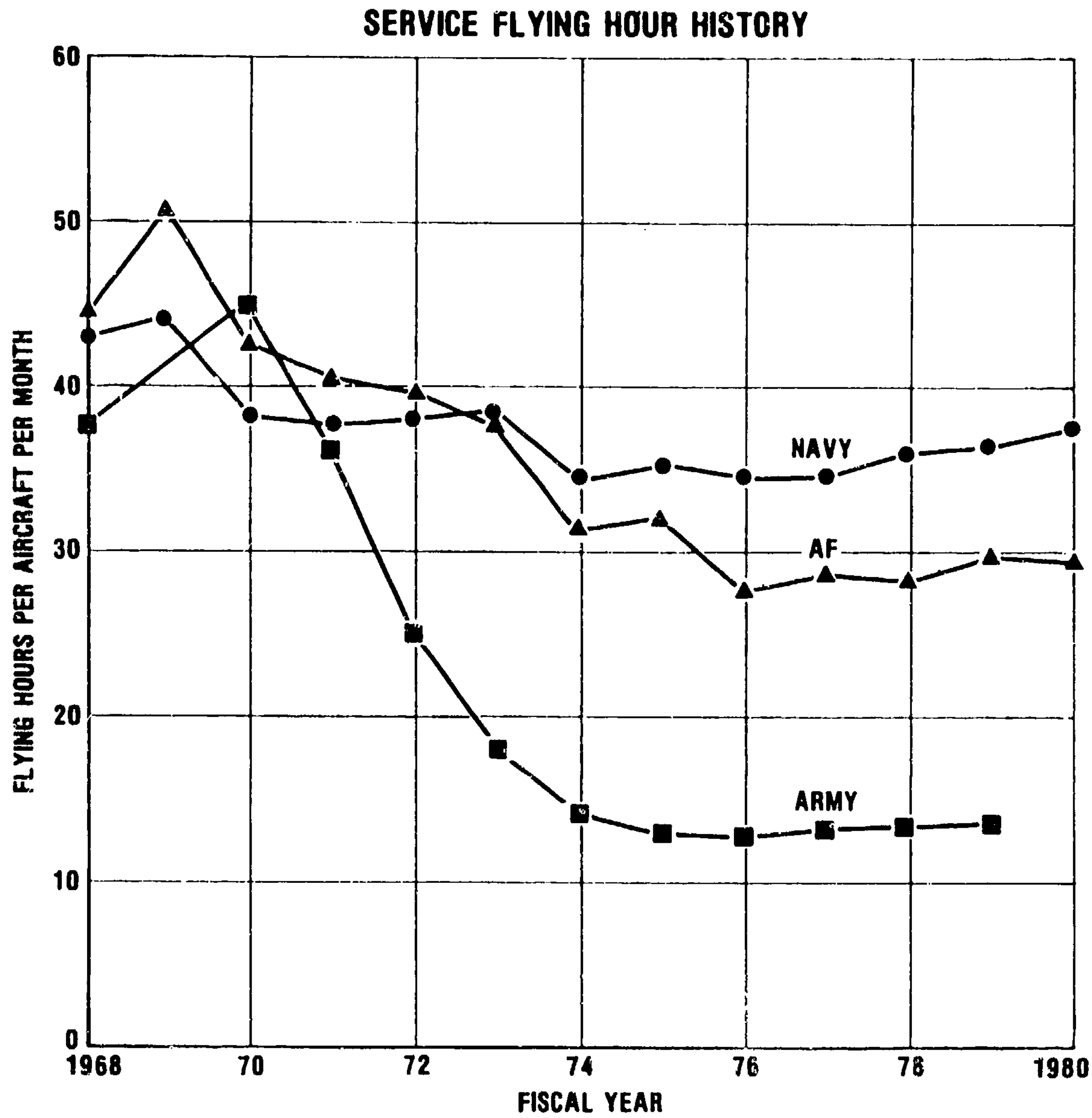
a) 9 HELOS, COMPARED WITH UH-60



b) UH-1/AH-1 VARIANTS, COMPARED WITH UH-60

SOURCE: IDA S-520
UH-60: US ARMY

FIGURE 10


SERVICE FLYING HOUR HISTORY
60
50
40
30
20
10
0
FLYING HOURS PER AIRCRAFT PER MONTH
NAVY
AF
ARMY
1968
70
72
74
76
78
1980
FISCAL YEAR

2.4 Avionics

We now move to the area of avionics. Figure 11 shows data compiled by IDA during the Electronics-X Study.* Unit production cost is taken to be an indicator of complexity, and this curve thus confirms that reliability decreases as complexity increases, unless special measures are taken to avoid this trend.

Figure 12 shows data similar to those in the previous graph (lower curve) on a more precise cost basis (the data were obtained on a proprietary basis during an IDA study of JTIDS). The upper graph shows that as the avionics equipments of the lower curve are replaced by a new generation of technology, the same implied reliability-complexity relationship holds, but, in general, the avionics equipment at a given cost is, on average, five times more reliable. The avionics system designer clearly has many options in using advancing technology, ranging from improving reliability at the same cost to increasing performance without losing reliability, or perhaps some compromise between these extremes.

Figure 13 shows that the newer generation of equipment shown in the previous graphs may cost twice as much to repair as the earlier generation. Taken together, these two sets of data (this and the previous slide) imply that in the avionics area we have gained approximately a factor of three in reduced support cost, in moving from transistor to integrated circuit technology over the period shown (roughly 1975-1978).

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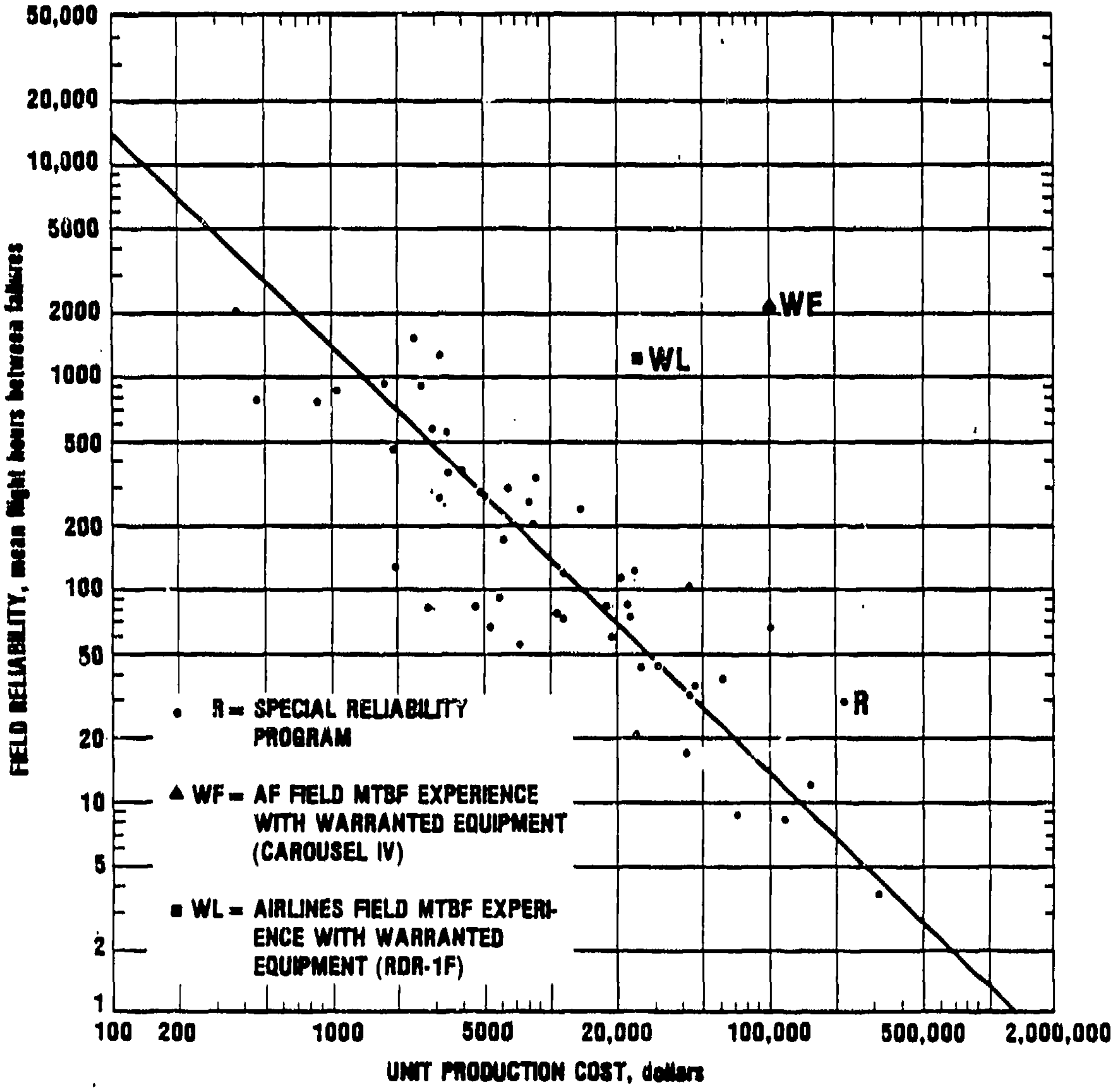
*Gates, Howard, et al, "Electronics-X: A Study of Military Electronics with Particular Reference to Cost and Reliability," (in two volumes), IDA R-195, Institute for Defense Analyses, Arlington, VA, 1974.

FIGURE 11

AVIONICS FIELD RELIABILITY VERSUS UNIT PRODUCTION COST



Source: Electronics-X (1973).

FIGURE 12

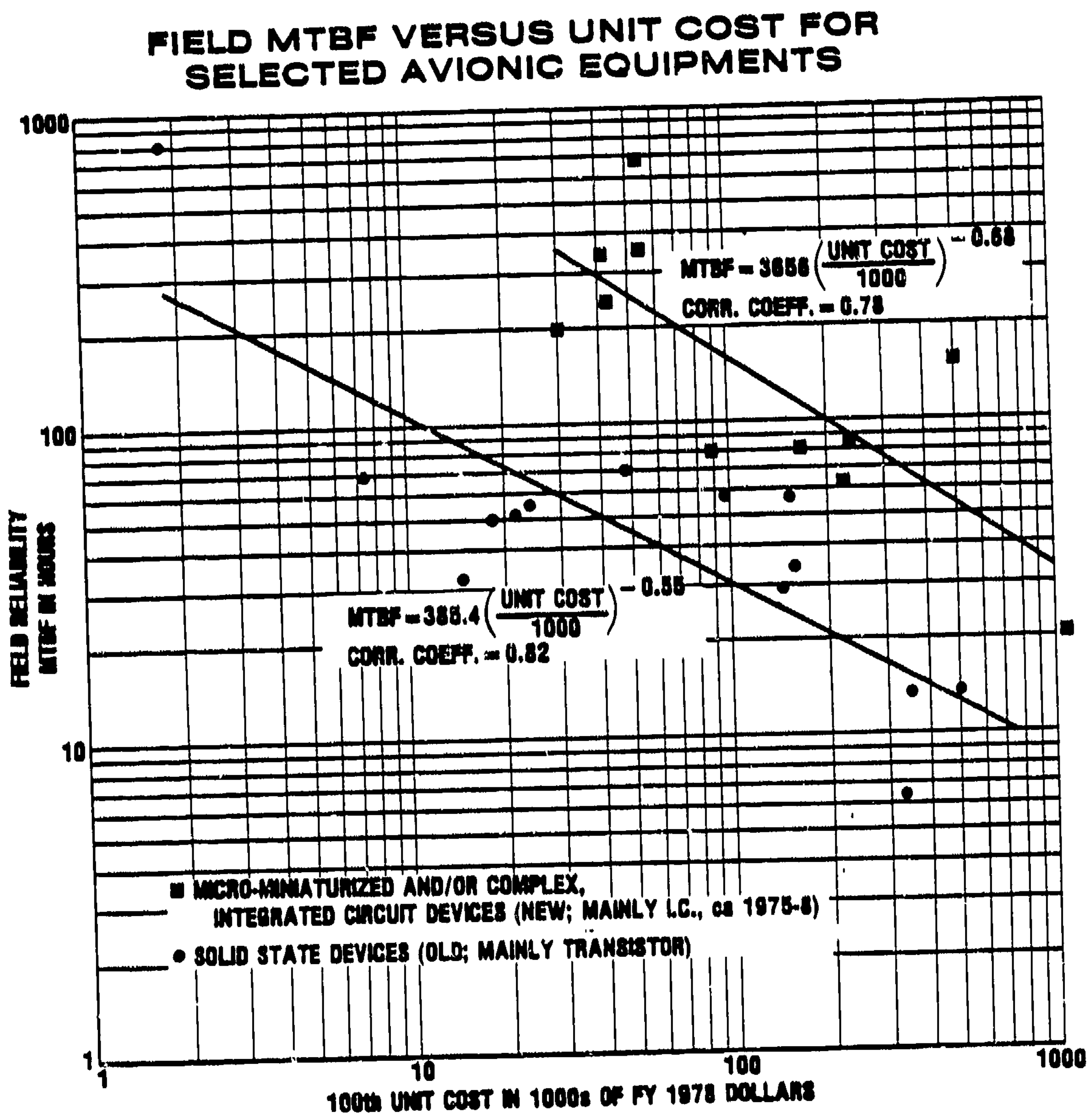
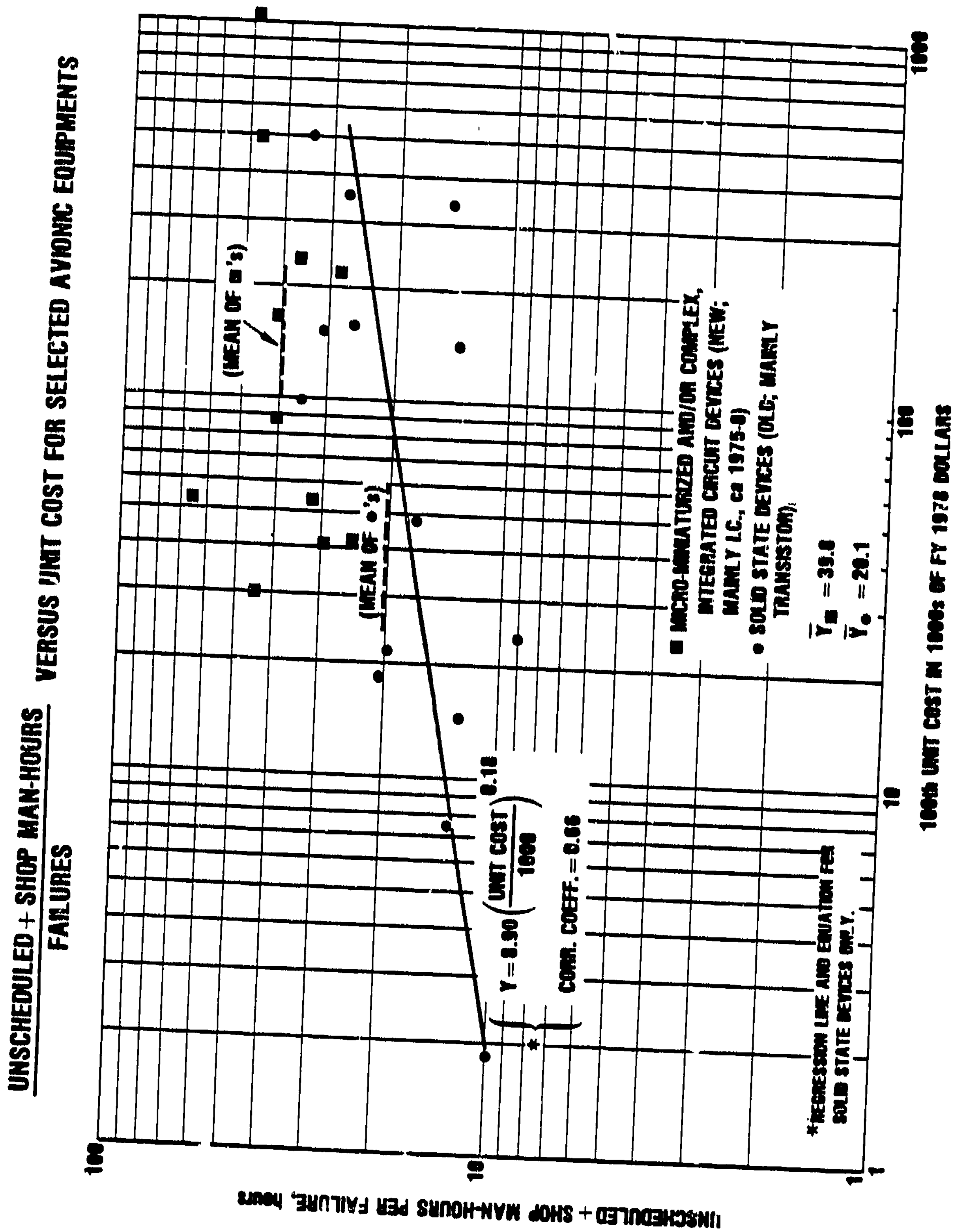

FIELD MTBF VERSUS UNIT COST FOR SELECTED AVIONIC EQUIPMENTS
MTBF = 3656 (UNIT COST / 1000) − 0.68
CORR. COEFF. = 0.78
MTBF = 386.4 (UNIT COST / 1000) − 0.55
CORR. COEFF. = 0.82
FIELD RELIABILITY MTBF IN HOURS
1000
100
10
1
1
10
100
1000
■ MICRO-MINIATURIZED AND/OR COMPLEX, INTEGRATED CIRCUIT DEVICES (NEW; MAINLY I.C., ca 1975-8)
● SOLID STATE DEVICES (OLD; MAINLY TRANSISTOR)
100th UNIT COST IN 1000s OF FY 1978 DOLLARS

FIGURE 13


UNSCHEDULED + SHOP MAN-HOURS / FAILURES VERSUS UNIT COST FOR SELECTED AVIONIC EQUIPMENTS
UNSCHEDULED + SHOP MAN-HOURS PER FAILURE, hours
100
10
1
100th UNIT COST IN 1000s OF FY 1978 DOLLARS
10
100
1000
(MEAN OF ■'s)
(MEAN OF ●'s)
Y = 8.90 (UNIT COST / 1000)^0.18
CORR. COEFF. = 0.66
■ MICRO-MINIATURIZED AND/OR COMPLEX, INTEGRATED CIRCUIT DEVICES (NEW; MAINLY I.C., ca 1975-8)
● SOLID STATE DEVICES (OLD; MAINLY TRANSISTOR)
Y■ = 39.8
Y● = 20.1
*REGRESSION LINE AND EQUATION FOR SOLID STATE DEVICES ONLY.

The two graphs in Figure 14, taken from two discussions about computers published eleven years apart, suggest the general trend of increasing reliability at reduced unit cost has held in the computer area and is expected to continue. This reinforces the implied conclusion from the previous avionics data (and the earlier calculator comparison) that in the electronic equipment area, support cost appears in general to be declining, while functional complexity increases -- a trend that is due largely to the advance of technology.

Because of great capability increases in devices (components), and a recent ability to design radars whose signal processing and control functions are performed by high-speed digital devices, the benefits just described for computers are also realized in fighter radars. Moreover, if reliability is made a key requirement of the initial specifications, the designer can apply the new component technologies specifically for that purpose.

The difference between MFHBF and MTBF is the increased operating time resulting from ground operations, which statistically adds about 50% to the flight hours. The preliminary data on the F/A-18 is based on about 535 flight hours at the Lemoore Naval Air Station. It is interesting to note that one F/A-18 fighter aircraft radar achieved 230 and another has accumulated 103 hours without failure. The MTBF for the F/A-18 radar is 106 hours. The F/A-18 radar has more air-to-air and air-to-ground operating modes than any other operational radar and has substantial growth potential via software development.

The chart shows that avionics can provide significantly more operational capability with a much lower life-cycle cost.

Figure 15, derived from the Electronics-X Study, illustrates another facet of the problem of measuring the effect of technological progression as it faces the DoD. Suppose point X represents a current system design (on a cost-performance curve) using current technology. With new technology in the offing, it may be decided to accept an increase of cost provided it will lead to a large increase in performance -- e.g., point 4a on the dashed line. However, actual experience with the technology may follow the dot-dash line instead. If so, adherence to the initial performance specification would cause much larger costs than initially expected. Another alternative in specifying the new-system requirement would have been to plan to use the advanced technology to reduce cost while achieving a more modest performance gain, as indicated by point 4b. While there are many

FIGURE 14

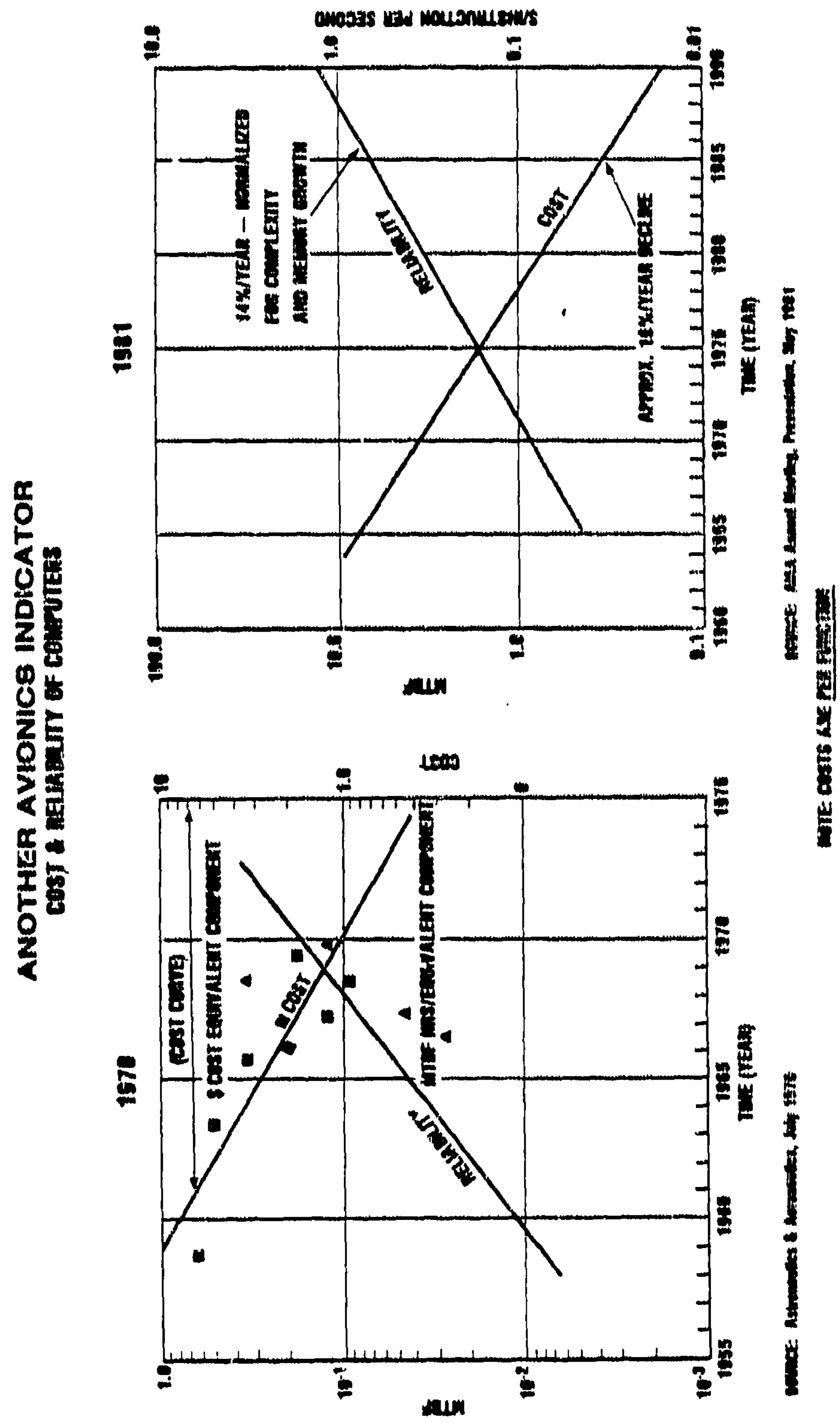
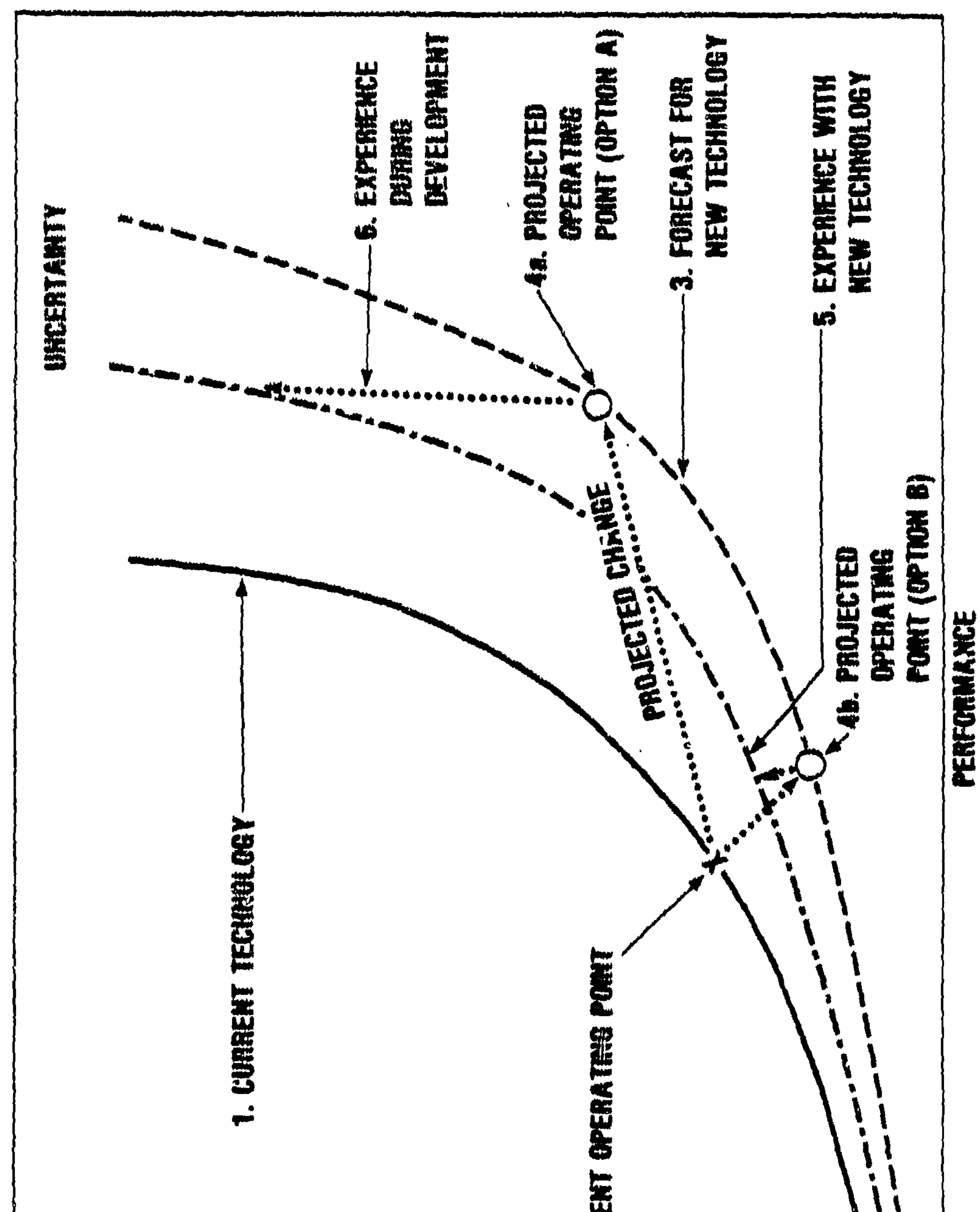

ANOTHER AVIONICS INDICATOR
COST & RELIABILITY OF COMPUTERS
1978
1981
MTBF
COST
$/INSTRUCTION PER SECOND
TIME (YEAR)
RELIABILITY
$ COST
$ COST EQUIVALENT COMPONENT
(COST CURVE)
MTBF HRS/EQUIVALENT COMPONENT
14%/YEAR — NORMALIZED FOR COMPLEXITY AND MEMORY GROWTH
APPROX. 18%/YEAR DECLINE
SOURCE: Astronautics & Aeronautics, July 1978
SOURCE: AIAA Annual Meeting, Presentation, May 1981
NOTE: COSTS ARE PER FUNCTION

FIGURE 15

EFFECT OF REQUIREMENTS DECISIONS ON COST



examples of the history described by point 4a, it is more difficult to find examples of the history described by point 4b -- one might be the laser-guided bomb* and another might be the F-16.

In summary, then, avionics reliability does decrease with increasing complexity for a given generation of technology. However, reliability is increasing for systems of comparable costs as technology advances. Although the cost per repair is increasing as technology advances, the frequency of repair appears to be decreasing faster than the cost of repair is increasing, so there is a net benefit.

2.5 General Observation

As a result of the IDA analysis, a few other observations and speculations can be raised. As seen, advancing technology is not necessarily related to declining readiness with increasing complexity. On the one hand, availability for F-111 < A-7 <A-10. At the same time, electronic equipment of a given generation becomes less reliable as it becomes more complex, but reliabilty is increasing as technology advances. These are countervailing trends and there appears to be no single relationship between advancing technology, complexity, and readiness.

On the other hand, even the limited data available indicates there are institutional factors which clearly have a strong effect on system operational availability. Among these are design trends (e.g., increasing number of replaceable units), budget allocation (e.g., for spares, flying hours), impacts on maintenance policies and practices (e.g., cannibalization), and interaction with personnel policies and practices (e.g., numbers, quality, training).

Clearly, operating and support requirements also depend on the extent to which the design is stressed by the operational requirements. However, data to explore this issue is scarce. The Panel supports the DoD initiative to obtain O&S data, including depot costs, on a system by system basis rather than by class. When this data is available, case by case analyses and cost/performance control will become easier.

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*deLeon, P., "The Laser Guided Bomb: Case History of a Development," Air Force Project RAND, Report R-1312-1-PR, June 1974.

2.6 Cost Trends by System

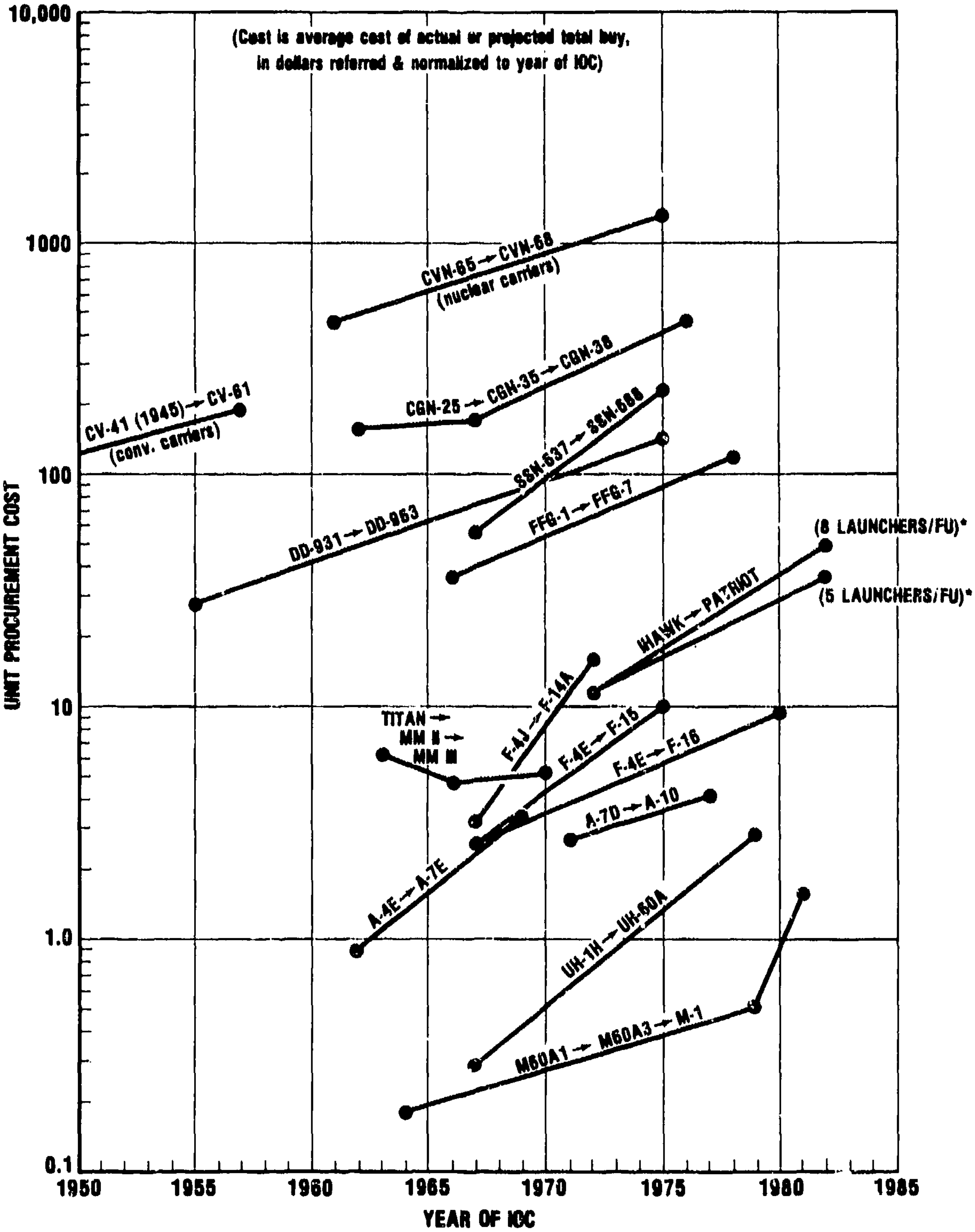
Figures 16 and 17 show the changes of procurement unit cost for the successive generations of systems which were reviewed. The costs shown are average costs for the total actual or projected numbers of systems acquired (in some cases of major ships the number is 1), and the date is the year of IOC. In Figure 17, the unit procurement costs of all items procured are referred to and expressed in dollars of the year of IOC. In Figure 18, the costs are all presented in terms of constant FY-81 dollars. Not surprisingly, the costs of successive system generations rise steeply when shown in terms of constant-year dollars normalized to year of IOC, while the rise is not nearly as steep when shown in FY-81 dollars. Of particular interest is the fact that the cost of major ships (except for SSNs) has barely increased in real terms, and has declined somewhat for the most expensive ships, nuclear-powered carriers. The cost of ICBMs has decreased as the technology has improved. The steepest intergenerational cost rises among the systems reviewed are shown by high-performance aircraft -- a fact well known from many prior reviews of defense system acquisition costs. The cost increases for tanks and utility helicopters, although relatively steep for the recent systems compared with their predecessors, are not large in absolute terms on a per-unit basis since these are the least expensive systems shown on the figure (and note that the costs are shown on a logarithmic scale). The data shown here does not account for the impact of variations in production rates or performance.

2.7 Cost-Performance Comparisons

As a means of assessing in general terms whether system performance has been advancing at least as rapidly as system procurement and O&S costs, the performance and cost data presented in the report of the IDA study were combined as shown in Figures 18 and 19. The ordinate of each figure shows, for selected systems, where comparison is possible in consistent terms, the ratio of an indicator of performance of a new-generation system to the same performance indicator for the system it replaces. The abscissa shows the ratio of unit procurement costs of the system pairs (Figure 18), or unit O&S costs (Figure 19), both in constant FY-81 dollars. The parity line traces the points at which the performance ratio and the cost ratio are equal: in the region above the line, performance increased faster than cost in the generational progression; below the line, performance increase lagged behind cost increase. Again, the impact of differing production rates has not been factored into this data.

FIGURE 16

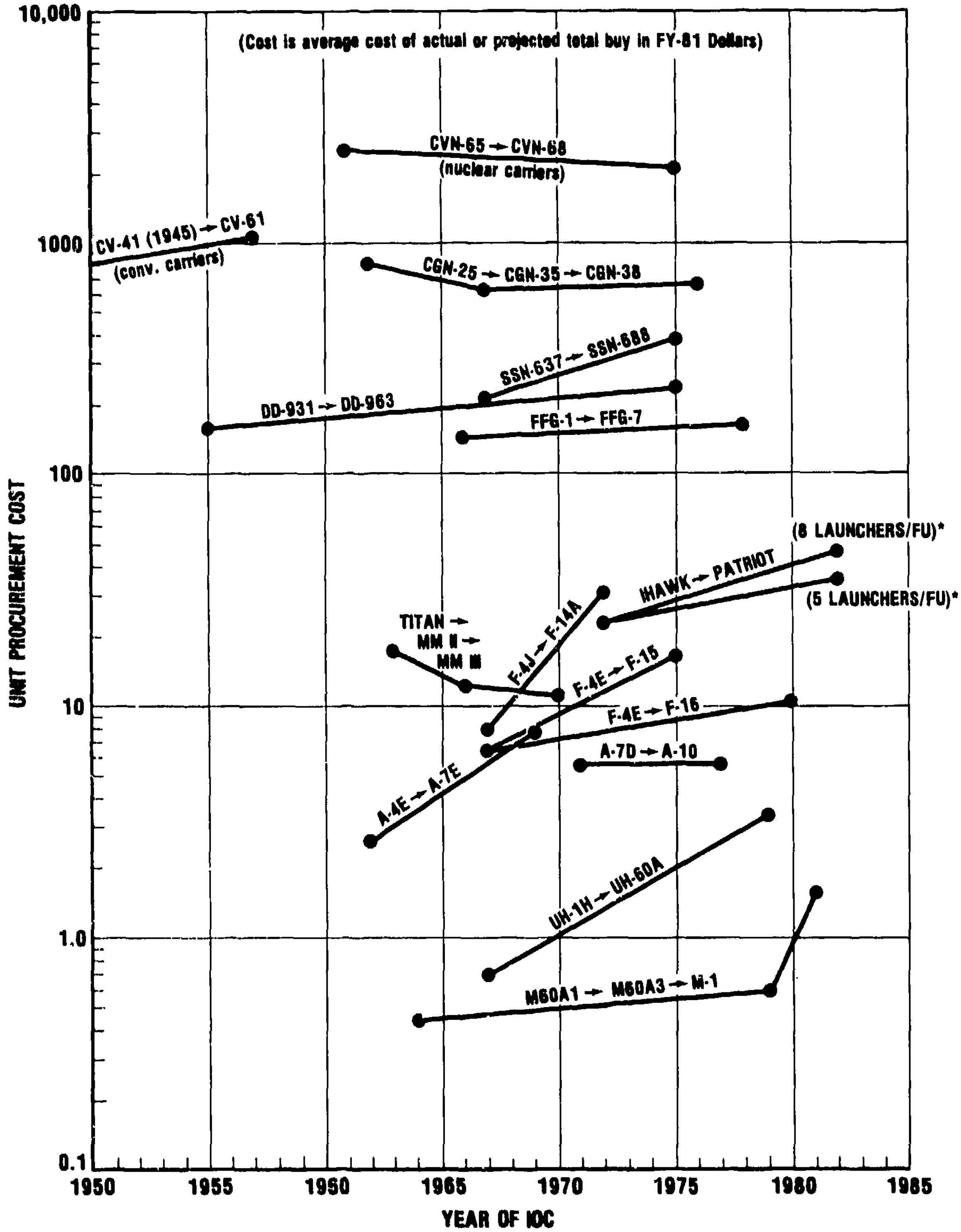
PROCUREMENT COST PROGRESSION IN YEAR-OF-IOC DOLLARS



*NOTE: "Standard" Patriot buy includes 5 launchers/fire unit; performance ratio was based on 8 launchers/f.u., projected use in Europe in the study providing the performance ratio. (f.u. = fire unit)

FIGURE 17

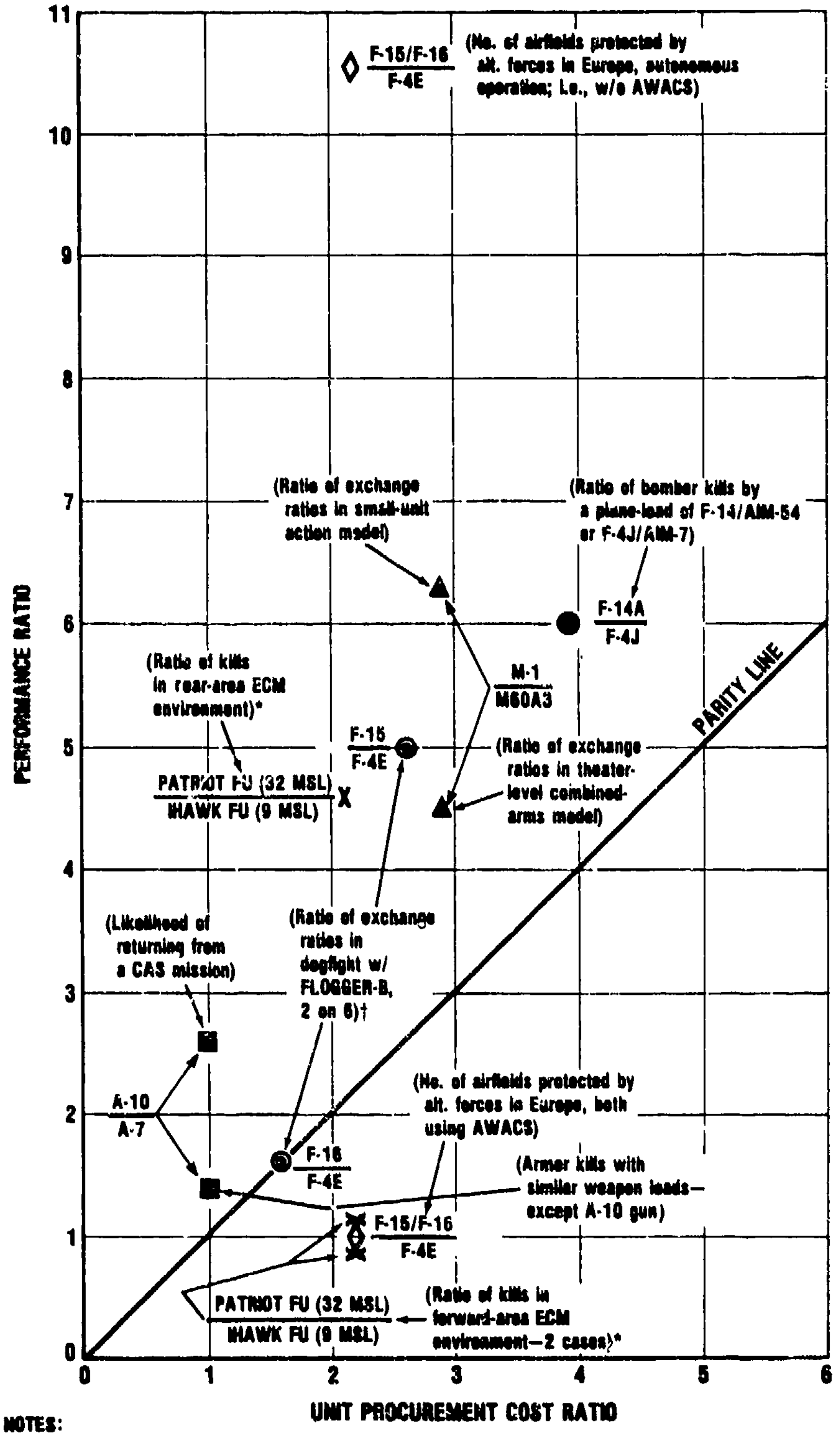
PROCUREMENT COST PROGRESSION IN CONSTANT FY-81 DOLLARS



*NOTE: "Standard" Patriot buy includes 5 launchers/fire unit; performance ratio was based on 8 launchers/f.u., projected use in Europe in the study providing the performance ratio. (f.u. = fire unit)

FIGURE 18

VARIATION OF PERFORMANCE RATIO WITH PROCUREMENT COST RATIO, SELECTED SYSTEMS AND MEASURES



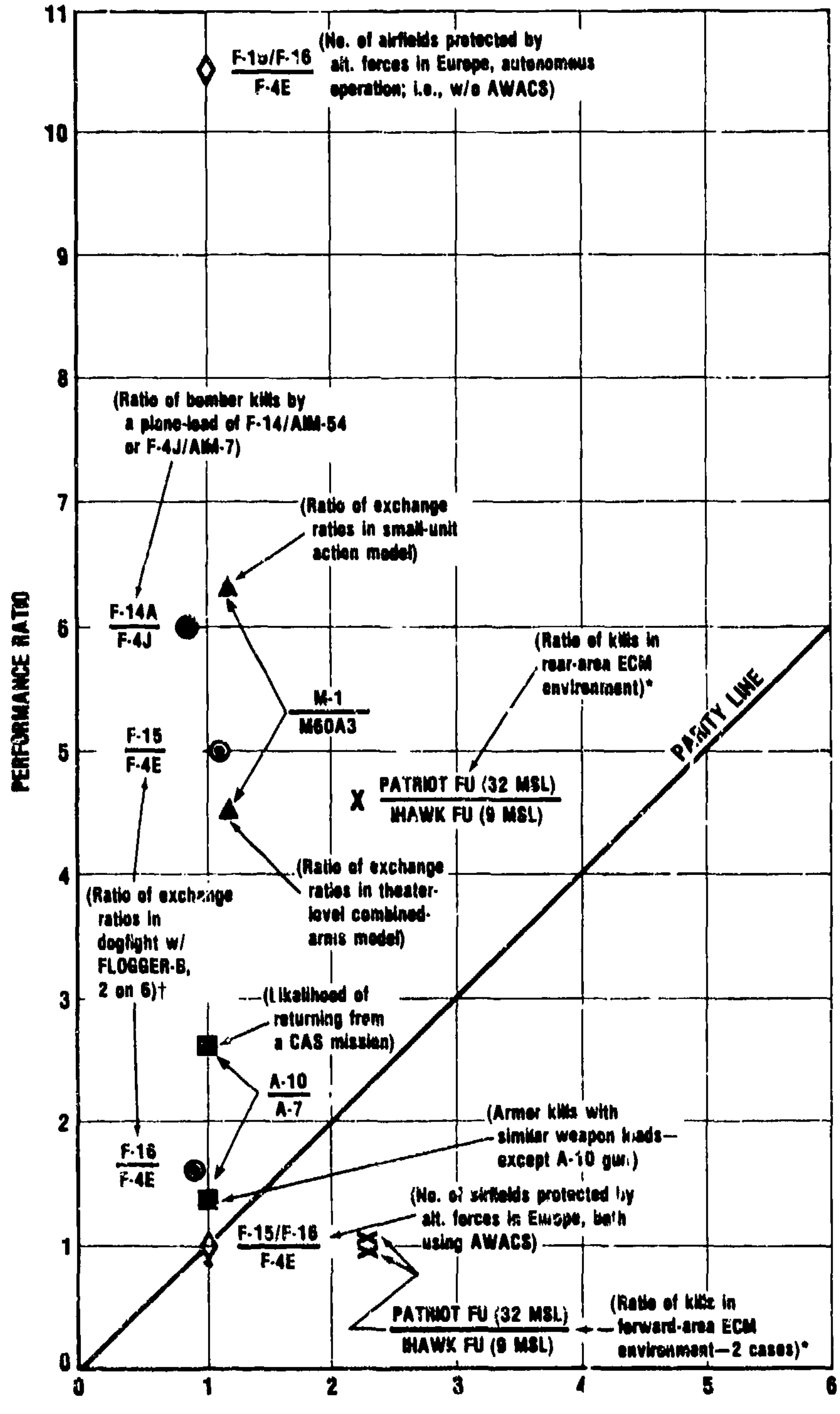
NOTES:

*These data for low-altitude engagements; PATRIOT/IHAWK ratio is ∞ at medium-high altitude since IHAWK capability in conditions shown is zero while PATRIOT is little degraded. Forward area results weighted by forward/rear ratio of PATRIOT kills. (f.u. = fire unit)

†F-16/F-4 comparison based on use of AIM-9L only; F-15/F-4 comparison based on use of AIM-9L plus AIM-7M.

FIGURE 19

VARIATION OF PERFORMANCE RATIO WITH O&S COST RATIO, SELECTED SYSTEMS AND MEASURES



NOTES:

*These data for low-altitude engagements; PATRIOT/HAWK ratio is ∞ at medium-high altitude since HAWK capability in conditions shown is zero while PATRIOT is little degraded. Forward area results weighted by forward/rear ratio of PATRIOT kills. (f.u. = fire unit)

†F-16/F-4 comparison based on use of AIM-9L only; F-15/F-4 comparison based on use of AIM-9L plus AIM-7M.

The performance indicators, and therefore the performance ratios, were all determined from analyses for which results comparing the system pairs were available, and in which special circumstances and specific assumptions apply. These circumstances and assumptions are given in detail in the IDA report. They are summarized briefly for each point on Figures 18 and 19. The PATRIOT/IHAWK comparison is the only one for which the performance indicators were modified from the simple ratios described on the figures. In that case, the performance ratio (i.e., ratio of kills) of PATRIOT to IHAWK was multipled by the ratio of calculated PATRIOT kills in the forward area to the calculated kills in the rear area, to reflect the potentially more severe degradation of that system by ECM in the forward area.

The conclusion that may be drawn from these figures is that, in general, for the systems examined and in the applicable circumstances, performance has been increasing faster than either procurement cost or support cost. The systems compared represent a broad spectrum of military capability and the circumstances of comparison represent, in a reasonable way, how the systems will be used.

Some exceptions to this general conclusion are apparent on the graphs. The calculated PATRIOT/IHAWK performance ratios, as modified, are much lower than the cost ratios for the cases where performance is considered severely degraded by ECM. The dogfight performance advantage of the F-16 over the F-4 is shown to be small, because the calculations included only the AIM-9L short-range missile (corresponding to current F-16 capability and the German version of the F-4E) and not the AIM-7 or a more advanced radar missile. The F-15 results show great advantage over the F-4 in the dogfight case, but the use of AWACS (whose cost is not included) could make the F-4 as effective as the F-15/F-16 combination in defending bases -- i.e., the ability to intercept attackers before they reach weapon release points (not the relative ability to shoot them down).

It is also important to point up the obverse of these exceptions to the general conclusion, which is not captured by the simple performance ratios. This is, that in every case there is some unique performance characteristic of the new-generation system that permits it to do something the system it replaces couldn't do:

- simultaneous, longer-range engagements for the F-14/ PHOENIX.
- tank-killing gun on the A-10.

- autonomous (i.e., no AWACS) operation for the F-15.*

- multiple simultaneous engagements, and high-altitude engagements, by PATRIOT under ECM conditions that severely degrade IHAWK or render it ineffective.

- greater mobility and agility of the M-1 tank.**

Positive and negative factors such as those outlined must be taken into account in assessing the significance of the comparisons and judging whether the performance advances in succeeding generations of systems are worth the cost increases.

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* The models used for the comparisons didn't reflect the differences in dogfight maneuverability of the aircraft.

**The models used did reflect the effects of the M-1 armor.

IMPACT OF THE SYSTEM ACQUISITION PROCESS ON READINESS

3. IMPACT OF THE SYSTEM ACQUISITION PROCESS ON READINESS

~~ral of the questions posed in the Panel Charter led to con- side ..on of various facets of the system acquisition process from requ..ements determination, through development, to operational testing and evaluation. The Panel's conclusions concerning the relationship of the acquisition process to system readiness are discussed in this section. In summary, the Panel sees no need for major changes in the existing acquisition process. Within the existing process, however, there does need to be increased emphasis on readiness in all phases. It is also clear that if we are to have operationally ready systems, we must provide the trained people to operate and maintain them, and we must purchase the spares required to keep the systems operating. The Panel was also encouraged to find that recent DoD memoranda are providing much of the required emphasis.

3.1 The Program Manager's Role in Readiness

The Panel has reviewed the Deputy Secretary of Defense memorandum of 30 April 1981 as it relates to readiness and sustainability and the 13 June 1981 memorandum on the same subject. The Panel fully supports the views expressed in these memoranda; however, we believe that it will be necessary for the Department of Defense to shift its focus somewhat if these critical recommendations are to be implemented fully.

The problem is basic. Senior acquisition executives in both government and industry maintain a strong interest in major weapon systems during their development and production. During these phases, a disproportionate emphasis is often placed on performance and cost, while actions required to ensure the readiness of the system once it is fielded do not enjoy the same attention. A shortfall in performance is noted quickly and corrective action is taken without delay. Projected shortfalls in system readiness are assessed more slowly and corrective action is often delayed, with the requisite authority often diffused.

Once the system has attained an initial operating capability, the situation rapidly worsens. The interest in our major weapon systems by senior managers often drops markedly at this point, perhaps due to the misguided notion that the most critical phase of the system's life cycl has just been passed. The fact is that the most difficult, and one of the least glamorous phases, lies immediately ahead. Attaining a high level of operational readiness for advanced weapon systems requires continual emphasis on such things as personnel selection, training, spare parts, and the logistic support organization, test equipment, and simulators. Attention to these critical areas must be focused early in the program and it must persist well into the operational lifespan of each system.

By definition, the program manager of any given system has overall responsibility for that system. At the present time, however, his authority is not sufficient to allow him to be fully responsible for the attainment of specific system readiness goals. His authority over the level of spare part support and types of spares to stock is usually incomplete. As the system is fielded, the authority of the program manager over personnel criteria, training plans, and the logistic support organization is, at best, remote. Yet all of these factors have a direct impact on the readiness of the system in the operational command.

The Panel believes, if the priority for system readiness is to be elevated to the same level presently placed on system performance, an identifiable system advocacy program must be institutionalized. The logical overall system advocate is the program manager and he must be given both the authority and the responsibility to perform this task. It would not be necessary to increase the program manager's directive authority to make him a more effective advocate. To be sure, this authority can and should continue to rest with the functional managers who would be properly charged with the responsibility to support the program manager. It would be necessary, however, to increase the program manager's visibility into issues relating to personnel, logistics, spares policy, etc. A program director carries out his program using a matrix organization which draws support from a variety of horizontally managed disciplines such as personnel, logistics, etc. He does not control these organizations or their funding. As a result, when the personnel demands of a given system are defined, they compete in the people arena with the demands of all the other systems and the program director does not control the success with which appropriate personnel are provided. Therefore, a key ingredient of an effective system is beyond the program director's ability to deliver. The Panel discussed the possibility of <u>vertical management</u> of all related resources by the program director and concluded that such an approach was not practical in most cases. It is conceivable that it might be workable for a very small number of very high priority programs, but the Panel does not recommend this approach and suggests that, if it is used, it should only be as a last resort. Instead, the Panel recommends that the program director and all other acquisition agents should have <u>vertical visibility</u> into each of these areas so that the support functions are given the priority necessary to achieve effective systems.

As one means of enforcing vertical visibility the Panel would recommend that program sponsors be required to have representatives of personnel, training, logistics, etc., present at all major program reviews. In this way these factors would become normal and important parts of the reviews. It is also suggested that readiness reporting include vertical visibility into the support factors.

Given this increased visibility, the program manager/readiness advocate could identify to the appropriate functional managers those high leverage items required to ensure a high readiness level for his system. He could provide an early warning on problems related to quality of support and could isolate those facets of the functional support system that would require modifications due to the peculiarities of his system. Finally, the program manager/readiness advocate could see that the money required to achieve the needed readiness level is identified in the programming process and is retained during the budget execution phase. The program manager should be required to provide his assessment of the consequences to system readiness of any proposed cutbacks in required funding.

It would be necessary that the program manager's office be properly staffed if he is to be an effective readiness advocate. His office must have an appropriate representation of logisticians and other support specialists, although the composition of the office would fluctuate as the program proceeded from one phase to the next. For example, more logisticians would be required after the system is fielded and these added support specialists could replace development specialists who presently are sometimes retained too long in the offices of program managers.

Although the essence of an effective system readiness advocacy program would establish the program manager as the key element, other agencies must participate as well. For example, the military departments should conduct comprehensive system readiness reviews, at least semianually. These reviews, using consistent measures of system readiness, should be conducted for all major weapon systems. An early alert of impending problems, signalled by a program manager or a military department, could lead to prompt corrective action and, if appropriate, an extensive probe in search of root causes. During the departmental review, as well as during the program manager's regular assessments, consideration should be given to tradeoffs across functions as well as within functions.

If the military departments perform their jobs effectively, there should be no need for greater involvement by the Office of the Secretary of Defense than under current arrangements, although it does appear appropriate to delineate responsibilities within the OSD staff (as well as other staffs) to ensure fully coordinated and focused support to the program readiness advocate. Considering the importance of improving system readiness, it is also recommended that each military department brief the top managers in OSD at least annually. This briefing should highlight the actual and projected operational readiness factors for each major weapon system, the corrective action taken, and the assistance required from the Office of the Secretary of Defense.

We believe there is no question that acceptably high readiness rates can be achieved for advanced weapon systems. We are also convinced that a change in management emphasis, as outlined in the prior paragraphs, is required if the increased system readiness is to be attained and maintained consistently.

3.2 Balancing Performance, Cost, Schedule and Readiness

As the Panel went through its deliberations it became clear that the preoccupation with modernizing the force, and the attendant emphasis on cost and schedule, had caused related factors such as personnel, training, logistics, reliability and maintainability, etc., to receive less priority and funding than is required to achieve an effective operational system. This problem has occurred because there has been inadequate funding, in some cases, to both modernize the force and maintain the current force at high readiness levels. This had led to conscious service decisions to modernize at the expense of readiness. A second factor in low readiness has been that existing DoD procedures for ensuring adequate treatment of the support functions have not been given the priority they deserve in the management of the acquisition process at all levels. It seems clear that what is called for is a balanced approach to all the factors -- design, cost, schedule, personnel, training, logistics, etc. -- which are integral to the acquisition and operation of effective weapon systems. We must be prepared to spend the funds required to provide the personnel, spares, training, and documentation to complement the system hardware and software. Equally important, consideration of these factors must begin in the concept definition phase and continue throughout the life of the acquisition program. Very early in a program the Services should establish, in the requests for proposals, realistic estimates of the manpower, personnel, training, and logistics support to be associated with the system. These factors should then be given appropriate weighting in the source selection process. In this way industry will have a statement of the support boundary conditions within which the system must operate. As discussed elsewhere in this report, availability to the user of a real system capability should be the measure used throughout the life of a program. Innovative support concepts should be evaluated early enough to affect hardware design. The concept of integrated logistics support should be broadened to one of total system support and added management attention provided at all levels. The Panel felt that only through actions such as these would long-term improvements in system readiness result. As a corollary observation, when it is necessary to cut the funds allocated to a program, those cuts should be made vertically across the design and support areas so as to avoid delivering a system which is unsupportable.

As noted above, the Panel believes more emphasis needs to be placed on readiness very early in the development cycle. A program director assigned to acquire some new vehicle, weapon, command and control center, or whatever is faced with a myriad of conflicting demands. They include achieving required performance within acceptable costs and schedules. Beneath that generality, however, there are many decisions which must be made and remade throughout the life of the program and which affect the burden placed on the DoD to maintain the acquired system in a ready state after it is deployed. In each program one must consider the numbers and skill levels of personnel which will be required to operate the system, but also to maintain it. This consideration must be made early in the program because the design of the hardware and software must be compatible with the capabilities which the operators and maintenance personnel can realistically be expected to have. A tradeoff is required between the sophistication of the system and the skills and numbers of personnel. For example, one can build a capability into a system for the hardware and software to automatically detect malfunctions and even to isolate the cause of the failure to various hardware levels. A decision to employ automated fault detection and isolation may permit more effective system operation with less skilled personnel. However, if poorly implemented, we will have paid the cost of acquiring a sophisticated capability, will suffer low readiness because the available personnel skills and tools were predicated on the design working, and be faced with the expensive choices of either redoing the system design and supplying more skilled personnel or building the fault detection and isolation system over again.

There are many other choices which must be made early in a program and which have major impact on the lift cycle costs and on anticipated readiness. For each system, a repair concept and a corresponding spares provisioning policy must be derived. How much of the system will be maintained at the operating locations, how much at an intermediate maintenance shop, and how much back at the contractor's plant? Will forward repairs consist of replacing logical units, cards, or components? Can the spares provisioning system be expected to have the correct spares at the proper locations to support the chosen maintenance concept? What maintenance tools will be provided, what training required to support the concept? If sophisticated fault detection and isolation techniques are to be used, what demands will be placed for personnel sufficiently skilled to maintain that system current as the operational system evolves? On the operational side, how much automation should be built into the hardware and software, how should that be traded off between the skills required of the operators, the costs associated with developing and maintaining such systems, and the proper allocation of decisions between man and machine? Some other areas include the use of contractor personnel in field maintenance, military specifications versus commercial standards, transportability requirements, use of higher order programming languages, choice of associated communications systems, etc.

All of the kinds of decisions discussed above are faced early in an acquisition program because they affect the design of the system being acquired. Procedures call for the kinds of tradeoffs discussed above to be made and for experts in training, logistics, etc., to participate in the tradeoffs. However, a program director is also faced with considerations where near-term needs conflict with overall goals. Minimum life cycle cost is always a goal; it is sometimes compromised by lack of funds in a given fiscal year and the need to revisit some of the earlier decisions with consequent impact on the factors which affect readiness. If the manpower, training, and logistics communities cannot react quickly enough, lower readiness is a natural result.

Another aspect of this general problem is that decisions made on any individual system acquisition program can probably be supported from a readiness point of view. Spares can be provided, adequately trained personnel made available in sufficient numbers, etc. However, the problem arises when one aggregates these decisions across all the programs of a Service, or across the entire DoD. The Services have now begun to consider the overall impact of their programs on manpower availability by skill level, etc. -- and they are encouraged to do more of that. The results of such analyses also need to be fed back to individual program directors so that they can make the difficult tradeoffs with the best possible information available to them.

As noted above, decisions made early in the program acquisition cycle have major impact on the eventual life cycle costs of a system. These include not only system design factors, but also maintenance concepts, training plans, personnel skill levels required, spares provisioning, etc. Although life cycle cost implications of such decisions are supposed to be considered at each point in the program, the DoD acquisition procedures should emphasize the profound effect which the early decisions made on these factors have on the eventual life cycle costs. Once made, it is a very costly process to make any major change. DoD also needs to expand the emphasis on aggregating by skill levels the requirements for operating and maintenance personnel and to provide that kind of information, together with a forecast of its availability over time, to program directors and others making choices between man and machine.

The data presented to the Panel clearly illustrates the underfunding of support-related items which is typical of times of relative peace. For example, the following data was provided by the U.S. Army:

		% Of Budget	
Year	Period	Systems	Support
1916	Peace	71	29
1918	WWI	42	58
1940	Peace	66	34
1945	WWII	42	58
1950	Peace	38	62
1953	Korea	26	74
1964	Peace	47	53
1969	Vietnam	39	61
1971	Peace	40	60
1973	Peace	43	57
1975	Peace	50	50
1978	Peace	54	46

The general trend of a peacetime readiness sag noted in the Army data has certainly continued to be evidenced during the post Vietnam era and hit a recent low during the Carter Administration. During this period, unusually low defense budgets, coupled with the extensive modernization commitments of all the services, put extreme pressure on our readiness posture.

Another example can be found in the conscious modernization versus support decisions of the Air Force during the late 1970's. The following chart shows the support impacts resulting from the TACAIR decisions to procure F-15's, F-16's and A-10's.

	% Of Requirement Funded	
Fiscal Year	Peacetime Operating Stock	War Readiness Spares
1978	86	49
1979	86	32
1980	50	15
1981	55	49
1982	75	60

While the above data tends to be a worst case example, a similar review of the other Services indicates that the trend is similar. Furthermore, the 'now' year dollar aspect of the readiness budget elements, as opposed to the 'then' year dollars associated with modernization, make readiness dollars an easy target during the Services' budget preparation, the DoD budget cycle, and congressional review. Except in times of conflict or perceived danger, readiness has not in the past had sufficient priority and has been reduced during each review until it is insufficient to maintain high readiness. We have not yet invented an adequate process for quantitatively measuring the impacts of budget tradeoffs on future readiness.

Another available indicator of the lack of attention given to readiness factors during the formative stages of a program is the DSARC scorecard. The statistics shown below were taken from DoD files and represent an across-the-board problem in all the Services.

Year	Unconditional Approval	Conditional Approval or Delay (Readiness) Issues)	No Decisions
1977	40	50	10
1978	38	47	15
1979	13	74	13

NOTE: Statistics are in percent of total DSARCS

The track record shows that the readiness malnutrition is a persistent problem which surfaces in DSARC reviews. Unfortunately, it resurfaces during Operational Test and Evaluation and again when the system is fielded.

In the Panel's view, then, the single most serious cause of unsatisfactory operational availability is the inability or failure to provide adequately for the support of deployed systems. Unquestionably, availability has been unfavorably affected by shortcomings in technical design and such shortcomings, in turn, result in the need for better, more rapidly responsive support systems. Technical shortcomings are usually overcome after some operational experience even though experiencing technical failures in deployed systems is quite clearly a poor way to learn that they exist. But even in systems that have been cured of their technical inadequacies, adequate support, especially for system use in training and other peacetime operations, is seldom provided. Even in systems alleged by some to have seriously inadequate availability (e.g., the F-15), the evidence is strong that when a good, adequately stocked support system is provided, operational availability is as high or higher than the design levels initially specified.

3.3 The Critical Transition From Development To Production

It is well-known in the system acquisition community that systems typically experience significant manufacturing and operational difficulties as they transition from the development phase to the production and operational phases. Successful operational deployments with high readiness require maturity of the hardware, software, training and the support system. Maturity can only be obtained through experience, and at the time of transition some of the key information necessary to achieve maturity is only just being accumulated. To help deal with the realities of this situation, program phases such as 'low-rate initial production' have been made part of some acquisition programs. Unfortunately, it seems that the time and money required to ensure an orderly and effective transition to production and operation has often been underestimated in planning system acquisition programs. The tacit assumption is made that almost all facets of the system will be in good order at the end of full-scale development. When they are not, one finds that the R&D funds are depleted, and that the pressure to continue the program can cause premature commitment to production to get the necessary fundin"

Clearly, we conduct full-scale development testing and initial operational testing to find the limitations in the utility of what has been built and the deficiencies in the way in which it has been built. We must, therefore, plan for and budget for sufficient time and money to reflect changes in the production system required to overcome identified deficiencies. Again, this is not something which has to be added to the current system acquisition process. It merely has to be given proper emphasis within the existing process. Even in accelerated programs we have to recognize that sooner or later we have to go through such a phase if we are to have systems which exhibit high readiness without extraordinary management support and funding. As noted above, the existing 'low-rate initial production' concept can be used for this purpose. From a production point of view, such a phase can be used to reveal producibility problems in the design, to obtain repeatability of the processes, stabilize hard tooling design, and to provide equipment for initial operational deployment. Substantial changes can result and they must be incorporated in the full production. In addition, testing in this phase of the program can also provide the information required to finalize changes in documentation, training equipment, test equipment, and spares provisioning. To effect these changes requires time and money and the program plan must reflect these factors.

A review of the program assessments and Secretary of Defense Decision Memoranda issued at the Milestone III decision point for programs in recent years confirms the seriousness of this problem.

Operational test and evaluation revealed deficiencies in reliability and maintainability, human factors engineering, safety, training, logistics, and software maturity. Decisions often had to be made on hardware/software which was not representative of the system to be fielded.

The Panel recommends that realistic planning for an orderly transition from development to production must be an integral part of the acquisition strategy on every program. Adequate time and money must be provided to gain the experience needed to ensure producibility of the system, and to ensure that all facets of the support required for an effective operational system are available and accurately reflect the production system. In addition, concepts such as configuration control and first-article compliance inspection need to be applied to each program in a manner consistent with the need for control and the need to quickly and economically reflect necessary changes with minimum lead time and cost. Each program is a little different from every other one and thoughtful application of our management techniques is therefore required. The Panel also recommends that substantial contractor involvement be included in early operational testing -- as instructors, observers, advisors -- so that the experience gained can more readily be fed back into the production system.

3.4 Preplanned Product Improvement (P^3I)

The Panel strongly supports the DoD initiative on preplanned product improvement. Continuing product improvements of major weapon systems have the advantage of fielding up-to-date technology and performance enhancements at much lower cost than new programs require. Such programs are less subject to the IOC pressures of major developments and have substantially less impact on spares and training support equipments. All of the military Services have used product improvement for modernization over the years. Examples include the Air Force AIM-9 B - E - J, the Navy AIM-9 D - G - H - L, the Army M48 - M60A1 - M60A2 - M60A3. The many versions of the F-4 and B-52 with their very long lives in the inventory are also excellent examples.

The systems that have been most successfully product improved over the years have started with substantial excess capability in one or more key characteristics -- range, payload, thrust, maneuverability, etc. -- which provided the margin within which improvements were continued as new technologies and new needs were combined to put new capabilities into the force.

3.5 Follow-Up, Find and Fix Improvements (F^3I)

Much of what was discussed above was directed at achieving long-term improvements in our ability to acquire and operate 'ready systems.' However, the Panel also addressed itself to what might be done to improve the readiness of systems which are already in the field. The Services already know which of their systems are of major concern from a readiness point of view. The Panel recommends that the Services consider the formation of 'readiness tiger teams' to review the systems which exhibit poor readiness to determine the major causes of the low readiness and to recommend corrective action. In particular, the Panel believes, based on demonstrated Navy efforts for example, that it is possible to identify those particular items, normally only a small portion of the system hardware, which are the causes of low reliability and to institute a successful program of corrective action. It takes a concerted effort, however, to emphasize the importance of readiness and to ensure that appropriate funding and effort to achieve it are provided.

With regard to deployed systems, the Panel found in several cases that perhaps 20% of the line replaceable units were accounting for 70-80% of the actual replacements. However, it did not appear that there was any concerted effort to identify these high failure rate items and to concentrate resources on early improvements in their reliability. Consequently the readily obtainable increase in availability, and reductions in maintenance efforts and spares consumption, are never achieved. The reasons for this lack of action are severalfold: first, it's not programmed (funded); second, the handover from developer to logistics/support people often takes place before such data is available; and third, the user is so used to living with that level of problem that his emphasis and interest is on the next round of performance improvements and not on more reliable systems.

SOFTWARE

4. SOFTWARE

Computers are becoming ubiquitous in both commercial and military systems. The military applications are being driven by the requirement to assist the command decision makers and the operators in processing the large volume of information available from modern sensors, with the accuracy and rapid response time necessary to effectively employ our high-capability weapons against a numerically superior enemy. The application of computers to real-time battle management brings with it the burden of developing and maintaining large software programs.

For some time it has been recognized that software represents the major development risk for command and control systems. However, as technology continues to dramatically increase the power of our computers, while making them both physically smaller and more reliable, computers -- with their attendant software -- are being applied in ever increasing degrees in our sensor, communications, weapons platforms, and weapon systems. More than that, they are also beginning to play major roles in our support systems, training systems, and in the systems we employ to monitor the performance of operational systems for both fault detection and fault isolation.

An Electronic Industry Association (EIA) study in the fall of 1980 indicates that by 1990, 60% of the DoD electronics budget, some $46B, will be in computer-related items and that 80% of that, or $37B, will be for software and services, with $9B for hardware. Software costs already dominate for some systems (90% of WWMCCS cost is estimated to be software), and we can expect a trend in that direction. The magnitude of this trend is not well recognized in the DoD and, unless it is, our ability to produce large, sophisticated software systems will become the major limitation in fielding the required mission capabilities.

Design and production of operational software tends to lag behind the associated hardware, and the software is often presumed to make up for system and hardware design deficiencies because it is assumed that software is relatively easy to design and modify. However, large software programs require detailed design, coding, checkout and documentation. They are expensive to produce, nearly impossible to make error free, and prone to operator-induced failures.

Software for support training and maintenance systems is often far down the development priority ladder and, therefore, tends to lag even further behind than the operational software with attendant negative impacts in system availability. Thus for systems such as the E-3A, the F-15, and the Patriot, we find large software packages being developed to help the maintenance personnel perform their tasks. However, these packages suffer from not having the same level of personnel expertise applied to their design and production as to the prime weapon system -- since the best people are assigned to the prime system. These support packages are growing to where they represent a major development expense in time and money. They also remain a major support problem during the operational lifetime of the system since they must be modified and kept current as the prime system evolves.

We should also recognize that not only are the number of applications of software growing, but the complexity of the tasks being levied on the software is also growing.

Clearly as we apply computers to new applications, we should take advantage of lessons learned from earlier work. We need to give software the needed emphasis early in the development. It is estimated that on the average it costs ten times more to correct a program error in the field than to correct it during development. We need to oversize the computers in the beginning, both in storage and running time, to accommodate system growth more readily. But most of all we need to understand how difficult and expensive it is to design, build and checkout sophisticated software and, therefore, to appreciate the need to actively manage such efforts. We also need to develop significantly better tools and techniques to estimate software costs -- in dollars, time and computer capacity -- so we can more realistically budget for its development and maintenance.

We also need to weigh carefully the system complexity versus operator/maintenance skill levels required. In the past, we have erred in the direction of demanding too much in the way of personnel skills, we must be careful not to go too far in the direction of using software sophistication to make up for personnel skills.

We also need to avoid the temptation to remove from the operator the decisions which are best made by him.

Another question we must face is field support of large software systems. It is likely that only for certain systems; e.g., WWMCCS or IDHS, can we afford to provide on-site maintenance of the system. This will place a special burden on us to produce well checked out computer programs. At the same time we need to concern ourselves about our ability to continue to operate when software errors occur in the field.

The U.S. currently has some 300,000 full-time programmers. The current shortage is estimated to be over 150,000. Since non-DoD applications of computers are also expanding rapidly, we face a severe shortage of programmers and computer scientists. In addition to working with the universities to graduate more people in these fields, we also need to undertake more research into automatic programming and into software verification tools. The Subpanel recommends that the DoD consider a program in which they would help pay to train people in the software field in return for an agreed Service commitment.

The Subpanel was pleased to learn that the DSB is conducting a study on embedded computer resources since, unless we do a better job of managing its development, it could grow to be the largest acquisition problem in the DoD.

In summary, the Subpanel believes that software is always a development item and must be managed like one. We must recognize the cost/performance uncertainties, manage it in ways analogous to development hardware, prototype early, redesign and recost.

PERSONNEL, TRAINING, AND READINESS

5. PERSONNEL, TRAINING AND READINESS

An obviously key ingredient of ready systems, perhaps the key ingredient, is adequate numbers of properly trained personnel. Again, the principle of vertical management visibility should apply. The system program director must have an obligation to ensure that the necessary trained personnel are available and, in turn, must have the appropriate visibility into the manpower and training organizations to carry out that responsibility. The Panel discussed how adequate numbers of personnel can be provided, the interaction between personnel availability and system design, and personnel training.

5.1 Personnel

As noted, the Panel discussed at length both personnel skill requirements, and the availability of adequate numbers of operating and maintenance personnel necessary to achieve ready weapons systems. In fact, readiness is achieved by trained, motivated people. A machine cannot be repaired unless it is touched by people, and the people must be supported by appropriate training and by on-site availability of the required parts, tools, and documentation. The importance of the personnel area is clear when one realizes that over the period from 1974 to 1981, the U.S. active duty manpower has remained fairly constant at 2 million. However, in that time the personnel costs have doubled to where they represented almost 50% of the FY-81 defense budget. At the same time, the average quality of the available personnel has tended to go down.

As indicated in some of the briefings provided the Panel, the manpower pool from which government and industry can select is shrinking. In addition, as our society continues to shift to a technological base, the requirements for certain critical skills is increasing dramatically both in government and in industry -- and should the economy improve, the competition will get worse. Some of the key fields are electronics, computers, and especially their associated software, health, system design and analysis, and skilled craftsmen. This means that the DoD must take all reasonable steps to help increase the numbers of people who go into careers in these critical areas, to attract them to the Services, to improve retention, and to make the very best use of those who do enter Service.

The Panel concerned itself with the aggregate problem created by the increasing number of high performance systems and their impact on the manpower and training requirements. We were pleased to find that the individual Services were already doing a number of studies to both understand the problem and its dimensions and to begin to examine ways to deal with the critical skill shortages which these studies are projecting. The Panel would suggest that these studies be continued and that the results be aggregated at the DoD level. Clearly, there are sufficient personnel of the required skills to operate and maintain selected high performance systems. The Panel found no evidence that individual high performance systems could not be operated and maintained by military personnel. On the other hand, it is not at all clear that that will be the case for the totality of systems which are now entering the force inventory. In fact, the Panel does not believe the Services can handle the problem unless complexity at the maintenance interface can be controlled.

Human factors engineering has been defined as the process of integrating all personnel characteristics (skills, trainability, physiological and psychological factors) into system design to ensure operational effectiveness, safety and freedom from health hazards. This definition transcends human engineering which tends to focus on the man/machine interface alone. To the extent we could, the Panel attempted to take the broader view of the personnel-related questions associated with readiness. For example, the Panel examined the question of how one might measure complexity as it affects the operator and maintainer. We concluded that as complexity increases, the requirements for specialty prerequisites, the number of system unique tasks, the training time, etc., all tended to go up but that one must be careful in using some or all of these measures since each of them can be affected by factors other than system complexity. For example, system specialty prerequisites may not have been validated over long periods for the newer systems, the training equipment may not have been adequate with the newer system, etc. As one examines particular cases, there does not appear to be any easy way to generalize the impact of higher performance systems on human factors engineering.

The Panel believes that all factors affecting readiness need to be addressed in the conceptual phase of a new system and throughout the development and operational phases. This approach is certainly required in the personnel area. We need to specify required personnel capabilities for both operators and maintainers in procurement documentation. To the extent practical and affordable, we need to reduce the physical and mental requirements and the numbers of personnel required. Such determinations should be made by groups which include representatives of the organizations which will eventually own the system. Explicit tradeoffs should be made early between hardware capabilities and personnel requirements. We should design to personnel capabilities which can be made available and should avoid going too far in the direction of smart machine/dumb man for at least two reasons. First, going too far in that direction creates a morale problem which eventually leads to the better people becoming discouraged and finding other jobs and, second, when such a system fails, the caliber of the people required to provide a backup capability are not available. Accomplishing such work early in the acquisition program will be difficult since we lack adequate methodologies to forecast skill-level potential, have few good measures of quality, and no common language to communicate between the hardware designer and the human factors engineering people. We have to develop and use improved methodologies to identify personnel requirements in the concept formulation phase, and to project the quality demands and the supply which could reasonably be expected to be available. In all of these activities, we need to consider the maintenance people as well as the operational people.

One of the things that we need to do better is to recognize the characteristics of the population from which the personnel will be drawn; for example, brought up on television, lower reading skills, etc. These factors then should be accounted for in the design, and exploited where possible. Job aids need to be a meaningful part of the system design process, but care should be taken not to create a monster in its own right by using job aids which depend heavily on sophisticated software packages. The operator/system interfaces need to more consistently take advantage of some of the newer approaches which have been developed, such as those used in aircraft systems. In our designs we need to employ realistic standards for human reaction and capability under stress. We should avoid designs which require too much operator interaction at one time or too fast a response. In a word, we should be careful to ensure that the design does not require tasks which approach the operator's limits of performance. Similarly, we should avoid designs which are not matched to the physical limitations of the maintenance people -- or which are beyond their problem solving capability or which force them to remember too much. Human factors engineering criteria should be an integral part of the source selection process and experts in the personnel field should participate in the proposal evaluation. Incentives for meeting human factors requirements should be considered for inclusion in the resulting contracts.

Other suggestions which the Panel believes are worthy of consideration include a requirement for the program director to track the availability of selected skills to ensure that personnel required for effective system operation are indeed available. Also, as system documentation is produced, representatives of the user should participate in its review.

On a more general basis, there are some indications that we are finding brighter minds in our recruits than we thought would be the case -- people who are capable of higher level training. We need to learn to exploit that possibility. We also need to consider incentives which might give more encouragement to enlisted personnel to improve their skills and, therefore, the stature of the tasks to which they can be assigned. On the other hand, we need to make it more difficult for the unskilled to tinker with the equipment. We should also strive for more commonality in how we establish personnel requirements from system to system to improve communication and to increase our flexibility in personnel assignments. As always, we need to make the best possible use of the available people through personnel selection, job assignment, job design, organizational analysis, and management techniques to meet combat requirements. We must avoid assuming that the best people will be available in every case. When a new area is beginning to come into existence, such as the nuclear field was at one time, we need to begin training people for work in such areas long before we have to field such capabilities. In summary, people-related matters deserve the highest level of attention, at least equal to any other factor, if we are to achieve ready systems. As a specific recommendation, the personnel organizations should have representation at DSARC meetings.

5.2 Training

Service personnel responsible for operator and maintainer training should participate in the early concept definition and system design phases. They should be responsible for defining the system training base in dollars and time -- and this activity should influence and interact with the system design. The output of the training process should be defined in terms of what tasks the trained personnel will be able to accomplish. The training process should also attempt to provide improved overall system awareness. Over time the training community should assume the task of assessing the effectiveness of the training program including man, machine, the training system itself, personnel selection criteria, learning rates, learning decay, etc. In this way, the training program can be adjusted to maximize the availability of the personnel required for achieving continued high readiness.

One of the major concerns of the early design phase should be the design and acquisition of personnel job aids -- what will be provided as part of the overall system design to assist the operator and maintainer to carry out their assigned tasks. The design of the job aids should be accomplished concurrently with the system design and they should be made available on the same time scale as the development and production prime mission equipment. Job aids should make full use of electronic information storage, retrieval, and delivery systems. In designing the job aids, one should keep in mind the tradeoff between job aids and training.

After much discussion, the Panel concluded that some fundamental changes need to be made in the approaches currently used for training of weapon system personnel. Today's training methods tend to emphasize information transfer rather than practice in carrying out the tasks which the operator and maintainer will be expected to perform. The Panel strongly recommends that there be significantly more emphasis placed on practice as part of the Service training programs. To do that will require much greater use of part-task trainers, rather than just full-system trainers, in order to provide hardware for large numbers of personnel to economically acquire the necessary hours of training. The proper mixture of part-task and full-system trainers should be determined on a case-by-case basis. Unfortunately, the word simulators has come to be synonomous with devices which replicate the operational equipment and, as a result, they have come to be sophisticated and expensive in their own right. A cultural change to emphasize training through practice, as much as possible, is required. The use of multiple part-task trainers reduces the complexity, cost, and associated lead time for training devices. The approach provides additional hands-on devices, increases the number of practice hours possible, and helps keep the training system configuration closer to that of the prime system at little or no additional cost. Only through practice will adequate operator and maintainer proficiency be achieved.

As in the other support areas discussed in this report, the training program needs to be directed at achieving a system -- especially the people in the system -- which is ready to perform in its wartime role. To do so will continue to require the use of simulators in order for personnel to safely and effectively master our more capable systems. However, personnel must also operate and maintain the full, actual mission system in order to be proficient. In particular, adequate flying and driving hours must be provided. We also have to provide for more operator firings of live missiles for those weapons which require continued pilot/weapon/target interaction after launch. Live firings are critical for training on weapons such as the Hellfire and the TOW. It is estimated that 600 Hellfire crews would require an annual expenditure of $30M for adequate live firings and that the corresponding numbers would be 1400 crews and $15M for the TOW.

Although this section addresses training for both operators and maintainers, the Panel put some special emphasis on the maintenance area since these personnel normally do not receive as much attention from a training point of view as the operating personnel. In the maintenance case, the typical trainee gets very limited hands-on experience and little or no remove/replace training. Maintenance personnel require training on performing the procedure itself. They also need practice in troubleshooting and in carrying out procedures that are not part of the normal repertoire. Such training should emphasize cognitive as well as physical aspects of the maintenance tasks. The training should also emphasize those tasks that the automatic test equipment will not do, and should provide for more system awareness so that the maintainer can relate more readily what he observes and what he does to improved overall system operation. And, of course, the documentation which is provided to the maintainer must be available on a timely basis and must accurately reflect the prime system -- goals on which we often fall far short.

The Panel reached a number of other conclusions with regard to training. There is considerable research related to training being performed. Organizations such as the Army Research Institute, the Navy Personnel Research and Development Center, and the Air Force Human Resources Laboratory should provide for improved technology transfer through briefings of the training commands, personnel organizations, and selected program directors.

The tendency to underfund training is especially devastating to multi-mission systems. As a rule, we train first for safety and then for the primary mission. Little time or money is available to train for the secondary mission and, without such training, the wisdom of building multi-mission systems is at best questionable.

The Panel feels that the suggestions it has made will lead to shorter training times, less dependency on long-lead system simulators, more up-to-date training equipment, and less self-induced system failures. The Panel also feels that the general approach suggested will permit lowering the competency requirements and thereby increase the use of more of the available recruits.

RELIABILITY AND RELATED FACTORS AS THEY INFLUENCE READINESS

6. RELIABILITY AND RELATED FACTORS AS THEY INFLUENCE READINESS

This section discusses the Panel's deliberations on a variety of areas whose interrelationships must be accounted for in the system design and acquisition process if we are to have operationally ready capabilities. These areas include reliability, maintainability and logistics. A separate discussion of built-in test equipment (BITE) is also included because the Panel would like to emphasize its concern about this area. BITE has great potential for helping to improve the readiness of systems, but to date at least we seem to have done very poorly in implementing this approach.

6.1 Reliability

The Panel was very impressed with the progress that the Navy has made over the last few years in improving their ability to acquire reliable systems. Most of what is discussed in this section recounts the techniques which they have found effective. The Panel strongly recommends that these approaches be adopted throughout the DoD.

The Navy currently employs a technique which they call reliability by design and manufacturing. The approach is in consonance with the Deputy Secretary of Defense direction issued earlier this year called for designed in from the beginning reliability, rather than a fix it up after-the-fact approach. The key to the higher levels of reliability which the Navy is achieving on its new systems is the emphasis on reliable design and manufacturing technology, not on numerical requirements and demonstration tests. The approach requires more oversight of the contractor's activities by the government, but greatly reduces the risk of reliability shortfalls in deployed systems.

It is important that the relationship between operational availability and reliability be clearly understood. The Navy has the same material readiness concerns as the other Services and does have some older systems which exhibit less-than-desirable reliability. However, modern systems where the new approach to designing in reliability has been followed do not have major reliability problems. The Navy approach identifies the engineering design factors and manufacturing processes to which reliability is sensitive, and then specifies and manages these design and engineering fundamentals. The emphasis in this activity is to recognize the various stresses in the proposed design (functional, packaging, heat, etc.), minimize those stresses to the extent possible, and manage carefully and continually those that remain. Even with this approach, however, one cannot achieve high-system availability unless the associated spares and trained personnel are also provided when and where they are needed. The fact that some newer systems appear to be less available than prior systems often has nothing to do with its complexity, or inherent reliability. Inherent reliability depends only on reliability and hands-on repair time, which in spite of its sensitivity to technician skill and training, is largely influenced by the weapon system design and can therefore be contractually specified. Operational availability is affected by personnel, spares, and other factors which cannot be controlled by a contractor. It turns out that while most newer Navy systems meet or exceed their inherent reliability levels, their operational availability is affected principally by the delay in the availability of required spares at the point of repair. This delay is termed the mean logistics delay time (MLDT) and is by far the biggest single factor affecting system availability. Investment in improving the availability of required spares is clearly a cost-effective approach to improving system availability on existing systems. Higher inherent reliability is necessary to assure the ability to complete a mission successfully, and to aid in reducing life-cycle costs.

In some ways our systems are indeed becoming more complex. At the same time, this complexity is providing the significantly improved capabilities required to deal with the threat and helping us to realize significant savings in related areas. For example, the integrated circuit/microprocessor explosion of the last 20 years or so is headed towards the availability, by the late 1980s, of very large-scale integrated circuits with as many as 30,000 digital logic gates in a single small component. In terms of engineering, this represents the potential for extremely complex functional capabilities. But in terms of reliability, we are seeing over five orders of magnitude of improvement because failure rates of systems using these components tend to be proportional to the number of packages, not to the number of gates in each package. At the same time, we will be spending 3000 times less for the same capabilities, in constant dollars, and reducing the labor required to manufacture something of this complexity by a factor of 18,000 compared to the pre-integrated circuit technology of the 1950s. So, despite the fact that the module has become much more complex, reliability, manufacturing, procurement, and support shows a vast reduction.

The Panel was briefed by the Navy on a large number of both complex and relatively simple systems. From this review, the Panel has concluded that there is no necessary correlation between complexity and inherent reliability, or between operational availability and complexity. The Navy has had relatively simple systems which have exhibited low reliability and operational readiness -- and also complex systems that have been both reliable and available.

Among the simple systems which were unreliable were the OC-14/SSQ-56 Bathythermograph probe, a number of solid-state power supplies, the AN/SSQ-77 Sonobuoy, and the AN/UYS-1 Analyzer Unit, Advanced Signal Processor. Among the reliable complex systems are the A-6E TRAM Detecting and Ranging Set, the F-404 Turbofan Engine, the F/A-18 Inertial Navigation System, and the AGM-84 Harpoon Missile Seeker. In addition, the F/A-18 Hornet aircraft, the DD-963 Class ships and the FFG-7 Class ships are all exceeding availability goals.

Clearly, the simpler the design the better the reliability will be, assuming both designs achieve the same performance. As one can see from the above information, high reliability and ease of repair are necessary, but not sufficient conditions for achieving high system availability. Although not discussed above, it seems that high inherent reliability is also the best approach to reducing the high current incidence of parts apparently having failed -- only to find that when they are removed and repairs attempted, the original failure cannot be replicated. The Panel recommends that we need to design in reliability from the beginning instead of planning to fix it up after the fact. We should provide incentives to the contractors for meeting the reliability requirements and penalties for not doing so.

However, it is felt that this approach will never completely solve the reliability problems and that, therefore, each program director should have clear responsibility to follow his system into the field for the purposes of identifying and fixing those items which turn out to be the principal causes of system failures. To do this the program director will have to program appropriate resources and ensure that those resources are available when the system goes into operation. It is the firm conviction of the Panel that a determined activity of this kind to eliminate the "high burners" early in the operational life of the system, when coupled with designed in reliability, will dramatically improve both the system reliability and operational availability.

As a final comment in this area, the Panel noted that we should strive for weapons systems which do not degrade during their operational mission. That is, our systems, through a combination of built-in reliability and preventive maintenance, should exhibit a very high probability of being able to complete an operational mission without degradation in performance.

6.1.1 Reliability of Modern Systems

It appears that when the F-15 program was established, reliability goals for some subsystems were set at ambitiously high levels, and optimistic assumptions were made about early maturity of reliability and of support equipment. During the first year of Air Force operations, the air vehicle reliability measured only half of what had been predicted (and what has subsequently been achieved with maturity). Moreover, the distribution of failures differed from the predictions on which initial provisioning was based, with the engine and the fire control radar key problems. The F-15 maintenance concept calls for the aircraft built-in test equipment (BITE) to isolate failures to a particular line replaceable unit (LRU). Once removed, the LRU is put on an Avionics Intermediate Shop (AIS) test station which isolates the failure to a shop replaceable unit. Immature BITE led to high false removal rates and, when coupled with the radar reliability problems, consumed the available spares, in turn causing excessive radar downtime. The AIS, at aircraft delivery, did not yet have complete fault isolation capability for all LRU's, had reliability deficiencies, and lacked adequate spare parts. This combination resulted in further delays in repairs and contributed to aircraft downtime. With system maturity most of these problems have been solved, though BITE false alarm rates remains higher than desirable. The fleet-wide air vehicle field reliability is 50% higher than that of the older F-4, with the later model F-15C/D even better.

While the performance outlined above was disappointing, it does not really establish that the F-15 is a problem aircraft nor that, properly supported, it cannot generate operationally acceptable sortie rates. During 1980, a number of European exercise deployments of the F-15 and its support systems were carried out (CORONET EAGLE, etc.). Unlike the normal domestic training environment of the aircraft -- characterized by submarginal spares complements and extensive cannibalization of aircraft -- these deployments were fully supported in both spares and manpower. The results were very high in terms of surge sortie rates and demonstration of a sustained sortie rate of 3.0. These results exceed the corresponding planning factors by 100% and the routine domestic usage experience by 329.3%. These data illustrate the extremely strong dependence of tactical performance and availability upon adequate on-scene spares availability and adequately trained support and operating personnel. Similar favorable results were achieved with the F-111 in the CORONET HAMMER exercise.

In the case of the F-16, operational test and evaluation data indicates that for criteria such as mission reliability, mean time between maintenance actions, and mean maintenance hours per flight hour, the F-16 is exceeding the DCP thresholds, but has not yet demonstrated achievement of the DCP goals. Insufficient performance data exists at this time to evaluate how well the system is actually performing in the field. The F-16 program learned from F-15 experience, anticiapted maturity problems, provided for the first operational wing to be collocated with the depot, and relied on contractor support for an extended transitional period.

The M1 tank is another case reviewed by the Panel. The reliability and maintainability requirements were established over ten years ago and called for the M1 reliability performance to equal or exceed that of the current inventory of tanks. For tanks, mission reliability is measured as mean-miles-between combat mission failure. A combat mission failure is a system failure which causes either the loss or the degradation of a combat mission essential function. The Army requirements for mission reliability were 272 miles in phase two of development and operational testing, and 320 miles in phase three. After early test results showed poor reliability performance, a concentrated reliability improvements program was undertaken and the latest available results indicate, depending on which organization analyzes the data, that the M1 demonstrated between 278 and 326 mean miles between failures. This is a dramatic improvement over earlier results and is approaching or exceeding desired performance. The results of the recent phase three tests are currently being analyzed.

A system failure for the M1 is defined as a malfunction requiring corrective action which cannot be deferred until the next scheduled downtime. The most recent data from Army tests indicates that in this case the M1 is showing better reliability than called for in the Army Materiel Need document. Results from the phase 3 development and operational tests are now being analyzed. On the other hand, the ratio of maintenance man hours to operational hours still exceeds the desired levels. The goal for this ratio is 1.0 and demonstrated performance ranges from 1.6 to 1.9.

The industry contract for the Patriot missile fire unit calls for a 40-hour mean time between mission critical failures. The DCP goal is also 40 hours with a 30-hour threshold. Analysis of recent test data yields estimates of from 4 to 13 hours, including some data on failures with unexplained causes. A series of fixes have been identified and will be incorporated in three steps. A test program to demonstrate the reliability improvement has also been defined. The missile itself demonstrated a .74 reliability during phase two of operational testing. Operational testing showed that the built-in test equipment (BITE) is performing significantly below requirements. For example, the specification calls for no less than 98% fault detection using BITE, and the demonstrated capability is approximately

60%. The specification called for no less than 75% fault isolation by the operator using BITE and the demonstrated capability ranges from 10% to 30%, depending on who interprets the data. In both the latter cases, failure of the operators to follow procedures is a significant cause of the poor performance.

For the Roland missile system, fire unit mean time between failures was specified as 43 hours at time of technology transfer testing, 72 hours at low-rate initial production, and a goal of 123 hours at maturity. At the time of the phase two operational testing, the system demonstrated a 28-to-34 hour MTBF. Missile reliability was specified at .95 and .76 has been demonstrated. It was also required that the systems have a 90% probability of completing a 72-hour mission using only organizational support. To date, test conditions have not yet permitted accurate assessment of the system's ability to meet that requirement or the 3.3 hour mean time to repair goal.

6.2 Maintenance

One of the major areas addressed by the Panel concerned the maintenance concepts used on our more capable systems and, in particular, the relationships between the maintenance concept and the associated personnel and training requirements. As is the case for most factors affecting readiness, the system maintenance concept, and its relationship to requirements for maintenance personnel, needs to be considered as an integral part of the early system conceptual definition and to be reviewed and adjusted throughout the life of the program as related factors change and as experience with the system dictates.

It is the conclusion of the Panel that the maintenance concepts employed on our high performance systems have been force fit into maintenance and repair structures which preceeded the advent of such systems, and that these structures are not well-matched to today's needs. There has been no multi-disciplinary look at how one should design such a structure in the light of the technology and performance of modern systems, and with due regard for factors such as the skills of available maintenance personnel, their training, the maintenance concept to be employed, impact of spares, transportation needs as a function of repair concept, etc. As a result, the Panel identified a wide variety of associated problems in the different systems we examined. These problems included shortage of skilled maintenance personnel, unnecessary maintenance, insufficient spares and unavailability of spares at the locations where they were needed, incompatibilities between test equipment and the maintenance tasks to be done at a given location, inflexible maintenance practices and less than adequate attention to building into the system design a capability to test system performance from an operability point of view.

There are many considerations one must make in designing and implementing an effective approach to maintainable high performance systems. One strives to achieve long operating periods with adequate mission capability before having to take a system out of service for repair. A variety of techniques exist for doing this -- such as the use of redundant designs. Normally such approaches cost more money on the front end, but we believe the payback is very large in the end. The design of the approach to maintenance should begin in the conceptual phase, as noted above, and one needs to address on a case-by-case basis what maintenance will be done forward where the system (and presumably the enemy) actually operates, what will be done at some intermediate location, and what maintenance and repair will only be possible back at some depot or contractor factory. Inherent in such considerations are a myriad of conflicting requirements. The higher the understanding and the capability of the maintenance personnel at the point of failure, the better the repair. However, combat tends to squeeze the repair capability away from enemy contact; i.e., away from the point of failure. Also, one needs to balance his ability to support various repair levels forward as a function of his ability to provide adequate spares and, in particular, to meet the transportation requirements associated with alternative approaches. The more understanding and capability one can provide at the point of failure, the greater the chances of minimizing the high costs and lower readiness which result from the high incidence of unnecessary repairs which seems to plague our systems today. The Panel therefore suggests that to the extent possible we need to have a level of understanding of system operation and fault isolation at the repair location which is above that required to carry out the repair itself. People with skills of this kind can be key factors in verifying the need to repair and in teaching the maintenance technicians to improve their techniques in that regard. As one moves the intermediate repair capability forward, he also begins to create a lucrative target for the enemy since these repair facilities tend to be large, heavy, expensive, require significant amounts of transportation to move, and represent major capabilities in maintaining a fighting force. As one moves the intermediate repair capability away from the point of failure the demands for spares, and the transportation of those spares increases. In any case, a tactical commander has to move and shoot -- and his support system must be matched to that capability.

In recognition of the shortages of highly skilled operators, we have tended to design our newer systems to achieve the required response times by designing the complexity away from the operator. In doing so we have increased the complexity of the tasks of the maintenance personnel by building systems which employ higher technology, often under constraints of smaller volume, and more stressful temperature environments. We have then tended to try to design complexity away from the maintainer also with the use of techniques such as built-in test equipment. As discussed below, such approaches create problems of their own. This approach has also tended to drive out of the system any manual backup capabilities. In turn, these factors increase the burden on the skills of the maintenance personnel. The lack of a backup capability increases the need for on-site maintenance skills to rapidly restore the system to an acceptable operating condition.

One of the obvious alternatives which the Panel discussed at length is the use of contractor personnel to assist in the maintenance of a ready system. It was the opinion of the Panel members that contractor maintenance should be used in the early phases of system operation, and should continue until system operation, including recurring spares requirements stabilizes and until the Services can supply sufficient numbers of trained personnel. This could be 3-to-5 years for high technology systems. By the time system operation stabilizes (that is, the change rate settles down), the Services will have had the necessary experience to better match the spares supply with need based on use. The concept of contractor logistics support should also be considered viable. It should be used most heavily in the immediate post-IOC period on a preplanned, rather than an emergency, basis as has sometimes occurred in the past. The contractor should have a defined task rather than operate side-by-side with military personnel and should not extend any longer than is cost effective. In doing this we need to be mindful of the morale problems created by unequal pay, distinctions in the challenge of the work given to the military and the contractors, etc., and, therefore, plan to phase over to military maintenance as soon as it makes good sense from a readiness and cost point of view. DoD Directive D 1130.2 should be revised to eliminate the restriction prohibiting DoD contracting for Contractor Engineering and Technical Services Personnel for a maximum of 12 months after the user activity reaches self-sufficiency which the Services define as the Operationally Ready date. It should authorize such services at any time the need is satisfactorily justified by the using activity.

Another area in which contractor support seems viable is in upgrading the readiness of existing systems. Teams of military/contractor personnel could review those systems which have exhibited poor maintainability in the field, provide remedial training of field personnel, reevaluate the tasks required at each maintenance level, etc. In the short run, contractors could be used to make up for shortages of appropriate military personnel.

In the longer term, we should consider a skilled maintenance crew concept with appropriate compensation, special uniforms, etc. We need to find ways to attract better people since, as the quality of the average person in maintenance goes down, the interest of the better people in that work will also go down. One of the approaches which the Panel discussed and which we suggest the DoD consider further is the use of an approach in which the Services and industry get together and define programs in which people would transition from a military career to an industry career with industry contributing to the initial training and the person being guaranteed an industry position in return for a period of military service. Another long-term possibility is that our modern systems could actually be maintained by lower skilled personnel if we did a better job of training. The Panel suggests that each of the Services undertake a test program to examine the feasibility of using less skilled personnel through the adoption of innovative training equipment and techniques.

6.3 Built-In Test Equipment

One of the approaches used in the newer systems to improve readiness through a maintainability point of view has been the use of built-in test and fault isolation testing capabilities. This approach is often referred to as BIT/FIT. A related concept, which does not use built-in equipment, is called automatic test equipment or ATE. The Panel believes that such approaches show great promise for improving our ability to keep high-performance systems ready, but that what has been achieved so far is grossly inadequate. The systems designed to detect faults and help the maintainer to isolate and replace the failed unit have become very complicated in themselves and, therefore, represent a large acquisition, maintenance and operating burden. In addition, to date at least we have not done well in designing fault detection systems which are sensitive enough to detect failures which significantly lower system readiness without also having very high false alarm rates. The high incidence of false failure indications cause much wasted effort in maintenance troubleshooting, unnecessary replacement of parts which have not failed, etc. In general, the BIT/FIT or ATE approaches have tended to increase rather than reduce the burden on maintenance personnel. The use of automatic test equipment forward has tended to drive repair capabilities rearward, which has in turn increased the need for replacement spares forward, increased the burden on transporting the items to be repaired and on returning them to the operating locations, and in some cases this combination has in fact reduced operational capability.

The Panel discussed at length the specification, design and production of built-in test systems. There appears to be a seriously inadequate theoretical foundation for the establishment of fault detection thresholds and for other aspects of the rational design of BIT and other fault detection and isolation equipment.

In the early 1970s, the proliferation of complexity within avionics equipments, coupled with the advancing state of digital technology, led to the birth of the "Built in Test (BIT)" cult. Concerns relative to the maintainability of equipments with a multiplicity of removable assemblies were quieted with the promise of automatic fault detection and isolation capabilities that stretched into the high ninety percentile range. While these promises looked good on paper and were incorporated into almost all specifications, the actual field performance has been nothing short of a disaster. The data shown below for a sample of Air Force equipments is representative of tri-Service experiences before substantive corrective measures are instituted.

A/C	Auto Fault Detection	Auto Fault Isolation	False Alarm Rate	Retest OK
E-3A	74	34	25	30
F-16A	49	69	45	25
EF-111A	62	71	38	19

NOTE: Data is in percent as determined by the user.

In almost every case, the data when massaged thru the legal definition process resulted in the contractor concluding that the specification requirements had been met. The net result is nonrecognition of a deficiency by the contractor, a nonusable BIT system for the user, a demand for increased flight line maintenance capability, a requirement for increased spares to cover the increased "float" of good assemblies in the repair system, and a larger-than-expected workload for the intermediate and depot level test equipment. In short, a total nightmare in terms of equipment readiness.

The divergence between expected and actual BIT performance is so large that the causes are sure to be wide ranging and very basic. The disjointed trail starts with specifications which are typically incomplete and overrestrictive at the same time. This anomaly is created by a total lack of specification of false alarm rates (false faults), while at the same time limiting the designer to a BIT circuit which doesn't exceed more than 10% of the failure rate of the circuit it's checking. In addition, the drive to achieve automatic fault detection and isolation capabilities in the high 90s is not traded off against false alarm potential or manual isolation capability. As would be expected, the design process is characterized by the priorities driven home in the specification. Thus, in the designer's mind, the major emphasis is to design a simple, highly sensitive BIT circuit in order to live within the boundaries described above. Thus, in the case of analog circuitry, the detection tradeoff between real failures and occasional transients becomes especially difficult.

Another difficulty that evidences itself during the design process is the manner in which design responsibility for complex weapons systems is assigned. In most cases, design responsibility is broken down by Weapons Removal Assembly or in groups of assemblies. With BIT being assigned on a system basis, the BIT designer must be heavily reliant on each subsection designer to achieve his goals. This requires the BIT designer to be very capable in the area of apportionment management, interface analysis, and interpersonal relationships. Unfortunately, experience indicates that industry is not strong in understanding how to successfully accomplish this task.

An analysis of the lessons learned on the Navy's E-2C aircraft shows an early history filled with the exact problem previously discussed. This was followed by a corrective action period, resulting in an eventual In-Flight Performance Monitoring System (IFPM) that is fully usable for organizational maintenance. The specific corrective actions employed for the E-2C IFPM are indicative of the basic BIT design incompatibilities and included:

- Desensitization of the BIT circuitry to electromagnetic interference to eliminate false alarms.
- Software integration of the BIT outputs to remove false alarms due to internally generated equipment transients.
- Addition of BIT sensors at Weapons Removable Assembly interfaces to improve automatic isolation to the correct assembly.
- Addition of test points to allow for a manual isolation capability as a supplement to the automatic BIT.

As a result of the E-2C BIT corrective action program, the number of false alarms were greatly reduced, the automatic isolation requirements of 81% (entire aircraft) was achieved, a manual capability was added to handle the 19% that couldn't be accomplished automatically, and the number of 'cannot duplicates' and 'retest OKs' were substantially reduced. In the end, the Navy deployed an aircraft system that is fully maintainable and supportable. The major question remaining is how to accomplish that end without the necessity of a major corrective action program.

The Panel strongly recommends that DoD undertake programs to study the design of built-in test and fault isolation systems which improve readiness without creating systems which are as complicated to own and operate as the prime mission equipment itself. This is a critical need in making our more capable systems more available to the user. The necessary R&D must also concern itself with the people problems associated with this approach. The system must be easier to use without being degrading to the maintainer. We must dramatically improve the reliability, maintainability and supportability of these systems. Clearly the test and diagnostic approach must be designed as a system, with special emphasis on the people involved, and in turn the design must be integrated with that of the prime mission system. The design should not ignore the contributions which personnel can make to an effective system. In the follow-on stages of development and test, priority attention equivalent to that given to the prime system must be given to the test and diagnostic system.

However, the use of built-in test equipment is driving a need for higher skills at the depot level. This leads to the suggestion that more contractor personnel be employed at depot level. The use of built-in test equipment, and the associated unit replacement policy, of course puts a heavy burden on the spares support to ensure that the proper replacement unit is available where it is needed.

6.4 Logistics

Replenishment of spares and components (as well as supplies) in the military services has traditionally used a logistics system that is based on user demand -- that is, requisition from the user to depot for items and amounts that are based on the user's recent consumption experience. For complex and newly fielded systems, this experience is limited and the support that it will require for some designated operational availability (A_o) will take considerable time to establish. In the meantime, the budgeting and planning for positioning of spares is an unreliable process and they have not been explicitly related to the desired A_o.

In deploying a new weapons system, the important questions to be answered early are: How many of each spare? and, Where should it be positioned in the supply system? The answers to these questions should be explicitly related to the operational availability that is desired. Ideally we would like to have a logistics arrangement that is planned in advance to support a desired A_o and by which spares are automatically sent to the proper place, at the proper time, and in the proper amounts. Several working models to do this have evolved among the Services, and we have seen the results of this "sparing to availability" approach as it was used on the Army's Artillery/Mortar locating radar systems, the Firefinder. In this case such a logistics analysis was done and provided a planning base that allowed spares to be budgeted for early in the acquisition cycle and resulted in the Firefinder reaching the required operational capability of 96%, an accomplishment that was judged not possible using a "demand-support system." There were other advantages of sparing to availability over "demand-support" that were exposed during the Army's experience with the system. First, down-time of the system decreased over what would have been anticipated with "demand-support." Secondly, effective utilization of operating personnel increased. At the same time, of course, the investment in initial spares was larger than has been customary and, because of this early investment in spares, the danger of obsolescence is greater.

It is also worth noting that the analytic model and data accumulated during operations provides a data base that allows rational decisions about what the sparing costs would be to attain any given A_o. Although this is not significant for Firefinder which has an A_o of 96%, for some systems which could be satisfied with a peacetime A_o of 60-90%, this cost information would be significant.

It is the conclusion of the Panel that DoD should direct that all acquisition programs for large, high performance systems should use the "spare-to-availability" model as early as possible in the program to estimate support costs, and as a basis for its eventual logistics support system.

As in all other support areas, it is necessary to consider the impact of logistics early in the system design and development process and to trade off spares requirements with system design, maintenance concepts, personnel availability, etc.

The Panel was briefed on a series of lessons learned as a result of a Navy Logisitics Review Group activity in which 50 audits were conducted and the results summarized in attempt to determine what improvements could be made in management, planning and execution of logistics tasks. Of the 400 individual findings developed, almost 25%

related to integrated logisitics planning. In some cases, the plans were nonexistent, in others incomplete, inadequate in detail and contained errors. There was also some indication that plans were not being followed after they had been approved -- and in particular not being used routinely as a basis for program management. The Panel supports the conclusion of the Navy study that regulations for logistics planning must be followed, that the process must be audited and that the program managers must develop these plans in managing their programs. The Panel also supports Navy recommendations that further guidance be provided on tailoring support requirements to a given system, and on budgeting and financing integrated logistics support.

Approximately 55 of the 400 findings concerned budgeting for logistics. The Review Group concluded that the Navy has to do a better job of assembling complete, integrated, and thoroughly justified budgets if they are to minimize shortfalls in the funding of support. In many cases the shortfalls were the result of incomplete identification of requirements by program management. There was also a lack of integration in total program budgets that encompass multiple appropriations.

The other major findings of the Navy study were that training plans should be developed early, that configuration control needs more management attention, technical manuals need to be of higher quality, operational availability goals need to be identified early and assessed regularly, built in test and other support equipment requirements should be identified early, and that additional resources are needed for logisitics management. It was also concluded that there has to be better planning for the acquisition and support of software.

In deciding what to buy for spares, we need to emphasize optimum system availability rather than optimum supply availability. There is also some evidence that a policy of directed stockage of selected mandatory spares (a push concept) is good for system availability and that it is not automatically more costly.

In determining the spares level required, the peacetime training necessary to permit the effective transition to the expected wartime surge rates should be examined. Sufficient spares to support the wartime surge rates obviously must be purchased and stored appropriately. However, we must also purchase the spares to permit the peacetime training of maintenance personnel required to be ready to support the wartime surge rates.

The Panel also suggests that the initial complement of spares be purchased on the same contract as the prime mission equipment to achieve economies of scale and to ensure that the spares are of the same quality as that equipment. This also helps avoid confusion over the responsibilities of the development and logistics agencies for spares in the early operational life of the system. When system support does transition to the logistics agency, the transfer should be well-documented and leave no uncertainties about which agency is responsible for support. In each phase of a program the responsibility should be centralized and clearly understood. Systems which are not adequately supported should be delayed until they are, before introducing them into the operational inventory.

As part of the maintenance concept, acceptable logistics delay times need to be determined; that is, acceptable delays between the time a part is needed and the time it is available at the point of repair. The delay actually experienced will be a function of reliability, spares investment and repair time. Sufficient spares must then be purchased and placed to meet the logistics delay time requirements. It is crucial that the spares purchase be based on realistic logistics system delay time. Long-lead funding for spares may be required to achieve necessary availability in the early operational life of the system. Even later in the system life, long-lead funding may be required for spares, especially those which involve critical materials. Another approach which the Services should employ in ensuring ready systems is the use of "operational floats." Sometimes major end items and major subassemblies, available to the operational commander, can be important means for him to maintain his system in ready status. Also, as a policy, the Services should distribute spares to the lowest logical organizational level to minimize downtime due to lack of spares, while continuing to be concerned about the cost savings which result from central management of high-value items.

To help avoid a system from becoming "not operational ready - spares (NORS)," the provisioning system should provide for highest priority reorder for selected key items without waiting for the zero stock condition to occur (e.g., NORS-priority even though the system is not yet NORS). The Services must learn to "micro-manage" critical spares which are in short supply. Fast moving items must be stored in greater depth. Spares must be positioned to improve system availability.

The Panel was encouraged that advanced analytical and modeling techniques are now starting to be employed to relate spares availability to readiness. These techniques attempt to balance investments in spares, reliability, maintainability, and manpower as these factors affect system availability. They can be tailored to each system individually, and applied early in the design phase as well as in post-deployment evaluation. The emphasis on system availability as the criteria for success, as opposed to the "demand" approach to spares, is also applauded since the Panel strongly believes that system availability should be the predominant spares criteria.

APPENDICES

THE UNDER SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

RESEARCH AND ENGINEERING

23 JUN 1981

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Defense Science Board Summer Study: Operational Readiness with High Performance Systems

You are requested to undertake a Summer Study to investigate how to achieve adequate operational readiness with high performance systems.

Reliability, availability, and maintainability of equipment in the field is a critical problem. There is concern that emphasizing sophisticated technologies to improve performance of weapons has degraded operational readiness. Evaluation of operational requirements and potential threats has often led to system specifications demanding high performance. In turn, this frequently led to complicated and sophisticated designs. The desire to field complex systems early, coupled sometimes with inadequate design, reliability, and testing can lead to systems characterized by high failure rates, high maintenance demands, and low readiness as indicated by some readiness indicators. But this is not always true, as is evident from a number of fielded high complexity systems with high reliability.

It is necessary to determine how to get systems having both the performance needed as well as adequate readiness. It is not clear if performance specifications have been set too high, whether complexity and sophistication are implicit in high performance, and whether the resulting support requirements are more than offset by the increased high performance. There is the question as to whether high performance requirements and sophisticated technologies have led to such high system costs that the Defense budget can no longer support either the procurement of adequate quantities for the forces or the provision of adequate war reserves, spares, maintenance personnel, and facilities. It is necessary to determine whether complex systems are necessarily of lower reliability than simpler systems, whether systems modifications in lieu of new developments can give better readiness, or whether system complexity and/or inadequate design has exceeded our training ability in operations and maintenance (considering the capabilities of personnel in the Armed Forces). Finally, there are indications of excessive "induced" failures during maintenance procedures as well as significant impact of removal of "no defect" items.

Critical questions to be addressed by the Summer Study include:

1. What is the general state and trend over time of operational readiness and support requirements (including the capability to deploy with adequate support) in the Services today with respect to major weapon systems and equipment? What are the primary readiness indicators and are they adequate?

2. What is the relationship between performance requirements, specifications, complexity, cost, manpower and logistic requirements (e.g., availability of war reserves, spares, maintenance personnel) and the readiness indicators?

3. How do we establish performance requirements that are adequate to meet our needs, but do not lead to systems with excessive sophistication and complexity? What is the role of pre-planned product improvement versus new systems in this area?

4. Must high performance systems necessarily be complex and sophisticated? Are there design techniques to ameliorate this and what are the cost, schedule, and test implications of these?

5. To what degree do our specifications, design, development and operational testing practices, and acquisition procedures lead to low reliability systems and how can we change this? What technologies offer the most promise to improving readiness and deployment capabilities and what efforts should be initiated to this end?

6. If adequate readiness cannot be obtained with high performance systems, could lower performance, lower cost, more available systems satisfy our defense needs in a fixed manpower environment? Alternatively would these needs better be satisfied by investing more in spares, maintenance facilities and personnel?

7. Should we have two classes of systems from the point of view of demands on operations and maintenance personnel (low quantity-complex systems like AWACS could require highly trained operations and maintenance personnel whereas most systems would place minimal demands for such personnel)?

8. What technical aids and other changes can be made in our field maintenance procedures to reduce the incidence of "induced" system malfunctions during maintenance procedures and the removal of "no defects systems"? What can be done to reduce maintenance times for true failures in the field? Can this be applied to systems currently in the field as well as new systems?

In summary, the panel should assess, and make recommendations concerning the impact of high performance and high technology on (1) operational availability of equipment, (2) skill and training requirements of operators and maintainers, (3) cost and affordability of adequate quantities of equipment, and (4) cost of support.

This Summer Study will be sponsored by Mr. David C. Hardison, Deputy Under Secretary of Defense for Research and Engineering (Tactical Warfare Programs). General William E. DePuy, USA (Ret.), has agreed to serve as Chairman, and Dr. Milton J. Minneman, OUSDRE/TWP, will serve as Executive Secretary.

Dick De Lauer

APPENDIX B - PANEL MEMBERSHIP

OPERATIONAL READINESS WITH HIGH PERFORMANCE SYSTEMS

*General William E. DePuy, USA (Ret.), Chairman
(Former Commanding General, U.S. Army Training and Doctrine Command)

*Mr. Charles A. Fowler, Vice Chairman
Vice President and General Manager, Bedford Operations, The MITRE Corporation (Former Deputy Director, Tactical Warfare Programs, Office of Director, Defense Research and Engineering)

*Mr. John H. Richardson, Member at Large
President, Hughes Aircraft Company

Dr. Milton J. Minneman, Executive Secretary
Special Assistant for Plans and Analysis, Office of the Under Secretary of Defense (Research and Engineering) (Former Director of Engineering, General Instruments Corporation)

Mr. Martin A. Meth, Deputy Executive Secretary
Staff Engineer, Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics)

SUB-PANEL MEMBERSHIP

PERFORMANCE BENEFITS VERSUS SUPPORT BURDENS

Mr. David R. Heebner, Chairman
Executive Vice President and General Manager, Washington Operations, Science Applications, Inc. (Former Deputy Director Tactical Warfare Programs, Office of the Director, Defense Research and Engineering)

*-DSB Members

*Dr. Malcolm R. Currie
Vice President and Group Executive, Hughes Aircraft Company
(Former Director, Defense Research and Engineering)

Brigadier General Delbert Jacobs, USAF
Deputy for General Purpose Forces, Directorate for Operational Requirements, Deputy Chief of Staff of the Air Force for Research, Development, and Acquisition

Mr. Jerry R. Junkins
Vice President and Group Manager, Equipment Group,
Texas Instruments Incorporated

Mr. Kenneth Richardson
Group Vice President, Radar Systems Group,
Hughes Aircraft Company

THE REQUIREMENTS PROCESS

*Mr. Lawrence H. O'Neill, Chairman
President, Riverside Research Institute

Mr. Harvey S. Fromer
Director, C-2 Reprocurement Program,
Grumman Aerospace Corporation

Mr. Milton L. Lohr
Executive Vice President, Flight Systems Incorporated
(Former Deputy Assistant Director, Tactical Ordnance and Missile Systems, Office of the Director, Defense Research and Engineering)

Mr. John H. Monahan
Vice President for Tactical Systems, Bedford Operations,
The MITRE Corporation

*Dr. Donald H. Steininger
Manager of Technical Staff, Research and Development Group, Xerox Corporation (Former Associate Deputy Director for Science and Technology, CIA)

Mr. Charles K. Watt
Deputy Director of Defense Test and Evaluation (Strategic and Naval Warfare Systems), Office of the Under Secretary of Defense (Research and Engineering)

Mr. Willis J. Willoughby, Jr.
Deputy Chief of Naval Material for Reliability, Maintainability, and Quality Assurance, Headquarters, Naval Material Command (Former Director of Reliability, Apollo Program, NASA)

MAN-MACHINE INTERFACE

*Admiral Isaac C. Kidd, Jr., USN (Ret.), Chairman
(Former Commander in Chief, Atlantic; Former Chief of Naval Material)

Mr. Harold D. Altis
Corporate Vice President, Engineering and Research, McDonnell Douglas Corporation

Brigadier General (Select) Joe J. Breedlove, USA
Chief, Aviation Systems Division, Office of the Deputy Chief of Staff of the Army for Research, Development and Acquisition

Dr. John D. Folley
President, Applied Science Associates, Inc.

Mr. Ralph H. Shapiro
Division Manager, Field Service and Support
Hughes Aircraft Company

Lieutenant General Philip D. Shutler, USMC (Ret.)
(Former Director of Operations, J-3, Joint Staff)

IMPACT OF COMPLEXITY ON DEFENSE RESOURCES

General John W. Pauly, USAF (Ret.), Chairman
(Former Commander in Chief, U.S. Air Force, Europe)

Mr. Robert L. Perry
Program Director, Strategic Assessment, The RAND Corporation

Mr. Michael Rich
Director, Resource Management Program, The RAND Corporation

Dr. Joseph Shea
Senior Vice President, Engineering, The Raytheon Company
(Former Manager, Apollo Spacecraft Program, NASA)

Dr. Alexander L. Slafkosky
Scientific Advisor, Office of the Deputy Chief of Staff
for Research, Development, and Studies
HQ, U.S. Marine Corps

Dr. Richard J. Trainor
President, Trainor Associates, Inc.
(Former Director, Systems Review and Analysis, Deputy Chief
of Staff, Research, Development, and Acquisition, Department
of the Army)

ASSISTANTS TO THE PANEL

Colonel Richard A. Gunkel, USAF
Director of Logistics, Air Force Test & Evaluation Center

Captain Kenneth L. Meek, USN
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Colonel John Borling, USAF
Assistant Director for Operations, Initiative and Joint Matters, Department of the Air Force

Lieutenant Colonel Andrew Casani, USA
RDT&E Coordinator, Department of the Army

Major William P. Comstock, USAF
Air Operations Officer, Department of the Air Force

APPENDIX C

RECOMMENDATIONS AT
SAN DIEGO MEETING

DEFENSE SCIENCE BOARD
1981 SUMMER STUDY (U)

OPERATIONAL READINESS WITH HIGH PERFORMANCE SYSTEMS (U)

AUGUST 1981
SAN DIEGO, CALIFORNIA

(1)
4138-1

RECOMMENDATIONS
(GENERAL)

WE STRONGLY SUPPORT ON-GOING OSD EFFORTS

- DEPSECDEF INITIATIVES ON ACQUISITION
  - ESTABLISH READINESS OBJECTIVES; MANAGE TO ACHIEVE THEM
  - PROGRAM MANAGER CONTROL/VISIBILITY OF SUPPORT RESOURCES
  - INCREASED USE OF CONTRACTOR INCENTIVES
  - PREPLANNED PRODUCT IMPROVEMENT (P^3I)
  - ADEQUATE TEST ARTICLES
- INITIATIVES FOR PROVIDING SPARES TO MEET A SPECIFIED A_O
- PRIORITY PLACED ON READINESS IN THE DEFENSE GUIDANCE

(21)
4138-1

RECOMMENDATIONS

- **REQUIREMENTS**

1. CONTINUE TO BASE REQUIREMENTS ON MISSION AND THREAT. OF THE OPTIONS REASONABLY AVAILABLE TO THE U.S., SEEK AN EFFECTIVENESS EDGE OVER THE THREAT THROUGH TECHNOLOGY IN SO FAR AS TECHNOLOGY CAN MEET THE OPERABILITY, RELIABILITY, AND MAINTAINABILITY STANDARDS REQUIRED. (USDR&E AND SERVICE SECRETARIES)

   - SET STANDARDS THAT PROMOTE DESIGNED-IN, AND MANUFACTURED-IN, RELIABILITY AND MAINTAINABILITY
   - ADD NEW TECHNOLOGY TO FIELDED SYSTEMS AS REQUIRED BY THE THREAT AND AS RELIABLE NEW CAPABILITIES BECOME AVAILABLE (P^3I)

(22)
4138-1

RECOMMENDATIONS

- INHERENT AVAILABILITY (A_I)

2. ESTABLISH HIGH RELIABILITY AND MAINTAINABILITY REQUIREMENTS FOR HIGH PERFORMANCE SYSTEMS. PROVIDE THE RESOURCES AND DEVELOP ACQUISITION STRATEGIES TO ACHIEVE THEM (USDR&E AND SERVICE SECRETARIES)

— SPECIFIC ACTIONS SHOULD INCLUDE

- ENGINEER RELIABILITY INTO HIGH PERFORMANCE SYSTEMS AT THE "SPACE SYSTEMS" MINUS 5% LEVEL (THAT IS AN A_I ROUGHLY 95% WITH EMPHASIS ON HIGH MTBF)
- DESIGN REPAIR TIMES (MTTR) SHOULD BE RELATED SPECIFICALLY TO ENVIRONMENT, SPECIFIC PERSONNEL SKILLS, EXPERIENCE, AND TRAINING
- PROGRAM AND FUND A SPECIFIC RELIABILITY, MAINTAINABILITY, AND PRODUCIBILITY ENGINEERING EFFORT **BEFORE** IOC. PROVIDE STRONG R&M INCENTIVES TO CONTRACTORS
- PROGRAM AND FENCE FUNDS (INCLUDING R&D) FOR R&M IMPROVEMENT BY THE CONTRACTOR DURING THE EARLY STAGES OF DEPLOYMENT
- STAY AT LOW RATE PRODUCTION UNTIL RELIABILITY AND PRODUCIBILITY PROBLEMS ARE LARGELY IN HAND
- PROVIDE SPACE, WEIGHT, AND POWER MARGINS IN WEAPON SYSTEM DESIGNS ADEQUATE FOR PRODUCT IMPROVEMENTS COMMENSURATE WITH THREAT PROJECTIONS

(23)
4138-1

RECOMMENDATIONS

- INHERENT AVAILABILITY (A_I)

3. TAKE PLANNING AND FUNDING ACTIONS TO MINIMIZE THE RAPIDLY INCREASING IMPACT OF SOFTWARE ON READINESS (USDR&E)

- IN THE ACQUISITION DIRECTIVES, REEMPHASIZE THE NEED TO MANAGE SOFTWARE AS A DEVELOPMENT ITEM
- PLAN AND BUDGET FOR CONTINUING DEVELOPMENT AND EVOLUTION OF THE SOFTWARE THROUGHOUT THE ACQUISITION AND OPERATIONAL PHASES OF EACH PROGRAM
- INSTITUTE A GOVERNMENT FUNDED 2 YEAR TRAINING COURSE IN THE SOFTWARE FIELD, WITH AN ACCOMPANYING 4 YEAR MILITARY COMMITMENT
- MODIFY IR&D PROCEDURES TO ENCOURAGE CONTRACTORS TO MAKE SOFTWARE-RELATED PROPOSALS
- EXEMPT SOFTWARE FROM THE REQUIREMENTS FOR SMALL BUSINESS/8A SET ASIDES
- ENSURE THAT THE DSB SOFTWARE STUDY INCLUDES READINESS CONSIDERATIONS

(24)
4138-1

RECOMMENDATIONS

- **OPERATIONAL AVAILABILITY — A_O**

4. MOVE READINESS UP TO AN EQUAL PRIORITY WITH PERFORMANCE IN THE WEAPONS SYSTEM ACQUISITION PROCESS (USDR&E AND SERVICE SECRETARIES)

   - DEVELOP A READINESS ADVOCACY PROGRAM IN DOD
   - AT THE BEGINNING OF DEVELOPMENT, DEFINE AND ESTABLISH TARGETS FOR SYSTEM SPECIFIC ELEMENTS OF READINESS; MANAGE TO THEM THROUGHOUT ACQUISITION
   - REVIEW READINESS PROGRAMS AS RIGOROUSLY AS WE NOW REVIEW PERFORMANCE AT EACH ACQUISITION MILESTONE AND INTO DEPLOYMENT
   - DIRECT EACH SERVICE TO DEVELOP A REAL READINESS ASSESSMENT CAPABILITY AS PART OF THE OPERATIONAL TEST AND EVALUATION PROCESS TO PROVIDE VISIBILITY IN MILESTONE MANAGEMENT REVIEWS

(25)
4138-1

RECOMMENDATIONS

- OPERATIONAL AVAILABILITY (A_O)

5. INCREASE THE EMPHASIS ON ENGINEERING COMPLEXITY AWAY FROM THE OPERATOR AND THE ORGANIZATIONAL MAINTAINER

— START A HIGH PRIORITY TECHNOLOGY PROGRAM ON MAN-MACHINE INTERFACE DESIGN, WITH INITIAL EMPHASIS ON BITE AND OTHER AUTOMATIC TEST EQUIPMENT (USDR&E AND SERVICE R&D DEPUTIES)

— WHEN REQUIRED, SET SPECIFIC PROGRAM GOALS TO REDUCE SKILL LEVELS (PROGRAM MANAGERS)

— USE CONTRACT INCENTIVES TO THAT END

— BRING THE PERSONNEL AND TRAINING COMMUNITIES MORE DEEPLY INTO THE FRONT END PROCESSES (REQUIRED OPERATIONAL CAPABILITIES, RFPs, SOURCE SELECTION, ETC.) (SERVICE SECRETARIES)

26

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RECOMMENDATIONS

- OPERATIONAL AVAILABILITY (A_O)

6. DURING INITIAL DEPLOYMENT OF SELECTED SYSTEMS MAKE INCREASED USE OF CIVILIANS (CONTRACTOR AND GOVERNMENT EMPLOYEES) FOR INTERMEDIATE AND DEPOT LEVEL MAINTENANCE (ASD(MRA&L) AND SERVICE SECRETARIES)

— MAKE A SKILL ANALYSIS AT FRONT END

— DETERMINE SERVICE CAPABILITY. IF UNABLE TO MEET REQUIREMENT:

- DRIVE DOWN SKILLS
- COMMIT TO MEET "X" PERCENT WITH MILITARY PERSONNEL
- PUT REMAINING REQUIREMENTS FOR SUPPORT IN SYSTEM CONTRACT
- TAPER OFF CONTRACTOR SUPPORT AT INTERMEDIATE LEVEL AS SYSTEM STABILIZES AND R&M RISES

— CONSIDER IN SOME CASES LONG TERM CONTRACTOR SUPPORT AT DEPOT LEVEL

(27)
4138-1

RECOMMENDATIONS

- OPERATIONAL AVAILABILITY (A_O)

7. INITIATE PROGRAMS TO USE ADVANCED TRAINING TECHNIQUES TO NARROW THE SKILL GAP (SERVICE PERSONNEL DEPUTIES)

- ADOPT PARTIAL-FUNCTION RATHER THAN MULTI-FUNCTION FULL SYSTEM TYPE TRAINERS SO AS TO ACHIEVE A BASIS FOR HIGH VOLUME REPETITIVE BASED TRAINING
- EMPHASIZE "PRACTICE" RATHER THAN "KNOWLEDGE" IN TRAINING
- PROVIDE ADVANCED SKILL PERFORMANCE AIDS FOR BOTH MAINTENANCE OPERATIONS AND TRAINING
- ESTABLISH DEMONSTRATION TRAINING PROGRAMS TO TEST AND ADVANCE THESE AND OTHER TECHNIQUES ON A SYSTEM SPECIFIC BASIS

(28)
4138-1

RECOMMENDATIONS

- **OPERATIONAL AVAILABILITY (A_O)**

8. INITIATE A MAJOR PROGRAM TO FILL THE SKILL GAP IN THE MAINTENANCE AREA (ASD(MRA&L) AND SERVICE SECRETARIES)

- FUND AN INCREASED RETENTION PROGRAM FOR UNIFORMED HIGH SKILL LEVEL TECHNICIANS IN CRITICAL SHORTAGE AREAS
  - REENLISTMENT BONUS
  - SPECIAL PAY INCENTIVES
- CONSIDER A MAJOR EXPANSION OF THE WARRANT OFFICER COMPONENT (OR EQUIVALENT) OF THE MAINTENANCE WORK FORCE
- RECRUIT DIRECTLY INTO THE WARRANT OFFICER TRAINING PROGRAM
- SET COMPENSATION TO TAKE INTO ACCOUNT THE FACT THAT IN THE DEPLOYED FORCE MIXED CIVILIAN AND MILITARY MAINTAINERS OFTEN WORK SIDE-BY-SIDE
- PERSONNEL PROBLEM — NET ASSESSMENT

29

4138-1

RECOMMENDATIONS

- OPERATIONAL AVAILABILITY — A_O

9. IMPLEMENT SPARES POLICIES WHICH CHANGE BASIS FOR SPARES REQUIREMENTS FROM ITEM DEMAND TO WEAPON SYSTEM AVAILABILITY (A_O) (SERVICE SECRETARIES)

— SUBMIT BUDGETS BASED ON WEAPON SYSTEM AVAILABILITY

— IMPROVE AND EXTEND THE USE OF ANALYTIC TECHNIQUES FOR ESTIMATING SPARES REQUIREMENTS

(30)
4138-1

RECOMMENDATIONS

- OPERATIONAL AVAILABILITY — A_O

> 10. BUY ENOUGH A_O TO SUPPORT PEACETIME REQUIREMENTS AND A BASE FOR WARTIME SURGE AND SUSTAINABILITY — 60-90% DEPENDING ON SYSTEMS (DEFENSE RESOURCES BOARD)

— PROVIDE FUNDS AND SPARES IN PEACETIME ADEQUATE TO:

- TRAIN OPERATORS UP TO WEAPONS CAPABILITY
- DEMONSTRATE SURGE/SUSTAIN CAPABILITIES TO WARTIME LEVELS
- BUY SPARES AND MUNITIONS FOR WARTIME SUSTAINABILITY

(31)
4138-1

RECOMMENDATIONS

• MANAGEMENT

11. STRENGTHEN THE CRITICAL SYSTEM (VERTICAL) COMPONENT OF DEFENSE MANAGEMENT (SECDEF AND SERVICE SECRETARIES)

— PROVIDE TOTAL SYSTEM READINESS VISIBILITY (A VERTICAL SLICE) FOR ALL FUNCTIONS AND ECHELONS THROUGHOUT DOD

— IN ORDER TO PUT ADEQUATE DEFENSE RESOURCES ON READINESS, USE THIS ADDED VISIBILITY OVER SYSTEM REQUIREMENTS AS A CROSS CHECK AT EVERY LEVEL OF THE PPBS AND THROUGHOUT THE PROGRAM EXECUTION PHASE

— REINFORCE THE VERTICAL TECHNICAL AND INFORMATION CHANNEL OF PROGRAM MANAGERS ALL THE WAY TO DEPLOYED SYSTEMS FOR

- PLANNING
- MANPOWER AND TRAINING
- SPARES REQUIREMENT ANALYSIS
- TECHNICAL FEEDBACK
- PRODUCT IMPROVEMENT

(32)
4138-1

APPENDIX D
COMMENTS ON
RECOMMENDATIONS

THE DEPUTY SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

14 SEP 1981

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS

SUBJECT: Operational Readiness for High Performance Systems

The Defense Science Board recently completed a Summer Study on Operational Readiness with High Performance Systems. I was recently briefed on the study and think it is an excellent analysis of the problem. The recommendations are far reaching in their implications. The DSB recommendations on management, manpower and technical areas related to readiness complement our initiatives to improve the acquisition process.

I would like your views and reactions to the DSB's recommendations, and approaches you suggest to implement them. The Study's briefing charts are attached, and the Panel Chairman is available to provide you with more detail of the findings and recommendations. Arrangements can be made through the DSB Executive Officer, Dr. Paul J. Berenson, X-75162. The final report will be available in a few months.

Attachment:
As stated

SECRETARY OF THE ARMY
WASHINGTON

3 DEC 1981

MEMORANDUM FOR DEPUTY SECRETARY OF DEFENSE

SUBJECT: Operational Readiness for High Performance Systems -- INFORMATION MEMORANDUM

This is in response to your memorandum of 14 September 1981 requesting our views, reactions, and suggested approaches to implement the Defense Science Board's (DSB) recommendations from their 1981 Summer Study. My staff has completed its assessment (Tab A) and agrees with the general thrust of the DSB's recommendations on operational readiness for high performance systems. There is a high correlation between what was recommended and our current efforts in these same areas. This is encouraging and serves to reinforce our belief that we are on track in our concentrated endeavor to make substantive changes and improvements to the acquisition process. We have strong initiatives in all the major areas recommended by DSB; we have also achieved substantial progress towards many of the readiness issues contained in their report.

The Army is firmly committed to the continued challenges of operational readiness. We are confronting the key readiness concerns expressed by the Defense Science Board and by our own analyses. This is not to suggest that we have arrived at perfect solutions to all of our readiness problems; they remain valid concerns, and the new initiatives outlined in the inclosure must be intensively pursued if measurable improvement in our readiness posture is to occur. However, a period of time must be permitted for maturation of these recent initiatives so as to determine how effectively they reduce the problems identified by the DSB before we generate other new approaches. You can be assured all of these efforts are being closely monitored. Where progress does not correspond with reasonable expectations, additional management action will be taken.

1 Incl
Tab A - Recommendations Analysis

Operational Readiness for High Performance Systems
Recommendations Analysis

The study recommendations fall into four major categories: Requirement Documents for Army Materiel, Inherent Availability, Operational Availability, and Management. Army efforts in these categories along with our suggestions and comments follow:

Requirements.

1. The recommendation in this area stated that we should continue to base requirements on mission and threat. There are two goals within this recommendation: set standards that promote designed-in, and manufactured-in, reliability and maintainability; add new technology to fielded systems as required by the threat and as reliable new capabilities become available (P3I). We agree with these goals.

2. Army materiel requirements are developed from mission needs, current and projected threat, and technological opportunities. Guidance has been implemented that makes improved reliability, availability, maintainability, and durability (RAM-D) an integral part of Army mission needs. RAM-D is designed-in and manufactured-in, and it is also subject to performance growth through preplanned product improvement. Technological opportunities are pursued not only to improve operational capabilities, but also to enhance RAM-D characteristics.

Inherent Availability.

1. One of the recommendations in this area advocates the establishment of high reliability and maintainability requirements, along with the provision of resources and the development of strategies to achieve them. A second recommendation is concerned with initiating planning and funding actions to minimize the rapidly increasing impact of software on readiness. We agree with these goals.

2. Current Army materiel acquisition policy prescribes that RAM-D goals will be defined in operational terms and will be realistically achievable in the field. These goals are design characteristics that are managed just like any other system performance parameter throughout the acquisition cycle. In the software arena, we have recently implemented specific acquisition policy for embedded computer resources that promotes improved software reliability. We have also implemented software standardization and acquisition policies.

3. While the goals for inherent availability should remain high, it is necessary to evaluate the benefits of extremely high inherent availability (95% suggested in the report) versus the factors of cost, schedule, and performance characteristics. Generally speaking, contractors can deliver whatever inherent availability we specify, if we are willing to pay the price in dollars, time, and additional maintenance burdens.

Operational Availability.

1. The impetus of the recommendations pertaining to operational availability is to bring readiness on par with performance in the acquisition process, increase emphasis on reducing complexity for the operator and organizational maintainer, increase use of contractor maintenance, narrow and fill the skill gaps in the maintenance area, implement spares policies based on weapon system availability, and sufficiently fill peace and wartime operational availability requirements. We agree with the thrust of these goals.

2. The Army has several initiatives ongoing to greatly increase the visibility and control of support resources thereby ensuring the systems being deployed will have all necessary ancillary equipment, software, and trained personnel necessary to achieve full operational effectiveness. We have recognized the criticality of the soldier-machine interface for some time and have several studies in progress designed to determine the effects of system complexity on operator and maintenance training. Our acquisition regulations are being clarified to enhance soldier-machine interface objectives, and materiel developers are increasing utilization of automatic and built-in test equipment. Front end skill analyses of new systems are required by Army regulations and have been subject to increasing emphasis as an integral part of the development process. The use of contractor support is an option that is being considered on a case-by-case basis in the preparation of a system's acquisition strategy. This support is already being used at depot level for some systems and is contemplated for others. In some cases, we anticipate replacing the contractor support with Army assests as they become trained. The Army has also begun a comprehensive Force Alignment Program to fill all critical skill gaps which significantly improves the controls for managing these skills. The effort includes increasing retention and recruiting from the 22-34 year old age group. Manpower and Logistical Analyses (MALA) are being institutionalized in the Army. They focus on reliability, manpower, operational availability, and cost. The MALA for the M1 Tank has been briefed to OSD, and others are planned for systems in the latter phases of the acquisition process.

3. Moving readiness up to an equal priority with performance in the weapons system acquisition process is a step in the right direction. However, we must first define the readiness equation at the beginning of development with system specific elements. Some examples of other factors to be considered in this equation are manning, skill levels, adequacy of diagnostics, spares, and facilities. Although we are engaging contractor support in overseas bases to perform maintenance functions, their continued employment during periods of conflict must be closely examined. We agree with the overall thrust of initiating programs to use advanced training techniques to narrow skill gaps. Skill Performance Aids (SPAS) have been used in the Army for this purpose for several years. We have two new initiatives which coincide with the DSB recommendations on training and personnel management. We are developing a new personnel management transition planning process by which the Army plans and programs personnel management support (people as opposed to positions) over time to satisfy those force requirements germane to the initial fielding and continued operation and

maintenance of a given family of weapon systems. We are also conducting an analysis of the training and personnel management impacts of twelve new systems into the force. A wide range of personnel and training management actions are planned to accommodate the introduction of the new systems. These planned actions are system specific and range from the establishment of system unique Military Occupational Specialties (MOS) and training courses for new soldiers to the inclusion of new skill/training requirements in existing MOS and training courses.

Management.

1. The single recommendation in the management area is strengthening the critical system (vertical) component of Defense Management.

2. We have used vertical technical and information channels for deployed aviation systems for many years, and recent changes have occurred within the Army Staff to accomplish vertical management for other fielded systems. We support the philosophy of decentralized management and suggest that the program manager and all other acquisition agents should have vertical visibility into each component area so that support functions are given the priority necessary to achieve effective systems. The Army Staff is also participating in efforts to improve the management of weapon system support funding and increase the program manager's involvement in support resource allocation and budget execution. These activities are in response to a request by the Assistant Secretaries of Defense (Comptroller) and (Manpower, Reserve Affairs and Logistics) to make recommendations and develop proposed implementation procedures that include more centralized resource visibility and coordination by the program manager. Two systems, Advanced Attack Helicopter and M1 Tank, have been selected to test these procedures.

DEPARTMENT OF THE NAVY
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20350

24 December 1981

SECRET--(Unclassified upon removal of enclosures)

MEMORANDUM FOR THE DEPUTY SECRETARY OF DEFENSE

Subj: Defense Science Board (DSB) Report on "Operational Readiness with High Performance Systems" -- ACTION MEMORANDUM

I am in strong agreement with the overall thrust of the Defense Science Board's report on "Operational Readiness and High Performance Systems" which recognizes the necessity of continuing to develop and acquire systems that are superior in performance to those of potential enemies; which points out that high performance is not necessarily incompatible with high availability and readiness; and which briefly outlines the steps and changes in emphasis required to attain high levels of availability and readiness.

Specifically, I agree that real improvements in the availability and readiness of new high performance systems will require balanced attention to all the major factors imbedded in the A_o equation, i.e., future systems should have a high "inherent availability;" they should be designed to match the skill levels of the personnel who will be available to operate and maintain them; and we should provide adequate spares and logistics support to attain the availability and readiness goals established at the outset.

With respect to the implementation of the DSB's recommendations, I also agree that many of the Weinberger-Carlucci initiatives to improve the acquisition process, which are being implemented as rapidly as possible within the DON, should not only shorten acquisition times and reduce the costs of new systems but result in the desired increases in the initial availability and readiness of future systems. However, as you well know, the related personnel, training, and software problems mentioned by the DSB are especially challenging ones, and we are, of course, committed to the task of addressing these critical problems vigorously and effectively.

However, the specific's in recommendation No. 8 (slide 29), which focus on the Warrant Officer program, are not concurred in. We presently have a well-balanced Warrant Officer program, the success of which is dependent upon a combination of military experience, leadership, and technical skills. To recruit directly into the Warrant Officer training program, or to expand it dramatically without the proper enlisted base would be counterproductive. The remaining specific recommendations are fully supported.

Subj: Defense Science Board (DSB) Report on "Operational Readiness with High Performance Systems"--ACTION MEMORANDUM (continued)

In closing, I would suggest that more emphasis should be placed on the role of test and evaluation (T&E) to ensure that both Inherent Availability and Operational Availability thresholds are met. In all other areas of the R&D process we deal in promises--T&E provides decision-makers with facts. In this respect, I commend to your attention the attached memorandum on T&E's role authored by Vice Admiral Bob Monroe, the Navy's Director of RDT&E.

John Lehman
Secretary of the Navy

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, D.C. 20350

IN REPLY REFER TO
Ser 098/355238

AUG 28 1981

MEMORANDUM FOR THE DEFENSE SCIENCE BOARD EXECUTIVE SECRETARY

Subj: Role of T&E in Achieving High Operational Readiness

Encl: (1) DoD Directive 5000.3

1. At the final San Diego briefing of the Defense Science Board summer study on "Operational Readiness with High Performance Systems," I suggested that the excellent product could be improved by inclusion of hard-hitting recommendations on making wise use of T&E to help achieve this readiness. The purpose of this memo is to suggest recommendations the Panel may wish to consider. Each of the following six paragraphs discusses one key T&E aspect and then shapes an appropriate recommendation for Panel consideration. The bottom line is that if T&E is used properly, high performance systems can have good operational readiness. If it is not, low readiness will almost certainly result.

2. Program Structure. From the day planning starts for a new program, T&E phases (both DT&E and OT&E) must be structured to provide data to decision-makers at the points where key decisions are needed (e.g., Milestone II, Milestone III). Although this seems obvious, it is rarely done.

Recommendation: In structuring programs, ensure that each major decision (e.g., entry into full-scale development, first commitment of production funds, commencement of rate production) is preceded by a T&E phase, the results of which will be used to guide the decision. For the production decisions, ensure that an IOT&E phase is included as well as DT&E. (Note: See enclosure (1), paragraph 3.)

3. Linkage Between RDT&E and Production. Even when programs are properly structured originally, as discussed above, little attention is paid to maintaining these key relationships when normal changes and delays occur. When development slips, it is customary to commence production on the original schedule. This results in unplanned concurrency, a program out of control, and fielding of systems which have limited effectiveness and unacceptable readiness.

Recommendation. In program execution, ensure that production remains linked to RDT&E. If a T&E phase slips, the subsequent decision point, and the actions dependent upon it (e.g., production) should normally be delayed accordingly, so as to maintain the essential program structure relationship.

Subj: Role of T&E in Achieving High Operational Readiness

4. Attention to T&E Results. All too often, T&E is regarded as a "wicket," which cannot be avoided but is an unnecessary burden. High readiness of the deployed system will only be attained if T&E is used as an important tool. Find-analyze-and-fix programs, and demonstration of problem correction through T&E, frequently cannot be pursued because the planned program structure allows no choice but production.

Recommendation: Structure and fund RDT&E programs with adequate time and resources to allow decision-makers to respond to T&E results with a non-production decision (when appropriate), as readily as a production decision.

5. Program Acceleration. It has become fashionable, when seeking ways to accelerate an urgently needed program, simply to increase concurrency (the overlap between RDT&E and production). The result is generally poor readiness of the deployed system. Also, it should be recognized that concurrency and production rate are inversely proportional. The more concurrency there is between RDT&E and production, the smaller the production quantities will be, in the first few years, while faults are found, production systems are tested, and design changes are made.

Recommendation: If it is desired to accelerate a program, increase yearly RDT&E funding, rather than leaving development funding and schedule fixed and simply starting production earlier.

6. T&E Thresholds. We have made a fine art of mishandling T&E thresholds. They are too high, too low, or address the wrong quantities. We use meaningless measures for DT&E, and technical ones for OT&E. Often we omit thresholds entirely. Our casual disregard often seems warranted by the fact that we do not intend to put great weight upon T&E results in any case.

Recommendation: Pay close attention to establishment of T&E thresholds. Focus them on the dominant, high risk, performance areas (for DT&E), and the key operational criteria (for OT&E). Establish levels that represent acceptable performance of deployed systems, and be prepared to have milestone decisions made in accordance with T&E performance against these thresholds.

7. Funding Flexibility. In most acquisition programs, we program inadequate RDT&E funds in the final years, and we program production funds too early (success orientation). When full-scale DT&E and OT&E is held near the end of development, and serious performance and reliability problems are found, good decision-making is inhibited by the fact that there is often no acceptable option other than production. In these circumstances, if DoD could transfer production funds to RDT&E

(a process now requiring prior approval by Congressional Committees--and 6-8 months' delay at best), wise decisions could be made in response to T&E results, and the performance and reliability of production systems would be markedly improved.

Recommendation: Convince Congressional Committees to allow SECDEF and Service Secretaries, without prior approval, to transfer production funds to RDT&E when T&E results so indicate. (Note: This is DEPSECDEF acquisition improvement initiative #15.)

8. I appreciate the opportunity to make this input to the Panel.

R. R. MONROE
Vice Admiral, U.S. Navy
Director
Research, Development, Test and Evaluation

DEPARTMENT OF THE AIR FORCE
WASHINGTON, D.C. 20330

OFFICE OF THE SECRETARY

October 29, 1981

MEMORANDUM FOR DEPUTY SECRETARY OF DEFENSE

SUBJECT: Operational Readiness for High Performance Systems (Your memo, September 14, 1981) - INFORMATION MEMORANDUM

The 1981 summer study conducted by the Defense Science Board (DSB) is a useful analysis of operational readiness implications for complex, high performance systems. In most instances, the DSB recommendations complement actions already underway within the Air Force as part of our continuing efforts to improve the readiness of combat forces. Many of the new initiatives undertaken in response to your April 30, 1981 memorandum on improving the acquisition process directly address the DSB recommendations. These initiatives will not be covered in detail as they are reported to your staff on a monthly basis.

In addition to the acquisition initiatives, several programs in the logistics and personnel areas respond to the panel's recommendations. In the logistics area, the need to better identify, assess, and manage logistics support requirements has been identified. Initiatives are underway to address these requirements. The personnel community is working diligently to develop programs to recruit, train, and retain our critical personnel. Existing programs and training initiatives that address the DSB recommendations include a Training Program Development Plan with trainer, user and researcher involvement; programs to use advanced training techniques to narrow the skill gap; programs that emphasize early training practice rather than knowledge, with follow-on skill progression training; and Air Force Institute of Technology (AFIT) short courses and advanced Degree Programs in computer sciences Improved pay, selective reenlistment bonuses, and numerous initiatives in critical skills management are underway to improve our retention.

While we generally agree with the recommendations on inherent and operational availability, the Air Force strongly opposes expanding the warrant officer program, establishing differential pay, and exempting software from the requirement for small business set asides. The Air Force warrant officer program was terminated in 1959 following the establishment of the E-8 and E-9 senior NCO grade structure. The issue was reviewed in 1974, 1976 and again in 1978, concluding in each case that the warrant officer program would be of no benefit to the Air Force. Air Force critical skill shortages are more severe at the middle NCO grades (E-5, E-6, and E-7) than at the senior NCO level (E-8 and E-9). The reestablishment of the warrant officer program would be at the expense of existing E-8 and E-9 authorizations. Thus, it would not put skill or experience where it is most needed. Furthermore, it would have an immediate and divisive impact on senior NCO retention resulting from increased layering of supervision and the dilution of prestige and authority, thus effectively reducing overall capabilities in critical, sortie generating skills.

Creating a differential pay system to eliminate the civilian/military pay mismatch would be administratively costly and severely impact on essential military institutional values with attendant adverse effects on readiness. The purpose of the military compensation system is to provide a reasonable standard of living and, equally important, to instill institutional values, such as cohesiveness, espirit de corps, and dedication to nation above self, essential in a military organization. Military service demands unique and extraordinary sacrifices--frequent moves, extensive periods of family separation, possibility of armed conflict and the relinquishing of certain individual rights. Monetary incentives alone are not sufficient to insure that a military force of sufficient size and quality will be available when needed. A differential pay system, based on skill criticality, would not further institutional values and in fact could degrade unit cohesiveness, espirit de corps and, ultimately, readiness. In peacetime, an artificially contrived marketplace compensation system would of necessity "chase" the problem since those skills identified as critical would constantly be changing as a function of dynamic military requirements and private sector demand. The marketplace approach becomes inappropriate in wartime because all skills are critical to the mission. For example, the avionics technician may be considered critical in peacetime, but in war the aircraft bomb loader or the runway repairman may well become even more essential to the mission. Therefore, since we are in the business to be prepared to fight and win a war, the military compensation system must be designed to enhance a wartime readiness posture. The current pay and allowances system possesses all of the essential ingredients to accomplish that objective. The key to alleviating any pay mismatches is to refine the existing system to establish a stable, visible and nonpolitical military pay raise adjustment mechanism tied to comparable types of work and levels of responsibility in the private sector.

Air Force experience with small business software contracts does not support exempting software from the requirements for small business/8A set asides. Furthermore, small business set asides are required by statute (15 U.S.C. 644) and any attempt to change the statute would meet stiff resistance.

In conclusion, the Air Force generally supports the recommendations of the summer study panel. Actions that address the key points in the study are embodied in the acquisition initiatives, personnel programs, and logistics programs. While a formal reporting system is in-being for actions associated with your acquisition initiatives, my staff can provide additional details on our other programs.

E. C. Aldridge, Jr.
Acting Secretary of the
Air Force

cc: Secretary of Defense

THE DEPUTY SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

19 SEP 1981

MEMORANDUM FOR CHAIRMAN, JOINT CHIEFS OF STAFF

SUBJECT: Operational Readiness for High Performance Systems

As you know, the Defense Science Board recently completed a Summer Study on Operational Readiness with High Performance Systems. I was briefed on the Study, and I am convinced of the importance of making improvements in the readiness area.

I believe that the JCS could make a substantial contribution in our efforts to improve readiness. After you review the attached briefing, which you received in San Diego, I would appreciate your personal views on what role the JCS could play.

Attachment:
As Stated

OFFICE OF THE CHAIRMAN
THE JOINT CHIEFS OF STAFF
WASHINGTON, D.C. 20301

CM-1112-81
8 December 1981

MEMORANDUM FOR THE DEPUTY SECRETARY OF DEFENSE

Subject: Operational Readiness for High Performance Systems

1. Reference your memorandum of 19 September 1981, subject as above: The Chairman has been briefed on the DSB report. Additionally, the Assistant to the Chairman met with General DePuy to discuss its implications, and participated in the latter's briefing for Secretary Weinberger.

2. The recommendations of the Defense Science Board Panel are thoroughly consistent with the views of the Joint Chiefs of Staff concerning the importance of managing development so as to field weapons systems which have high intrinsic availability, and which are both readily manned by personnel of the all-volunteer force, and readily maintained without high costs for spares, or excessive NORS outages. The Chairman has asked me to assure you that he will vigorously support such management in all his activities, including his role as a DSARC member.

3. When General Starbird was in DDR&E, there was an effective champion for rigorous testing of developing systems. You may wish to review the present OSD organization to insure that you have such a readiness protagonist. Additionally, the Chairman endorses the DSB panel's recommendation that the ASD (MRA&L) act as the proponent for thorough pre-IOC investigation of the manning aspects of developing systems.

FOR THE CHAIRMAN, JCS:

Paul F. Gorman

PAUL F. GORMAN
Lieutenant General, USA
Assistant to the Chairman, JCS