IMPACT OF TECHNOLOGY ON MILITARY MANPOWER REQUIREMENTS, READINESS AND OPERATIONS

HEARING

BEFORE THE

SUBCOMMITTEE ON MANPOWER AND PERSONNEL

OF THE

COMMITTEE ON ARMED SERVICES UNITED STATES SENATE

NINETY-SIXTH CONGRESS

SECOND SESSION

DECEMBER 4, 1980

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IMPACT OF TECHNOLOGY ON MILITARY MANPOWER REQUIREMENTS, READINESS, AND OPERATIONS

THURSDAY, DECEMBER 4, 1980

U.S. SENATE,
SUBCOMMITTEE ON MANPOWER AND PERSONNEL,
COMMITTEE ON ARMED SERVICES,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:05 a.m., in room 235, Russell Senate Office Building, Hon. Sam Nunn, chairman, presiding.

Present: Senators Nunn and Warner.

Staff present: George F. Travers, professional staff member; Paul C. Besozzi, general counsel; John T. Ticer, chief clerk; Robert S. Doston, Alton G. Keel, Jr., James R. Locher, Don L. Lynch, E. George Riedel, and Carl Smith, professional staff members; Ralph O. White, research assistant; and Mary A. Shields, clerical assistant.

Also present: Frank Gaffney, assistant to Senator Jackson; Arnold Punaro, assistant to Senator Nunn; Charles Stevenson, assistant to Senator Culver; Bill Lind, assistant to Senator Hart; Christopher Lehman, assistant to Senator Warner; Jim Dykstra, assistant to Senator Cohen; and Mike Donley, assistant to Senator Jepsen.

OPENING STATEMENT BY SENATOR SAM NUNN, CHAIRMAN

Senator NUNN. The subcommittee will come to order.

Today's hearing is focused on the impact of technological sophistication and complexity in new U.S. weapons systems on military manpower requirements, unit and materiel readiness, military operations, and the rate of force modernization. The subcommittee has the valuable opportunity to hear directly from the most senior managers of the U.S. defense technology effort: Dr. William J. Perry, the Under Secretary of Defense, Research, and Engineering; and Dr. Robert Fossum, Director of the Defense Advanced Research Projects Agency. Both Dr. Perry and Dr. Fossum are highly regarded by the Congress for their excellent work on difficult defense issues.

I would like to especially commend you, Dr. Perry, for your outstanding efforts on NATO-related initiatives, including Family of Weapons and other cooperative programs, and I believe that many of the initiatives you have gotten underway in the last year or so are going to pay great dividends in the future, provided we have continuity and some follow-through by both the new administration and by the new Congress.

Underlying America's entire defense effort is a basic strategy of using our superior technology as the decisive edge in confrontations

with our potential adversaries, especially the Soviet Union. While the Soviets have outspent the United States in military research and development over the last 10 years and have made significant technological advances, the United States retains a clear margin of technological superiority. We must effectively apply this technological advantage.

While the basic strategy of exploiting our technology lead remains sound, several key downward trends in the U.S. military effort suggest major problems in the Department of Defense's development and and acquisition programs, and possibly in the extent to which we have sought to apply technology. The weapon and equipment modernization of U.S. military forces—which is so necessary and urgent—is proceeding at a rather slow rate and has fallen far short of plans. Procurement programs have been plagued by substantial real cost growth leading to program stretchouts, inefficient annual production quantities, and eventually procurement bowwaves.

At the same time, the readiness of current U.S. forces and weapons has been declining despite the large portion of the Defense Department budget allocated to operating costs. The Department of Defense is having difficulty in effectively maintaining and operating the current hardware inventory. For example, Department of Defense data have shown that on the average, only 56 percent of the U.S. Air Force's F–15's and only 53 percent of the Navy's F–14's—America's best fighters—were mission capable in fiscal year 1979. The operations and maintenance account appears underfunded; the impact of correcting an O. & M. funding deficit, if it exists, would have a further adverse effect on the size of the already reduced procurement program.

The United States appears to be in a cycle of continuously shrinking military hardware inventory which is less and less ready. In light of the current inability to procure sufficient quantities of weapon systems and to operate and maintain them with a high degree of reliability, our entire procurement strategy is subject to question, and I think that this hearing this morning will begin to raise those questions. I don't pretend here today to have the answers, but I do believe that we have got to begin a search for a meaningful dialogue on these issues. Of special concern, it may be that the substantially increased levels of Defense spending that the Senate, and I believe increasingly the country, overwhelmingly favors will not correct the fundamental problems that these negative trends represent unless certain changes are made.

The strategy of using America's technological advantage against potential adversaries has led to the pursuit of higher effectiveness weapons systems based upon highly advanced technology and involving greater complexity. However, when fielded, many of these higher effectiveness weapons systems have not performed as expected and have required extensive and costly modifications. The lower reliability of these systems in the field may substantially compromise their higher effectiveness, and questions whether we are fielding immature technology which is beyond our manpower and dollar resources to maintain are certainly increasing in the military services and in the Congress. Moreover, operating costs of these systems have put sharp limits on the ability to realistically train U.S. fighting personnel.

Without a doubt, there are certain defense areas where we must field the most advanced technology available to us, update it frequently, and pay the price—whatever it may be—in both dollars and skilled people. The military threats that confront America demand this kind of capability. The question is whether we have unnecessarily extended this approach in too many areas.

The development and acquisition decisionmaking process may also be flawed. Three problems have been noted. First, the process is too lengthy—it takes too long for the United States to field its military technology. In far too many areas, the United States has the technology lead in the laboratory, and the Soviets the lead in fielded equipment.

Second, the connection between technology being developed and military requirements, tactics, doctrine, and especially cost, appear far too tenuous. Instead of having a problem looking for a solution, we too often have a solution looking for a problem. In either case, we have worried too little about what it will cost.

Third, there has been a proliferation in the number of weapons platforms, often accompanied by frequent, marginal changes to these platforms. By pursuing so many systems and accelerating the rate of modification, we may be overextending our available moneys, training capabilities, and logistics.

Associated with the slow rate of force modernization are problems in the U.S. defense industrial base. These problems are reflected in soaring production costs and longer delivery times. Identifying and correcting the causes of these problems must be part of our overall defense revitalization effort.

This subcommittee with its focus on military manpower has long been concerned about the apparent incompatibility of the U.S. procurement strategy and the shrinking base of U.S. military manpower skills. While the Armed Forces are having trouble recruiting enough personnel to fill the ranks, the most significant problem is that we are unable to attract the right mix of personnel. Shortages of skilled people are substantial. Moreover, as senior military officials have publicly noted, there is a hemorrhage of talented, experienced personnel leaving the military service. These personnel constraints, unless corrected, may undermine our procurement strategy and minimize the utility of our hardware investments.

The timing of this hearing is extremely important. I am personally, as I think most people following the defense area recognize, committed to substantial and steady increases in U.S. defense spending over a long period. Yet, there appears to be major problems with the current way of doing business.

As we begin a determined effort to revitalize America's defense capabilities, we need to study these problems and rethink our approach and strategies. To assist in our efforts, we have before us today senior officials who have been grappling with these problems for a substantial period from positions of significant responsibility. These massive problems in the field today that I have addressed in this statement reflect work and decisions primarily made in the 1960's and the early 1970's. The work that has been done in recent years, particularly that work done by Dr. Perry and Dr. Fossum, in many cases is not yet reflected in the field.

What the subcommittee would like to know is what we have learned from our current set of problems and what new approaches and strategies have been developed for the decisions of today and tomorrow.

Dr. Perry, again let me welcome you and Dr. Fossum. We are pleased to have you. I don't know of any two people who are more respected on Capitol Hill than you two, and so we are pleased to have you and look forward to hearing from you.

I understand you have an opening statement, Dr. Perry. Dr. Fossum, do you have a statement also?

Dr. FOSSUM. Yes I do, Mr. Chairman.

Senator NUNN. All right, Dr. Perry, why don't you proceed, and then we will hear from Dr. Fossum.

Mr. PERRY. Thank you, Senator Nunn.

With your permission, I would like to enter my written statement in the record and then make verbal comments to emphasize the highlights of that statement and to give a few examples not in the statement.

Senator NUNN. Fine. We don't want to cut you short. We are going to have members in and out this morning, and I am going to stay here as long as necessary.

So you go ahead and give your views as you see fit.

[The prepared statement of Dr. William J. Perry follows:]

PREPARED STATEMENT OF HON. WILLIAM J. PERRY, UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

IMPACT OF TECHNOLOGY ON MILITARY FORCES

Technology as an Offset to Numbers.—The disparity in military equipment investment between the Soviet Union and the United States amounted to $240 billion in the last decade. Our strategy to deal with this disparity recognizes that it is infeasible to compete directly with the Soviets in quantities of equipment built. To match the Soviets gun for gun, tank for tank, or missile for missile, we would have to roughly triple our production of weapons. Then, as those weapons were deployed, we would have to double the size of our peacetime Army to man them. Instead, our strategy aims to offset the Soviet advantage in numbers by applying technology to equip our forces (and those of our Allies) with weapons that outperform their Soviet counterparts. Fundamental to this strategy is the fact that the United States leads the Soviets by five to ten years in many of the basic technologies (e.g., microelectronics, computers, jet engines) which are critical to our advanced weapons.

Today the Warsaw Pact armies have deployed a tank force that is more than twice as large as that of NATO. A conventional estimate is that weapons such as tanks must be four times more effective to offset a two times numerical superiority. Our strategy is to provide an offset, not with tanks that are four times better, but instead to supplement our smaller tank force with a combination of anti-armor systems:

(1) Surveillance systems that allow us to observe the enemy forces at all times—day or night, fair weather or foul, at any spot on the earth,

(2) Secure, jamproof information transmittal systems that tell the fire control center where a target is, not where it was,

(3) Positioning systems that give the precise location of our forces, and

(4) Guidance systems such that missiles, once fired, are independent of third party TV, wire, or laser guidance and can make a direct hit on a target with the first shot, even when countermeasures are employed.

We have made major advances during the past four years in technology critical to such military systems. By placing a sharp focus (and major funding) on critical areas, we have widened our lead over the Soviets—a lead which I believe will be decisive in maintaining our overall qualitative advantage.

Let me illustrate by example the application of our technology to achieve the performance edge critical to air superiority. The Soviets today have superior

ground forces in Europe and that situation is not likely to change in the foreseeable future. But even with this advantage it is hard to believe that they would initiate an armored assault if they could not control the air space over Europe.

Therefore, it is crucial that we maintain our superiority in the air. I believe we have air superiority today, but that capability is eroding. We have it today because our airp'anes and our pilots are superior to those of the Soviets. But the Soviets are introducing new airplanes—the MIG–23, the Modified MIG–25, and the MIG–27. These airplanes are not modeled on the simple, straight-forward designs of the MIG–19 and MIG–21. They are sophisticated, very capable, airplanes.

By the mid-1980s, while we still expect to have some advantage in airplane performance, it will be a narrow performance edge and perhaps not sufficient to compensate for the numerical advantage of Soviet air forces. They are now producing tactical aircraft at a rate about 2 times our rate and have been doing so for several years. So we are facing a substantial problem.

My solution to that problem is maintain a critical performance edge. We could do that by increasing the aerodynamic performance of our aircraft, providing greater speed, greater maneuverability and greater acceleration. In my view, we have reached the point of diminishing returns with improved aerodynamic performance; adding more aerodynamic performance will not provide a performance edge sufficient to warrant the added complexity involved. An alternative is to substantially improve the fire power of our aircraft and improve the tactical information systems which support their operations.

We are building a new missile called AMRAAM which will have a standoff range of about 30 or 40 miles. It will be able to engage more than one target at a time, and it will have a fire-and-soon-forget capability. This combination will provide a substantial tactical advantage relative to our present missiles or relative to any missiles which the Soviets will have in a comparable time frame.

We are also developing a new tactical information system which will present the pilot with what amounts to a situation display. It will show him where all of the other airplanes near him are located, who they belong to and what they are doing. This information will be extremely valuable if it is timely, accurate, and if we can present it in a simple form so the pilot can grasp it just by looking at a display.

We think the combination of presenting the pilot with that kind of information and giving him superior fire power will make the critical difference in dealing with airplanes which are almost as good as ours, but which outnumber us by 2 to 1. The missile will allow the pilot to engage, even if outnumbered, and the tactical information system is designed to minimize the probability of having to engage when outnumbered. That is, even if we are outnumbered globally, we don't have to be outnumbered locally if we know where everybody is located and can deploy accordingly.

So by selectively focusing and applying our technology, we can maintain the performance edge critical to maintaining air superiority. Microelectronics technology will play a critical role both in maintaining air superiority and in providing the next generation of electronics critical to our future anti-tank guided missile systems.

APPLICATION OF TECHNOLOGY TO REDUCE COMPLEXITY

I have discussed the application of technology to gain the performance edge critical to our forces in the face of a numerically superior opponent. But technology can also be applied to simplify the operation of our systems and reduce maintenance. Many of the problems we are experiencing with reliability and maintainability are unfairly blamed on high technology; the problems are often the result of old systems in need of modernization. But we have not been as effective as we could be in fully exploiting our technology to simplify the operation and maintenance of our systems.

Technology can be employed in many ways. It can be used to make weapon systems simply elegant. But it can also be used to make weapon systems elegantly simple, and in so doing decrease the requirements on military manpower.

Just as civilian users of pocket calculators or video games do not need in-depth knowledge of the semiconductor technology which makes such devices possible, so military users of systems utilizing our high technology need no specialized technical knowledge about the technology involved to use these systems effectively. Users of the Global Positioning System need only be trained to operate the receiving equipment, they do not need to understand the details of how the

satellites, clocks, and other sophisticated equipment operate. In this sense, the technology is "transparent"; the user sees the end result and not the technology which makes the operation possible.

I would now like to illustrate the application of our technology to reduce operational complexity with some specific examples.

PRECISION GUIDED WEAPONS

We have begun the expedited development of a third generation of precision-guided weapons. These new weapons will have major advantages over present systems. They will operate in nearly all weather conditions, be "fire-and-forget," and be capable of destroying the target on the first shot. If properly designed, this third generation of precision guided weapons will reduce the operational burden of the launch crew, reduce their vulnerability, and reduce the need for extensive crew training (since the weapon can be aimed and fired without the need for crew guidance of the weapon to the target).

These new weapons find, home-on and kill targets, and also have built-in test (BIT) and checkout circuits which allow the operator to push a button and get a "go" or "no go" indication as to the weapon's operational status.

AUTOMATIC TEST EQUIPMENT (ATE)

At the same time that we are applying technology to greatly improve the effectiveness and utility of our military systems, we are faced with growing shortages of qualified operating and maintenance personnel. Some of these pressures support the drive to more easily operated and maintained equipment. Devising proper automatic test equipment will help us do our job.

As an example of the impact of ATE on manpower requirements, the crew of USS Eisenhower requires 48 hours to check its electronic warfare systems. A mobile dockside automatic test system can do the same job in 30 minutes. A recent study of the Navy's Operational Readiness Monitoring System illustrated that for small combatants, the ATE system saves 745 manhours per week. Likewise, an Air Force study showed that ATE provided a 50:1 to 100:1 test time reduction over manual testing for digital circuit boards. These manhour savings translate into a significant reduction in maintenance manpower and cost, and also impact operational readiness.

BUILD-IN-TEST (BIT)

Our technology can be used to test for, identify, isolate, and reconfigure failures in a component or subsystem so that they do not result in total system failure. Our efforts along these lines have been called built-in-tests (BIT). The potential benefits of BIT are in improved readiness, reduced time to repair, reduced maintenance manpower requirements, lower spare parts requirements and improved test station productivity. The average cost of adding BIT to a weapon system is roughly 10% of the system acquisition cost. An average life cycle cost savings of about 35% has been achieved on systems which average a 5/2 ratio in life cycle cost to acquisition cost. Thus, the return on investment with BIT is roughly 8.75 to 1.

A recent industry/joint Service automatic test project study identified a 30% improvement in system availability as a consequence of BIT and improved methods of testability. The same study highlighted the impact of automatic test in support of nonelectronic systems and equipment. Enhanced maintenance of ships, trucks, and tanks is projected to provide a 30% reduction in maintenance manhours per operating hours, a potential 20% reduction in the cost of spares, and a potential 10% reduction in fuel consumption of internal-combustion engine-powered equipment.

SIMULATORS AND TRAINING DEVICES

Another area where proper application of our technology can pay large dividends is in simulators and training devices. Early identification of manpower, logistics and training demands is in line with OMB Circular A–109, which stresses the need for front-end analysis as part of the early planning and system definition phase.

Through the use of inexpensive learning and entertainment devices, such as are now found in homes and arcades across the nation, we hope to be able to train our personnel more effectively in less time. The quicker we get them out

of school and into the operational unit, the more time they will have to work productively during their term of Service.

We know from an evaluation of Navy and Air Force data that computer-assisted/managed instruction, which is an individualized method of instruction, is as effective in training military personnel as conventional, classroom instruction. It also saves about 30 percent of the time needed to complete technical training courses. Training systems such as these will help us speed new recruits to their initial assignment and allow them to spend more useful time on the job. We anticipate that the next step is to miniaturize such devices and, by making them portable with self-contained computational power, have them available for remedial or advanced instruction at all bases or locations. Such systems will also be able to prescribe individually tailored instruction to meet particular job assignments. One of our "brassboard" systems in our Very High Speed Integrated Circuits Program is devoted to just such an application. The use of microprocessors and even faster, cheaper integrated circuits will make such devices not only possible, but relatively inexpensive.

System maintenance is a headache which seems to afflict even the most efficient systems. Often our problems are not organic at all, but are due to human error over which we could have some control. For example, a series of surveys indicated that from 14 to 35 percent of the corrective maintenance actions which occurred over one year involved the removal of non-faulty parts. These actions consumed from 9 to 32 percent of the maintenance manhours actually spent. Therefore, we have placed increased emphasis on finding better ways of training maintenance technicians. Our programs range from the development of computer-controlled simulators for training maintenance procedures associated with avionics, propulsion, radar, communications, etc., to developing more generic training aids and devices which can be moved to and from the work areas. These simulators can function like actual equipment for training purposes, but with improved safety and convenience. Current examples show the simulators being from 10 to 50 percent the cost of trainers using actual equipment. They can also demonstrate a wider range of malfunctions than can be arranged in actual equipment and are usually much less expensive to buy.

The origninal push for simulation came from the aviation community. Since WWII, flight simulators have been used for procedure and instrument training. However, with the fuel crisis of 1973, we have placed continued and increasing emphasis on the utilization of flight simulators to save fuel, improve performance and reduce training related accidents. Numerous studies both by DoD and the airlines have shown that it is cost-effective to utilize simulators for training in many of the flying tasks. For example, we know that the cost of operating flight simulators is about 5 to 20 percent that of their comparable aircraft. Pilots trained in simulators reduce the time required to train inflight with the actual system by about 50 percent. But cost savings are not the only benefit. The Air Force has recently demonstrated that students trained on an A-10 simulator were ready to land sooner and could be qualified the first time they went to the range to drop bombs. In general, they far surpassed the A-10 students who did not use the simulators.

A continuing problem plaguing those who must provide tactical training is how to realistically simulate engagements. We have done this by developing laser "bullets"—eye-safe, battery-operated gallium arsenide pulse coded lasers. Exercises using this MILES (Multiple Integrated Laser Engagements System) are planned for the National Training Center. They will allow battalion size exercises that will provide a method for casualty assessment, enable a critique of two-sided engagement and allow for training repetition using various tactics and weapons. Recent exercises in Germany using MILES have brought praise from commanders and troops alike. This method of training is being seriously considered by many European countries. We will soon be evaluating a tank gunnery system using the MILES approach.

SUMMARY

In these few pages I have described our offset strategy of applying technology to counteract a numerical disadvantage in military equipment. To be effective, our technology must be applied selectively to achieve a performance edge which is critical to the outcome of engagements. I have also discussed the application of technology to counteract the pressures resulting from shortages of qualified operating and maintenance personnel. Our objectives are to apply technology to improve reliability and maintainability; to use our technology to make servicing and testing equipment much less labor intensive; and to use the exploding

technology of microprocessors in automatic test equipment, built-in-test, and in simulators and training devices that enable our forces to effectively and efficiently operate and maintain their equipment.

STATEMENT OF HON. WILLIAM J. PERRY, UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

Mr. PERRY. I would first of all want to identify myself with the opening statement which you made which points out the set of problems which the Defense Department is faced with. Nothing I say today should be taken as minimizing my concern or what the Congress concern should be for those problems.

The issue that I would like to address, though, is the extent to which technology contributes to those problems as opposed to the extent to which technology can be used as a vehicle for the solution to those problems.

QUANTITY VERSUS QUALITY

First of all, let me address what is often referred to as the quantity versus quality argument—that we should have larger quantities of equipment in our forces to deal with the Soviets' quantity increase instead of trying to offset it with technology.

I believe, Mr. Chairman, that we have no real choice in this matter and that we simply have to depend on our technology to give us a performance advantage to deal with the quantitative advantage possessed by the Soviet Union. Let me give you a simple example just to illustrate this point.

We have today about 10,000 tanks in our forces. The Soviets have 40,000 to 50,000 tanks. If we then had a strategy of trying to match them in quantity, it would be necessary for us to build another 30,000 or 40,000 tanks to match the Soviets one for one, tank for tank. Quite aside from the difficulty of achieving this in any reasonable amount of time, let me point out that that would involve, as a minimum, taking our tank production from about 1,000 a year, as is now planned, to numbers like 3,000 or 4,000 a year in order to catch up with the Soviets in 10 years' time, even if they produce no tanks during that time.

I am pointing out that it would not only be difficult to catch them in quantity, but it would involve production increases not of 20 or 30 percent; but of 300 or 400 percent. Then, even if we were to achieve this tripling or quadrupling of tank production and we were to have now in our forces 40,000 or 50,000 tanks, we would have the very real problem of how we would man those tanks—getting the tank crews and support for those tank crews.

In simplest terms, we would have to roughly double our peacetime army if we were to try to match the Soviets in the quantity of equipment that they have deployed.

I just don't think that this is feasible. All of my planning has been based on the assumption that that is not feasible, and therefore we require a performance offset in order to be competitive with the Soviets.

SOVIETS SPENDING MORE

The second broad point I would like to make is to address what I consider the myth that the Soviets, as contrasted to the United States, are pursuing a strategy of building simple, reliable, cheap equipment

and therefore buying lots of it. It is true that the Soviets build large quantities of equipment, but this is not because they are building simple, cheap equipment. It is because they are spending substantially more than we are in the production of equipment.

The CIA estimates that over the decade of the 1970's the Soviet Union invested $240 billion more than the United States in military equipment. That investment alone, that $240 billion, accounts for the difference in quantities of equipment between the United States and the Soviet Union. It is quite clear that if we had spent that amount of money, or even half that differential, we could have competed in quantities of equipment, had we chosen to.

So the reason for their large quantities of equipment have nothing to do with the choice, quantity versus quality, on their part. It simply stems from the fact that they are spending very substantial amounts of money on military equipment.

Now, a related point is that they in no way have decided to go for a strategy of simple, reliable, cheap equipment. That may very well have characterized their strategy during the 1960's, but it did not characterize their military equipment strategy during the 1970's or during the 1980's.

If we look at their present aircraft, for example, the Mig–23, and the Mig–27, as contrasted with their earlier airplanes, the Mig–19 and Mig–21, we see very complex and very expensive aircraft. These aircraft involve variable swept wings, which is an area of complexity and expense which the United States has gone away from in its latest designs. In simple comparison—net assessment—I would say that the Soviet tactical aircraft today are probably more complex and more expensive than their American counterparts.

SOVIET NAVY

If we look to the navy, we see that whereas 10 or 15 years ago they possessed a navy which could best be called a glorified coast guard, today we see a navy with nuclear cruisers, we see aircraft carriers underway, we have seen just in the last few weeks a report of a submarine approaching 30,000 tons displacement being launched. All of these are indicative of a strategy for building large, sophisticated, complex, expensive equipment, and that certainly characterizes the Soviet navy today as well as the Soviet air force.

And finally, when we look at their ground forces, I cite the T-72 tank, the BMP and the SA-10, which is their latest air defense system; all of these are of equal complexity or greater complexity than their counterparts in U.S. equipment. The SA–10, for example, which is their closest equivalent to the Patriot missile, is probably more complex and more expensive than the Patriot, and as hard as it may be to believe, it took even longer to develop than did our Patriot missile.

So I would like to suggest to you that the myth that we are competing with an opponent who has a strategy of simple, cheap, reliable equipment, is just not borne out by any of the facts.

So to me, the issue is not whether we use technology as an offset; it is how can we do it in such a way that it does not aggravate the kind of problems which you were describing in your opening statement, cost, reliability, operation, and maintainability problems.

Senator NUNN. I want to make it clear that I agree with you on that. It is not a question of whether we need technology or whether we need to continue our lead, it is a question of whether we are doing it in the wisest way and whether we can improve that.

Mr. PERRY. That is exactly the issue, in my mind. It is not only whether we can make our decisions that way, but I would add an additional point: I believe it is quite possible to use technology not just to aggravate those problems, but to use technology as a direct means of attacking those problems, and I will give you some examples today how I believe that can be done.

So to put, then, my views in context, I believe that it is necessary to use technology to get performance advantages, and I will give you some examples of how that will be done.

Second, I believe technology that we are incorporating today is technology which will improve reliability, make the equipments easier to maintain and easier to operate relative to the equipments that are now in the field.

Senator NUNN. Well, Dr. Perry, let me ask you a question on that point, which is a very positive sign.

Has there been a change in recent years that has led to that—certainly I think you would agree that we have got a lot of problems in what is out there now?

Mr. PERRY. Yes, we do.

Senator NUNN. When did the strategy shift, if it has shifted? When was the realization brought about that we were experiencing problems in the field, reflecting back on R. & D.?

Mr. PERRY. I think it is not so much a question of strategy shifting as that the technology has evolved, and the technology that is available to us today is inherently more reliable, easier to operate and easier to maintain. As we wen from vacuum tubes to discrete circuits, to large scale integrated circuits, we have evolved a technology which is inherently easier to maintain and easier to operate, and that is—I am oversimplifying, but that electronics technology I think is the key to the evolutionary improvement in our modern systems, and that technology is fundamentally more reliable, easier to operate than the equipment that it replaces. But that technology is just now starting to come into our equipment, and it is not reflected to any great extent in the equipment which our troops operate and maintain today.

EQUIPMENT PROBLEMS DESIGNED IN 1950'S AND 1960'S

The problems they are having are largely with equipment which was designed in the 1950's and 1960's and built in the 1960's and 1970's, not equipment that reflects the technology of the 1970's. And as the modernization program that is now underway provides—getting our new technology into equipment which we are producing and getting that equipment into the field—we should see dramatic improvements in all of these areas.

I don't mean to suggest that it will happen automatically. It is important to keep a focus on the use of technology to reduce complexity rather than simply to improve performance. But I do start off with the first contention that it is necessary to use our technology to get improved performance, but we can do it in such a way that it

improves reliability, makes systems easier to maintain and operate, and finally—and this last statement will probably strain your credulity more than anything I will say—is that we can use technology to reduce the cost of systems. All of the evidence seems to be contrary to that, but I believe that, and I would like to give you some examples to illustrate why I believe it.

Now, first of all, let me take the point on high performance. When we are trying to improve the performance of our systems, we basically have a design choice, and it is a choice between using technology which increases complexity and technology which reduces complexity, and I would like to give you a few examples of decisions we have made in the last 5 years or so.

An example of getting improved performance with increased complexity is, for example, introducing a variable swept wing in a tactical airplane. Now, here is a clear example where you can demonstrate that the airplane with the variable swept wing will outperform an airplane with a fixed wing under a whole variety of scenarios which you might imagine for a tactical fighter.

TORNADO AIRCRAFT

Senator NUNN. What is an example of that kind of plane?

Mr. PERRY. An example in Europe is the Tornado aircraft, which is a variable swept wing, and we would compare that with the A–10 or the F–15 or the F–16 which have fixed wings. In the United States, an example is the F–111. In the Soviet Union, many of the tactical airplanes that they have built in the last 10 years or so have had variable swept wings. So we see a clear example of where in the Soviet Union and in fact in Europe they opted for getting performance by complexity, and in the United States with the A–10, the F–15, and the F–16, we backed away from that complexity. The complication of putting that box in there and the gears that make for the sweeping wing is not only an expense and a weight on the airplane, but it is a major factor in reliability and maintainability.

F–100 ENGINE

So that is one example I would give. Another example is the engines we put in our fighter airplanes today, the F–100 engine, which in my opinion is a fine engine and probably the highest performance engine in the world today. This engine was designed to maximize performance, and in order to get that maximum performance, we accepted reliability, endurability problems.

When we went to the next step, the next generation of an engine development, or next half-generation, which is the F-404 engine, we accepted less performance, less thrust-to-weight ratio in order to get better reliability and more maintainability.

So I suggest that is an evolution in that direction. And that is not meant as an insidious comparison between two different engine designs. In each case the engine was designed to meet the perceived requirements at that time. But there is an evolution toward backing away from the last 10 percent of performance in order to get an extra 50 percent or so of durability and reliability.

Another—an example of how to get performance in a different way—is the Amraam missile. This is an advanced medium range air-to-air missile which we are developing now for our fighter airplanes. This missile will allow our fighter aircraft to engage in air combat at longer ranges, at ranges of several tens of miles instead of ranges of a few miles. We put the premium on the performance of the missile rather than on the aerodynamic performance of the airplane. And again, it represents an approach of going to an improved weapon. The missile itself, the Amraam, is very sophisticated and has very high technology in it. But it reduces the burden of complexity on the airplane itself. So it is a design choice where we put in the very best technology we can get in the weapon, but by doing that, we ease the problem on the design of the airplane.

One other example I would give to you of this nature is the laser-guided projectiles, where we are putting very sophisticated technology, a laser homing system, in an artillery shell. That is an audacious thing to do when you consider how complex and sophisticated that technology is, and we are putting it in a shell which has to be shot out of a cannon. We have designed that, built it, tested it, and we are now putting it into our forces.

PERFORMANCE FOR SIMPLICITY

In my judgment, that is an example of using performance for simplicity, not for complexity, because it allows us to use this sophisticated technology to take a very simple piece of equipment, namely, all of our 155 millimeter howitzers in the Army today, and convert them into precision-guided weapons.

So we are using technology to make something we already have more effective instead of building a whole new weapon system.

Senator NUNN. Dr. Perry, I have to vote. We will take a brief recess.

Mr. PERRY. All right.

[A brief recess was taken.]

Senator NUNN. Dr. Perry, please continue.

Mr. PERRY. I was discussing at the time of the vote the use of technology to improve performance.

I wanted to pivot over to the more direct issue of the hearing, which is using technology to make equipment more reliable, easier to maintain and easier to operate. I would like to take an example both in the field of engines and in the field of electronics.

Pointing out a fact which people don't think much about anymore, but the evolution from the propeller engine to the jet engine, quite aside from what it did in the performance of military aircraft, has made an enormous improvement in reliability, making engines easier to operate and easier to maintain. The reliability of commercial transport airplanes today stems from the inherent reliability of the jet engines being used, here is a clear example of where the technology gave us a very great improvement in the ease of maintenance and ease of operation, and an improvement in reliability.

Now, we are today trying to achieve those same benefits in tanks and helicopters. That is a harder step to make, but as we introduce turbine engines into tanks and turbine engines into helicopters and make other changes in helicopters that have to do with the design of

the gears, we would hope to be able to achieve factors of perhaps two, three, or four improvement in reliability and ease of maintainability.

We simply accept today that helicopters have short endurance, short mean times between failure, very high maintenance hour requirements, and I argue that that need not be accepted, that we can be directing our technology so that we are diverting our helicopters to achieve the same kind of inherent reliability and ease of maintenance that we are getting with a standard jet transport plane. We are heading in that direction. The helicopters that have been designed and are being built today for the Army, the UH-60, the advanced attack helicopter, will incorporate many of those features, and we should see dramatic improvements in reliability and maintainability as those helicopters come into the inventory.

XM-1 TANK

It is ironic, I believe, that the feature of the XM-1 tank which has received the most adverse publicity relative to reliability and maintainability has been its engine, whereas, in fact, the main reason for having that engine in the tank, in my judgment, is that it will give us substantially improved reliability and maintainability over the engine in current tanks. And it is because we are making a move toward a turbine engine that we are getting the basic reliability potential that you have in going from a propeller to a jet engine in an airplane.

We had substantial problems in the early testing of that engine, making that turbine engine operate satisfactorily in a ground environment. I might also point out that when we first introduced jet engines into airplanes we had substantial problems having them operate properly in an airborne environment. Those problems were solved. They will also be solved—and in fact I believe have already been solved—for the turbine engine in the tank.

A final comment about technology in engines is that a main thrust of our advanced technology program today is the development of what is called rapid solidfication technology, which is a new way of making metal alloys which will allow us to build components for jet engines which should allow for operation at temperatures 100 to 200 degrees Fahrenheit hotter than we can currently operate engines.

Now, if we are able to achieve that, which I believe is a probability, then we will have a design choice. Let's say that we have designed an alloy that will accept 200 degrees Fahrenheit hotter temperatures. We can now take that technological bonus and divide it between performance and endurance. We can give half of it to performance, getting more thrust out of the engine, and we can give the other half to endurance by operating with a derated engine, which is something that we are reluctant to do today because we need every last pound of thrust in the engine.

So that is where the technology is going, and it does give us the potential of making those kinds of design tradeoffs.

The view that I have on this problem and that I think is characteristic of the current view in the Defense Department, is that the bonuses from those technological developments should be used at least as much to improve reliability and endurance as to get improved performance. And it is a clear choice that we have when we take the technology and apply it to a new design.

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ELECTRONICS

If I go to the field of electronics, I wanted to start off with an example which is well known to everybody, namely, the hand-held calculator. If we consider the comparison between the hand-held calculator and the machine that it replaced, the electro-mechanical desk calculator, we see cost reductions of a factor of a hundred, we see very, very substantial improvements in reliability and maintainability, and no increased difficulty in operation—if anything, greater simplicity of operation. I believe that example characterizes the introduction of large scale integrated circuits to systems. They are inherently more reliable, easier to maintain than the discrete circuits or the vacuum tubes or the electro-mechanical devices which they replace. And as we evolve more and more of that electronics into our military systems, we will begin to reap the benefits from that.

Now, a question has been raised as to whether this kind of complexity in systems doesn't make it more difficult to operate, and I would simply point out to you that in most of these systems we are talking about, the very sophisticated electronics in them is entirely transparent so the operator. One does not have to understand solid state physics to operate a hand-held calculator. You have no idea what technology underlies the buttons that you press.

A more recent example is evident as you go into the supermarket today and you take your groceries to the checkout counter. In some of the more advanced stores today, you discover that they have an automatic checkout device, where the checkout clerk simply moves your product across a beam of light and the bill is automatically tabulated. What you are not aware of when he is doing this, and for that matter, what the checkout clerk need not be aware of, is the very sophisticated technology that goes into that—the lasers and and computers which are used to make that system operate. What you are also probably not aware of is that besides tabulating your bill for you, this is a system which is providing basic inventory control for the store.

So here is an example of where very sophisticated technology is used to make major advances in an operation, in this case, a very simple operation of a supermarket. But the people who use this equipment require no knowledge at all of the technology that is involved. It is, as we say, totally transparent to them.

DECREASES IN COST

The final point I want to make about technology is that it can be used and it should be used to make our systems cheaper. A major thrust of our advanced technology program today—the largest single advanced technology program we have—is the VHSIC program, V–H–S–I–C. It is intended to accelerate the introduction not only of large scale integrated circuits into military equipment, but very large scale integrated circuits as well. For a given size chip, it will increase the number of functions, the number of bits on that chip by about a factor of a hundred over the present capabilities, and it will at the same time increase the speed of operation.

Now, if you look back in history at the microelectronics revolution, and you see these units getting smaller and smaller, there is a

very important result of which is sometimes overlooked: the cost improvement. There is an interesting chart which unfortunately I did not bring with me to show you today, but I can describe it to you. It charts the cost per bit versus years in the last 10 to 20 years, and it shows that every 2 years the cost of a bit has been cut in half for the last 20 years. This reflects the introduction of large scale and very large scale integrated circuits.

Extrapolating that for you a little bit, that means that in 10 years time, the cost for performing a given electronic function would be one-thirtieth of what it was 10 years earlier, and in 14 years time it would be one-one hundredth. So you are getting these very remarkable decreases in cost.

Somebody calculated once that if the automobile industry had made the same kind of progress that the electronic industry had made, you would be able to buy a Chevrolet today for 25 cents. But we won't try to stretch that analogy too far.

This is perhaps the only technology today where in addition to getting performance improvement, we are getting dramatic decreases in cost, and as we introduce those functions into our military systems, we should be able to get the benefit of that cost reduction.

Senator NUNN. Are you saying that most of those cost reduction items have not yet been introduced and are not reflected in procurement costs with which we are currently struggling?

Mr. PERRY. That is correct. These are systems that are in development now or just entering production now. I should also point out that when you make an advance you get a technological bonus, and you can either use it for performance or you can use it for either endurance or in this case cost reduction. As you reduce the cost per bit b-1 a factor of a hundred, you have two choices. You can either have the costs go down a factor of a hundred or you can have the complexity go up a factor of a hundred. In most cases we have chosen the latter, that is, we have chosen to make our systems have more computing capability.

And so you see in modern missiles today complete computers—microcomputers—performing very sophisticated functions. What we have done is to take almost all of that technological bonus and use it not for cost reduction, but for performance increases. That is a design choice which we have available to us every time we make a new system. Had we elected to do it the other way, we could have used that advanced electronics to have cheaper systems.

Senator NUNN. Do you think that we have made a mistake in the general trend toward using that technological advance for complexity rather than for efficiency?

Mr. PERRY. No, I don't, not in general, although I think one has to look very hard at each case.

Let me give you an example.

We have used our large scale integrated circuits to get more computing power into a system. We have made the overall system cost much, much lower as a result, even though we have more electronics in it. I think the best, most obvious example I can think of is the cruise missile, where we have a microcomputer using large-scale integrated circuits with very sophisticated electronics. As a result of that, we have achieved the performance levels we wanted on a missile whose total weight is only about 3,000 pounds. Now, because the weight of

that missile was only 3,000 pounds, we are able to put 20 of them on a B–52.

And now, if we step back and look at this whole weapon system and say its function is to deliver 20 missiles to such and such a range, and say what is the alternative to this advanced electronics, we can see one alternative clearly in front of us in the Soviet air-launched cruise missile. The Soviet air-launched cruise missile performs essentially the same function as ours. It doesn't do it quite as well. It doesn't have as much accuracy, it doesn't have as much range, but it is performing the same kind of a function. It weighs somewhere between 20,000 and 30,000 pounds. Therefore, if we were to put that cruise missile on a B–52, we would be able to carry only three or four of them. To put it another way, to deliver the same number of missiles, we would require five times as many B–52's.

Obviously putting the cost in the missile to get that sort of a weight reduction saved us the cost of buying the larger number of airplanes. So one has to step back and look very broadly at the military function that is being performed to decide where to put the investment. In this case, putting the investment in the microcomputer so that the overall system could be light weight was, I think, a good decision.

MAN-TECH

There is one other comment about technology to get a cost reduction. We have a major program in the Defense Department today that goes by the name of Man-Tech, which is a nickname for manufacturing technology. The whole purpose of that program is to use our technology to improve our manufacturing process techniques so that we can reduce the cost of equipment which we produce.

I don't want to take time today to go into the examples of that program. There are many of them. They have been quite successful. I can submit for the record perhaps a few describing Man-Tech programs which, through the application of technology, have led to reduced production cost of a system. That program again is in its infancy. The payoff is in the 1980's; we have only a few examples of payoffs so far in the 1970's.

[The information follows:]

MANUFACTURING TECHNOLOGY

To summarize, the DoD Manufacturing Technology Program is a broad-based, production oriented program supporting the DoD Research, Development and Acquisition Program by providing new and innovative manufacturing technology which will result in more economical, timely and reliable production of DoD materiel. Projects are expected to result in "factory floor" applications of productivity enhancing technologies and are viewed as "seed money" investments designed to reduce the technical/fiscal risks of follow-on production of Defense systems and components. The ManTech program is predominately procurement funded (from 12 separate commodity accounts). With the exceptions of the ammunition and large caliber weapons areas, most projects are executed by the private sector after approval by one of the Military Services. Roughly 600 to 700 individual projects are active at any time.

Funding of the DoD ManTech program over the past several years has been (dollars in millions); fiscal year 1975, $81; fiscal year 1976, $91; fiscal year 1977, $115; fiscal year 1978, $118; fiscal year 1979, $125; fiscal year 1980, $156; and fiscal year 1981, $155.

RECENT ACCOMPLISHMENTS

$16,000 savings per T700 engine (a total of $60 million at the scheduled production rate) resulting from an improved compressor component machining process. The MT investment was $740,000. Implementation will cost $14 million.

$13 million annual savings ($332/unit) resulting from processes established to mass produce modular synthetic camouflage screens. The MT investment was $2.6 million.

A computer controlled ultrasonic turbine disk inspection system reduced inspection time by 50 percent, reduced human interpretation of data and permitted the use of near net shape forgings. The latter also reduces machining costs and conserves critical materials.

An automated center core propellant loading and assembly process reduced cost by $6/unit and eliminated the need for 61 production line personnel. Total savings amount to roughly $12 million for the buy quantities in the FYDP.

A ship's beam bender reduces the cost per bend from $200 to less than $10. Because the device can bend a 40 foot steel ship beam (23 inch web and 10 inch flange maximum) to an accuracy of ¼ inch, it also reduces subsequent welding costs by providing a more accurate beam fitup.

Laser welding of the XM-1 tank engine recuperator plates is expected to reduce engine costs by $400 per unit by increasing welding rate from 50 to 235 inches per minute.

Senator NUNN. I was going to say that if we have gotten payoffs on all of this morning, we are in worse shape than I thought because the per unit costs have been going up substantially on all of these systems.

Mr. PERRY. Well, in fact, let me summarize my comments and I will address that specific point.

I commented on the Soviet philosophy, technology, and to put it in simplest terms, I said they are emulating the worst features of the United States. That is, they are going to technology in its most complex and its most sophisticated form. They are using everything they can to get increased performance, and as a result, they are already ending up with systems which are much more complex than the systems they had in the field 10 years ago, and in fact, much more complex than the systems we are now building and putting in the field.

In terms of operating, training, maintenance, support for that equipment, the Soviet problem during the decade of the 1980's is going to get very much more difficult than it was during the 1970's, and all you have to do is imagine the difficulty of the maintenance crew on the Mig-19 when the Mig-19 is replaced with a Mig-23 or a Mig-27. That crew is going to have an enormously more difficult problem. They are going to have to have more sophisticated training. They are going to have to have more spares. Their problems are going to be magnified, I think, by a factor of three or four or five as that new airplane becomes their responsibility to maintain.

On the other hand, our maintenance and support problems are going to get relatively better than they are as we go from an F–14 to an F–18, as we go from an M–60 to an XM–1, because we have used our technology in the design of those airplanes and the design of the test equipment and support equipment that goes with them to make the maintenance and reliability better. That's the good news.

The bad news is that that technology is not yet in very many of the systems we have in the field, and it will be many, many years until it is. And even as we start to deploy our XM–1's and our F–18's, and even as

we start to employ the equipment with this new technology, the systems that they replace will continue to be in the field. We will have M–60's in the field probably until the end of the century. We will have F–4's in the field probably into the 1990's. And therefore we will continue to have problems. Not only do we need to pay adequate attention to the spares and support and maintenance problems with our new systems, but we will continue to have the problems with these older systems, and the problems will be compounded because in 1985 they will be 5 years older than they are now.

So I don't want to suggest that our maintenance and support problems are going to be getting easier in the future, in the next 5 years or maybe even in the next 10 years——

Senator NUNN. And consequently, the skill levels are not going to be any less demanding in the next 5 to 10 years.

Mr. PERRY. Not in that time period. I think it is going to be extremely important, then, that we provide the support, the budget support, the manpower support necessary to keep those equipments operating in a suitable state of readiness. As we put together the 1982 budget, as strong an advocate I am of this technology I have described to you, and the modernization program I have described to you, I considered that the first priority in that budget was providing adequate O. & M. so that we could achieve suitable levels of operational readiness for the equipment we already have.

Senator NUNN. There recently was a statement by a top ranking Army official that basically said that the weapons in the field now are easy to operate, less complex, and that the skill levels needed to operate them were less than they had been in the past. Would you generally agree with that regarding the Army? It seems to me you have disagreed. I'm talking about in the field now.

Mr. PERRY. All right, in the field now, I guess I would tend to agree with that. My comments applied to the equipment which is now being built in the Army's modernization program, and equipment that is just starting to go into the field for which we are and just starting to develop training courses: the XM–1, the UH–60, the F–18. This new generation of equipment already has incorporated in it many of the features I have described to you, and in addition, I have described technology underway to build and improve on that with respect to reliability and maintainability and operability.

Senator NUNN. What I am saying is that the Army official said that the equipment that is in the field now has less skill requirements than the equipment in the past, and it seems to me that is contradictory to what you have said.

Mr. PERRY. There is a trend in that direction. I just don't think that the equipments I have—I am not sure what equipments he was referring to.

Senator NUNN. I think the artillery fire control system was the example given.

Mr. PERRY. Well, I would agree with that, yes. I used to operate an artillery fire control system many, many years ago, and the introduction of simple computers to perform those functions is an enormous simplification of operation relative to doing things with slide rules and charts, which is the way we used to do them.

RECRUITING PROBLEMS

Senator NUNN. What about the next 5 years? The Army is having the most serious problem of recruiting what we call category I's, II's and III's in terms of intelligence level. In the next 5 years, looking at what you know of the Army in a general sense, is the skill level required out in the field going to go up or down?

Mr. PERRY. I want to differentiate. The word "skill level" is a little hard for me to come to grips with. The requirement for operating—for sophistication in operating and maintaining equipment—I think will tend to go down over the long term, but we are going to have a short-term increase. The reason for that is because we are introducing many new systems into the Army over the next 5 years. And it is not that any one of those systems is more complicated than its predecessors, but there will be a lot of new systems being introduced, and therefore we are going to have a lot of training on the use of those new systems. The training requirements are going to increase over the next 5 years simply because of the numbers of new systems that will be introduced.

Senator NUNN. How about the next 10 years?

Mr. PERRY. I would expect after the mid-1980's to start to see that requirement decrease some, in terms of operating and maintaining equipment. I want to separate it out from all the other skills that are required.

Senator NUNN. Right.

Mr. PERRY. But in terms of operating and maintaining equipment, from about the mid-1980's on, we should begin to see real benefits from the modernization program now underway, without having all the turbulence of the introduction of new systems that we see right now.

TECHNOLOGY FOR TRAINING

Now, I have left one final area that I would like Dr. Fossum to discuss—as well as anything else he would care to—which has to do with using technology for training. Whether the system is easy or difficult to operate, our systems are more and more expensive. In some cases training with them involves firing them, and it is more and more expensive and less and less likely, therefore, that a soldier is going to get an opportunity to fire a Stinger missile or a new generation antitank missile or an Amraam air-to-air missile. A fair question that evolves is can our service people be adequately trained if they do not have experience in firing the weapons, firing the missiles which they are using.

A partial solution to that problem is the use of simulators, and I did want to spend some little time giving you an example of some of the simulation work we are doing.

But I would give one caveat for that. That work is in its infancy today and it is a good many years away from having a major impact on our training.

But on all of these issues, it takes a long time to get them developed, produced and in the field. But the time at which we have them in the field is measured from the time at which we start a serious effort to get them. What I am describing to you today is a serious

effort which in some cases is still in the development stage, in other cases, like the F–18 and the XM–1 tank, we are actually producing improved equipment and it is now starting to go in the field.

Now, Bob, would you like to pick up from there?

Let me just make one quick comment. This is Dr. Fossum's third anniversary as the Director of DARPA, and it is therefore a memorable date for him. I thought we ought to have a birthday cake for him or something.

Senator NUNN. We are delighted to have you here on this occasion.

STATEMENT OF DR. ROBERT FOSSUM, DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY; ACCOMPANIED BY DR. CRAIG FIELDS, CYBERNETICS TECHNOLOGY DIVISION, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Dr. FOSSUM. Mr. Chairman, I am pleased to be here on this third anniversary. It is a pleasure, really, to be invited to testify before this committee. I do have some prepared remarks that I would like to go through, and I will try to tailor them to the time remaining.

With me today, Senator Nunn, is Dr. Craig Fields of the Cybernetics Technology Division of our Agency, and our modest program in applications of technology to training and readiness is under his immediate direction.

We also have brought some materials to demonstrate some of these applications if time allows.

Initially I would like to present a conceptual framework for technology investment strategies, which is a key issue that you were addressing, in my view. These I will present as I perceive them in the Department of Defense. In each case I will try to clarify these strategies with examples, and these examples I will draw mostly from the DARPA program.

I would then like to suggest possible alternatives in procurement strategies which are implied by these technology strategies. I again qualify my remarks by noting that my position is that of a technologist and not an operator or procurement person. Therefore I will present opinions. Finally, I would like to illiustrate DARPA projects in training technology which is an application of the technology base of the Department and of the commercial sector, just as Dr. Perry has pointed out.

INVESTMENT STRATEGY

The investment strategy available to the research and development community, whether military or commercial may be thought of as four substrategies. The first substrategy I propose to call the mission and product improvement strategy. In the commercial sector, a planner would call this a market penetration strategy. Basically, Defense investments here are aimed toward improving the existing system concepts, thus enabling them to perform their existing military missions in an improved manner. We are all familiar with this strategy since in my opinion it is sort of the traditional procurement strategy. The requirements process generally drives these investments, it drives them not only in procurement but in the whole R.D.T. & E.

process. New aircraft and tanks with modern technology incrementally better than their predecessors are usually the result. Those who would have us meet our competitors, the Soviets, with more numbers but improved systems implicitly advocate a technology investment strategy which emphasizes this area.

As Dr. Perry has pointed out, with the present levels of defense spending, it is not clear to me at least that this would adequately meet the threat posed by our competition. Certainly a commercial firm in an intense competitive environment would undoubtedly fail if it only followed this strategy, the market penetration strategy. Consequently, we have under Dr. Perry's guidance, initiated a second strategy of investment, that of new technological products, but primarily again, to meet the existing missions as we understand them in the services today.

This second strategy places emphasis on developing systems based upon technology in the commercial, as we have talked about, as well as the military technical base which, when such technology is successfully injected into operational systems, results in substantially improved performance for existing military missions. And I emphasize the word "substantially improved." I would call this the new systems strategy, and emphasize that it is new systems primarily to meet existing missions.

As an example of such a system, I would point to the Assault Breaker concept now in the demonstration phase. As you know Assault Breaker will, if inventoried, allow the tactical commander to interdict second echelon armor moving into the main battle area. It utilizes new and advanced technology of radar, information processing, and various terminally guided submunitions concepts to accomplish this important interdiction mission, but it does it without the use of penetrating aircraft. This program, managed by DARPA, is being conducted jointly with the Army and the Air Force technology community, and we also have substantial inputs from the operational folks in each service.

In my opinion, this system concept, though in the early stages, provides an excellent example of technology push which will be difficult for our adversaries to meet in kind in a few years because of its high technology content.

MANPOWER STRATEGY

There is a third strategy which we also use, and it is here that manpower, especially in terms of talented military officers, is most important. They in fact play the key role, and in this case it is to adapt existing technological products to new missions, using existing technology to new missions through modification of doctrine and tactics, and devising new doctrine and tactics. I would call this the new mission and tactics strategy. A commercial firm's corresponding strategy would be called market development, taking what they had and applying it in different ways.

Technological investment here involves primarily modification or supplementing existing systems concepts to enable the force to end run the competition so to speak. To manage intelligently this application of technology requires technically competent, operationally oriented

and aggressive officers. It should not be left to civilians because civilians are not soldiers, sailors or airmen: that is, they really are not operators.

In DARPA, about one-third of our technical staff are military officers with excellent education and military backgrounds. And I have observed that some of our most useful projects, those in DARPA, have been initiated by technical military officers who come from operational assignments. I will give you an example of that to illustrate the strategy, and it is the Siam antiaircaft missile, Siam meaning self-initiated antiaircraft missile, and while it is technologically sophisticated in the seeker itself, which is a multimode seeker, most of the system, as it was synthesized, was simply adaptation of existing technology and hardware that was almost off the shelf. Most interesting, however, is the mission to which Siam applies, in, of all things, air defense against foreign ASW aircraft attacking a submarine. This constitutes a new mission. It allows new tactics by adapting the existing technology. It allows new tactics in the submariner in how to counter the opposing ASW forces.

NEW MISSIONS AND NEW TECHNOLOGY

A fourth and final strategy of investment combines the last two strategies into joint new missions and new technology development, and it is here that DARPA spends most of its money. I call this the combined strategy, and the corresponding commercial strategy, which is well known in the commercial marketplace, would be called diversification into new markets with new products. Investment here is most demanding of military officer technical manpower in the R.D.T. & E. phase, but offers the possibility of enormous payoff in military advantages.

An example of such a program in DARPA—and there certainly are other examples in the services—is the space-based laser weapon program. Several years ago DARPA funded technology development aiming toward high energy laser applications to conventional military missions such as replacing guns and replacing missiles in aircraft weaponry, in ship defense and so forth. In the mid-1970's these programs were transitioned to the services who have done an exemplary job of moving the technology along toward weapons in these existing mission areas. At that time DARPA departed from these missions to look at new missions of space defense with new technology, uniquely advantageous in space. We believe that the success in our space-based laser program will enable active defense of our vital war-fighting space assets against physical attack.

Interestingly enough, there is great interest in the Department using space—and the word, I emphasize, is using space in various ways, such as in the ways we use the ocean, but only a slowly emerging consciousness that the use of space for high value war-fighting assets demands a corresponding commitment to the active defense of these assets against a possibly determined enemy. Our space-based laser program constitutes a technology push in an area of no existing military requirement as such, but which at the same time will allow great payoff in terms of defending our war-fighting assets.

In summary, then, there are four possible technology investment strategies. It is my belief that rather than considering these funds as being a simple pot of money that is applied anywhere that the Department likes, that we do in fact in a considered approach apply these funds in the method that I have described with these strategies inherently in mind.

With respect to these technology investment strategies, as practiced in DARPA and other Defense agencies and the services, the Armed Services Committee of both Houses has given tremendous support, in my view, over the past 4 years. This year, concern has arisen that technology may be misapplied resulting in degraded performance due to reliability and maintainability and problems of that type. Further concern has been expressed that too much investment in technology may be occurring at the expense of force levels.

As an example of this concern, the House Appropriations Committee earlier this year produced a mark which reduced the DARPA budget from the authorization conference levels by almost 18 percent, certainly a measure of their concern. This is a clear signal to pay more attention to the issue than this has been given, and certainly I understand.

Before going into examples of technolcgy investment in training, let me address the two issues above somewhat more directly. First, it is my opinion that investment in the tech base of the Department of Defense is an excellent investment. As Dr. Perry has commented, the tech base has many direct spinoffs to the commercial sector, and conversely, but it probably has more spinoff than later investments in the R.D.T. & E. process.

U.S. HAS EDGE IN TECHNOLOGY

In addition, Dr. Perry pointed out, it is in technology that we now have the edge. It seems to me that it would not be a prudent policy to allow that edge to erode. On the other hand, if there is dissatisfaction with our investments, it may be worthwhile to examine the balance of funds invested to support each of these four strategies. In other words, look and see if we are investing correctly in each one of these four strategies, and insure that the balance is consistent with maintaining and increasing the technological lead as Dr. Perry has mentioned.

With respect to force level problems and the balance between investment in technology and force levels, I would suggest that there are alternative strategies available in the procurement process. And certainly there is not one single alternative but many, but let me give you an example of one possible strategy which is not distinct from the way we are procuring things now, but has a different flavor probably than the way procurement is done now.

Succinctly stated, one such alternate strategy would emphasize the following:

First, we could buy fewer distinct major systems but buy each in larger quantities.

The second part in the strategy would make major new system buys only when substantial improvement—and I underline the

words "substantial improvement"—in at least one dimension of performance is achieved with certainty; this says something with regard to the abandonment of an incremental improvement policy or way of doing things, that is, investment heavily in the first strategy. This is akin to abandoning, somewhat, stretching the product line in industry.

The third part of this is that you can't have everything; therefore you would have to accept initially somewhat degraded performance when the system is applied to some missions it is not necessarily optimized to perform.

Fourth, we could attempt to incrementally improve the system with alternative subsystems during its service life to overcome the initial degraded performance and extend its useful mission areas.

Fifth, and this is where it impacts, the strategy impacts the tech base, regardless of what the strategy of procurement is, it is important to insure that the tech base itself; that is, the balance between the four separate substrategies of investment in the tech base supports the particular procurement strategy that we intend to adopt.

What are the possible advantages of this strategy? Well, they include, first of all, the possibility of larger force levels through larger buys, and that is a key issue of concern in the Congress and also in the Department of Defense. The strategy begs the question, however, of adequate manning levels to handle those larger buys, as Dr. Perry has pointed out.

On the other hand, force levels may reduce an existing pressure in the procurement process to inventory a follow-on system. This pressure usually comes from force levels themselves.

If we have fewer generic systems in the inventory, this in turn I think you would agree can simplify the logistics, the maintenance and the training problems which are of primary importance to this committee.

Senator NUNN. Dr. Fossum, is that strategy you just outlined being given serious consideration in the Department of Defense? I detect that you might at least think that it should be given more serious consideration.

STRATEGIES FOR PROCUREMENT

Dr. FOSSUM. There are in each system procurement, and in each service and within the Department tailored strategies for procurement. I am not aware of an explicit statement of this particular option, nor have I discussed it extensively with Dr. Perry. I am only illustrating that in fact there are alternate strategies that should be studied, certainly on the basis of an outline of the strategy I would now propose.

Senator NUNN. Is anybody studying these points that you have made? I am hearing more and more private opinions along this line, but I never hear anything official. I just wonder if it is something that really is being given serious consideration, if there are a lot of knowledgeable people that are moving in this general direction, recognizing some of the problems which are rather obvious, or whether it is your unique idea that nobody else is focusing on now?

Dr. FOSSUM. Well, I would suggest that we have used strategies of this type in the past, and that we are forced in certain instances to use them now.

I would also suggest that I am not aware of a stated policy that this is a strategy we should actually always consider or use.

But again, it is mushy between the existing policy of procurement in R.D.T. & E. versus this particular case because in certain instances this is exactly what is going on.

Senator NUNN. It is, but there are so many different elements in procurement, so many different elements making up requirements, and so many different services involved that unless somebody at the very top levels sets forth these general goals, then you are going to have a continuation, I think, of what we have seen in the past—trying to make incremental improvements to weapons systems, cutting down the numbers of buys, increasing the per unit cost, driving the quantities down, and in many cases, making them more difficult to maintain and rely upon. There are always going to be exceptions, there are always going to be areas where this kind of a policy wouldn't fit.

Now, I understand Dr. Perry is saying we have all of these things coming down the road, and I, because I have a great deal of faith in Dr. Perry, would give that a great deal of significance. But I must say there are people here in Congress who have heard Dr. Perry's testimony in years past and would say they heard that in the 1950's, they heard it in the 1960's, they heard it in the early 1970's and we are hearing it again today about the 1980's. We always have things on the drawing board that are going to make dramatic improvements in every direction. They just don't ever seem to be put in large quantities out in the field.

Dr. Perry, do you believe that we ought to take a look at a general articulation of a new policy that would be more along the lines that Dr. Fossum has just outlined, or do you think that this is what we are already doing?

Mr. PERRY. We have not—the Secretary of Defense has certainly not articulated that as an explicit policy following procurement. I would say that that philosophy is very strong, maybe even dominates my own thinking, and in particular, the notion of going for new systems only when significant, not incremental improvements are at hand.

Senator NUNN. Would you agree there are so many component parts in the services—the requirements all the way up and down the line, the contractors getting involved—that unless it is more of a national policy rather than just your individual policy, it is going to be hard to carry out this kind of trend in a rather significant way?

Mr. PERRY. It is, that's correct.

I do think, though, that that is a reasonable description of the philosophical underpinnings of our reviews in the DSARC council in the last 4 years at least, and I think the——

Senator NUNN. But if you are fighting everybody from down below all the time, there is just so much of this policy that can be put into effect. When I talk to contractors, they tell me if we had some kind of long-range strategy where they could get the numbers up in terms of their planning, that it would make an enormous difference in the procurement cost. But if you are going to make incremental changes all the way along in the systems, you are precluded from that kind of cost saving.

INCREMENTAL CHANGES

Mr. PERRY. My problem with answering that is that I believe that that philosophy has permeated every production decision we have made in the last 4 years.

Senator NUNN. Let's take a specific example. When we moved from the F-4 and A-7, we developed the F-14, the F-15, the F-16, the F-18 and the A-10. That is five systems, basically, to take the place of two.

We have had enormous costs in all of these systems. This was before your time, but backing up, do you think we should have taken a look at whether we really needed five new types of planes?

Mr. PERRY. That is going back to a decision time where I was not participating in the decisions, but I don't believe that the number of airplanes that we are developing now is excessive. That is, the alternative, fundamentally, the alternative would have been building a single fighter airplane for both the Air Force and the Navy, and a good case can be made for that, but the opposite case is that we not penalize all of the Air Force airplanes with the extra structural and the extra weight requirements needed to make them carrier-suitable is a fairly heavy penalty.

I have heard both sides of that argument, and it is sort of a 60-40 type argument, but I come down on the side of the 60, which is that the decision which was made then to go to two different airplanes is probably a correct decision.

The second half, philosophical half of that decision was that we should go for a high-low mix, that is, each of the services should have a low end. The decision to go to an F-18 and an F-16 was basically a recognition of the fact that the F-14 and F-15 were very expensive airplanes and we ought to have something less expensive coming along to give us quantity in the fleet.

Senator NUNN. Before we go further, let me ask Dr. Fossum about your views on whether we needed that many different planes.

Dr. FOSSUM. Senator Nunn, I am really not qualified to give you an answer on that. I did not go through anything involved in that decision process. I think that is the right type of question, however, and whether we need to develop all of those planes or whether it would have been wiser at the time these decisions were made to consider buying fewer systems, say the F-14 and the F-15, excluding the A-10 from the discussion, and then wonder if we bought more of these units in those systems, because as I have stated, those systems are not as good in certain areas as the F-16 and the F-18, but could we examine whether we could accept that degradation without having to procure a whole new system, and were there other ways, through subsystems, missiles and so forth that we always load these airplanes with anyway, that would make them extend their missions into other areas even though they may be degraded in that performance.

I am not suggesting we build an airplane for all people. I am suggesting that the airplane be of good performance in one area, and we examine very carefully whether it will perform missions in other areas with a certain minimum of modification. And one of the reasons for that is simply to achieve some substantial force levels, and to achieve also returns to scale which small buys simply do not achieve.

Senator NUNN. I have got about 10 minutes before I have to go for another vote. Maybe we could wrap up your presentation in that time, and then I will come back for more questions.

Dr. FOSSUM. I will be through in 5 minutes.

Senator NUNN. Fine.

TRAINING TECHNOLOGY

Dr. FOSSUM. Returning, then, to the technology and out of the procurement process, let me illustrate the training technology. The program in DARPA is modest but well illustrates the applications of technology, mostly commercial, to the important problems of training and readiness.

Based upon inputs from our military colleagues, our perception in DARPA of the training problem is shown in this chart.

DARPA PERCEPTION OF TRAINING PROBLEM

Fewer recruits to do a harder job;
Less qualified recruits of lower motivation;
Fewer opportunities for training: Limited equipment availability, in part due to poor maintenance high cost of materiel, fuel;
Poor retention of skilled personnel;
Greater variety and complexity of tactics, strategy, doctrine, policy, scenarios;
High cost of current training including heavy personnel commitment;
Limited budget for training R. & D.

These problems are not independent of those listed there. For example, poor retention of personnel, particularly for maintenance, increases the cost of maintenance and sometimes limits the opportunity for training with complex equipment, as Dr. Perry had pointed out.

Based upon these problems, the essential characteristics of the program that we have is shown in chart 2.

DARPA TRAINING TECHNOLOGY: CHARACTERISTICS

Training in the field, at the job site;
Low cost commercial hardware; high availability for learning inexpensive commercial maintenance;
Self motivating contests, games, speech interaction, attractive graphics;
Training without instructor intervention;
Use communications to keep training up-to-date in the field, at the job sites.

Not surprisingly, the commercial technology plays a major part in synthesis of our training aids, just as commercial technology of electronic integrated circuits plays a major part in some of our major weapon systems. The heavy use of microprocessors will allow remote reprograming of simulators and training aids in the field, even from the continental United States.

DARPA TRAINING TECHNOLOGY: PROJECTS

I. Low cost portable training simulators;
II. Maintenance and operations aids;
III. Interactive video systems.

In chart 3, I have listed the three major projects, and I will go into only one of these, low-cost portable training simulator, maintenance and operator aids, and the interactive video systems.

The major commercial technology used is the emerging video disk technology which is compared in chart 4 with a high fidelity

VIDEO DISK	HI-FI AUDIO
VIDEO DISK	RECORD
½ HOUR TV/SIDE	½ HOUR AUDIO/SIDE
1800 RPM	33⅓ RPM
VIDEO DISK PLAYER	TURNTABLE
LASER, PHOTO-CELL	STYLUS, CARTRIDGE
MOVING ARM	TONE ARM
REFLECTANCE	VIBRATION
MASTER VIDEO TAPE	MASTER AUDIO TAPE
→ MASTER VIDEO DISK	→ MASTER AUDIO RECORD
→ PRESS VIDEO DISKS	→ PRESS RECORDS

VIDEO DISK SPECIAL CAPABILITIES

- **54,000 PICTURES/SIDE**
  - 30 PICTURES/SECOND x 60 SECONDS/MINUTE x 30 MINUTES
- **EACH PICTURE HAS AN ELECTRONIC I.D. NUMBER**
  - 1 - 54,000
- **RAPID ACCESS TO ANY PICTURE**
  - 1/30 SECOND TO 3 SECONDS

record disk. Not only are these video disks of substantial fidelity, but each of the 54,000 pictures recorded on a side is individually addressable and callable by a rapid access system. Thus, with a smart microprocessor, various training and scoring scenarios may be played.

With regard to cost, the commercial availability of these devices makes it possible to produce in quantity a medium cost simulator as indicated in chart 4.

Senator NUNN. Tell me the basic advantages of video now.

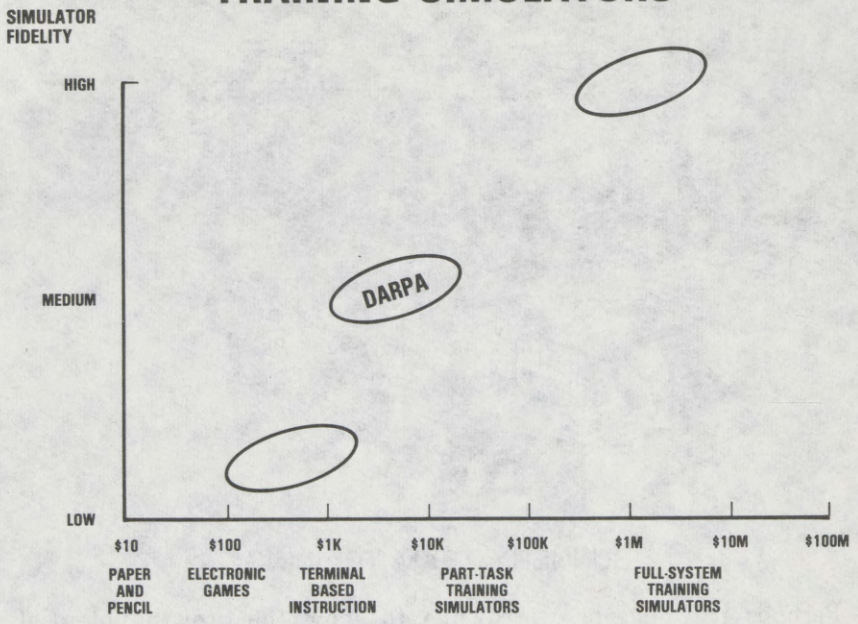
Mr. FOSSUM. There are two basic advantages—well, several. One of them is the amount of video pictures that can be stored, 54,000 on each side.

The second one is each individual frame or picture is callable in terms of a number by a computer. So different sequences of movement of pictures can be displayed, depending upon the training scenario, and we can show you this here in just a moment.

There is a third advantage, obviously, and that is if we are using commercial technology here, we are able to achieve procurement costs which are substantially lower than if we had a special purpose thing. So it is the addressability and controlability of the access by a microprocessor, along with scoring, knowing what is in that picture. And there will be a demonstration. I think you will see that in just a moment.

It is desirable to produce a medium fidelity training simulator, because learning the decisionmaking aspects of many military ac-

DARPA LOW COST, PORTABLE TRAINING SIMULATORS



tivities, for example, what tank to shoot first, what kind of ammunition to use, does not depend on exact reproduction of reality. It doesn't depend on being a totally good simulator. It is desirable, essentially, to have these medium level ones because we can get them out to the forces even in the barracks. The situation is analogous to home computers that teach chess, they display a schematic view of a chess board with recognizable but approximate pictures of the chess pieces rather than exact replicas of real chess pieces from some chess set.

I have brought with me a tank gunnery simulator for the M–60, and I invite you to actually try it at your convenience at the end of this hearing, and if you won't have time, I would like to show you at this time a picture, a video of what in fact takes place during the simulation.

Senator NUNN. We will take a brief recess while I vote.

[A brief recess was taken.]

Senator NUNN. We will get back to the testimony.

Dr. Fossum, you didn't quite finish; did you?

Dr. FOSSUM. Senator, it is my belief that I have done enough, and in the interests of your time, perhaps you would like to stop here. I have some other things, but you have seen the demonstration. The film that I have is nowhere near as instructive as actually trying the demonstrator, so I will not show that.

Senator NUNN. Was that film on how you have simulated training?

Dr. FOSSUM. It was a film which demonstrates the use of the simulator.

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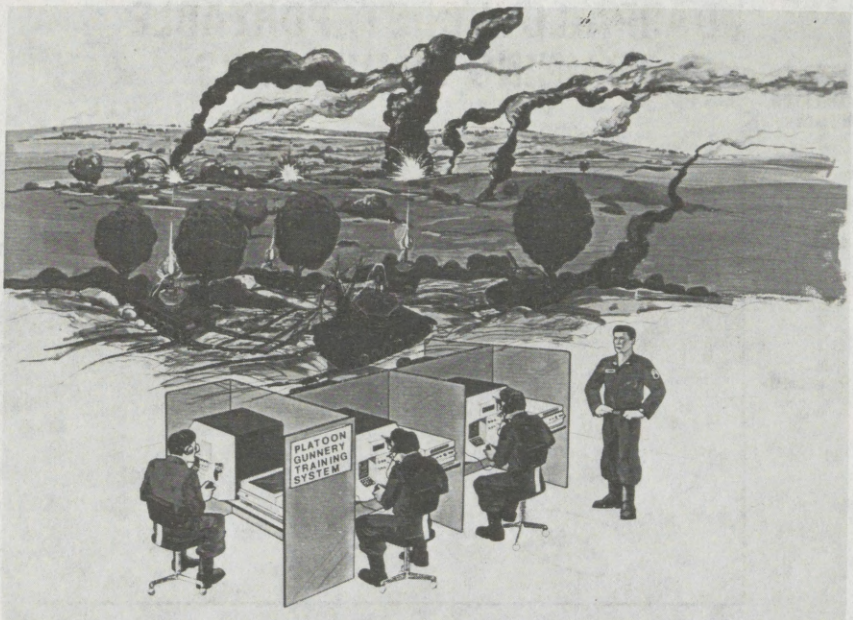
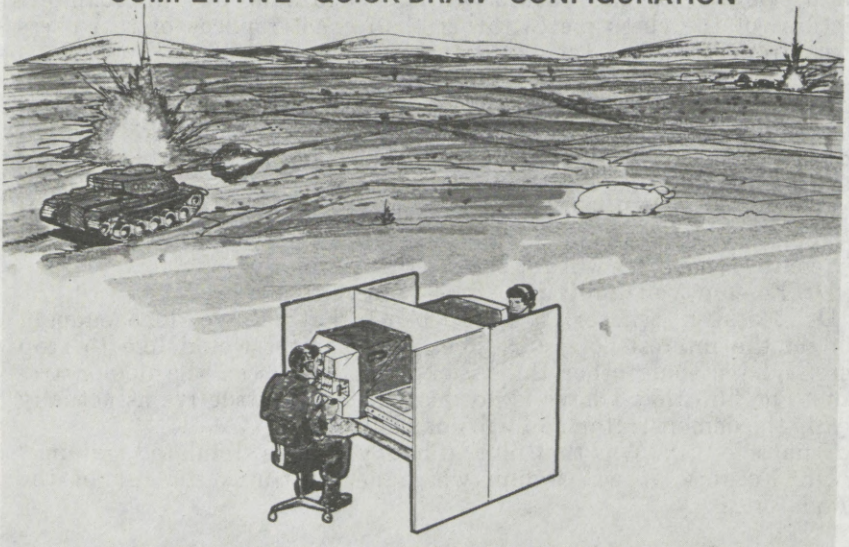


GUNNERY TEAM TRAINING

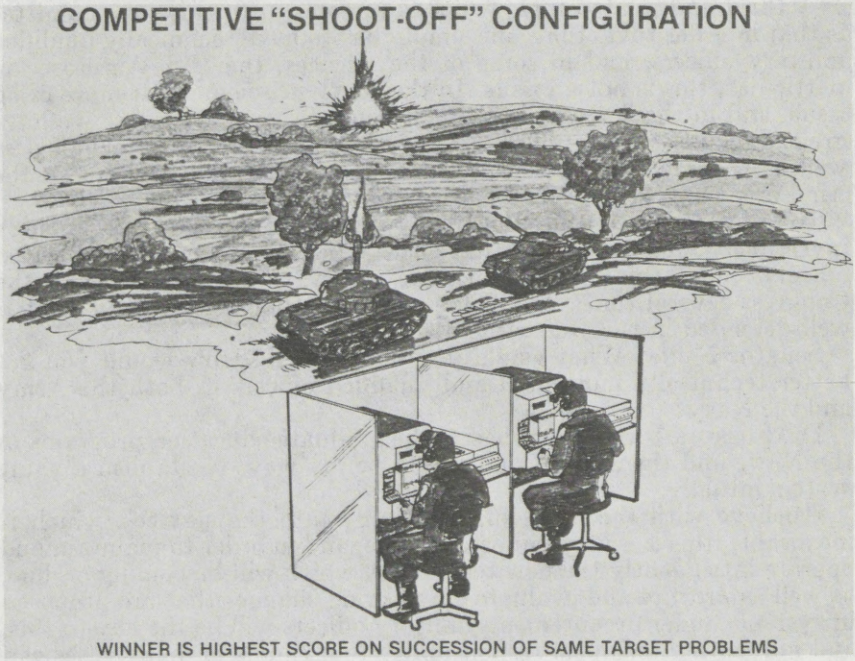
Perhaps it would be worthwhile to show the growth potential of this technology, and the next chart shows the way this actually could grow into multiusers. We are in the process of extending this technology to team training, both training of groups of gunners in different simulated tanks, and training of teams, that is, the driver and the gunner, within a single tank.

COMPETITIVE "QUICK-DRAW" CONFIGURATION



WINNER IS HIGHEST SCORE ON SUCCESSION OF ONE-ON-ONE ENGAGEMENTS

In the next chart, No. 7, we are in the process of making the terrain simulator more competitive to increase the motivation and fun of using the device, and there is one illustration here.



And in the last chart that I will show, this shows the modularity and flexibility of the trainer concept in all of this, essentially an architecture of tying together through the use of the microprocessors and the videodisk at each place, an architecture of training that I think will be useful at this middle level that we are describing in most of our program.

Senator, I think I will not go on, then. This is the gist of what I wanted to say today. I thank you very much for inviting me.

Senator NUNN. Thank you.

I would like to ask both of you a question. Dr. Fossum, I will pose the question to you first.

With your experience in industry and in the last 4 years in the Defense Department, what recommendations on structures and processes related to development and acquisition would you make? What recommendations for change would you make to facilitate or help facilitate more timely, affordable and reliable systems?

Dr. FOSSUM. I believe that an immediate recommendation I would make is that a substantial amount of emphasis be put on the adaptation of the training technology we are talking about to a variety of readiness and maintenance of skill applications. We have a modest program. We are very happy with this program, and we will do our level best to insure that the program finds its way in the mid-1980's, hopefully, into the forces. That is a training issue.

I would hope as a second issue that we could examine the balance that is placed upon the different strategies of technology investment

that I enumerated in the beginning, and probably place more emphasis rather than less emphasis on the new technology development for the very reasons Dr. Perry pointed out, and secondly, into the areas of new technology adapted to totally new missions.

A third and related issue which is of concern to this subcommittee is that in order to do that, one simply has to have technically qualified military officers, and in some of the services, the U.S. Air Force in particular, this is not an issue. In the Navy it is somewhat more of an issue, and in the Army it is a tough issue. I say this because we have great difficulty finding officers whose value system is also technical as well as their military career, to come into the agency, except in the Air Force case. We are more successful there.

In order to have an intelligent investment in these new technology investment areas, we must have the input of adequately educated officers, and I think this is an issue which has been brought to the Congress several times, but I don't observe that it is an issue that is well defended in the Department.

Senator NUNN. What would you do about it? How would you get better technically motivated and qualified officers in both the Army and the Navy?

Dr. FOSSUM. I would emphasize the graduate education programs in the Navy and the Army. That would be my way to establish a value system initially.

I believe with the input of technology into the services, which is inexorable, this is a very important issue, and in order to maintain and operate intelligently the new tecnhology which will be coming on line, as well as procure and evaluate engineering changes that are proposed in systems under procurement, military officers will be the key to this, and abrogating technical responsibility to civilians in many cases can be done, but in very key cases it cannot. Engineering changes should be evaluated not only from the utility of the technology that is brought to a system, but from the military utility, to evaluate whether it is useful to make this change during the procurement process or not, because changes cost money.

That is an example.

Senator NUNN. Dr. Perry, what would you advocate based on your experience? What changes, if any, would you advocate in our overall effort to get equipment in the field in a timely fashion, that can be maintained, that has durability and that also has the kind of effectiveness that I think you have well described this morning?

Mr. PERRY. I would continue to put additional emphasis on our introduction of competition in the procurement process, extension of competition in the procurement process, and I would go to multiyear contracting as opposed to the year to year contracting which we do now. Both of those factors will lend themselves to more efficient procurement and I think lower unit costs with more stability in the procurement process.

Senator NUNN. Do you think you can have contracting without having Congress go to a multiyear budget?

I happen to favor going to multiyear authorizations and appropriations, but do you think you can do the former without the latter?

Mr. PERRY. We can do it but we require legislation to be able to do it effectively.

Senator NUNN. Is that problem being studied now over in DOD? Have you got some people looking at that carefully?

Mr. PERRY. Yes. The minimum change we need is removing or raising the limit on termination liability on multiyear contracts. That is the minimum step. The maximum step is going all the way to multiyear authorization and appropriation. But I would propose a more modest step to begin with so we can demonstrate the approach. Then we can identify programs where we have stability and proceed with multiyear contracting, even though we don't have multiyear authorization. I can identify a dozen programs where we could do that immediately just by removing the limitation on termination liability right now.

Senator NUNN. Is this administration likely to propose that in the form of legislation before you leave office?

Mr. PERRY. Yes.

Senator NUNN. Is it in the mill now?

Mr. PERRY. Yes, it is. And I believe that we will make that proposal, and I would hope—and I do believe—that it will be followed up by the next administration. I don't believe it is a partisan issue in any sense.

Senator NUNN. I certainly want to help on that because I agree with you completely. I have heard from some of your people an extended, rather indepth presentation on some of those issues. Do any other things come to mind now?

Mr. PERRY. I believe we should put a greater emphasis in the future in the thing which I have called Man-Tech, the manufacturing technology program. I think there is very great payoff in the procurement process in doing that, and then I would underscore what Dr. Fossum says about greater emphasis on the training aids. I think there is going to be a great payoff in that.

Senator NUNN. What are the main advantages of going to the multiyear contracts, and also multiyear authorizations and appropriations?

Mr. PERRY. There are a whole host of benefits to multiyear contracting, but in my judgment the single most important one is that it provides a contractor with a long term, stable business prospect which then provides him the incentive to invest in modernization of his plant and facilities. On a year-to-year contracting basis he takes a substantial business risk in investing in the tools and equipments which are necessary to do a specific program most efficiently. If he can look forward to a 3- or 4- or 5-year production of that, as he would in a commercial business, then he can make an investment which has a 3- or 4-year payoff.

So it puts our contractors in the business of planning for the medium to long term instead of planning year to year, and there should be great efficiencies evolved from that.

Now, there are some smaller benefits that come out of it as well which I wouldn't want to underestimate, such as being able to buy components and parts and supplies in larger quantities—in 3- or 4- or 5-year batches instead of buying them a year at a time. You can get price breaks from that. You can hedge against scarcity of materials and also get schedule benefits from that. There are many other benefits, too. But to me the single most important one is pro-

viding our contractors with a stable base which allows them to investment in modernization of facilities so they can get greater productivity.

Senator Nunn. Dr. Perry, can the United States afford, with feasible levels of Defense spending—feasible, in my view is a real growth of anywhere from 5 to 8 percent at least in the next immediate 2 or 3 years when we have severe economic problems, inflation and so forth—do you think we can procure, operate and maintain as many high technology weapons systems as currently planned?

Mr. Perry. I think if we have 5 to 8 percent real growth in the procurement account, that we can carry out the modernization program which we are embarked on and carry it out with a reasonable efficiency. We will not carry it out at the speed with which we would like to carry it out because we have a lump coming into the system all at once and we are going to have to phase that lump out in order to accommodate a gradual increase in the budget.

But we have not had—I want to emphasize—real growth in the procurement account. We really have not achieved that for the last few years——

Senator Nunn. Because of the inflation.

Mr. Perry. Because the inflation in the industries from which we are purchasing is higher than the nominal inflation plus the factor of growth which we thought we were getting.

Senator Nunn. Does that include the 1981 budget?

Mr. Perry. No, that does not include the 1981. Depending on how it finally turns out, the 1981 budget may provide for a substantial real growth in the procurement account. And the 1982 budget, I trust, will maintain that real growth.

Senator Nunn. But the 1979 and 1980 budgets really haven't?

Mr. Perry. The growth which we thought we were getting in the 1978, 1979, 1980 budgets in the procurement account were eroded by higher than projected inflation. And I am not just talking about the difference between the forecast and actual OMB inflation factors but also the fact that the inflation in the aerospace industry was higher than the OMB inflation factors by maybe as much as 5 percent in some years.

And so a 5-percent real growth just evaporated. When you translate that growth into the budgets, into the number of tanks and airplanes and ships you can buy, we actually were declining for those 3 years because of that inflation.

Senator Nunn. Could you furnish that for the record in more detail?

Mr. Perry. Yes, I will be happy to.

[The information follows:]

Dr. Perry. The attached table provides a comparison of real growth in the procurement budget for 1977 through 1981 using inflation rates provided by the Office of Management and Budget (OMB) and by a public accounting firm, Coopers and Lybrand. The OMB inflation rates for 1979 and 1980 are based on a broad price index while the Coopers and Lybrand rates for 1979 and 1980 are based on a sample of inflation experienced on aerospace contracts during those years. As the Coopers and Lybrand study only covered the two middle years in the tables, the OMB inflation rate was included in the Coopers and Lybrand table for 1978. The inflation rate during the two years covered by the Coopers and Lybrand study tracked closely with the consumer price index change for that period. A Data Resources Incorporated projection of the consumer price index was used for the last year in the Coopers and Lybrand table.

A comparison of the two tables shows less real growth using the Coopers and Lybrand inflation rates than using the OMB factors. On a cumulative basis since 1977, real growth using OMB factors is 14.2 percent as compared to 6 6 percent using the Coopers and Lybrand inflation rates.

PROCUREMENT ACCOUNT INFLATION ANALYSIS

[In percent]

	OMB inflation rates		Coopers and Lybrand inflation rates	
	Annual rates	Annual growth	Annual rates	Annual growth
Year to year:				
Fiscal year 1977–78	9.3	1.4	9.3	1.4
Fiscal year 1978–79	9.7	−5.8	10.1	−6.1
Fiscal year 1979–80	9.2	3.4	14 9	−1.7
Fiscal year 1980–81	8.4	17.0	10.0	15.3
Cumulative since fiscal year 1977:				
Fiscal year 1978	9.3	1.4	9.3	1.4
Fiscal year 1979	19.9	−4.4	20.4	−4.8
Fiscal year 1980	30.9	−1.2	38.3	−6.5
Fiscal year 1981	41.9	+14.2	52.1	+6.6

Senator NUNN. What about R. & D.? Have we had real growth in the last 2 through 4 years?

Mr. PERRY. We made a fairly detailed statistical analysis of our procurement account, and I have substantial data to back that up. I don't have the same set of comprehensive data on R. & D., but to answer your question, I believe we have not had growth in the R. & D. account for the last 3 years. It has been essentially a flat budget.

Senator NUNN. Could you furnish what is available?

Mr. PERRY. Yes, I will.

[The information follows:]

R.D.T. & E. INFLATION

The following information is provided to show the effects of inflation on Research, Development, Test and Evaluation (RDT&E) over the past 10 year period:

[Dollar amounts in millions]

Fiscal year	R.D.T. & E. program [1]	R.D.T. & E. fiscal year 1981 dollars [2]	Real growth (percent)
1971	$7,123	$14,769	
1972	7,584	14,920	1.0
1973	8,020	14,882	−.2
1974	8,200	13,969	−6.1
1975	8,632	13,519	−3.2
1976	9,520	14,023	3.7
1977	10,585	14,584	4.0
1978	11,503	14,736	1.0
1979	12,372	14,620	−.8
1980	13,556	14,738	.8
1981	16,023	16,023	8.7

[1] Fiscal year 1971–79—FYDP history; Fiscal year 1980—FYPD, September 1980; Fiscal year 1981—Appropriated.
[2] DOD—Deflators Dec. 5, 1980.

Mr. PERRY. Part of this problem has gotten translated into an assessment that our programs were having abnormal cost growth or overruns, and indeed, in some programs we had cost growth, which I would define as the need for more man hours or more materials to do the project than we had forecast. But that represented only a small part of our problems in cost growth. The major part of our cost growth problems, in my experience with the procurement

program in the last 4 years, has been higher than forecast inflation. When you look at inflation of 10 to 15 percent a year, which we have been in the last year or 2 in the aerospace industry, you can see that in over a 4- or 5-year period you are talking about doubling the cost of equipment, and we haven't geared our minds even to thinking about what that means. We talk about an XM–1 tank whose cost at the time we forecast the program back in 1972 or 1973 was a half million dollars, and our best estimate today is that that tank is still at about a half million dollars in those year dollars. But in fact, when we come to the Congress and ask for money for it, we are going to be asking for more like a million and a half, because the difference between the inflation in 1973, say, and the inflation in 1984–85, when most of those are built, is going to be about a 3-to-1 factor.

Senator NUNN. In your opinion, are we fielding weapons systems with immature technology?

Mr. PERRY. No; I think we are very conservative on that point. I wouldn't say it has always been the case, but in my experience in the last few years, there has been a high degree of conservatism relative to not only developmental testing of equipment, but more importantly perhaps, the operational testing. We have produced equipment before we have completed the operational testing, in some cases even before we completed the development tests. That is, we have high concurrency in many of our programs, but we are not fielding equipments that have not had the technology pretty well wrung out in both development and operational tests.

We have been criticized for taking too long to get our equipment in the field, that is, spending too many years testing it, but in my judgment, this testing—particularly the operational testing—is well worth the time and the money we put into it, and we get many benefits from it.

Senator NUNN. If you look at the equipment out in the field today, generally speaking, without getting into each different weapon system, do you believe that the equipment is performing as your predecessors expected it to perform? The general impression of the answer to that question is probably in the negative. Is that an erroneous impression, or does it have some validity?

Mr. PERRY. I am——

Senator NUNN. Is the question too broad?

Mr. PERRY. I am trying to go from the broad question to thinking of specific categories.

Let me try something a little less broad than that by going to our tactical airplanes, for example, as one category of equipment. I think they are achieving the performance objectives that were expected of them. I think they have turned out to have more reliability and maintainability problems than were projected. I don't think adequate attention or consideration was given to that in their design, considering the equipment which is now in the field.

In the case of ships, I think they are achieving performance objectives that were expected of them, but at a higher cost than was anticipated.

In the case of the ground equipment, I think the difficulties of operating and maintaining the equipment were higher than were

anticipated, but again, the performance objectives were being achieved. That is a——

Senator NUNN. So performance expectations have been fulfilled?

Mr. PERRY. Generally.

Senator NUNN. But the reliability and maintenance and those kinds of expectations, generally speaking, in the Tactical Air area, have not been fulfilled?

Mr. PERRY. Yes; and it is because of that judgment—and that judgment preceded my term in this job—that there has been a greatly increased emphasis on operational testing, and a greatly increased emphasis on building in reliability and maintainability features during the design process, to the extent, as I indicated, that many people criticize us for spending so much time and effort and money in that field because we are slowing down the entry of equipments in the field, and we are raising the cost.

But there has been a very, very substantial effort there which in a sense is a reaction to the problems which I have described to you.

Senator NUNN. Dr. Fossum, let me ask you that same question.

In your general view—and you can narrow this down as you think is necessary—do you think that the expectations of your predecessors have been fulfilled with respect to maintenance, durability, reliability, as well as performance?

Dr. FOSSUM. Well, it is my opinion that the systems that were procured, and are in procurement are quite capable systems except in those areas that we have had technological problems and sometimes unforeseen problems which had to be wrung out.

I have no example of where we failed to meet the technical specification that was laid down at the time that we initiated the program or my predecessors initiated a program, that is, a program that goes all the way through procurement. I have numerous examples, of course, in DARPA, where our goals were so high that we could not meet those, but that is in the beginning phases, the tech base and exploratory development and advanced development phases. That happens often and it should happen often. We should set goals very high.

Once we have passed into engineering development with a specific set of goals, it seems to me that we do quite well. I support Dr. Perry's view that there are technical problems that will arise there, and the exact ones that you are most concerned with have arisen.

I have no other information to shed on that particular area.

HIGHLY SOPHISTICATED WEAPON SYSTEMS

Senator NUNN. Dr. Fossum, in June 1980, GAO issued a report on the implications of highly sophisticated weapon systems on military capabilities. The GAO concluded, and I quote from that report:

> The sophistication of many weapon systems developed today is one of the contributing factors that has led to budget problems, inventory shortfalls, and a low state of readiness for certain combat categories.

GAO further concluded that a much better balance between performance and reliability must be obtained.

Are you familiar with this report, and do you have any comments on whether you share that general view?

Dr. FOSSUM. Mr. Chairman, I am not familiar with that report, and therefore I have no comments on that, except to say that in many instances, as Dr. Perry has pointed out, where we are forced because of long procurement times, to move systems into inventory without adequately wringing them out in the test and evaluation, we oftentimes have retrofit problems which stem from quickly moving things into the inventory, into an initial operational capability. This is an attempt to compress the time because of service operational requirements, and because of the need to increase force levels.

I am not sure what the GAO report was addressing, but there are many reasons and many dimensions of the problems of reliability. Therefore I would suggest that there possibly is another view of why we occasionally have difficulty with engines or things of this type.

Senator NUNN. Their final conclusion was that a much better balance between performance and reliability must be obtained. I think that is entirely consistent with what both of you have said this morning.

Dr. FOSSUM. I agree.

Senator NUNN. That that is the kind of balance you are trying to achieve and believe you are now achieving to a better degree than in the past.

Mr. PERRY. I would comment that my principal criticism of the GAO report is that it is about 5 years out of time synchronism. That is, it describes a problem which we recognized more than 5 years ago and made substantial modifications in our development and procurement process to try to accommodate. Some people believe we have overcompensated in that respect, and the changes I am talking about are not changes which I am standing up to take credit for. They were already underway a year or two before I came into this job, very very substantial emphasis on achieving reliability, maintainability in the design phase of systems, and to the extent that at every stage of the DSARC review, the first milestone, second and third, those are principal factors which are evaluated. The system has to pass those so-called RaMd milestones—that is an acronym for reliability and maintainability and durability—before it can proceed in the development and production process.

Senator NUNN. Dr. Perry, let me ask you one other question.

If someone were to take the position that we can afford to lower the quality of personnel of our military forces now—and I have in mind more particularly in the Army—because we have more capability in the systems coming in and therefore less skills are required. We have already gone through this to some degree. That has happened in the last year intentionally in the Army. Is that consistent in the short term—the next 4 or 5 years—with what you see as the problems of the Army?

Mr. PERRY. No, no. First of all, the operating and maintaining of this sophisticated equipment is only one aspect that describes the quality of personnel needed in the services.

Senator NUNN. Right.

Mr. PERRY. But even if you focused on only that aspect, and even if you believed that the technology we are describing to you is going to have these improved properties in terms of operability and main-

tainability, that is not 5 years away from now. It will be 10 years from now before there is a significant percentage of the equipment in the field that has those characteristics.

The process of producing and getting this equipment in the field will take many years, and certainly during the decade of the 1980's and to a certain extent on into the 1990's, the equipment that is now in the field is still going to include a high percentage of the equipment that we have there now. The M–60 tanks, the M–113's, F–4 airplanes, those are going to be a large percentage of the equipments that we have in our operational forces.

Senator NUNN. Dr. Fossum, do you have any comment on that point? Would you generally agree with Dr. Perry's analysis?

Dr. FOSSUM. I agree with Dr. Perry on that point, Senator Nunn.

Senator NUNN. Could you flash back to one of your first charts? The one I have in mind is the one that related to the perceptions of the DARPA in terms of training. I believe it had the word "perceptions" at the top.

DARPA PERCEPTION OF TRAINING PROBLEM

Fewer recruits to do a harder job; less qualified recruits of lower motivation; fewer opportunities for training: limited equipment availability, in part due to poor maintenance; high cost of materiel, fuel; poor retention of skilled personnel; greater variety and complexity of tactics, strategy, doctrine, policy, scenarios; high cost of current training including heavy personnel commitment; and limited budget for training R & D.

Dr. FOSSUM. That's right. This is the DARPA perception of the training problem, not just the weapons. It is restricted to the training.

Senator NUNN. Does this apply to all the services, or do you have a particular service in mind?

You say the first perception is fewer recruits to do a harder job. The second is less qualified recruits of lower motivation. Is this your perception of all the services now, or do you have those first two in mind for a particular service?

Dr. FOSSUM. This is an homogenation without any attempt to single out certain services as having particular problems vis-a-vis the other services. I would not care to comment which ones have each of these individual problems.

Senator NUNN. Right.

Dr. FOSSUM. And they are very much an interactive set of problems.

Senator NUNN. Thank you. I am inserting questions to be answered for the record by Senator Jepsen and Senator Thurmond.

[The questions, with answers supplied follow:]

QUESTIONS SUBMITTED BY SENATOR ROGER W. JEPSEN

UNITED STATES VS. SOVIET QUANTITY AND QUALITY

Senator JEPSEN. Dr. Perry, you have commented that it is not feasible for the United States to match the Soviets in numbers or quantity and that our strategy has been to apply technology in equipping our forces with more capable systems or, loosely speaking, better quality.

How do you determine the proper quantity/quality balance? In your view, do we currently have about the right balance or have we swung too far to the quality side of the equation for example? What are the cost tradeoffs that are considered in determining the proper quantity/quality balance? For example, what comparisons have been made between the cost of procuring and maintaining more

capable weapons versus the cost of producing and manning a larger number of weapons?

Answer. The DOD weighs numerous factors in arriving at the force structure and modernization plans that are presented to the Congress. The basic concept is to produce forces that are judged adequate to execute the military strategy of the incumbent administration. Adequacy is a judgemental thing, of course, but it reflects a review of the kinds of wars we could expect to fight, the circumstances in which they would be fought, and what kinds of outcomes we would consider acceptable. An adequate force must also be attainable. It must be a force that can be built, manned, and supported at the time it is needed. We must rely on historical evidence to guide us in evaluating the degree of difficulty and likelihood of success in accomplishing scheduled improvements.

The Carter administration's fiscal year 1982–86 Five Year Defense Plan makes several major steps toward greater reliability sustainability, and overall readiness of the general purpose forces. Several difficult tradeoffs were made in preparation of this budget. The tactical aviation programs show clear emphasis on readiness over marginal gain in force levels through near-term procurement. For example, the F–15 program is ended as planned with 729 aircraft funded through fiscal year 1983. The F–16 program is slowed from 120 to 96 aircraft per year, and the A–10 anti-tank aircraft is canceled 138 aircraft short of the previous year's estimate. In comparison, funds being added for flying hours to increase reliability and aircrew proficiency will permit the present rates of roughly 10 to 12 sorties per aircrew per month to rise to about 18 per month by the mid-1980s. The DOD annually has reviewed alternative force structure and procurement options for improving overall force effectiveness. Many of these comparisons addressed longer-term future needs, and there were differing opinions on how to balance "quantity" and "quality" for uncertain future needs. The net result in the Carter administration was to retain both higher and lower "quality" systems in production even at the expense of uncomfortably low annual production rates. In the case of the one Guided Missile Frigate (FFG) requested, priced at about $500M, it is clear that interest in keeping all future options open reached excessive bounds.

Selectivity will have to be exercised in the application of higher "quality" systems in the future force structure. We cannot afford to have all weapons possessing the full range of the best capabilities. Various likely combat needs can be met with weapons lacking the full range off technologically feasible options. For example, Guided Missile Frigates (FFG) can be used for some antiairwarfare tasks; only a comparatively small number of surface combatants need have the large Aegis fleet air defense system. We must assess the threats we will face and not provide more capability than will be needed.

IMPACT OF TECHNOLOGY ON MILITARY MANPOWER REQUIREMENTS

Senator JEPSEN. Dr. Perry, cite tactical aircraft as an example where we currently have an edge in air superiority due to the performance edge of our aircraft, but that in your view, this edge is slowly eroding. You point out that the Soviets are outproducing us by two to one in tactical aircraft but at the same time they are introducing more sophisticated, more capable aircraft. You state that your solution is to continue to strive to maintain a critical performance edge. Why, in your view, is this the preferred approach?

Dr. PERRY. Retaining a critical performance edge is not only the preferred approach, because it captalizes on our technological superiority, but it is the only approach, since it is infeasible to compete with the Soviet Union in the quantity of tactical aircraft built. The performance edge I refer to is the ability to detect the enemy aircraft sooner, engage him at extended stand-off range, bring greater firepower to bear, and maintain situational awareness to provide localized numerical superiority whenever possible. The key to success is not necessarily defeating his entire force, but in defeating that portion of his force which is critical to the thrust of his attack and thereby disrupt the conduct of his operation.

Senator JEPSEN. There are critics who point out that only about 50 percent of our combat aircraft are mission capable now due to oversophistication. How do you respond to this?

Dr. PERRY. I disagree. It is too simplistic to state that oversophistication is the cause of combat aircraft being nonmission capable. Many of the problems we are experiencing with reliability and maintainability which have been blamed on high

technology are in fact the result of older systems in need of modernization. In addition, many weapons systems are capable of performing the major portion of the assigned mission even though some of the on-board equipment may not be operationally ready (Mission capable as opposed to Fully Mission Capable). A recent exercise—Coronet Eagle—in which F-15 aircraft were flown to Europe and then operated for 20 days turned out over 1,000 sorties with a Full Mission Capable (FMC) rate of 79.6 percent and a scheduling effectiveness of 96 percent.

Advanced technology, properly applied, offers to us the opportunity to produce weapons systems with a critical performance edge while at the same time providing the reliability and maintainability needed for effective operation.

Senator JEPSEN. It is often pointed out that our air-to-air radar guided missiles did not nearly perform to specifications in Vietnam, yet you mentioned the new sophisticated AMRAAM radar missile as one key to maintaining air superiority. How do you reconcile this with past experience?

Dr. PERRY. The radar missile employed in S.E. Asia, the Sparrow AIM–7, was based upon 1950s technology with its ingerent reliability, maintainability, and operational limitations. As a semi-active missile, successful guidance was contingent upon continuous illumination of the target by the aircraft radar. Aircrews were hampered by systems operability considerations—proper and timely pre-launch preparation, the rather restricted launch envelope, the necessity to separately illuminate each target until intercept, etc. These factors mitigated against successful missile employment and limited the number of air-to-air engagements.

AMRAAM, on the other hand, will be based upon the latest electronic technology with the attendant advantages. This technology provides a significant improvement in performance capability, yet makes AMRAAM easier to maintain and operate. AMRAAM is specifically designed to reduce pilot workload and increase his options. The missile may be launched in several automatically selected operational modes, including a degraded aircraft radar mode. Aircrew action consists only of select, arm and fire. The launch envelope is larger than that of the Vietnam era SPARROW, and is much less sensitive to target maneuver, illumination requirements, radar glint and scintillation, background clutter, and ECM. The active radar seeker provides a launch and maneuver capability, and the ability to simultaneously launch against multiple targets provides a force multiplier effect. For example, the latest versions of SPARROW and SIDEWINDER, the AIM-7M and AIM-9M, enjoy vastly improved captive carry and in-flight reliability over the versions employed in S.E. Asia by virtue of more advanced technology. Operational test failures still occur, but when they do, they are generally the result of a systems limitation rather than a reliability failure AMRAAM will reduce the operational limitations still further. It will succeed where AIM-7M would fail by the very nature of the weapons system.

In summary, the combination of greatly enhanced performance, reliability, and ease of employment are the reasons why I believe AMRAAM to be one key to maintaining air superiority. The sophistication of the AMRAAM system makes possible performance undreamed of in the S.E. Asia experience. However, this sophistication does not imply overwhelming complexity and degraded reliability. In this case, sophistication reduces pilot workload and increases weapons systems effectiveness.

Senator JEPSEN. Some analysts have pointed out that the cost of maintaining and supporting more sophisticated systems will be prohibitive, that O&M costs would increase, that funds for investment will thus go down, resulting in fewer systems being procured at even higher unit cost; in effect, a vicious cycle of decreased investment funds, increased unit cost, and decreased numbers of systems being procured. How do you respond to this?

Dr. PERRY. I have stated earlier in my remarks that it is necessary to use our technology to get improved performance of a weapon system, but we can do it in such a way that it improves reliability, makes it easier to maintain and makes it easier to operate. We can also use technology to reduce the cost of systems, even though the evidence in the field seems to be to the contrary to that; however, most of these equipments were developed in the 50s and 60s. We have recently developed and are planning to use very large scale integrated circuits in our military equipment. This is perhaps the leading technology today where in addition to improving performance, we are getting dramatic decreases in cost.

Questions Submitted by Senator Strom Thurmond

UNIT ROTATION

Senator Thurmond. Has the Defense Department seriously considered training, deploying and rotating entire troop units as integrated wholes to increase their effectiveness in handling the more advanced weapons of today?

Answer. The Army is considering a test of this concept, which if approved, would begin during fiscal year 1981. The test concept envisions forming combat arms companies of first term enlistees who will remain in these companies for their initial three-year enlistment. The companies would remain in the United States for a minimum of 12 months and then deploy for 18 month unaccompanied tours in Europe or 12 month unaccompanied tours in Korea. The purpose of the test is to determine if units consisting of personnel who have been stabilized and trained together are better prepared for combat than units supported by the individual replacement system.

The Marine Corps employs a unit rotation system to support its Division and Air Wing in Okinawa. Infantry battalions and Tactical Air Squadrons rotate to Okinawa for a six month un· ccompanied tour and are then replaced by another unit from the sustaining base. This system has worked well for the Marines because of a favorable ratio of 3 or 4 units in the United States for every one unit overseas.

The current Air Force fighter/reconnaisance force structure in the CONUS is inadequate to support unit rotation overseas; e.g., approximately one to one. The Air Force requires a three to one CONUS support base with like aircraft/missions. Specialized—high technology—aircraft/systems would necessarily remain deployed overseas which would require theater training of rotating personnel. Crew members and support personnel would be rotated each 179 days—thus, the short time in theater and required training would lower proficiency and unit experience levels. Unit rotation under these circumstances would be detrimental to readiness, morale and retention. Overseas fighter/reconnaisance combat force structure supports NATO/PACOM commitments and should not be altered solely for the purpose of structuring a CONUS/overseas mix which is favorable to a unit rotation program. The House Appropriations Committee (HAC) Surveys and Investigations staff last year conducted an inquiry into utilization of the Unit Rotation Concept for Overseas Deployment of United States Military Personnel and intends to recommend that, in view of the inadequate CONUS rotation base, unit rotation plans be deferred for the Air Force.

TRAINING AND PERSONNEL TECHNOLOGY

Senator Thurmond. To what extent has human factors technology been applied to reduce fatigue, boredom and self-hypnosis in advanced systems?

Dr. Perry. Advanced systems dictate that operators be capable of performing a variety of primary and secondary missions. As new sensors, weapons, controls and displays are incorporated into advanced systems, the allocation of functions between man and machine becomes critical. A major role of human factors engineering is to reduce the gap between what systems demand and what operators can do. The Services, in coordination with NASA have been developing computer-aided human engineering methods which assist the designers in properly allocating functions and effectively designing their associated controls and displays. These aids are being systematically applied by the Services and industry during the design of new systems. Examples of these efforts are: (*a*) Development of a series of computer based operator decision aids for anti-submarine warfare and command and control that will reduce tactical decision time by 15 to 30 percent in selected applications. (*b*) Voice generation and recognition systems under development will allow operators to communicate with the system by spoken command and to receive computer generated voice responses. Such systems shows a reduction of 30 to 50 percent in input time under heavy workload conditions, with more than 50 percent reduction in input errors. (*c*) New computer models of the human operator allow predictions of workload for new weapon systems and system updates before hardware is built. Using this capability operator tasks can be assigned to achieve an appropriate level of workload; this avoids the performance loss and fatigue due to overload and the lack of alertness resulting from too simple a job. The utilization of these burgeoning capabilities will reduce workload and assist operators during all phases of weapon systems management and operation.

CHEMICAL WARFARE TECHNOLOGY

Senator THURMOND. What new technologies have been developed to increase the offensive capabilities and staying power of our troops on the chemical battlefield?

Dr. PERRY. The threat of chemical warfare continues to be of great concern to the Department; as a result, we have increased research and development efforts and are attempting to exploit the capabilities available in both industry and the universities to stimulate new concepts and ideas needed to improve equipment in deficient areas. A few examples of current programs to improve our capabilities follow.

Remote detection and personal dosimeters are being pursued to provide early, rapid and more sensitive alarms and warning devices. Medical antidotes, prophylaxis and casualty care will be improved to enhance treatment of chemical casualties. Innovative approaches to new materials for the next generation of individual protective clothing, as well as improved personal mask materials, are being pursued. Decontamination fluids and dispensing equipment to allow improved mobility by more rapid and thorough decontamination of equipment, personnel and areas and under active investigation. Collective protection for armored vehicles and rapid, cheap modifications to structures to provide rest and relief facilities is proceeding well. Safe simulant materials to allow realistic training and to quantify performance degradation are under active study with several interim simulants already approved. Programs in the development of safe binary munitions are being increased to provide necessary tactical capabilities to the retaliatory stockpile.

CHEMICAL WARFARE PROTECTION

Senator THURMOND. How can we prevent the total immobilization of our troops by the simple presence of chemical agents?

Dr. PERRY. The major thrust of our programs is to rapidly improve the defensive posture of all forces in order to survive a chemical attack and to continue military operations in a contaminated environment. All programs are structured to allow rapid procurement and deployment of both new and improved equipment items. This, when combined with a greatly expanded training program, will permit continued operations in the near term.

Key defensive items in final development are the new individual protective mask, modular collective protection equipment for armored vehicles, a chemical attack warning and transmission system, rapid decontamination techniques and equipment, and advanced detector and alarm systems for both liquid and vapor. These are being supplemented by product improvement measures for existing, fielded equipment to improve performance. An active procurement program is rapidly equipping all forces and an operations and maintenance program is providing funds for the acquisition of expendable items such as protective overgarments, gloves, boots, aircrew special flight ensembles, and to allow for training and readiness exercises. Of special note is the initiation of appropriate unit exercises which indicate we can survive and continue operations now, the goal is to provide a sustained operational capability in a toxic environment as soon as possible.

PRODUCTIVITY OF THE FIGHTING MAN

Senator THURMOND. What quantitative evidence do you have that all this new technology has actually increased the unit productivity of the fighting man in combat?

Dr. PERRY. Human factors engineering is a technology whose products are only recently being systematically applied as weapons systems. Some key accomplishments to date which have resulted in more productive use of personnel are: (*a*) A Crewstation Assessment of Reach (CAR) Model was used on the F–18 to evaluate the pilot's physical size in relationship to cockpit configuration. As a result, the number of pilots able to safely operate the aircraft was increased from some 20 percent of the population to over 80 percent. This application resulted in an estimated savings of $10 million. Similar use of the CAR Model was made on the AV–8B and SH–60B; (*b*) Development of a standardized inflight air combat maneuvering measurement technique resulted in threefold superiority in kill ratio and a 76 percent decrease in missile envelope recognition error when used on the Tactical Air Combat Training System; (*c*) The development and

utilization of a part-task training system for night carrier landing training resulted in a 40 percent decrease in the number of pilots who failed to qualify on their first landing attempt; (*d*) Recent advances in computer based instruction provided a 25 percent reduction in the time required by students to complete technical training courses; and (*e*) Transfer of training studies at Williams Air Force Base, Arizona, measured the effectiveness of air to surface training using an A–10 simulator. Results showed that the similator trained pilot consistently got an average of 20 percent closer to the target than those not receiving simulator raining.

The results of these studies demonstrate how productivity of our fighting man can be improved if given proper training and a system designed for effective man machine interface.

FOREIGN SOURCES

Senator THURMOND. To what extent has new technology lessened our dependency on foreign sources for supplies of strategic materials and fuels?

Answer. New technology has permitted us to lower the specific fuel consumption of our new aircraft and surface vehicle propulsion systems, thus lessening the total amount of fuel used on a particular mission. New technology in combustors and fuel systems has permitted the use of broader specification fuels, thus permitting the use of more of the crude oil from a barrel.

Advanced technology training devices such as pilot trainers, driver trainers and target trainers; and new computer programs to analyze fuel consumption patterns of buildings, facilities, and bases have reduced our unit fuel consumption in the face of increased operating requirements.

Improved ship hull designs, further streamlined aircraft and aircraft appendages, and new transmission designs are in development. The impact of these technologies will be seen in future years.

Less progress has been made thus far in reducing need for importing strategic non-fuel materials. Improved metal processing methods such as powder metallurgy and isostatic pressing have reduced waste (sometimes very high) from extensive machining of rough forgings and castings. Work now in progress on Rapid Solidification Technology shows great promise of making available substitute alloys for applications now requiring large amounts of critical imported metals such as chromium and cobalt.

Senator THURMOND. To what extent have new technologies or systems analysis raised our readiness levels or reduced mobilization times?

Answer. We believe that technology improvements over the past decade have had a beneficial effect on the major readiness contributors of reliability and maintainability. For example, new technology used in designing automatic test equipment can substantially reduce maintenance time, which is a major contributor to "non-readiness". New materials such as composites, which are being used in many of our new weapon systems, will require less maintenance and reduce spares costs. Overall, we are able to deploy our newer, more capable weapons systems (for example, A–10 and F–16 aircraft) with readiness levels equal to or better than our older less capable systems.

MULTIFUELS

Senator THURMOND. What has become of the multi-fuels program to increase the operational flexibility and resupply capabilities of our fighting vehicles and aircraft?

Answer. DOD is pursuing the multi-fueled engine program and a broadened fuel specification program. The purpose of the latter program is directed toward increasing the ability of DOD to utilize fuels that do not meet the current fuel specifications. The Army, Navy, and Air Force have pursued this program by blending components into specification fuels and determining the point at which performance and/or engine function is affected.

In multi-fueled engines, the Army has completed work on the T–700 helicopter engine that has been qualified to operate on JP–4, JP–5, and JP–8 by simple engine/fuel adjustments.

The Air Force has engines that have some multi-fuel capability. The T–76, J–52, and J–69 will operate on JP–4 and JP–5; the J–79 and TF–30 will operate on JP–4, 5, and 8; the F100 engine will operate on JP–4 and JP–8. When new engines are developed, multi-fuel options are considered for incorporation into the program.

The Army has developed a multi-compression ratio diesel capable of broadened fuel operation and a broadened fuel requirement was incorporated in the adiabatic diesel program.

All Military Departments are examining ground/ship/station diesels, turbines, and boilers that can be operated with a range of fuels. The basic technological problems include pre-ignition, pre-heating of fuel, premature high pressures fuel carbonization, ignition energy, variable fuel flow control systems, and fuel injectors that can control and tailor sprays over a wide range of viscosities and densities.

Senator THURMOND. What positive steps have been taken to assure the adequate quality and quantity of water supply for men and equipment in the Persian Gulf Theater of Operations?

Answer. On 22 Septemger 1980, Department of the Army was designated the Department of Defense (DOD) Executive Agent for Land-Based Water Resources. The Army is developing doctrine and organizational and operational concepts for provision of water. It is also responsible for water resource research, development and acquisition for all DOD components. The current focus is on a plan to provide minimum essential water support equipment for a moderately sized force, and a longer term plan for larger forces.

A systems approach has been utilized to develop requirements for the provision of water. Materiel required includes equipment for detection, production, treatment, distribution, storage and cooling of water. Each is a critical link in the water supply system.

Doctrinal studies and analyses conducted to date indicate that the technology and equipment needed to solve the water resources problem exist. A very limited amount of equipment for production and treatment of water is presently being procured and a variety of commercial items are under consideration. Selected military equipment, which was designated for distribution and storage of petroleum products, has been identified and can be used for water only in an emergency, provided it has not been contaminated.

The issue of Host Nation Support for water in the Southwest Asia region is also being carefully considered. A variety of studies are ongoing to determine what water resources are available, and initiatives are underway to obtain bilateral agreements for Host Nation Support.

Although a series of water resources funding initiatives have been undertaken, to date they have been largely unsuccessful. A DOD directed amendment to the President's fiscal year 1981 budget, including funds for water resource equipment, was presented to the Congress in November 1980. However, it was postponed without prejudice to the next session of Congress. The Army is anticipating and prepared to submit an fiscal year 1981 supplemental for water equipment. The Army's capability to support a deployed force will improve only after equipment requirements are funded. The lack of funds has delayed the acquisition and fielding of needed water support equipment.

Senator THURMOND. Can WWII Corps of Engineers water points produce jet engine quality water?

Answer. Demineralized water is required. Corps of Engineers water points were not able to produce jet engine quality water. The current Reverse Osmosis Purification unit was not designed to produce demineralized water. Potable water can be used in an emergency if flushed immediately thereafter with demineralized water. The US Air Force uses an air transportable demineralization unit to produce the water at isolated airfields. A sufficient number of units are in the inventory to support KC–135 operations in a given theater of operations. A requirement exists for additional units. Most modern airfields produce demineralized water for use by jet aircraft.

Senator NUNN. I understand that the Office of the Assistant Secretary of Defense, Program Analysis and Evaluation, has developed a viewgraph presentation of approximately 100 viewgraphs of a case study of the impact of technology on Air Force tactical air modernization and readiness.

Are you familiar with that presentation?

Mr. PERRY. Yes, I am.

Senator NUNN. Would you please take the necessary actions in coordination with the other appropriate Defense officials to have this

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viewgraph presentation with accompanying narrative documented and forwarded to the Senate Armed Services Committee. I know it may take some time to get that together. We would like to have that for inclusion in this record, if it is appropriate.

Mr. PERRY. Yes, I will discuss this with the Assistant Secretary of Defense, P.A. & E. and see what he can do to be responsive to that request.

Senator NUNN. I would also like to get your individual views on the study, Dr. Perry.

[The information follows:]

IMPACT OF TECHNOLOGY ON MILITARY MANPOWER REQUIREMENTS

Dr. PERRY. There are many issues raised in Mr. Spinney's briefing "Defense Facts of Life." I personally agree with many of Mr. Spinney's findings, including the desirability of reducing unnecessary complexity in our weapon systems. But I believe that his analysis ignores the most critical underlying consideration—the fact that our weapon systems must be designed with sufficient capability to defeat our potential adversaries. Modern Soviet fighter aircraft, unlike their earlier designs (e.g., MIG–19, MIG–21) are sophisticated, expensive aircraft with all-weather, all-aspect, and beyond-visual-range (BVR) capability (and with a look-down/shoot-down capability under test). It is quite clear therefore that an all-weather, BVR, look-down capability will be required in our fighter aircraft to stand up to Soviet fighter aircraft in combat. Thus, the issue is not whether a modern airplane such as the F–15 or F–16 is more complex than an obsolete airplane such as the P–51 or F–86, which could not perform the required mission, but rather whether the modern airplane is no more complex than it need be to perform its mission adequately. I believe the F–15, F–16, and F–18 all pass that test. Moreover, it is important to note that modern technology—especially microelectronics—not only allows us to achieve superior performance, but also allows us to reduce cost, maintenance and operating problems, and to increase reliability. These advantages are only now beginning to be felt in the field because systems incorporating microelectronics technology have only been in production in military systems for a few years. However, commercial systems using this technology already are well established—hand-held calculators, small business computers, electronic wrist watches, microprocessors in automobiles, and video games. For example, a hand-held microelectronic calculator is considerably cheaper and much more reliable than its predecessor (the electro-mechanical desk calculator), because of the inherent reliability and increasingly lower cost of large scale integrated circuits. Large scale integrated circuits are indeed "complex," in some sense of that word, but that complexity is "transparent" to the user, and, in fact, leads to decreased complexity of usage and decreased cost.

The experience of the U.S. and Israeli Air Forces shows that the capability of the F–15 weapon system far exceeds that of other aircraft, not only as perceived but also in reality. Compared to the F–4E and carrying equivalent armament, the F–15 has dramatic increases in maneuverability, combat radius, and radar performance. In actual Israeli combat, the F–15 enjoys a 10 to 0 margin of superiority. Every country that has evaluated the F–15 for their defense forces has declared its capability as unexcelled. Furthermore, this jump in capability was accompanied by a reduction in complexity through the application of advanced technology (see Figures 1–4).

For example, the F–15 was designed with 5 fewer flight control devices, 97 fewer electrical connectors, 184 fewer fuel plumbing connections, 66 percent fewer hydraulic filters, over 300 fewer lubrication points, and a reduction of more than 50 percent in the types of fasteners compared to the F–4E. However, there are areas, such as the engine fuel control system, where the F–15 has more parts than the F–4.

The air-to-air combat experience cited for the Korean, Vietnam, Arab, Israeli and Indo-Pakistani wars generally involved close-in missiles. Since conversions to tail attacks are required when using close-in missiles, high exchange ratios can result when one fighter has a turn rate advantage or if he surprises his opponent

FIG. 1.—F-15A/F-4E COMPARISON EQUIPMENT

Equipment	F-15A	F-4E
Windshield (pieces)	1	3
Canopies	1	2
Nose landing gear (wheels)	Single	Dual
Flaps—Leading edge	None	4
Speed brakes	1	2
Vertical stabilizers	2	1
Spoilers	None	2
Rudders	2	1
Hydraulic filters	7	21
Electrical/avionics "black boxes"	106	294
Electrical connectors	808	905
Flight control devices	9	16
Drag chute	None	1
Fuel couplings requiring safety wire	20	40
Fuel level control valves	5	7
Lubrication points	202	510
Number engine disconnects (per engine)	10	34
Environmental control system packages	1	2
Fuel cells/tanks (excluding integral)	4	7
Fuel cells—integral	2	2
Ejection seats	1	2
Wiring (in feet)	69, 800	96, 312
Flight control linkages	92	93
Fuel system plumbing connections	97	281
Cockpit instruments	30	48

FIG. 2.—F-15A/F-4E COMPARISON

	F-15A	F-4E
Operational readiness rate (ready hour possessed hours or rate) (percent)	80	70
Turnaround time (air superiority mission) (EM)[1]	6	15.5
Man-minutes per preflight (ground crew)	58	88
Man-minutes per postflight (ground crew)	126	231
Man-hours per phased inspection cycle (6 phases)	117	345
Airframe overhaul	None	None
Access doors/panels:		
Total area in square feet	571	528
Total quick access in square feet	283	55
Total number of doors/panels	305	211
Percent accessible without work stands	82	66

[1] Elapsed minutes.

FIG. 3.—F-15A/F-4E COMPARISON—COMPONENT REPLACEMENT TIMES (HOURS)

Equipment	F-15A	F-4E
Engine	0.31	3.20
Wheel and tire assembly	.26	.85
Brake assembly	.91	2.25
Fuel booster pump	.33	6.78
M61 gun	2.75	2.38
Missile launchers	.27	.35
Pylon (wing)	.33	3.42
Pylon (centerline)	.33	N/A
Main landing gear	3.51	5.80
Nose landing gear	3.53	2.05
Aileron	2.70	2.80
Stabilator	2.20	4.80
Generator	1.36	2.80
Hydraulic pump	.50	3.53
JFS (F-15A) versus ATS (F-4E)	1.50	2.66
Wing	46.79	N/A
Relays	(1)	(2)
Canopy—Forward	2.90	7.53
Canopy—Aft	NONE	7.53
Flap (TE)	1.95	2.00
Rudder	.70	4.20

[1] Plug in. [2] Hard wired.

FIGURE 4.—F-15A/F-4E COMPARISON FAULT ISOLATION

Built-in test:	F-15A	F-4E
Avionics	Yes	Limited.
Flap system	Yes	No.
Flight control servos	Yes	No.
Fuel system check out panel	Yes	No.
Antiskid	Yes	No.
Fuel quantity gaging system	Yes	No.
Fire warning system	Yes	No.
Failure cues/indications:		
Avionics status panel	Yes	No.
Engine events history recorder	Yes	No.
Cockpit bit panel	Yes.	No.
ECS valve position indicators	Yes	No.
Fuel valve position indicators	Yes	No.
Sight gages:		
Engine oil	Yes	No.
L/R AMAD oil	Yes	No.
CGB/JFS oil	Yes	No.
CSD/IDG oil	Yes	No.
Landing gear strut pressure	Yes	No.

in an attack from the rear. In Korea, the F–86s were able to get many surprise attacks or at least biased favorable starting conditions. But in Vietnam, the Soviets had learned the value of surprise and vectoring, and the MIG–21s generally had a starting condition advantage. Training advantages resulting in many surprise attacks dominated Arab/Israeli and Indo-Pakistani air battles.

The fighter threat of 1985 and beyond will be much more capable, armed with all-aspect weapons, BVR missiles and look-down/shoot-down capability with a multi-shot fire control system. These features will reduce the value of turn rate advantage and surprise. Within-visual-range (WVR) armament will not be adequate by itself on friendly fighters because they would often be outranged by the threat BVR missiles before being able to close for within-visual-range combat. The Air Combat Evaluation (ACEVAL), a large exercise of simulated enemy forces versus U.S. forces with better armanemt, taught that kill rates for outnumbered forces were low—on the order of 1:1 to 3:1—when restricted to close-in combat. Since the U.S. expects to be outnumbered by the threat, much larger exchange ratios are required to preclude loss of a war of attrition. ACEVAL also taught that the BVR missile achieved most of the kills even though positive visual identification was required.

When one fighter has a distinct radar range and BVA missile range advantage, it is capable of achieving very high exchange ratios. This was experienced in a benign environment by the F–15s in the Category II tests at Edwards often referred to as World War IV. In these tests, the F–15 had such an advantage in detecting first, firing first, and often not experiencing any return fire that exchange ratios exceeding 10:1 were often experienced.

Everyday we see more and more evidence of threat growth, both quantitatively and qualitatively. Quantitatively, the disturbing aspects of being outspent are amplified by comparing development production programs. Tactical aircraft production in the past decade has seen the USSR achieve a build rate peak of approximately 1,300 per year compared to approximately 600 in the best U.S. year. In total we have been outproduced by more than a factor of two. The USSR has produced over 10,000 fighters of increasing capability in a succession of new models while the U.S. has produced fewer than 5,000. Qualitatively, the concern with this force buildup is that all indications point to a tactical fighter force consisting predominantly of aircraft with all-weather, all-aspect, look-down, shoot-down beyond-visual-range capability as reflected in Figure 5. Thus, the actions of the Soviet Union indicate that they too have chosen to produce highly capable airplanes that would be called "highly complex" in Mr. Spinney's terminology.

We cannot hope to meet this threat with a tactical aircraft force that is inferior in these characteristics. Comparisons in Mr. Spinney's paper relate cost to "complexity" without recognizing the value of increased capabilities. A prominent Air Force tactician, B/Gen John Burns, once said, "If you think superiority is too expensive, try inferiority."

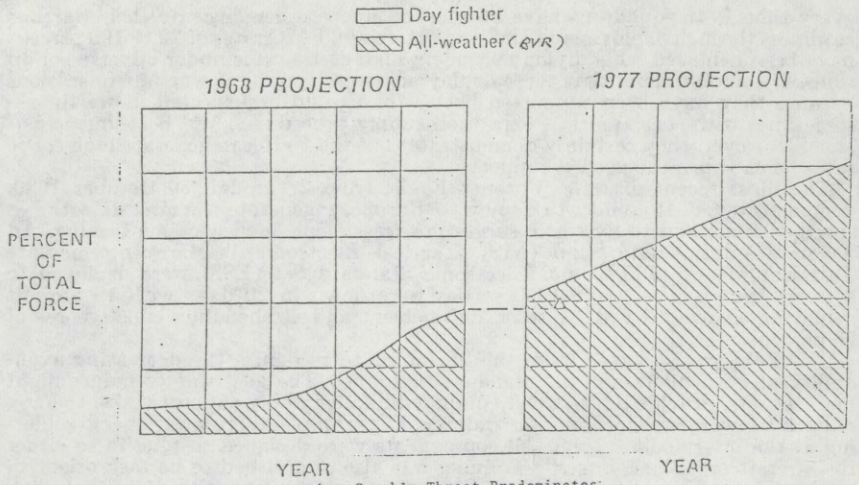

Figure 5. All-Weather Capable Threat Predominates Air-to-Air Combat Capability

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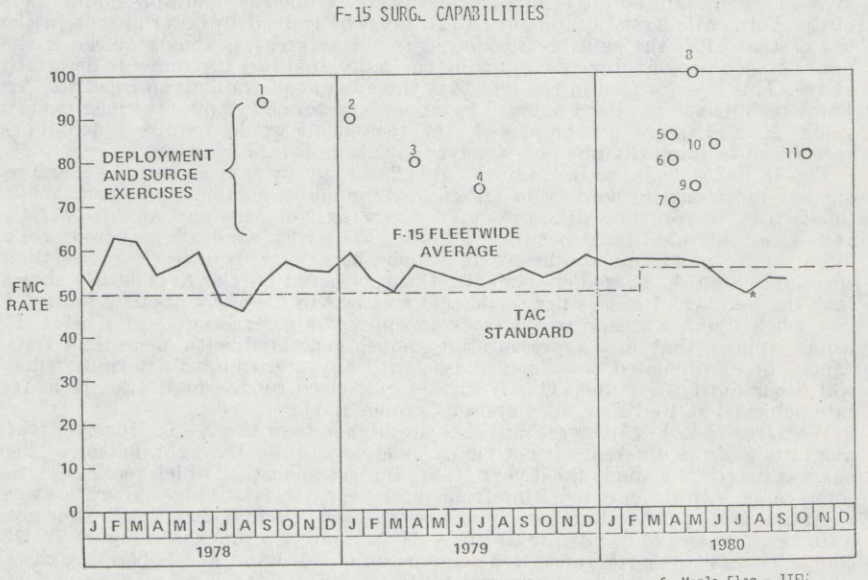
Mr. Spinney is critical of F–15 readiness and surge capability, the use of a "remove and replace" maintenance practice, and the deployment of the Avionics Intermediate Shop (AIS) to diagnose avionics faults.

First, the question of F–15 readiness. The F–15 has consistently met or exceeded the TAC standard for Fully Mission Capable (FMC) rate as shown in Figure 6. This has been accomplished under routine peacetime operating conditions with less than the required number of personnel and the proper skill levels. Moreover,



*Below TAC STANDARD because of engine problems.

1. Bitburg Surge - 36TFW
2. Prized Eagle Deployment - 1TFW
3. ORI - 49TFW
4. Maximum Push - 32TFS
5. Team Spirit - 18TFG
6. Maple Flag - 1TFW
7. Eagle Thrust 80-3 - 1TFW
8. Dawn Patrol - 32TFS
9. Kadena Surge - 18TFG
10. Red Flag 80-4 - 49TFW
11. Coronet Eagle - 33TFW

Figure 6. F-15 Surge Capabilities

every time F–15 squadrons have been called upon to demonstrate their wartime readiness through deployments and surge exercises, FMC rates of 70 to 100 percent have been achieved while flying extremely high sortie rates under adverse conditions. I wouldn't claim that these deployments are typical of wartime operations because they have been supported better than could be expected in wartime—sometimes with special airlift, expedited supply procedures, and host-unit assistance. However, they certainly demonstrate that the F–15 can generate high sortie rates when it has the needed support.

The most recent exercise, Coronet Eagle, from 2 through 30 October 1980, demonstrated F–15 ability to deploy to Europe, regenerate the aircraft within a specified time, and to fly sortie surges in excess of planned wartime tasking. An Avionics Intermediate Shop (AIS), Tactical Electronic Warfare Intermediate Test Equipment (TITE) and Electronic Standard Set (ESS) were deployed to support the exercise. Over 1000 sorties were flown in 20 days with 18 aircraft achieving an overall FMC rate of 79.6 percent and a scheduling effectiveness of 96 percent.

The F–15 was designed from the beginning to recognize the decreasing availability of both pilots and maintenance personnel. The goal was to reduce flight line test sets, provide built-in test equipment, and simplify support tasks, thereby requiring fewer personnel and less training. For example, there was to be no soldering at the intermediate level. All components were designed to plug in to either the aircraft or "Black Boxes". Training was also established to be task oriented, by design, not because of the complexity of the system. The logic of not spending extensive classroom time learning how the system works when the maintenance tasks did not require it, justified reduced formal classroom training and more OJT.

Troubleshooting modern avionics is best accomplished via automated test equipment at both the intermediate and depot level. The 45 Line Replaceable Units (LRUs) are supported on three unique Automatic Test Stations which are under computer control. The computer hardware and associated switching equipment comprise approximately 20 percent of the Test Station. The remainder of the hardware is made up of standard test instruments such as voltmeters, signal generators, oscilloscopes, etc., such as were employed by military technicians in WW II when maintaining electronics hardware. While the operators/maintainers of the Autmoatic Test Equipment (ATE) must be trained to be proficient in the use of the ATE, the skill level required is not as great as that required if the maintenance personnel were employing the individual test instruments described above. This is evidenced in the fact that the amount of training afforded the Air Force technicians has been reduced by about a factor of two over the past twenty years. If ATE were not employed, the technician would require much more specialized training than he now receives to accomplish his mission.

The 18 F–15s deployed to Coronet Eagle flew high sortie rates, but the exercises did not represent the variety of stresses attendant to combat operation. While this is true, the previous data presented regarding Not Mission Capable (MNC) and Mean Flying Hours Between Failure (MFHBF) were all gathered while flying under peacetime conditions in which there were even less stresses than encountered on the surge deployments. Data gathered on the AID clearly shows that the number of LRUs per sortie sent to the AIS drops by about a factor of two when flying wartime sortie rates as opposed to peacetime sortie rates. It would appear that any representative model generated with peacetime data cannot be extrapolated on a linear basis, with any precision, to determine what will occur during wartime. This is further evidenced by the high aircraft FMC rate achieved at Red Flag 80–4 and at Coronet Eagle.

We agree that F–15 Operating Costs are higher than the A–10. However, the magnitude of the difference is not nearly as great as slide 37 would indicate. This chart is based on a single fiscal year (1981) budget allocation which represents, in some cases, adjustments resulting from prior year deficits. Budget allocations of operating costs tend to fluctuate from year to year. We find that the F–15 is not 4 times as expensive to operate as the A–10 but only 2.5 times (see Figure 7). Of course, there is little relevance to a comparison of F–15 and A–10 operating costs since the A–10 has absolutely no capability to perform the F–15 mission.

The Air Force predicts organizational, intermediate and depot spares costs using the same computational procedures for all weapons systems. The inherent problem of determining spare parts requirements is predicated on the ability to determine failure rates of parts prior to aircraft entering the inventory. This abil-

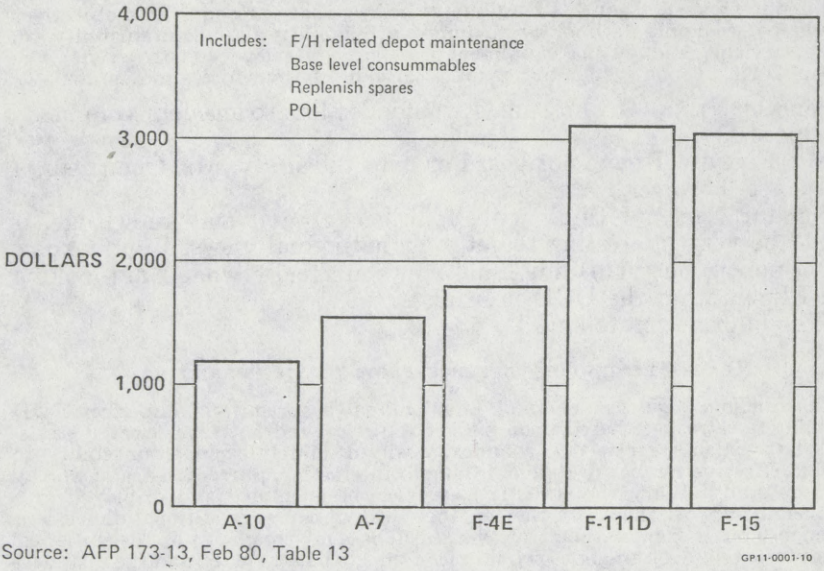


Figure 7. Variable Cost Per Flying Hours

ity, or inability, is not dependent on the complexity of the aircraft. Increases and decreases in POMs do not represent, as was stated by Mr. Spinney (slide 38) the difficulty in predicting future depot burden. The concepts established on the F–15 in the beginning of the program are still being adhered to and the programed depot burden has not changed as slide 38 portrays. The main points that should be stressed however are:

The F–15 is supportable and capable of high sortie rate production.

The F–15 is designed to simplify the fighter pilot's job by utilizing advanced technology.

The F–15 does produce a unique and necessary combat capability for the USAF.

The F–15 is not the complex, technological nightmare that is suggested.

The F–15 cost is not excessive if procured at reasonable rates.

The foregoing statements address only a few of the many points raised by Mr. Spinney. My comments have related directly to the F–15 only because Mr. Spinney chose the F–15 as his example of what he perceives as a general tendency to embrace overly complex solutions to our mission needs. The point is arguable and I will not claim that the proper balance has been achieved in every instance. However, a careful look at the steadily increasing capabilities of the Soviet forces leads me to a belief that I hold with great confidence; that is, that it is not possible with any quantity of weapons to win a war against the Soviet Union unless our weapons possess characteristics that allow our forces to use these effectively. The characteristics change as the Soviet forces become more capable, and today the characteristics required in our weapons make it essential that we apply our technology.

The majority of the F–15 development testing was completed in 1975. Two new fighters are entering our inventory, the Air Force F-16 and the Navy F/A-18, and these aircraft offer high performance platforms with advanced avionics packages capable of performing the fighter and attack roles. Advancements in digital, multiplex avionics technology have permitted much more capability and flexibility to be packaged in a smaller volume than ever before. Reliability and maintainability were primary design objectives in these aircraft and from fleet data and test results, it appears that the net result will be low maintenance and high operational availability at reduced cost of ownership.

I feel that technology must be applied to counteract a numerical disadvgetana in military equipment. My prepared statement discusses the application of technology to reduce the pressures resulting from shortages of qualified operating and maintenance personnel. I continue to believe that our acquisition objectives should be: to apply technology to improve reliability and maintainability. to make servicing and testing equipment less labor intensive and to provide the best possible weapon system our country can build for our forces to operate.

Senator NUNN. Dr. Fossum, I would also like to get your comments on this study.

Mr. FOSSUM. I have not heard or read the study, Mr. Chairman. I will do so, however.

Senator NUNN. I think with your background and knowledge, it would be very interesting to get your individual views. I don't know DOD policy, but your individual views are really what I am looking for. I know what the DOD position is.

[The information follows:]

DARPA REVIEW OF "DEFENSE FACTS OF LIFE" BRIEFING

The briefing, "Defense Facts of Life," raises the premise of imperfect DOD planning in retrospect based upon budget statistics, and portrays selected statistical data which suggests that complexity will ultimately exclude our ability to achieve effective combat readiness. I found it interesting, provocative, and worthy of more study. While the statistical evidence is assembled and displayed in a manner to support these two themes, there are, of course, additional dimensions which also merit examination. However, I will base my comments on the statistical data presented, even though I would recommend that the data and the qualifications of its collection should be carefully assessed to avoid potential, perhaps inadvertent biases. I certainly agree that it is unwise to introduce complexity into, modern warfare systems for the sake of exploiting advanced technology, i.e. technology for technology's sake.

Turning first to the treatment of DOD budget planning (the PPBS), I do not find it incongruous that the five year projections show relatively smooth growth curves (Slide 11). This has been the historical nature of the entire Federal budget for many years. The short term influence of hostilities is a natural perturbation of this smooth DOD budget growth curve. Additional smaller perturbations arise from the congressional review process and periodic changes in each administration's emphasis of defense funding vis-a-vis non-defense budgets. The budget peaks during periods of hostility, when averaged with the more gradual year-to-year changes, bias the long term growth picture. The sharp reductions in post-hostility periods warp the statistics when they are treated on a year-to-year percentile basis. This effect is most pronounced in the investment account (Slide 16) since procurement and construction can be rapidly reduced. The O&S account (Slide 17) does not change so dramatically in these periods since there is no rapid draw down in personnel. The RDT&E account (Slide 18) reflects a relatively smooth long term growth, with short term changes mostly characterized by administration policy decisions. There should clearly be a concern for the steady growth in the retirement budget (Slide 19) which, as the author comments. is now approaching the RDT&E level. I agree with the author's observation that small percentage increases in the O&S budget, since it is the largest component, puts pressures on the other accounts under a relatively constant overall budget level. However, perhaps the O&S account could be held down if investment funds were used to acquire systems which needed fewer O&M personnel to operate and maintain them, and which reduced the support requirements by improved reliability. This may sound like an argument against complexity but I maintain it is also an argument for improved reliability, self-verification and increased automation. Some of the most complex subsystems available today, the micro computers, are simultaneously the most reliable and require the least maintenance.

The second part of the author's theme relates complexity to the rising cost of modern weapons and the apparent reduction in operational readiness. Unnecessary complexity is certainly undesirable; it increases failure modes, increases support costs, and degrades the training program. However, the arguments presented in the briefing bear further examination. Modern aircraft, capable of engaging and de-

feating high performance threat aircraft, of necessity must also be high performance, all weather aircraft equipped with systems for engagement beyond visual range, for look-down, shoot-down performance and for other advanced capabilities. These increases in mission complexity naturally demand more sophisticated aircraft subsystems, sensors and weapons complements. The advent of high thrust-to-weight engines, advanced light weight materials, microelectronics and large scale integrated circuits in recent years have made this advanced mission capability possible. The packaging of this high technology into remove-and-replace modules is a proper step in the direction of greater readiness in our combat aircraft. The inherent greater reliability of these systems will be evident as the technology matures under increasing production rates and with the benefit of feedback from field experience. Readiness is achieved by high reliability subsystems, adequate spares provisioning and ease of maintainability. Modular construction, and self or automated verification, leading to remove-and-replace simplicity, will facilitate the maintenance process. There is no alternative to adequate spares provisioning; however, technology devoted to major reliability improvements can help reduce these requirements. The needs can only positively be determined through field experience.

I agree with the author's statement that, "Advanced technology and high complexity are not synonymous." It is my perception that there are stressing missions and stressing technologies. Where current technology is stressed or stretched too far to reach the more stressing missions, readiness suffers. Such experience is evident where we apply technologically improved subsystems as block changes to in-inventory systems. Reaching for stressing missions in this manner frequently shows a drop in operational readiness due to some overstressed subsystem(s). Reliability degrades, unit cost increases, maintenance becomes more difficult and costly. Conversely, advanced technology, especially if unconstrained by evolutionary block change requirements, can be structured in a composite manner to achieve these stressing missions. In fact, by careful aggregation, innovative technology can lead the way to achieving new or different missions which are not possible without this advanced technology. These missions then become technology driven rather than requirements driven. These technology breakthroughs can yield the force multipliers we seek as alternatives to the quantitative arms race. The Stealth technology is perhaps a typical example of advanced technology opening up mission opportunities unavailable to the model evolution approach. The bottom line of the author's briefing is that "technology should and can increase readiness, not draw it down." Technology applied in a non-stressing manner, applied to major advances in reliability, maintainability, and training, and applied to an asymmetric manner so that it cannot be readily matched or countered by an adversary can, in fact, lead to marked advances in combat readiness.

Senator NUNN. Thank you.

And also would you request that we would like the official view of the Air Force on the study?

Mr. PERRY. I am sure you will get it.

Senator NUNN. I already suspect what it is, but I would like to have it in writing so that it can be reviewed.

AIR FORCE REVIEW OF "DEFENSE FACTS OF LIFE" BRIEFING

The Air Force has reviewed the OSD/PA&E briefing "Defense Facts of Life." This analysis has been received and debated throughout the Air Staff for the past two years. It brings out facts and realities that challenge our planning; however, the briefing uses static defense dollars as its standard of measurement. The Air Force uses the current and projected capabilities of the threat as its standard of measurement in structuring its tactical forces. The threat determines the requirements for the forces and employment concepts. Forces must be capable of dealing with the threat which is increasing in both quality and quantity.

While the OSD/PA&E briefing correctly identifies the fact that higher capability aircraft generally require more resources in terms of personnel and spare parts to operate, it does not discuss the productivity of those systems once engaged in combat. Recent deployment exercises like Coronet Hammer, F–111Ds to England, and Coronet Eagle, F–15s to Germany, have shown that our most capable aircraft can be operated at rates in excess of wartime plans if properly supported with spare parts.

The report correctly points out the under funding of readiness items. The Air Force has now made an unprecedented commitment to make essential improvements in our near term warfighting capability. This commitment consists of major shifts in funding priorities away from aircraft procurement and into our readiness accounts.

Two presentations are currently available which discuss some of the central issues presented in the PA&E briefing. One is the Tactical Air Forces' briefing on force requirements, and the other is an Air Force Studies and Analysis briefing on the impact of different force options.

Senator NUNN. I want to thank both of you very much for your testimony today. I think that you both have a tremendous record of service to this country, and I don't know of any two people that have more expertise in this area. I don't know what your futures hold as far as the Department of Defense is concerned, but I know wherever you are you are going to maintain your interest in national security, and we hope you will continue to give us the benefit of your views.

Mr. PERRY. Thank you very much, sir.

Senator NUNN. Dr. Fossum, thank you.

[Whereupon, at 12:57 p.m., the subcommittee recessed subject to the call of the Chair.]

DEFENSE FACTS OF LIFE

Franklin C. Spinney

December 5, 1980

This staff paper represents the preliminary views and findings of the author. It has not been reviewed by the Department of Defense and therefore should not be construed as reflecting an official position of the Department.

Today, there seems to be general agreement on the need to strengthen our military. There is also considerable debate over just how this ought to be done. Defense Facts of Life is an attempt to make a constructive contribution to this debate. Before proceeding, I would like to make a few introductory comments.

(Slide 1) First, and foremost, this briefing presents an independent minority view. My colleagues and I believe that our nation faces a long-term defense problem of fundamental importance and our objective is to stimulate informed debate over the need for, and the shape of, basic changes in the collective process of defense decision-making and planning. In this spirit, this briefing is an attempt to determine the realism of our current plans, and to articulate the leadership challenge facing defense decision-makers over the coming decade. To do this, we will focus on the evolution of Air Force tactical fighter aviation. It would be a mistake to view this problem as being peculiar to the Air Force or solvable by the Air Force. A cursory review of the other services revealed similar, if not worse, problems.

All levels of decision-making in the executive branch, the legislative branch, and the private sector contribute to the pattern of behavior discussed in this briefing. Consequently, everybody is at fault and nobody is at fault. This lack of a neat structure, and an awareness that the problem has been building up for many years, lead to the conclusion that there are no easy solutions, quick fixes, or management gimmicks to make it disappear. The fundamental need is for strong informed leadership and a collective will to change. We hope that this can be achieved through a rigorous above-board self-examination.

Secondly, for the past two years, this briefing has been presented many times, and at many levels, within the defense department. Our experience has been that it is contentious and often evokes strong emotion. On occasion, in the heat of the moment, it has been interpreted as an argument for smaller budgets, or as an argument against advanced technology. This view is totally incorrect. We need more money to strengthen our military; however, we believe that unless we change the way we do business, more money could actually make our problems worse. Inextricably combined with the broad issue of how we spend our money, is the issue of how we should use our superior technology--specifically, should we continue to increase the technological complexity of our weapons? Do the positive qualities of high complexity weapons outweigh their negative qualities? Advanced technology and high complexity are not synonomous.

There may be ominous precedents for our current dilemma. Would increased defense budgets in the mid-to-late 1930's have made any difference to the French in 1940? France entered the war with more tanks than the Germans, the world's most technologically sophisticated trench, and a fatally flawed strategy based upon a stagnant appreciation of World War I's lessons and an emphasis on using emerging technology to solve old problems.

Overview

(Slide 2) To discuss this complicated issue, we will start by articulating the basic nature of the planning task in terms of the uncertainties that must be faced by decision-makers. Next, we will take a general view of the pattern of change in our budgets, costs, and force structures over the last thirty years to gain insight into our actual decisions in an uncertain world. We will then examine the case of Air Force tactical airpower in detail to show that budget increases do not change the general pattern. Next, we will examine the uncertainty surrounding our investment plans in order to see how our desired future compares with past reality. Finally, we will examine our perceptions of military capability and evolve the long term consequences of continuing increases in the cost and complexity of our weapons.

Nature of the Planning Problem

(Slide 3) The plans that we are concerned with in this briefing primarily consist of our financial plans (specifically the Five Year Defense Program or FYDP); and secondarily, those plans that link our war plans to the FYDP (specifically, the Air Force War and Mobilization Plan or WMP). These plans are intended to provide the forces in being needed to prosecute our war plans. To do this in the real world, decisions and plans must reconcile the tension between perceived threats and limited resources. Uncertain and menacing threats generate a long menu of requirements that can only be funded out of a limited pool of resources.

The bureaucratic process for reconciling the tension between desires and resources culminates in the publication of the January FYDP. The FYDP is the only document published by DoD that incorporates all the hard decisions between two covers; and consequently, it is the authoritative statement of defense policy. We are <u>not</u> saying that budgeting should shape policy; budgeting should reflect policy. If it does not reflect stated policy, then budgeting is determining real policy, and formal policy statements are meaningless. During our discussion, we will attempt to uncover what the FYDP says our policy is by examining the future consequences of today's decisions.

(Slide 4) Although the defense debate tends to focus on hardware procurement, a superior military force is a synthesis of men and machines. We want to develop and field technology that blends harmoniously with the patterns of human behavior under conditions of war. Ideally, this blend should be the fundamental criterion for evaluating the potential of an emerging technology. Unfortunately, as our hardware increases in complexity, this blend of the man and machines becomes more difficult to understand or predict primarily because the man-machine relation has also increased in complexity. We will see that this problem is compounded by unrealistic perceptions of weapons capability--e.g., perceptions that ignore human contributions.

(Slide 5) Moreover, we often do not have enough resources to simultaneously fund both our hardware needs and our people needs--a fact that raises the general question of how we should value our people and machines when

we have to make this difficult choice. Only successful commanders can provide us with insight into the answer to this question. Napoleon once said: "The moral is to the material as three to one." Over a hundred and fifty years later, General Bruce Clarke, one of the finest armored commanders of World War II, made the statement shown in this slide to Congress. We note with interest that General Clarke's experience was in "industrial war" while Napoleon's was not, yet he is making the same basic observation: Machines are important, people are more important. Our historical research indicates that this observation seems to be a dominant attitude among successful commanders. Unfortunately, we will see that this profound truth can be forgotten in a decision process that tends to focus on hardware procurement.

(Slide 6) Since we will be using the term "complexity" throughout this briefing, it is appropriate that we define it precisely. This slide states our operational definition. The implications of increasing complexity are clear: increasing complexity runs up the number, increases the variety of arrangements, and complicates the coordination of the parts--and, thereby, decreases one's ability to comprehend the whole. Increasing complexity is a cost because it decreases our ability to understand, and consequently, makes it more difficult for us to adjust to, or shape, internal or external change. Put another way, increasing complexity increases our rigidity in a game where survival of the fittest makes flexibility a paramount virtue.

We have been willing to pay this cost of increased complexity because we believed that we were getting an increased capability that compensates for this increased cost. During the first part of the briefing, we will attempt to articulate the accummulating cost of complexity in terms of its impact on men and machines; in the latter part, we will discuss the nature of this perceived increase in capability. This discussion will be imbedded within the overall examination of the realism of our planning process. We will see that the two subjects are inseparable.

(Slide 7) We face increasing difficulty in reconciling the tension between desires and scarce resources because our philosophy for using emerging technology has generated a cost structure that is growing at a much faster rate than our budget.

(Slide 8) Uncertainty is compounding our problem of coping with the cost income squeeze. Although today's decisions can impose rigid burdens far into the future--e.g., we are likely to be facing the O&S costs of the TRIDENT SSBN appropriated in FY 80 in the year 2010--we face great uncertainty in predicting the future. To understand the planning problem, it is necessary to understand the impact that these uncertainties have on our perceptions and decisions.

The central impact of threat uncertainty to the planner is that when this uncertainty is combined with proliferating technological opportunities, it is easy to generate a virtually unlimited menu of desires or perceived

needs. From a practical viewpoint, there will never be enough money to fund all these desires. As will be seen later in the presentation, the increasing complexity of our hardware increases our sensitivity to the long term threat uncertainty because the interaction of our emerging cost structure with our budgeting process leads to low readiness; and therefore, makes us more vulnerable to short-warning threats.

(Slide 9) Turning to the budget uncertainty, today there appears to be a national consensus to increase the defense budget. The crucial question facing decision-makers is how long this consensus can be maintained. In a democracy, consensus can change quickly and unpredictably. Moreover, this normal uncertainty is likely to be magnified over the coming decade by our economic problems. Our current plans for unprecedented peacetime growth in the Defense budget must be financed ultimately by a national economy that is in serious trouble. The GNP is growing more slowly than in the past and is becoming more unstable. The economic uncertainty that we face today may be greater than at any time in the post-war era.

Our nation faces a very serious long term productivity problem--the solution of which will entail a large investment of private capital. There is even talk of a national reindustrialization program. Since poor productivity performance implies that our ability to generate the needed investment dollars out of an increasing income is limited, there is likely to be increasing pressure to cut personal spending or government spending in order to free up the required capital. Compounding this problem are many disincentives complicating both private decisions to save and invest and government decisions to control spending and taxation--this slide lists a few.

In the near term, the basic uncertainty facing defense planners revolves around the question of how constraints on the growth of Federal spending will be allocated among legitimate competing needs. A squeeze on government spending will increase the constituent pressure on Congress, the President, and DoD and there is no guarantee that the pattern of constituent pressure will correspond to the needs of national defense. In other words, even if we obtain our overall DoD budget goal, we may have externally imposed constraints on our pattern of spending. For example, the constituent pressure for major hardware procurements is likely to be higher than pressure for increases in the training budget. If such pressures prevail, the effect would be an uncontrolled trade of combat skills for increased hardware procurement. This may be good or it may be bad--the point is that it is externally imposed.

We live in an uncertain world. Since we can not control this external uncertainty, our planning system should recognize it and hedge against it. In particular, our decisions and plans should anticipate the need to change and provide a strategy for reducing the real costs of responding to budget change. Admittedly, this is an abstract concept. During this briefing we will try to make it more concrete. The real costs caused by our pattern of short-term change are accummulating; they take the form of lost opportunities--e.g., reductions in training, reductions in supplies, deferment of maintenance, etc.

(Slide 10) We will see that the increasing complexity of our weapons is magnifying this real cost of adjusting to change by: (1) increasing investment, operating, and support costs; (2) increasing the uncertainty surrounding our cost structure--particularly for our operating and support costs; and (3) stretching out the time horizon for the cost consequences of current decisions.

(Slide 11) Within the Pentagon, the bureaucratic mechanism that is intended to cope with these uncertainties is the Planning, Programming, and Budgeting System (PPBS)--a system that assumes certainty. Each year, we make a specific projection of overall budget growth for five years into the future. We also project detailed dollar costs five years into the future for over 2000 program elements. The PPBS has become so cumbersome and infected by bureaucratic gaming, that as we get nearer to the January budget deadline, we are responding more to the bureaucratic constraints imposed by the system rather than using the system as a tool to adjust to changing circumstances. This chart shows the PPBS results (in current dollars) from the FY 81 President's Budget--note the smooth growth in the outyears.

(Slide 12) Thus, we have a planning system that assumes certainty in future budgets and costs to cope with an uncertain real world of budgets and costs. This naturally raises a question concerning the realism of the plans produced by this system.

A General View of Change in the Post-World War II Era

(Slide 13) In this section we intend to analyse the variability of the DoD budget over the last 30 years. We need to understand how our budgets have changed in the past because the pattern of behavior will provide insight into how our planning/budgeting system copes with the uncertainties discussed in the preceding section. We can then compare this historical pattern with the future pattern implied by our plans to gain an historical perspective of the realism of our plans.

This chart displays the DoD budget in constant dollars (i.e., the effects of inflation have been removed) since 1951. The major categories are: (1) O&S--or operations and support--this category represents our operating budget and it consists of the operations and maintenance accounts plus the military personnel accounts; (2) investment--this category consists of all the procurement and military construction accounts; (3) RDT&E--the sum of all the research, development, test, and evaluation accounts; and (4) retirement--the military retirement account. Concerning the behavior of this budget over time, the following observations are important for our analysis:

- There has been no tendency towards long term growth.

- The budget changes quite dramatically in the short term; some changes have been very abrupt; other large changes have taken place over a somewhat longer period.

- The causes of these budget changes fluctuate over time. We can loosely identify these changes with fluctuating political/economic conditions--e.g., Korea, the strategic build up in the mid-50's, the ICBM/SLBM build up and the improvement of the general purpose forces of the early 60's, Viet Nam, etc. Many of these causes are inherently unpredictable.

- The budget has a short term tendency to increase and then decrease. In this regard, the longest period of sustained real growth since the end of WWII has been three years. We haven't been able to correlate this pattern of behavior with any particular factor, it just appears that there is some type of internal compensating mechanism at work. It may suggest that consensus in a democracy is quite variable in the short term.

Today's budget levels are, in part, determined by past budget levels--the more recent past being more important than the distant past. We know where we are today, our real interest is how we get to our desired levels in the future. Therefore, in the next slide we will look at how the budget changes from year to year.

(Slide 14) This slide presents a time track of budgetory changes; each year, the PPBS process precisely predicts an almost flat five year future growth pattern (averaging 5% per year for the FY 81 budget) for this curve. The norm in plotting this curve is as follows: the point at FY 55 indicates that the FY 55 budget total was approximately 5% greater than that of FY 54; FY 56 was approximately 6% higher than FY 55, etc. The experience of our last 30 years shows frequent sharp changes in the rate of budget change; however, if we look at the smooth growth of our PPBS planned budgets, we see that we are planning for small changes in the rate of change. For example, 5% growth projected over five years would be a horizontal line. Plans tend to emphasize the horizontal dimension, reality tends to emphasize the vertical dimension--an observation that suggests a mismatch between plans and reality.

(Slide 15) Changes over time don't seem to have a predictable pattern. This slide ranks these changes in order of their magnitude from the largest decline on the far left to the largest increase on the far right, independent of when in time the changes occurred. The horizontal axis measures the positive and negative magnitudes of the changes. Since we are looking at 30 years, there are twenty-nine annual changes; rather than numbering the vertical axis from one to twenty-nine, it is numbered in terms of percentiles. The 50th percentile (i.e., the median) is the point at which there are an equal amount of larger changes as there are of smaller changes. It is analogous to an average and it represents the long term growth of our overall budget. The chart states the obvious: over the long term, a median of minus .4% growth means that the budget has shown no tendency towards sustained growth.

The interquartile range is the range of budget changes that represents the middle 50% of the data. The interquartile range distinguishes the

more normal mid-range of values from the more extreme values (note: the middle 50% is an arbitrary choice, we could have just as easily selected the middle 80% without changing the essence of our analysis and conclusions). The central idea of a rational planning strategy designed to cope with these changes would be to expect and hedge against unpredicted change as large as this mid-range in order to reduce the "real cost" of adjusting to "normal" change.

We will now present a similar analysis for the different budget categories. Taken together, these different patterns of behavior are the key to understanding the intimate relation between the question concerning the realism of our plans and the question of how we should use advanced technology. The following slides have also had the effects of inflation removed.

(Slide 16) Taking the investment budget first, we note the following important observations:

- Investment is a large account, generally running between 40 and 50 billion dollars (FY 81 $) annually.
- Annual change can fluctuate wildly from year to year. Each year the PPBS predicts a precise five-year projection of this curve.
- Over the long term, this account has shrunk more than the overall budget (i.e., the median = -2.4% versus -0.4% for the overall budget).
- Notwithstanding the long term shrinkage, the imbalance in the interquartile range indicates short term attempts to grow the investment account--there are occasional years of large growth.

(Slide 17) Turning to the O&S budget, we note the following observations:

- It is another large account-approximately twice the size of the investment account.
- Its fluctuations are more moderate than the investment account changes.
- The median growth rate (-0.8%) is not appreciably different from the overall median growth rate (i.e., -0.4%). O&S has remained relatively constant over the long term while investment has shrunk and this has occurred despite the fact that DoD's total forces have shrunk significantly in terms of people and equipment over the long term. In other words, relative to the investment budget, and relative to each force unit, the O&S budget is growing.
- The imbalance in the interquartile range indicates short-term attempts to shrink the O&S budget--there are occasional years of major cuts.

(Slide 18) Regarding the RDT&E budget, we note the following observations:

- Relative to Investment and O&S, it is a small account--although its leverage on Investment and O&S is, of course, enormous.
- RDT&E grew from around 1951 to 1964, then generally declined until 1971, and has remained roughly constant since 1972.
- The RDT&E account determines the type of technology and the resulting costs that we have to live with in the Investment and O&S accounts.

(Slide 19) Turning to Retirement we note:

- This account has grown steadily from an insignificant level to a level that is approaching the RDT&E account.
- The rate of increase has declined over time; but, we should note that we are still seeing significant positive growth, which while a low percentage by historical standards, is compounded on a much larger base than in earlier years.

(Slide 20) This slide summarizes the interquartile ranges and the medians for the overall budget and its different categories. The left end of the bar is the 25th percentile, the right end is the 75th percentile, the arrow indicates the median, and there is a line at zero to provide perspective. There is a cricial mismatch between the long-term and short-term dynamics of the O&S and Investment budgets. In the short-term we try to shrink O&S and we try to pump up Investment; however, over the long-term, Investment is shrinking relative to O&S. In other words, we have not been converting our short-term desires into long-term reality.

In a general sense, this pattern reflects a tendency to reduce our current readiness to fight in order to modernize for the future; however, because of rising operating costs, the price of even low readiness is rising inexorably over the long-term. We will see that this is happening despite a long term decline in the overall quantity of people and equipment. Moreover, modernization is being slowed and forces are declining because (a) the cost of replacement is increasing and (b) because the long-term budget constraint has made it necessary to squeeze total investment growth in order to relieve the unavoidable long-term growth pressures in the O&S and Retirement accounts. We should also note that, because of its large size, a small percentage of increase in the O&S account can put enormous pressure on the Investment account. This pattern of pressures may also explain the apparent cessation of growth in the RDT&E account.

We have uncovered a pattern of destructive growth--when some parts of the whole start growing faster than the whole itself, they start eating up the remaining parts. One could think of this as a form of organizational cancer. The short-term strategy of trying to hold down growth in the O&S account to pump growth into the Investment account does not cure the problem because although we have been able to hold O&S growth to a level

approximating overall growth, we have reduced force size and we are accumulating a current readiness bill (in terms of deferred people and material costs) that is not reflected in the budget data. Sooner or later, this bill will have to be paid.

This pattern of behavior can be expected to continue as long as costs, particularly operating costs, grow faster than the budget. We need more money, but a planning strategy that depends on steady increases in budgets over the long-term to solve this problem is a high risk strategy because: (1) it ignores historic patterns of budget growth--i.e., it requires the occurrence of unprecedented and continuing budget increases; and (2) it ignores the long-term impact of the growing economic uncertainty. The challenge facing decision-makers is to shift the long-term and short-term behavior patterns depicted in this slide towards a more harmonious interaction--regardless and independent of overall budget levels. It is a leadership challenge because it requires the inspiration of a collective will to impose the interests of the whole on the activities of the parts. It is a bipartisan problem with no easy solutions because this pattern of behavior has built up over a long period of time and it will take a long time to change it.

The remainder of this briefing is designed to: (1) support the points made in the preceding three paragraphs; (2) to show that budget growth, by itself, is not a solution; (3) to show that current plans for historically unprecedented growth (averaging 5% per year for five years after inflation is taken out) still display the same unrealistic short term tendency to hold down O&S while pumping up Investment--i.e., the same pattern of desires that we have been unable to convert into long-term reality in the past; and (4) to show that the way we are applying our superior technology (i.e., the RDT&E account) is a central cause of the continuing problem--i.e., the undesireable consequences of increasing technological complexity can be expected to grow if we continue in the direction implied in our plans.

(Slide 21) Before proceeding with the rest of the briefing, this is the appropriate point to introduce and explain an analytical tool that we will use later on. This set of investment growth percentages for a five-year period was computed in the same way that the bars of the preceding slide were computed. The top bar on this slide is identical to the investment bar of the preceding slide--i.e., it displays the interquartile range and the median of the year-to-year budget changes. The second bar displays the interquartile range and median growth percentages for the group of two-year budget changes--i.e., for the set of data: (51-53, 52-54, 53-55, ..., 78-80). The third bar displays similar data for the three-year changes--i.e., (51-54, 52-55, ..., 77-80). The fourth and fifth bars display similar data for the four-year and five-year changes. These data describe the postwar historical pattern of growth for a five-year period. We will use this data to compare our five year investment plans to past reality. For example, if the third year of today's investment plan is at the 75th percentile of the group of three-year growth percentages, this would indicate that, in the past,

only 25% of the time did we experience enough three-year growth to achieve the third-year investment level we are planning today. It says nothing about the first or second year of the plan.

(Slide 22) Essentially we have found that our overall budget has been relatively constant over the long-term, while it increases and decreases sharply in the short-term. Now, we will take a quick look at costs to gain a perspective on the magnitude of long-term cost growth. We will defer the discussion of the increased capability that we are getting for this increase in cost until the last section of the presentation. First, the cost of a tank. Note, that the cost is in constant dollars to take out the impact of inflation and is normalized for a constant quantity to take out the impact of learning in a production process. It was not possible to take out the effects of overhead for different production rates, so it is not a strict "apples versus apples" comparison. As a practical matter this abstraction does not affect the pattern of growth. Also, for the newer systems (e.g., in this case the XM-1) costs are based upon early production estimates and experience suggests they are likely to grow over the planning projections. The essential point is: costs are increasing at high, and perhaps increasing, rates.

(Slide 23) Next, the cost of a fighter; we see the same pattern. Again, the costs are normalized for inflation and production quantities. Although there are some exceptions, this same pattern of growth generally applies to ships, helicopters, munitions, armored personnel carriers, missiles, etc. Moreover, as we stated earlier, operating costs are following a similar pattern of growth. For example, we will see that the F-15 costs almost twice as much to operate per flying hour as the F-4E.

(Slide 24) Turning now to the interaction of a relatively constant budget and rising costs, we see that the Air Force has reduced its active inventory of aircraft dramatically. Now we have had a changing mix of aircraft--e.g., many bombers and transports have dropped out-and ballistic missiles, which are not shown, have entered the inventory. So we are not saying anything about capability, we are just saying that overall numbers have declined dramatically. Note also, that our plans--i.e., the dashed line beyond 1980--indicate a slight reversal in this trend.

(Slide 25) Looking at the Navy's fighter/attack forces, we see a similar decline. Note again, our plans for the future imply a change for the better in the rate of decline.

(Slide 26) The story is basically the same for ships. This concludes our discussion of the general patterns of change in the post-war era. We are now going to do a more detailed case study of Air Force tactical fighter aviation to illustrate the general interaction of readiness and modernization.

Impact of Relative Budget Growth on Readiness and Modernization:
The Case of Air Force Tac Air

(Slide 27) The case of Air Force tac air is particularly important to our understanding of the general problem discussed in the preceding section because Air Force tac air has been relatively free of the budget constraints affecting DoD as a whole. Even so, this section will show that tac air's problems today are qualitatively the same as other categories. This suggests that higher defense budgets, in themselves, are not the answer to our problems.

This slide displays the evolution in the Air Force force structure (for the moment we will neglect the ICBM) during the post-war era. We see that a profound shift has occurred. Up until 1960 or so, the Air Force was a strategic air force; today, as far as aircraft are concerned, it is a tactical air force. Tac air has avoided massive force structure declines by increasing its share of a shrinking pie. For whatever reasons--and this is a neutral statement--tac air has not been subjected to the degree of budgetary constraint affecting the Air Force and DoD as a whole.

(Slide 28) Turning our attention to the input side, we see that this shift in force structure was accompanied by substantial increases in tac air's share of the total Air Force budget (and now we are including ICBMs)--over the last 19 years, tac air doubled its budget share. That share is projected to decline in the future due primarily to planned strategic increases. The budget went up and down during this period; this chart says that when the Air Force budget increased, tac air generally increased at a faster rate; and when the Air Force budget decreased, tac air generally decreased at a slower rate. In other words, tac air was generally less constrained than the Air Force as a whole--it had relatively higher budget growth.

(Slide 29) Turning to investment, we see this relation between changing budget shares and changing budget levels more clearly. In 1962, tac air had 21% of the Air Force budget; it was 58% in 1980. Although the Air Force as a whole declined precipitously after Viet Nam, tac air has made an impressive recovery. Between 1973 and 1980, tac air investment sustained an average annual real growth rate of over 10% per year. The current investment program (i.e., the FY 81 Budget) is planned to peak in FY 1982. So, by any reasonable measure, tac air has had a much stronger budget growth pattern--particularly in investment--than most budget categories.

(Slide 30) We will now examine readiness; we should recognize from the first that this is probably the most confusing area of defense to evaluate. There is no simple measure, and there never will be a simple measure, of combat readiness. Ultimately, when you talk about readiness to go to war, you're talking most importantly about esprit de corps, leadership, willingness, combat skill--that is to say, first and foremost the readiness of our soldiers; and secondarily, the readiness of our machines. The ambiguity surrounding readiness forces us to look at it from several

perspectives. Our general, although by no means complete, picture of readiness includes perspectives of pilot readiness, material readiness, and readiness of the people and material in the support structure.

Wars are fought in the present, not in the future. Generally, readiness should be viewed from a short term perspective. If there is one thing the crises in Iran, Afganistan, and the one brewing in Poland, should teach us, it is that we should be ready to go to war on short notice. Therefore, a crucial question in any assessment of readiness is: How long will it take to gear up our people and our machines for war? Although we can not answer this question in detail, the trends and patterns discussed in the following slides should be viewed in the context of this question.

In the case of tactical fighter aviation, aircrew skill and tactical acumen are probably the most important contributors to combat effectiveness. They are also the most difficult to evaluate. We know from historical analyses that pilot skills have generally dominated material differences in air war since World War I. We also know that we will never be able to predict the future environment of an air battle; and therefore, success lies in the pilot's ability to survive, learn, and adapt in an unpredictable changing environment. These thoughts suggest that we should train as much as possible, as realistically as possible, and in as great a variety of circumstances as possible. Finally, we know that realistic training is also an essential ingredient in the development of those moral qualities that contribute so much to success on the battlefield--e.g., leadership, esprit de corps, the spirit of self-sacrifice and soldierly virtue, etc.

The important factors when assessing aircrew readiness are the intangibles. This slide shows that since the Viet Nam peak in FY 1969, the opportunity to train has declined; it says nothing about the quality or variety of the training. It shows flying hours and sorties per aircraft. Since the number of aircrews per aircraft is greater than one, it overstates aircrew flying hour and sortie rates. Certain aspects of training improved during the seventies. For example, the initial Red Flag exercises introduced new aspects of realism into training. However, the average pilot only flew around 8 or 9 Red Flag sorties in FY 79. In air to air training, our pilots seldom get the opportunity to practice in air battles of greater than 2 versus 2 dimensionality. Yet, we know from the AIMVAL/ACEVAL tests that an increasing number of participants changes the nature of combat and the tactics required. And almost all combat involves 2 versus 2, 4 versus 2, 4 versus 4, or still larger numbers. Lets ask the pilots how they feel about current training.

(Slide 31) This slide shows the results of an aircrew opinion survey taken by the Air Force in FY 1978. It is not the most scientific survey; this slide depicts the cummulative response of aircrews to the question: How many flying hours per month do you require to maintain combat readiness? In 1979, the average fighter crew member flew approximately 16 hours per month--generally, this represents 11-12 sorties per month. Now flying

hours are not the best measure--one hour of cross-country flying does not have the value of one hour of air combat maneuvering. Even so, it is clear that less than one-third of the interviewees were satisfied with 16 hours per month or less. In contrast, during FY 69, pilots in the United States training for Viet Nam were flying twenty-six hours per month--a rate than was sustained through FY 73. For purposes of comparison, it is our understanding that the average Israeli fighter pilot tries to fly somewhere between 25-30 hours and 35-40 sorties per month. Moreover, even on a cross country, Israelis are in a combat training situation and subject to being engaged shortly after their wheels are off the ground.

(Slide 32) We also know that we face a serious pilot retention problem, this slide shows an increasing cumulative loss rate for those pilots with between six and eleven years experience (it is our understanding, although we have been unable to verify it yet, that the loss rate was somewhat lower in 1980). It is often argued that low combat readiness can be rectified in short order; however, when faced with this situation, we are forced to recognize that it takes eight years to get eight years experience. While a person can be trained to fly and fight in less than eight years, it often takes longer to develop the moral qualities mentioned earlier. We are losing hard to replace resources. Why are the pilots leaving the service?

(Slide 33) Again we have to turn to surveys--and surveys have serious problems. Often a word--such as "professionalism"--connotes different things to different people; however inaccurate, they are a major source of insight into what is essentially a non-quantifiable human problem. This slide displays the results of a survey sponsored by the Air Force Office of Scientific Research (it expanded the research of two Air Force Academy instructors) that was summarized by the Air Force Times newspaper in November, 1980. It indicates that there may be much more to the retention problem than pay and benefits.

(Slide 34) Shifting our focus to material readiness, this slide displays several FY 79 (the FY 80 data is in preparation) base level material readiness indicators for both the Air Force and the Department of the Navy. We have arranged the aircraft in approximate categories of relative complexity. Recalling that we defined complexity as a quality of the "whole," these categories account for more than the aircraft; they also account for the material and people in the support structure at the base level and at the depot level.

It is appropriate that we make some general comments on this data before discussing it in detail. First, these indicators describe peacetime conditions; they do not represent what is possible in war. However, in a relative sense, the patterns are probably indicative of the relations that would prevail in war. For example, if one aircraft is consistently better than another in terms of a set of maintenance measures, we would expect that relationship to hold at higher levels of flying activity unless there are specific reasons to indicate the contrary. In addition, institutional incentives can materially affect the way certain data is

generated and reported. For example, if an organization's management were interested in maximizing peacetime sortie rates and mission capable rates (calculated on a seven day, 24 hour basis), this value system might affect the weekly activity pattern as follows: fly as much as possible in the early part of the week to run up the sortie count, decrease flying flying to reduce breakage and emphasize fixing during the latter part of the week, and then let the fully mission capable planes sit all weekend. It is probably a universal military fact of life that career maintenance personnel rapidly develop an exquisite talent for understanding and manipulating such institutional value systems. So, the data may be significantly affected by subtle influences that are imperfectly understood. Finally, it is very difficult to compare these data over time; definitions and incentives can change over time, and often these changes are not traceable.

With these reservations in mind, we will now describe the general patterns revealed by the data:

- NMC(%). This factor measures the average percentage of aircraft that were "Not Mission Capable" during FY 1979. It is calculated on a twenty-four hour clock, seven days a week. It means that the aircraft type in question, e.g., an F-111D, was not capable of performing one of its primary missions; for that fraction of time, it may still have been flyable or capable of flying its missions in a degraded mode. As a practical matter, each aircraft has a list of mission essential equipment and this measure says that at least one of the items on that list is broken.

  These lists can change over time and they can arbitrarily vary between similar aircraft for similar missions. For example, the F-111D and F-111F would perform similar conventional missions in a European scenario; however, for the F-111F, a radar warning receiver (RWR) is a mission essential piece of equipment but the RWR is currently not on the mission essential list for the F-111D. Thus, the F-111D can be fully mission capable without an RWR, whereas the F-111F would be partially mission capable. The reason for this apparent contradiction is that there are not enough RWRs to go around. Since the F-111F is higher priority than the F-111D, the RWRs were taken out of the F-111Ds and put in the F-111Fs. RWRs for the F-111Ds are now programmed for procurement in the future. In effect, the F-111D's definition of "Fully Mission Capable" has been materially affected by resource constraints.

  The NMC data indicates a rough relationship between complexity and NMC. It is not a perfect relationship, but it does seem to suggest that as planes get more complex, they tend to break more often--there are more things to go wrong on a complex aircraft.

- MFHBF. The numbers in this column are actually the mean flying hours between maintenance events; we are using them as a surrogate for Mean Flying Hours Between Failure. It is a measure of reliability. It is an average measure that is derived from the total number of events and the total hours. The number does not mean that something breaks on an F-15 every 30 minutes; an F-15 may fly for a long time with no maintenance events; then suddenly, several can occur. The number represents the average for a year. As we would expect, we see an inverse relationship between complexity and reliability. Simple planes tend to have a greater overall reliability than complex planes.

- Maintenance Events Per Sortie. This measure is roughly equivalent to the average number of maintenance actions needed to prepare an airplane for another flight once it has landed. Again, one sees a general relationship between increases in this number and increases in complexity.

- MMH/S. Maintenance Manhours Per Sortie. This factor represents the total workload required to prepare the airplane for its next flight after it has landed. Again, we see the same general relationship. We also note that, in general, the Navy factors particularly for low and medium complexity aircraft, are higher than the Air Force numbers. In part, this may reflect the increased stress of carrier operations, sea corrosion, and the more cramped working conditions of carriers. These numbers suggest that using technology to increase complexity may also increase the labor intensity of our equipment. In the aggregate, rather than substituting capital for labor, we may, in fact, be increasing the relative proportion of labor by converting to more complex hardware. In other words, increasing complexity may be contributing to a declining "tooth to tail" ratio. We will come back to this point.

- Cann-WR/100 Sorties. Cannibalizations and War Reserve Withdrawals Per 100 Sorties. This factor measures relative shortages of spare parts. If operating stocks are short, maintenance personnel have the option of temporarily obtaining the spare parts from the war reserve spares kits (i.e., the WRSK) or of taking the parts off a aircraft that is temporarily grounded (i.e., cannibalization). For the Air Force the number displayed in this column is the average number of times either of these activities occurs per 100 sorties. The Navy numbers are just the average number of cannibalizations per 100 sorties. Since cannibalization contributes to maintenance manhours, this difference may contribute, in part, to the higher MMH/S numbers for the Navy.

Even shortages of spares appear to be related to increasing complexity. Several factors contribute to this phenomenon; however, we should first note a factor that does not relate to complexity. That factor is the age of the aircraft. Older aircraft (e.g., A-7s and F-4s), that are going out of the inventory, tend to have sufficient spares. On the other hand, newer aircraft (e.g., F-15s and A-10s) can be short of spares because we tend to defer procurement of some spares until we get experience with failure rates--the idea being that we can build a sounder inventory strategy over the long-run if we wait until demand patterns stabilize. Unfortunately, our experience has been that this deferral tends to be extended for a very long time--the F-111s being a case in point--an observation suggesting that "resource constraints" contribute to the deferral.

Increasing complexity contributes to spares shortages in the following ways: (1) The tendency to overestimate a system's reliability increases as complexity increases, and consequently, the tendency to underestimate spares requirements increases. This happens because the reliability calculation mathematically assumes that each part of a system has an independent failure pattern; however, in reality, interactions between the parts materially affect their failure patterns. The net result is that failures occur more often than expected and this generally gets worse as the number of interactions (i.e., complexity) increase. (2) Failure patterns tend to be more unstable over time for complex equipment than for simple equipment, consequently, it becomes more difficult to establish a stable inventory policy. For example, the semi-annual rates for the F-111 have fluctuated between 6.1 and 21.0 maintenance events per sortie; the less complex A-7 has fluctuated between 1.9 and 4.0. For the newer aircraft, the F-15 has fluctuated between 2.8 and 7.0 events per sortie while the relatively simple A-10 has smoothly declined from 4.7 to 1.2. (3) Finally, spares for complex aircraft are generally more expensive and therefore, the impact of funding shortfalls tends to be higher.

- MM/Acft. Maintenance Manning Per Aircraft. This is the number of maintenance people per aircraft assigned at the base level. Again we see increasing labor intensity for more complex aircraft. There is also an increase in skill requirements. We see a big difference between the Navy and the Air Force. In part, this difference probably reflects the space constraints of the carrier.

- Workload. This number is calculated from the data on this slide. It is a measure of the burden on the individual. It is calculated by multiplying (sorties per month) by (maintenance manhours per sortie) and dividing this by (maintenance manning per aircraft); the product (i.e., workload) has the dimensions of maintenance manhours per man-month. Now this does not represent the total activities of the individual, it represents his sortie related maintenance activities. We see that the burden on the individual increases as complexity increases. This is particularly striking for the Air Force when one views the sortie data--the A-10 with a low workload, flew the highest sortie rate; the F-111 with the highest workload, flew the lowest sortie rate.

It is clear from the relations displayed on this chart that increasing complexity embodies increasing support costs. In peace, these increases translate to higher readiness costs; in war, these costs take the form of a more intricate less flexible support structure--a support structure that is more vulnerable to disruption when the unexpected occurs. This peacetime cost/ wartime vulnerability does not exist just at the base level; increasing complexity ties us more closely to stateside depots and makes us more vulnerable to disruptions in the relationship between the base and the depot.

To get an idea of this emerging relationship, we will examine what appears to be a persistent anomaly in the general pattern of the base level material readiness indicators. The high complexity F-15 looks better than the medium complexity F-4 in many base level measures--i.e., MFHBF, Maint. Events/Sortie, MMH/S and Workload. It turns out that the F-15 embodies technology, that in effect, transfers some maintenance from the base to the depot. To get a view of the impact of complexity (remember: complexity is a quality of the "whole") on readiness, we have to include an examination of the relationship to the depot. We will use the example of the F-15 to illustrate a general phenomenon of high complexity systems--particularly high complexity electronics. We will discuss, first two specific relationships between the base and the depot; and second, a more general view of the impact of increasing complexity on the depot.

(Slide 35) The high complexity avionics of the F-15 was designed around the remove and replace concept of maintenance. This concept intentionally transfers some base level maintenance back to the depot. In a general sense the "black box" idea works as follows: The F-15 has onboard "built in test equipment" (i.e., BITE) that tells the pilot or the crew chief that a failure has occurred in a particular "line replaceable unit" (i.e., LRU). The flight line crew chief then removes the LRU--a simple task--and takes it to the Avionics Intermediate Shop (AIS) for repair; he then goes to supply and gets another LRU, puts in the F-15, and the F-15 is ready to fly. This concept enormously simplifies flight line maintenance of the F-15; and if supplies are available, it is possible to generate very high sortie rates.

If we are to understand the full impact of this maintenance concept, we must look first to the AIS, then to the depot. The F-15 contains 45 LRUs that require a computer to diagnose the fault in the LRU. Each of these 45 LRU's can be diagnosed on one, and only one, of three computers making up a set of automatic test stations. Moreover, each computer can only check out one LRU at a time. Physically, the LRU is a rack containing solid state electronic circuit cards. These cards are known as Shop Replacable Units (i.e., SRUs). In theory, the computer identifies the SRU that is the source of the LRU's problem; the technician then removes the bad SRU and replaces it with a good SRU obtained from supply. The SRU is then shipped to the depot for repair--there is no capability to prepare SRUs at the base level. A wing of 72 F-15s (containing 72 x 45 = 3240 LRUs) is currently assigned two sets of three computers; a single deployed squadron of 24 F-15s would have one set of three computors to maintain 24 x 45 = 1080 LRUs.

While the concept looks simple and efficient on paper, it results in many subtle complexities in the support structure (at the AIS and the depot) that enormously complicate peacetime and wartime maintenance. First, the readiness of the F-15 is critically dependent upon the readiness of the computers in the AIS. In addition, the computers' maintenance and operation is very dependent upon highly skilled people--people that are almost impossible to retain because their skills are in great demand by civilian companies. Military technicians are often able to double or triple their salaries on the outside. It is our understanding (we have not yet obtained the official data to confirm this) that in the last quarter of FY 1980, out of a population of 33 eligibles in the TAC F-15 force, no AIS computer technicians reenlisted.

The availability of the computer test stations are a critical bottleneck to F-15 operations. (In FY 80, the computer was "mission capable" 80% of the time--up from 50% in FY 79.) Moreover, when the computer breaks, it can be very difficult to fix because of maintenance and supply problems. First, maintenance appears to be very dependent on the skill of the operator--skill that is in short supply. Second, although the computers have self-diagnostic capabilities, malfunction isolation is a difficult and time-consuming task. On occasion, it is only possible to identify the general location of the malfunction. If there are no shop standards available, the time consuming task becomes one of randomly changing the circuit cards until the faulty card is identified. Third, the computers are quite reliable; they contain a very large number (over 130,000) of extremely reliable parts. So when failures occur, they tend to take on a random pattern that is difficult to predict and stock against. Moreover, the parts are very expensive. The net result is that high costs preclude a low risk inventory policy when risk viewed from a peacetime money perspective at the base level; and often the computers cannot be fixed immediately because the spares are not available. Put another way, high costs generated by complexity has forced a high risk inventory policy when risk is viewed from a wartime operational perspective.

Given that the computers are working, the maintenance task is aggravated by long test times and the "Cannot Duplicate" (CND) problem. To hook up an LRU to the computer, the LRU must first be plugged into an Interface Test Adapter (ITA) and then the ITA is plugged into the computer. This can be a time consuming task in itself--sometimes taking up to 30 minutes. The computer then checks out the LRU--again a time consuming task, averaging about three hours, but sometimes taking as long as eight hours. Since the computer is limited to hooking up and checking one LRU at a time, no other LRUs can be checked out during this period. Compounding this limited productivity problem is the fact that the LRU checks out OK a significant percentage of the time. In other words, the computer could not duplicate the fault indicated by the aircraft BIT and the test time was, in effect, wasted: during the seven month period of December 1979 through June 1980, the monthly CND rate for the entire F-15 fleet fluctuated between 25% and 41%, the median monthly rate being 28%. In this situation, the operater generally puts the LRU back into supply. A small percentage of the time, a particular LRU will repeatedly exhibit the CND problem (repeat and recur); in such cases the LRU is sent to the depot.

We face the equivalent of the CND problem at the depot where the SRUs and "repeat and recur" LRUs are tested and repaired. This is known as the Retest OK or RETOK rate; and for the same seven month period, the F-15s monthly RETOK rate fluctuated between 24% and 29% of the time. In most of these cases, the SRU or the LRU is sent back to the field. In short, the spare part has traveled through the pipeline for no reason.

These support problems have the following impacts:

1. Spares requirements are increased, if only to account for AIS down-times, long test times and the pipeline effects; but because the spares are so expensive, shortages induce increased cannibalization. Moreover, increased cannibalization can increase the failure rates--those boxes that are working fly more sorties, failures tend to be sortie related, and cannibalization itself can increase breakage--and so the process can magnify itself.

2. While skills at the flight line are somewhat reduced, there is an increased dependence on hard to retain skills in the AIS.

3. Originally, the black box concept was justified in terms of peace-time economies and a standard 30 day war reserve spares kit (WRSK) was to be configured for war. In essence, this meant that we planned to stock 30 days worth of remove and replace (RR) spares; and theoretically we would not become dependent on the computers until the 31st day. However, in reality, high spares cost makes the cost of this option prohibitive, so a 30 day RRR (remove, repair, and replace) WRSK concept was adopted. Under RRR WRSK, only five days of RR spares are stocked, and the computer (and its support tail such as airconditioning and power generation equipment) must be deployed to, and set up at, the wartime operating location by the fifth day. Under the assumption of computer availability, enough SRUs would be stocked for twenty-five days operation. The cost incentive for adopting this increased early dependence on the computer is considerable--the 30 day RR WRSK kit for an F-15 squadron costs approximately $129M, whereas a 30 day RRR WRSK kit cost around $32M. We estimate that it would cost an additional $1.2B to convert nine CONUS based F-15 squadrons and two F-111D squadrons to RR WRSK. Moreover, RRR WRSK increases operational risk because: (a) there is less margin to absorb the unexpected at the base level; (b) dependence on a timely well regulated flow of parts from the depot is increased; and (c) the AIS is a high value point target. RRR WRSK has been exercized in two overseas deployments (one involving 18 F-15s and the other, 18 F-111Ds) and the aircraft did, in fact, fly high sortie rates for a period of one month at their overseas locations. These exercizes however did not represent the variety of stresses attendent to combat operations.

(Slide 36) The use of technology to transfer base level maintenance back to the depots is not limited to avionics, it can also occur in engines. For example, this slide depicts the F-100 engine's (i.e., the F-15's and the F-16's engine) fuel control to the equivalent fuel controls on the J79

engine that is used to power the F-4. The numbers speak for themselves. The only row needing explanation is NRTS/MTBF which is an acronym for Not Repairable This Station/Mean Time Between Failure. NRTS/MTBF is the average time between those failures that can not be repaired at the base level. There is very little base level capability to repair the F-100 Unified Fuel Control or UFC. When the item can not be repaired at the base, it is necessary to ship it to the depot. Consequently, NRTS/MTBF is a measure of the operating time between trips to the depot. This chart shows that the F-100 UFC is more closely tied to the depots and it illustrates the general operational cost of transferring maintenance back to the depot. We become more dependent upon the well regulated flow of high value items through logistics pieplines connecting a geographically dispersed support base. These logistics pipelines are very vulnerable to disruption resulting from enemy attack or from that always present villan in war--the unexpected.

(Slide 37) We can get a more general idea of the impact of increasing complexity on our support structure by relating depot costs and spares costs to the flying hour program in order to come up with a comprehensive measure of operating cost per airplane. To estimate these variable costs, we must allocate the overhead accounts (i.e., depot maintenance and replenishment, spares) to each aircraft. This slide displays Air Force estimates of these variable costs. There is a strong relationship between the replenishment spares and depot maintenance categories with increasing complexity. In a general sense, this implies an increasing dependence on the smooth functioning of the supply management system and the depots. It also implies a decreasing tooth-to-tail ratio. Moreover, our ability to forecast this burden over the five-year planning period appears to decrease as complexity increases. In other words, the uncertainty surrounding the planning of readiness-related activities (e.g., flying hours, spares support, etc.), and by inference, readiness improvements, appears to increase as complexity increases. To get an idea of this problem, we will compare the stability of these aircraft flying hour cost factors for the F-15 and the A-10.

(Slide 38) Each year, the Air Force Program Objective Memorandum (AF POM) projects the depot costs and replenishment spares costs five years into the future. The AF POM, published in May, is the initial draft of the AF budget that is finalized the following January. For example, AF POM 79 is the first estimate of the FY 79 budget. The POM's cost factors (they are known as the "POM Typicals") are calculated by relating the projected depot maintenance and replenishment spares budgets to the projected flying hour program. Cost factors are in terms of dollars per aircraft flying hour. The cost factors are not true costs, they are derived by allocating overhead budgets--a process that is subject to considerable arbitrariness. It is clear from examination of the data that cost factors change considerably from year to year and, most importantly, these changes appear to be much larger and more unpredictable for the more complex aircraft.

Several patterns are evident from the data in this slide:

- The data is in current dollars, so year to year changes in the estimates reflect uncertainties in projecting inflation. All things being equal for a specific year--say 1983--we would expect to see a gradual increase in the numbers as we went down a column because we tend to underestimate inflation; and as we get nearer to the year in question, we have to increase our estimates to account for the emerging inflation differential. However, it is clear that all things are not equal.

- F-15 Depot Maintenance: The estimate of future depot maintenance requirements changes dramatically from POM to POM. Each POM forecasts a smooth profile that grows slightly in current dollars during the out-years. However, the following year, the POM forecasts an entirely different profile. Clearly, it has been difficult to predict the future depot burden of the complex F-15.

- A-10 Depot Maintenance: In contrast to the F-15, the relatively simple A-10 has much less variability from POM to POM. The A-10's future depot burden appears more predictable.

- F-15 Replenishment Spares: There was a big change between POM 80 and POM 81 because, in part, the formula for the spares calculation changed; however, the F-15 was affected more than most aircraft. Also, comparing the FY 81 POM to the FY 82 POM for the years beyond FY 81, we see that POM 81 predicts declining spares requirements and that POM 82 predicts increasing spares requirements. Clearly, it is difficult to predict F-15 spares consumption.

- A-10 Replenishment Spares: Each POM predicts smooth growth during the outyears; there has also been a gradual decrease in requirements over time.

If we compare the cost factors for two older, more logistically mature, aircraft--e.g., the high complexity F-111D to the medium complexity F-4E, we see the same, albeit less stark, general pattern.

We now summarize our discussion of the impact of complexity on material readiness: Base level data suggest a general relationship between increasing complexity and decreasing material readiness. Increasing complexity increases depot costs, and appears to tie base level activities more closely to depot activities. Increasing complexity also appears to increase our dependence on responsive, well regulated distribution of high cost spares through the supply system. Since high value items are in short supply, the supply system (the informal as well as the formal) tends to track them individually and flows tend to be in response to precise demand requirements--this requires precise regulation based upon detailed data. Thus, we see an evolving support structure--from base to

depot--exhibiting an increasing variety of more intricate man-machine relations that are becoming more difficult to coordinate. As one would expect from our definition of complexity, there is evidence suggesting that our ability to comprehend these emerging relations, and to predict future needs, decreases as complexity increases.

(Slide 39) The Warsaw Pact threat is the main threat to be countered by our tactical air forces; however, the basing structure in Europe is not adequate to support the deployment planned in the AF WMP. Base support consists of our permanent European bases--i.e., the Main Operating Bases or MOBs--and European bases that normally do not support US aircraft--i.e., the co-located operating bases or COBs. This chart compares the scheduled (as of FY 85) WMP deployment to the current MOB and COB support capability as a function of time. It gives an idea of the increased support that is needed to support the deployment. The COB support is increased after M-day by moving limited supplies to designated COBs. The decline in support after D-day is due to consumption of COB stocks. We estimate (roughly) that it would take an additional investment of $1.6 billion to build up and harden the COB/MOB infrastructure to a point were it can support the deployments in the AF WMP.

In addition to spare parts and infrastructure shortfalls, we are short of munitions. The full funding of the munitions objectives (goals that are determined, in part, from the activities embodied in the WMP sortie rates) would require an additional investment of approximately $4.4 billion.

(Slide 40) The capability to repair battle damage is a major contributor to tac air readiness. During Viet Nam, the ratio of damaged aircraft to lost aircraft fluctuated between 3 to 1 and 6 to 1; in the 1973 Arab Israeli War it was 3 to 1. Rapid battle damage repair is a major contributor to the Israeli AF's combat capability. During Viet Nam, the depot backlog of damaged aircraft reached a point where it took two-years to get an F-4 repaired. As equipment becomes more complex; battle damage becomes more difficult to repair. However, with the exception of the A-10 battle damage repair kits, this major contributor to combat readiness currently funded at an unrealistically low level. The battle damage repair problem is generally not considered (with the exception of the A-10) in the design of our aircraft.

This concludes our discussion of material readiness. We will now turn to our final readiness category; namely, the readiness of the people in the support structure. We will focus on maintenance personnel.

(Slide 41) The number of people needed to support a fighter is increasing over time. This chart displays the change in direct and indirect manning per fighter over time. Indirect manning is an allocated estimate of the contributions of those people in the overhead activities. The change over time is more important than the absolute magnitudes. We note the following patterns in this chart:

- Looking at the endpoints, and neglecting the Viet Nam hump, we see that manning has increased by a factor of about 40%.

- When we went to war in Viet Nam, a huge increase in manning occurred. Part of this increase was caused by the pipeline effects of the rotation policy limiting Viet Nam tours to one year. Nonetheless, it is clear that the increased wartime activity required more people per aircraft.

- The reduction in activity after Viet Nam is accompanied by reductions in manning.

- Although not shown, we note that, notwithstanding general increases in direct manning per fighter (i.e., maintenance personnel), the requirements for technical specialists have increased at a faster rate during the 1970s.

The WMP assumes a short warning war, and projects a surge to very high monthly activity rates for the first month. As we have seen, the labor intensity of our force is increasing and we are becoming more dependent on the smooth functioning of a geographically dispersed support base. In view of these trends, this chart raises a general question of whether or not we have enough people in our system to satisfy the short term demands of the WMP.

(Slide 42) In addition to needing more people per aircraft, we noted that our force is becoming more skill intensive; however, during the 1970s, we cut training times significantly. Training has become more task oriented, with less general theory; and, although the individual may be initially more productive in routine activity, he has less general background to fall back on when the unexpected occurs.

Training reductions in the presence of increasing skill requirements are concrete examples of how the real costs of adapting to budgetary change can be magnified by increasing hardware complexity. This is a specific example of general short term tendency to reduce growth in the O&S account by shifting the costs to non-budgetary categories--i.e., reduced personnel readiness, and, because OJT is less efficient, reduced material readiness.

(Slide 43) Declining experience levels are compounding the problems caused by reductions in training. This chart summarizes the declining reenlistment rates for the three tactical air forces--i.e., TAC, USAFE, and PACAF. Loss rates are much worse than implied by this chart because reenlistment rates quantify the reenlistments as a percentage of those eligible to reenlist. It turns out that eligibility rates may run as low as 50% of the entering population. The decline in second term reenlistments is particularly disturbing because these are experienced people making career decisions. The impact of these declines is being magnified by the increasing personnel requirements increasingly complex equipment and the need to fill out a growing force structure.

In contrast to the pilot retention problem, it appears that pay is a crucial issue in the retention of maintenance manpower. Highly skilled maintenance technicians are doubling and in some cases tripling their salaries when they go to the private sector; moreover, this salary increase is combined with better working conditions, higher status, and shorter hours. Often they get jobs doing contract maintenance on the same equipment they were working on while in uniform.

(Slide 44) Declining retention offsets part of the expected savings from reductions in training time by increasing training quotas. We are currently short of technicians in the higher skill levels. Over the long term, this retention problem will be compounded by demographic changes.

To summarize, we face an increasing scarcity of people and skills that is being magnified by shortages in the present and by increasing demand in the future. Throughout the 1980s, the tactical air forces will embody labor intensive technology (when viewed from the perspective of the total support structure); consequently, we should expect personnel and training costs to increase significantly during the coming decade. We see how the O&S budget can increase over the long term, even though we try to cut it in the short term.

(Slide 45) We will now summarize our entire discussion of AF tac air modernization and readiness, and relate it to our plans for the future. Compared to other DoD categories, AF Tac Air has been relatively free of budget constraints. In particular, tac air has undergone a vigorous post-Viet Nam modernization program. Between FY 73 and FY 80, the tac air investment budget grew at an average annual rate of 10.4% after the effects of inflation were taken out. During the last eight years (i.e., FY 73-FY 80), the AF tac air investment program totaled approximately $52 billion (in constant FY 81 $); this compares to a tac air investment of $68 billion (in constant FY 81 $) during the eight years of Viet Nam (FY 65-FY 72). This comparison is particularly impressive when one considers that much of the Viet Nam investment was in consumables, military construction, and other war-specific programs; whereas, the post Viet Nam investment has been concentrated in the procurement of weapon systems.

The 1970s were also characterized by steady reductions in personnel and material readiness. Readiness related investments in spare parts, infrastructure, and munitions stockpiles were deferred and training tempos were reduced. This slide summarizes some of the trends we have discussed. Our modernization program has resulted in a force that is more costly and difficult to operate--particularly when viewed from the perspective of the entire support structure. Increasing complexity has increased also the uncertainty in our support cost structure.

When one considers that the emerging tac air force is more expensive to operate in terms of people and material costs, that we are currently at a low level of personnel and material readiness, and that the force is programmed to grow in size, it is clear that increases in combat readiness require major increases in the funding of readiness related investments and particularly in the O&S budget. This gives us a simple policy question to ask the FYDP: What is our policy towards increasing tac air readiness? To answer this question, we will look at the funding growth that is programmed for the next five years in the FYDP. In this sense, the FYDP is an authoritative statement of our intent.

(Slide 46) Turning first to the tac air O&S budget, this chart shows the historical track and future O&S program (i.e., FY 81-85) in constant FY 81 dollars. We note that there is an average annual real growth rate of roughly 4% programmed into this account for the next five years. The total Air Force budget is expected to grow at about 5% per year-so, tac air O&S is not quite staying even in terms of budget share. More importantly, this budget is only programmed to get pilot flying hours up to an average of 20 hours per month fy FY 84. In addition, this funding profile assumes no real growth in operating costs per plane--clearly an optimistic assumption in view of the uncertainties we uncovered in our discussion of the support base, particularly the flying hour cost factors. Significantly, twenty hours a month and 4% real growth drives us to the same level of resources (in constant dollars) that was required in FY 72 to fight a war in Viet Nam, fly 26 hours a month in the states, and fly somewhat less in Europe.

(Slide 47) The O&S increases were new in the FY 81 budget as evidenced by the five year funding profile programmed in the FY 80 budget. In FY 80, we programmed no significant growth for the outyears even though the overall AF budget grew at an average real growth of 3% per year. This no growth pattern was also reflected in the preceding five year plan of the FY 79 budget. In other words, the five year programs of the past three tac air O&S budgets all reflected a desire to hold future O&S growth to a lower level than that programmed for the total Air Force budget.

(Slide 48) Looking at investment, this chart shows that although the impressive post Viet Nam growth is tapering off; the budget is programmed to remain at a high level for the next five years. Despite this high level of funding, this investment program underfunds the replenishment spares required to support the flying hour program because it assumes spares will be delivered with one year lead time. Delivery lead times are currently averaging two years, and because the flying hour program is growing, delivered quantities will fall short of those needed to support the planned increases. The annual funding totals do not reflect these lead time induced shortages nor the additional funding required by the inflation differential. This problem will become particularly acute with regard to the large increases in flying hours now programmed for FY 84 and FY 85. In these circumstances, implementation of the growing

flying hour program (an effort to improve pilot readiness) is likely to reduce material readiness by increasing cannibalization or war reserve withdrawal rates. This budget also does not fund the deferred readiness related investments in infrastructure or munitions stockpiles. (Note: air-to-air missile stockpiles are an exception. Current plans program very large increases in these particular stockpiles.)

The FY 81 five year investment plan peaks in FY 82--i.e., it peaks in the year after the budget year--but it stays at a high level for the entire program period. This behavior occurs in an overall environment of 5% real growth programmed for the Air Force.

(Slide 49) Last year, in the FY 80 budget, the planned five year investment peaked in FY 81--again, the year after the budget year--and the investment budget declined in the years after the peak. The FY 80 DoD budget was programmed to grow at 3% per year. In the FY 79 budget, the peak occurred in FY 80. The moving peaks and the overall increase in the investment budget between FY 80 and FY 81 depict the investment "bow wave"--a phenomenon characteristic of investment programs. The "bow wave" is a reflection of the interaction of the short term tendency to pump up the investment budget with the long term tendency to shrink investment: Growing operating costs are squeezing the investment budget over the long term; we don't fulfill all our near term investment desires, so we defer some of them until next year. This process of deferral slows production and is a source of cost growth in the out-years of the investment budget. A further complication arises because we are continually adding new items to our menu of desires, but we seldom cancel existing programs. The net result is that we are continually under pressure to try to grow the investment budget. This process is being magnified by the growth in our operating and investment costs. If our plans assume that the out-year overall growth rate increases (as it did between FY 80 and FY 81), the investment budget tends to expand into the "vacuum." It is significant that tac air still exhibits the "bow-wave" phenomena--the continued existence of which suggests that "budget constraints" may not be the source of its existence.

Even after the impressive modernization of the mid-to-late 1970s, tac air plans still do not contain major increases in readiness-related investments and the O&S budget. In view of tac air's emerging cost structure, 4% O&S growth in an overall budget that is planned to grow at 5% does not represent a major financial commitment. It does represent a large quantity of money. Twenty hours a month is less than our pilots were flying in FY 73. Furthermore, given the uncertainties in flying hour costs, support personnel readiness, and in the increasing complexity of the support structure, it appears that 4% real growth is a very optimistic estimate of the resources needed to move from our present state of 16 hours per month to 20 hours per month. Finally, readiness-related investments in spare parts are insufficient to support 20 hours a month and the shortfalls in war reserves and infrastructure will persist through 1985. This evidence suggests that the price of low

It therefore appears that the FYDP does not embody a policy commitment to significantly increase the readiness of the AF tactical air forces during the next five years. The impact of 4% real growth is diluted by increasing operating costs. The downstream consequences of increasing complexity are not being faced by our planning system. This observation raises the question of what we expect our forces to do if we have to go to war during the next five years.

(Slide 50) If a NATO/PACT war were to occur in FY 82--i.e., next year--the Air Force WMP lays out the activities we would perform in general terms of forces deployed, sortie rates, and loss rates over time. Recall that the WMP is the link that translates our war plans into financial "reality." This chart is an attempt to put these WMP projections for FY 82 into perspective by comparing them to the two "best" months of performance in the European theater of World War II. June, 1944 represented the most intense month of operations in the ETO in terms of sorties per aircraft; March, 1945 was the month of maximum total effort in the ETO. Since we are making a gross comparison of very different conflicts, it is easy to read too much into this chart. Interpretation of this chart should be limited to the following points.

- The WMP assumes a short warning war; in contrast, June 1944 was 30 months, and March 1945 was 39 months after the declaration of war. In WWII the national economy was mobilized for total war; during the first month of a NATO/PACT war the US economy will not be mobilized for total war.

- The WMP plans to have less aircraft in theater for the first month than were in the ETO in either June or March.

- The WMP also plans for higher attrition in the first month than we suffered in either June 1944 or March 1945. Since damaged aircraft outnumber lost aircraft; presumably, this differential implies that the WMP plans for a greater occurrance of battle damage in the first month than occurred in either June or March 1944.

- Notwithstanding a smaller force, a shorter preparation time, and a higher loss rate, the WMP envisions that we will fly more sorties in the first month of a European War than we did in either June 1944 or March 1945 and it envisions that we will be able to do this by next year!

Our historical research suggests that the main reasons for the low sortie performance in WWII were lack of spare parts and an inability to repair battle damage--problems that will exist next year. Sortie rates were also lower in WWII because of the longer fighter escort missions--missions that lasted up to 9 hours as opposed to 1 to 1½ hour average of today's sorties. On the other hand, during World War II, depots were located in theater and we were operating from secure bases--luxuries we probably would not have in a NATO/PACT war. Caveats such as these could

go on for ever; however, they do not change the central point: the WMP envisions a near-term capability to conduct an incredible number of sorties on very short notice.

Thus, Tac Air financial plans embody short term decisions to hold down growth in the readiness accounts; yet, we see that these plans are linked to a WMP that assumes very high current readiness. This observation suggests a planning system that is not tied to reality.

(Slide 51) Looking at the overall financial plans of each of the services, we see the same general short-term pattern projected for the next five years. Each service is trying to hold down O&S growth while pumping growth into investment. Moreover, the weapon systems planned in these programs are much more complex than the weapons being replaced.

To understand why the Tac Air O&S account is held to 4% real growth when the overall Air Force budget is growing at 5% per year (after inflation), we also need to look at modernization in other mission areas. During the 1970s, modernization of the strategic and mobility forces was deferred; most of the budget growth went to tac air. This was necessary to absorb rising Tac Air investment costs. Consequently, as we enter the 1980's, we need to modernize these other mission areas. In general, these modernization plans in these other mission areas envision to modernization with more complex systems; and therefore, we are faced again with increasing unit costs as well as the downstream support problems that come with high complexity equipment. Although, AF plans for 5% per year annual in the total budget growth for five years, overall AF O&S growth is held to 2% per year because these high cost modernization programs require 10% annual growth. This is the environment in which tac air was able to squeeze out 4% O&S growth.

The Army and Navy plans show the same general pattern of trying to hold down O&S in the short term while pumping up investment, albeit at different budget levels. There is slight evidence suggesting that as budget growth increases, the disparity between short term O&S and investment increases. Furthermore, both services are in a state of low readiness, are experiencing increasing personnel and operating costs, and are faced with growing complexity in their support structure. Consequently, there is reason to expect long term increases in their operating costs--increases that are not accounted for in these plans.

The behavior pattern depicted in this slide is evidence of our desires and we see that these desires match up to our historical short term pattern. Unfortunately, our budget analysis revealed that we have not been able to convert our short-term desires into long-term reality. Is there any evidence to suggest that the future will be any different from the past? These plans, if implemented, ensure that readiness will remain at a low level for the next five years because the O&S accounts and the readiness related investment accounts do not reflect the in place and emerging growth pressures in our support structure.

The increasing complexity of our hardware has generated the growing cost structure that stimulates the mismatch between our short-term and long-term behavior. Notwithstanding the short-term tendency to pump up investment and hold down readiness, the increasing complexity of our hardware leads to long-term growth in the cost of low readiness--i.e., unavoidable costs--which, in effect, squeezes the modernization budget. Modernization is further slowed because the cost of replacement is increasing so rapidly. Finally, overall growth in the investment budget has not come to pass over the long term due to an uncertain, but real, budget constraint.

Many argue that the answer to this dilemma is a budget that increases continually and reliably--a budget that must grow at least as fast as the cost of replacement weapons plus the cost of operating them. Unfortunately planning on this solution is not realistic in the long-term because the budget is dependent on an unpredictable long-term factor--the democratic political consensus. Furthermore, even if it were possible to ensure long term growth, our review of tac air does not support the belief that a growing budget will solve our problem. In the last five years Tac Air implemented a budget profile that is very similar to that shown in this chart (5% overall real growth, 12% investment growth, and 0.3% O&S growth) for a total investment of $38.5 billion (in FY 81 constant $). Although growth of the modernization budget has now tapered off, the budget is programmed to remain at a high level. In fact, in the next five years, the tac air investment budget is programmed to spend $44.3 billion (FY 81 constant $) or 15% more than was spent in the preceding five years. In other words, the successful implementation of a budget profile similar to that depicted in this slide--a budget profile that effected a drawdown of other mission areas--did not solve tac air's modernization problems: we are still trying to hold down readiness-related expenditures in order to modernize

The short term strategy of reducing readiness and pumping up investment treats the symptom, not the cause, of our planning problem. Our bias towards short term investments in weapons of increasing complexity is the cause of the long term cost growth. The interaction of long-term cost growth with long-term uncertainties in the budget (a reality of our political process) and the threat (a reality that makes an increasing menu of desires psychologically acceptable), when combined with special interest pressures, has resulted in short-term behavior patterns that magnify the long-term readiness-modernization squeeze. The case of tac air is more one of how we spend our money than one of how much money we spend. The Department of Defense needs more money in the short-term, but if it is spent in the same way, our problem could get worse.

The Uncertainty Surrounding Investment Plans

The interaction of the short-term bias towards investment in high complexity weapons with the long-term budget uncertainty is a central feature of our discussion. We can examine this interaction by comparing our short

term desires (as depicted by our investment plans) to the long term pattern of change uncovered in our budget analysis. This historical perspective will enable us to perceive the distance between our desired future and past reality. The question of planning realism then becomes one of judgment as to whether or not it is reasonable to assume that current factors will generate enough pressure to overcome this distance.

We intend to ignore two major factors affecting the uncertainty surrounding our investment plans. The first is inflation: we will examine the uncertainty in terms of constant dollars. However, the Congress appropriates current dollars and our plans exhibit a chronic tendency to underestimate future inflation. Consequently, when the true inflation emerges, our budget is smaller in real terms than was anticipated. Since inflation is currently high and unstable, this problem is getting worse. Moreover, the inflation estimation problem is magnified in the more complex weapon systems because these systems generally have longer spend-out periods.

The second factor relates to the current state of low readiness. The investment uncertainty calculated in the budget analysis reflects an interaction with readiness changes. However, the 1970s witnessed a steady draw-down of readiness. We are currently in a state of low readiness, we have fielded equipment that is much more difficult to maintain (when viewed from the entire support base) at a high level of material readiness, and we face unprecedented manpower problems--particularly in the high skill areas. Although in the past, short-term modernization growth could be "financed" out of short-term readiness reductions; this may be much less feasible in the future. Even if low readiness were deemed acceptable for the next five years, the rising cost of low readiness could require either decreases in investment growth or unplanned increases in the overall budget.

Inflation and low readiness combine to make the planning problem worse. Because we will ignore these two factors, the ensuing discussion should be viewed as being optimistic in the sense that the degree to which we perceive our investment plans as being unrealistic is underestimated.

(Slide 52) This slide overlays the planning range that we developed in the budget analysis (i.e., the dashed lines) on the five-year investment program projected in the FY 81 President's budget. The solid lines are budget lines that depict each service's budget and they are additive-the top line of the Air Force budget is also the sum of the three budgets. The planning range is projected from FY 80 because at the time of this charts' construction, FY 80 was the latest appropriation. In essence, FY 80 tells us where we are, the top solid line tells us where we want to go, and the dashed lines tell us how we moved forward in the past.

Recalling the budget analysis, the planning range summarizes the historical pattern of DoD's investment budget growth over a five-year period. To understand its meaning, we will describe the 75th percentile line (the same interpretation applies to the median--i.e., 50th percentile or the 25th percentile):

- FY 80 is the starting point--it represents an achieved budget level. We want to estimate the chances of change from this level if history were to repeat itself.

- The 75th percentile point at FY 81 represents the 75th percentile of the historical groups of year-to-year percentage increases, based on the last 30 years' budgets. It has been normalized to FY 80 so that the dashed line at FY 81 depicts a budget level that corresponds to a "75th percentile change" from the FY 80 level. In other words, if history were to repeat itself over and over, we could expect that, 75% of the time, the actually achieved level for FY 81 would be less than or equal to the dashed line level indicated on the chart.

- The 75th percentile at FY 82 represents the 75th percentile of the distribution of the historical groups for two-year percentage increases. Recall from the budget analysis that this change makes no assumption about the intervening first year change. This point has also been normalized to the FY 80 budget level. It should be interpreted as follows: If the changes of the last 30 years were to repeat themselves, we should expect that 75% of the time the actually achieved FY 82 level would be less than or equal to that indicated on the slide

- Similarly, the 75th percentile at FY 85 represents the 75th percentile of the group of five-year percentage increases. This point makes no assumptions about the intervening four years and it is normalized to the FY 80 level. If history were to repeat itself, 75% of the time the actually achieved FY 85 level would be less than the point indicated by the 75th percentile.

- This portrayal is optimistic in the sense that it reduces the distance between our plans and past performance because it ignores the short-term tendency to increase and then decrease. It is very unlikely that a 75th percentile increase would be followed by another 75th percentile increase.

This understanding of the planning range enables us to use it as a norm to evaluate the investment pressure of each service's budget as well as the total investment budget. We are going to ignore inter-service patterns, and apply the DoD-wide planning range to each service. This pressure can be viewed as being directly related to the distance by which the budget top line exceeds any one of the percentile lines.

Looking at the DoD Investment Program as a whole, we see that we are under less pressure in the near term than we are in the far term. All years are well above the 50th percentile and the pressure builds up steadily over the five-year period. This is another reflection of the "bow wave" phenomenon; and from a historical perspective, it means that our plans embody very optimistic assumptions about future budget growth. Towards the end of this section, we will calculate the percentiles of each service's budget top-line. We will now examine each service budget.

(Slide 53) We see that the Army is under high pressure over the entire period. The Army is planning major increases in the complexity of its hardware; it faces severe readiness problems, particularly in the area of skilled manpower; and it does not have the tradition of handling complex equipment that the Air Force has. In view of the pattern revealed in the case of AF tac air, these observations suggest that the Army may be laying the foundation for similar, if not worse problems, and that these problems are likely to persist well into the 1990's.

(Slide 54) The Air Force is under less near term pressure than the Army, but Air Force investment pressure explodes in the outyears. The main source of this growth is the M-X program which has funding implications well beyond FY 85. Note that this program contains no investment funds for a new manned bomber or a new fighter.

(Slide 55) The Navy is under less near-term pressure than the other services, but the pressure builds up steadily in the outyears. In fact, this depiction is somewhat misleading because it does not reflect the long-term implications of the Navy's modernization program. Whereas the Army investment program is smaller than those of the Air Force or the Navy and the source of the Air Force pressure can be traced to a few causes, the Navy has the largest investment program and there are many sources of long-term pressure. In particular, we will see that the pressure to grow the shipbuilding and fighter procurement accounts is likely to remain with us into the 1990s. The Navy currently also faces severe personnel and material readiness problems, perhaps even more serious than those of the Air Force. Moreover, the Navy is modernizing with high complexity hardware, so we should expect that long term increases in the cost of Navy readiness will continue for the forseeable future. These comments suggest that even if the Navy implements its current modernization plans, its readiness-modernization squeeze could worsen during the coming decade. This issue will become clearer in our discussion of aircraft procurement and shipbuilding accounts.

(Slide 56) We will now examine some interactions between these accounts. It is important to realize that there are no simple cause and effect relations governing these interactions. The overall investment account is under enormous pressure. There are all sorts of individual programs competing for limited funds; and since we exhibit a tendency to avoid hard decisions to cancel programs, this bureaucratic competition results in what might be characterized as a "leveling process." Consequently, individual programs or entire budget categories can change quite unpredictably

from year to year. We will observe this interaction (at a very superficial level) by examining the aircraft procurement programs of the DoD budget. To start, we note that the overall aircraft procurement program is under considerably less pressure than DoD investment taken as a whole.

(Slide 57) Army aircraft procurement is under very little pressure in FY 81, but it explodes in the out-years. The source of this explosive growth is the Advanced Attack Helicopter (i.e., AAH or AH-64) program. Although the UH-60 program appears to be winding down in FY 84 and FY 85, we should note that only about one-half of the planned UH-60 force structure is procured by FY 85. This low level of UH-60 funding in FY 84 and FY 85 will result in an unrealistically low production rate. Note also that replenishment spares are funded at a very low level for the entire five-year period.

(Slide 58) If we compare the FY 81 Army aircraft procurement program (shown in the previous slide) to the FY 80 program, depicted in this slide, we see a very different profile. (Note: these programs have been aggregated differently; this difference does not affect our discussion.) In the FY 81 budget, major funding for the AH-64 begins in FY 82; there is very little funding planned for FY 81. However, we see in this slide that the FY 80 budget projected major funding in FY 81. The UH-60 program has also changed quite dramatically: in the FY 81 budget, there was a major draw-down of funding in FY 83 and FY 84; however, this slide (i.e., the FY 80 budget) shows that no such draw-down was envisioned as recently as a year ago. So, plans are subject to considerable year-to-year change over the entire five-year planning horizon.

(Slide 59) This slide gives us one reason why it may be necessary to hold down the near-term pressure in the aircraft account. The weapons and tracked vehicle procurement program is under enormous near-term pressure; this observation also applies to the Army's missile procurement account. Again, note the level of replenishment spares funding depicted in this slide.

(Slide 60) Turning to Air Force aircraft procurement we see that it is under much less pressure than the Air Force investment program as a whole--only modest growth is planned. The source of Air Force growth is in the missile account.

(Slide 61) In contrast, last year's budget planned for steady declines in aircraft procurement after FY 81. Recall that the FY 80 DoD budget assumed 3% annual real growth and the FY 81 budget assumed 5% annual real growth. This relief of the five-year top-line constraint enabled the out-year aircraft account to expand via near-term FY 81 budget decisions. The C-X was added in the FY 81 budget, there were major increases in aircraft support equipment and facilities and spares were increased (recall however, that spending assumptions still underfund

spares). Notwithstanding this overall increase in the five-year program, the procurement plan for A-10s and F-15s was slowed and stretched in the FY 81 budget. The A-10 has had an interesting history of programmatic changes: The FY 80 budget projected the last year of the 733 aircraft procurement program would be in FY 81. In the FY 81 budget, the rate was slowed and extended to FY 84; however, an additional 96 airplanes were procured to compensate for higher than expected peacetime attrition. In the FY 82 budget (currently in preparation), it appears that there will be no procurement in FY 82 (and beyond); the total buy is now reduced to 687. (Note: it is possible that 24 aircraft could be added in FY 82 bringing the total to 711.) Increased budget growth does not necessarily stabilize investment planning; the Air Force changes illustrate the short-term tendency to add new programs when planning pressure on out-year expenditures is eased.

(Slide 62) The Navy/MC aircraft account is under modest near-term pressure, but it builds up in the outyears. The average annual real growth for the five-year period is 10.4%. Note that this account does not contain the AV-8B; and with the exception of the F/A-18, this program tends to focus on low-rate procurement of a large variety of complex aircraft. Although the F/A-18 is currently planned for high rate procurement, it is also a high complexity aircraft.

(Slide 63) Even with 10.4% real growth, the Navy is not procuring enough aircraft to maintain its force structure. The dashed lines on this chart are estimates of the upper and lower bounds of the number of aircraft required annually to make up for losses through aging or peacetime time attrition. The bars depict the number of aircraft procured in each year of the FY 81 budget. In spite of the fact that the Navy's aircraft procurement plans are extremely optimistic from a historical perspective, the successful achievement of these plans will still result in an accumulating shortage of airplanes until the mid-1980s.

(Slide 64) The shipbuilding account is a major source of long-term pressure in the Navy budget. This pressure is one reason why the Navy cannot pump more growth into the aircraft account. Although in the near term, it is under very little pressure, it builds up steadily in the out-years. Moreover, the declining size of the Navy fleet coupled with the concentration of modernization funds in small numbers of very complex ships (e.g., Trident, and Aegis) imply a long-term Navy force structure problem. The rising operating costs of high complexity aircraft and ships can be expected to magnify the Navy's readiness-modernization squeeze for the forseeable future.

(Slide 65) The five-year shipbuilding program is also subject to short-term change. The FY 80 program is markedly different than the FY 81 program.

Thus we see that our five-year procurement programs have changed markedly from year-to-year, that increases in out-year funding do not guarantee program stability, and that funding profiles appear optimistic in an historical perspective. This short-term tendency to change our five-year program raises two questions concerning the uncertainty surrounding our current plans. First, what is the likelihood that current plans will change markedly in the near term? Second, what form might these changes take?

(Slide 66) This slide addresses the first question by translating the percentile of the investment top-line for each service into a historical probability of achieving our planned growth. For example, if the investment top-line is at the 95th percentile of the historical pattern of change, then assuming history repeats itself, there is a 0.05 probability that sufficient funds will be available to fund the program in the particular year in question. This chart displays these probabilities for each year of each service's five year program. In simple terms, this slide says our investment plans are historically very optimistic--to the point of being unprecedented. If history repeats itself, the liklihood of not obtaining the funds required by our plans is so great, a conservative planner should assume it is inevitable.

Do foreseeable factors warrant this planning optimism? Can we realistically make short-term decisions to commit ourselves to programs having long-term consequences when this commitment presumes a long-term future budget environment that is so different from that of the past 30 years?

Perhaps current political externalities have generated a consensus to increase the defense budget in the near term, however, the curves in this slide embody the long-term "budget growth" effects of similar political externalities in the past such as: the Korean War, those perceptions leading to the strategic buildup of the mid-50s, the Hungarian Revolution, Sputnik, the missile gap, the Berlin Wall, the Cuban Missile Crisis, the Viet Nam War, and Czechoslovakia. It is obvious that the cumulative effect of these political externalities has not been able to generate a growth pattern that is compatible with the growth pattern in our plans. Other factors also influence the defense budget. For example, our nation faces severe economic problems; and if solutions to these problems conflict with defense expenditure plans, it is quite conceivable that defense plans would be adjusted according to the needs of the national economy. Finally, internal defense-related factors may affect investment plans. For example, even if we received our planned overall budget growth for the next five years, the current low state of personnel and material readiness coupled with the rising cost of increasing readiness could dictate a substantial shift of funds from investment to readiness related accounts.

We are dealing with an environment that is prone to change; our problem is that we have a rigid planning system that assumes we can predict the future. The problem is compounded by the fact that the future we predict is radically different from the past, and by the fact that we do not formulate a hedging strategy to cope with an emerging reality that is different from our predictions. Since we do not plan for change, when it occurs, we respond on an ad hoc basis. This brings us to the question concerning form of the changes that we have to face in the future.

(Slide 67) This slide compares the FY 81 budget to the November 1, 1980 estimate of the Basic level of the FY 82 budget. (Note: Although current estimates are somewhat different due to the ongoing budget process, the overall pattern is unchanged.) These changes assume a budget level of $204 billion (FY 82 $) level in FY 82--represents 10% real growth over the FY 81 budget. It compares constant dollar and quantity changes projected for the four common years of both budgets. This slide depicts how a five-year program can decrease when the budget grows.

The procurement quantities of helicopters and tactical aircraft are programmed to decline by 20%-30%, this will result in less than a 10% reduction in total program cost and growth in the program unit costs of 20% to 40%. Tracked combat vehicles, ships, and precision guided munitions (PGMs) costing less than $50,000.00 all show quantity reductions, total program cost increases, and substantial program unit cost growth. Although PGMs costing greater than $50,000.00 appear different, the cause of this anomoly is a large quantity increase in the procurement of missiles at the lower end of the price spectrum. The changing mix is the principle cause of the depicted change pattern.

We have uncovered one form of change: Projected budget increases are accompanied by reductions in procurement quantities and growth in unit cost. It is important to realize that these changes occurred after the effects of inflation were taken out. One reason underlying these changes is that individual programs tend to grow in cost over time--this year's cost estimates for the next five-years tend to be higher than last year's estimates. The effect of cost growth in time is one of underfunding out-year procurement quantities in a given five-year program. When the out-years get closer in subsequent budgets, it becomes necessary to either reduce quantities or increase overall funding. Furthermore, overall funding increases do not guarantee a solution because, as we have seen, there is a tendency to initiate new investment programs when our-year planning constraints are changed in the direction of increased future growth. In this way, short-term decisions (with long-term consequences) in the presence of cost growth and uncertainty are a source of continual pressure to expand the investment budget.

Summarizing this discussion, we have seen that our five-year investment plans can fluctuate unpredictably from year to year. These plans project overall growth requirements that are exceedingly optimistic from a historical perspective; moreover, they are accompanied by unrealistically low projections of growth in the readiness accounts. Finally, the uncertainty surrounding the magnitude of the future cost growth implies an investment funding requirement that is even larger than the one projected in our investment plans.

In effect, our desires are expanding unpredictably against a constrained environment that is changing unpredictably. Even though our short-term decisions try to pump up the investment budget, the long-term interaction of these internal and external uncertainties result in reduced procurement quantities--i.e., slower modernization--and declining force structure--as well as low material and personnel readiness.

The Growth in Complexity and Perceived Capability

Our perceptions of uncertain future threats are factors shaping our forces over time. However, these perceptions are not determined solely by the threats facing us; our perceptions are also influenced, in part, by the generally held beliefs of our institutions. Since the end of World War II, the dominant influence shaping growth and change in the US military has been the view that our military superiority should be based upon technological superiority. We have seen that our strategy for technological supremacy has resulted in a force that continuously increases in complexity and cost over the long-term. Our genuinely superior technology has been directed towards increasing a quality known as "capability"--a quality that seems to embody the continual need to increase complexity.

(Slide 68) The F-16 is a good example of how a weapon system can grow in complexity and cost over time. From the viewpoint of cost management, the F-16 has a relatively good record; there are no horror stories associated with its cost history. Nevertheless, the constant dollar cost of the F-16 has grown substantially over the initial developmental estimate made in 1972. In this case, most of the cost growth is attributable to increasing complexity--such as the addition of complex air-to-ground avionics and the AIS to support the avionics--and furthermore, these increases are likely to continue with the planned addition of the AMRAAM and Lantirn. What started off as an austere high performance within visual range air-to-air fighter will be transformed by the late 1980s into a lower performance radar missile air-to-air fighter with avionics intended to attack ground targets in night or adverse weather. These increases in the complexity of the F-16 imply downstream cost and supportability consequences that were not imagined when the decision was made to develop the F-16 in 1972--consequences that, although still imperfectly understood, we will have to live with in the year 2000.

Looking at general trends of growth in the complexity and cost of fighter technology over the last thirty years; we find that in constant dollars, avionics costs have grown by a factor of about 40-50, engine costs have grown by a factor of about 15-20, and airframe cost by about a factor of 5. In avionics, most of the cost growth has been associated with trying to obtain the ability to shoot down enemy fighters at very long ranges and in all weather conditions, and associated with trying to obtain a night/all-weather air-to-ground capability. Often engine technology appears directed towards purely technical goals such as higher pressure, temperature and by-pass ratios. Airframe cost growth has resulted from the complex installation requirements of the increased avionics and the expensive materials and complex inlets associated with speed requirements beyond Mach 2.

Up to this point, we have viewed increases in complexity in terms of the accumulating cost to readiness, force structure, and modernization. However, we also have to ask what this increased cost is buying in terms of increased military capability. At best, combat experience is ambiguous on this point.

For example, in the case of air-to-air combat, it is not clear that increasing avionics complexity has yielded combat dividends that warrant the cost growth. F-86's using machine guns in Korea got about a 10 to 1 exchange ratio over Korean Mig-15s. In contrast, 15 years later, the F-4 in Viet-Nam, with its complex all-weather beyond visual range (BVR) radar missile capability only achieved about a 2 to 1 exchange ratio against the clear weather, within visual range Mig-21. The lethality of the Sparrow missile, .08 to .13, turned out to be at least a factor of 5 lower than predicted. In the 1967 and 1973 Arab-Israeli wars, Israeli Mirage III's (a mid-1950's technology day-visual fithter) achieved better than a 20 to 1 exchange ratio against Arab Mig-21s. In the 1971 Indo-Pakistani War, Pakistani F-86 MK VI aircraft got better than a 6 to 1 exchange ratio against Indian Mig-21, SU-7, and Hawker Hunter aircraft.

Many argue that the visual rules of engagement in Viet Nam precluded the F-4 from maximizing its BVR capability, and that Viet Nam results are not indicative of BVR performance in a European war because the rules of engagement will be different. Even if this argument were true, and the evidence is not clear on this point, we now find that the benefits of the complex BVR capability are contingent upon precise rules of engagement in an uncertain future war--namely the authorization to fire at a target before it has been positively identified.

The picture is also ambiguous with regard to the benefits of increasing complexity in propulsion technology. The chart depicting the variable cost per flying hour (in the discussion of AF tac air) suggests that the afterburning turbofan of the F-15 uses less fuel per flying hour than the turbojet in the F-4; however, the complexity of the F-15's engine makes it much more expensive to support logistically--a cost difference

that in all probability will swamp any fuel savings. Although many of today's fighters have a top speed of Mach 2, we can not expect to use this performance in the vast majority of plausible combat scenarios because most of the fuel is consumed while accelerating to Mach 2.

Thus we see that the benefits of increasing complexity are not self-evident or clear-cut. There is no argument about whether or not we want increased capability. The relevant questions are: How should we perceive capability? Does increasing complexity increase capability or decrease capability? This section discusses these questions by examining the impact of three generally accepted preconceived notions that shape our perceptions of capability. For the sake of brevity, we will refer to these preconceived notions as: (a) the faith that emerging technology will revolutionize capability and cost; (b) the mechanistic attrition mind-set, and (c) the idea of war being a manipulatable deterministic process that can be centrally controlled. These notions will be explained as they are introduced.

We can not answer questions about capability by analyzing an individual weapon's effectiveness in isolation. Capability, like complexity, is a quality of the "whole" and it can never be described by a single number. Recall from Gen Clarke's and Napoleon's statements that the synthesis of men and machines into a military capability involves very important intangible considerations--e.g., moral strength, esprit de corps, skill, etc. Any evaluation that ignores these intangibles is at best a very partial and, by necessity, an ambiguous view.

The acid test of war is ultimately the only unambiguous indicator of capability. Moreover, the lessons of combat continue to be difficult to interpret. All other indicators or measures are ambiguous because they are based upon speculation about a future interaction between forces whose self-interest and survival dictate that they act and react unpredictably. (Note: if you are predictable you are vulnerable.) Now we can reduce part of this uncertainty through testing and training, but we can never remove its dominant aspects. Perceptions of capability will always be shrouded by a veil of speculation and ambiguity. For example, how does one compute the effectiveness of esprit de corps?

Our definition of complexity and our discussion of material readiness revealed that increasing complexity increased the uncertainty in our support structure. This ambiguity combines with the inherent ambiguity surrounding any discussion of capability to soften resistance to the seductive promise that advancing technology will simultaneously provide revolutionary increases in capability and revolutionary improvements in supportability. We know that on rare occasions, technology has revolutionized war. How can one prove ahead of time that a new, imperfectly understood technology will not revolutionize the ambiguous conditions of a future war?

The preconceived notion that advancing technology will provide revolutionary changes in cost and capability plays upon these uncertainties. It increases our toleration of the mismatch between the short-term and long-term budget behavior because it suggests that the future will be different from the past. Let us examine how this argument works. First, we will consider two cases (i.e., the F-111D and the F-15) where it was predicted that increased complexity would be accompanied by improvements in supportability, then we will examine a current case (i.e., PGM's) where more capability is being promised for less money.

The first case concerns the F-111D and the Mark II avionics. In the late 1960's, advocates of the Mark II avionics system predicted that highly sophisiticated all-digital technology would provide a revolutionary increase in systems reliability. At that time, it was argued that despite its complexity the mean time between failure (MTBF) would be in excess of 60 hours. On October 8, 1968 the Secretary of the Air Force (in a letter to the Deputy Secretary of Defense) predicted that the Mark II avionics would require less maintenance manhours per sortie than the less complex avionics in the A-7D--i.e., 1.42 MMH/S for the Mark II versus 2.79 MMH/S for the A-7D's avionics. Despite the complexity of the Mark II system, it was argued that emerging technology would significantly improve maintainability-i.e., the future burden of the F-111D would be quite low.

In actual fact, quite the opposite has happened. For example, during FY 80, the Mark II's MTBF was well under three hours and the MMH/S averaged 33.6--i.e., over twenty-three times as large as the predicted MMH/S.

On April 1, 1974, Aviation Week and Space Technology published an article entitled "Simplicity Is Stressed In F-15 Operations and Maintenance" (pp. 50-53). The article indicated that the F15 would require less maintenance and fewer maintenance personnel than any other high speed fighter in the USAF inventory. The F-15 was guaranteed to require no more than 11.3 MMH/FH (compared to 24 MMH/FH for the F-4E), that the MTBF would be a factor of 4.3 greater than the F-4 (i.e., 5.6 versus 1.3 hours), that the F-15 would require no new skills beyond those already found on fighter bases, and that the F-15 would require 15% less manpower than the F-4E. During the last two fiscal years the F-15 required 26.7 MMH/FH and the F-4E required 29.9 MMH/FH. These numbers do not include depot labor. In FY 79, our table on material readiness indicators suggests that the F-15 MTBF is much closer to the F-4s--the ratio of MFHBFs is 1.25 to 1 (.5 versus .4), our discussion of the AIS indicated there is an enormous increase in skill requirements, and the F-15's maintenance manpower requirement is virtually identical to the F-4. Taking depot costs and replenishment spares costs into account, current AF budget data indicates that the F-15 costs about twice as much as the F-4 per flying hour to support.

(Slide 69) Our third case concerns the revolutionary promise of precision guided munitions or PGMs. These weapons are currently very expensive and over time their cost and complexity have steadily increased. This slide depicts this evolution for five families of these weapons: the AIM-9 is the heat seeking Sidewinder air-to-air missile; the AIM-7 is the semi-active radar guided Sparrow air-to-air missile--AMRAAM is its fully active follow-on; AGM-65 is the Maverick anti-tank missile--its guidance has evolved from TV (A/B) to laser (C) to imaging infrared (D); GBU-8 and 15 are TV guided bombs; AGM-45 and 88 are the Shrike and HARM anti-radiation missiles-missiles that home on air defense radars.

On August 11, 1980, Business Week published an article, entitled "The New Defense Posture: Missiles, Missiles, and Missiles," suggesting that the next generation of "missiles so smart they will change the face of warfare" (p. 76) will be in the hands of our military forces by 1985 or so. Historically, the general pattern of evolution has been that once a particular smart weapon is fielded, some unpredicted limitations or problems crop up and a more complex or "capable" follow-on version is developed, presumably to overcome these unforeseen limitations. In the case of air-to-air missiles this evolution has been going on for almost 30 years. The following exerpt taken from the Business Week article (pp. 77-78) describes this pattern for the case of the Maverick missile:

> "Maverick went into development 10 years ago as an electro-optically guided missile that carried a tiny television camera in its nose. The theory was that its camera would photograph a potential target, and the missile would then lock onto it. But the camera did not work well in clouds or at night. So, three years ago, the Air Force turned instead to the development of an infrared guidance system for Maverick.
>
> The infrared device helped make Maverick an all-weather missile, but it also left a lot to be desired. Its sensors spotted targets imprecisely, and its signal-processing computers were too often uncertain about where to steer it. Sometimes the hot spots it saw turned out to be flares fired as decoys. Because it did not see full shapes or images, Maverick still could not distinguish among real and spurious targets well enough to make a truly one-shot weapon.
>
> Evolutionary developments in infrared and radar guidance systems have made the latest models of Maverick, as well as missiles known as Sidewinder and Sparrow, better than their predecessors. But the air-to-ground Wasp and a new missile called AMRAAM (for advanced medium-range air-to-air missile), now in development, should be vastly better systems." (emphasis added)

Now our slide indicates that the imaging infrared Maverick (AGM-65D) will not be operational for some time yet the Wasp is already being advocated on the basis of the AGM-65D's deficiencies. Later on in the article (p. 78) one advocate predicted "that by the end of the decade, the computers in missiles will come very close to comparing with the human brain. 'Our missile' he says 'will be not just smart but brilliant.'" The article goes on to predict that although Wasp is vastly "smarter" than Maverick, it should only cost about $25,000 (p. 80) or about one-third the price of the infrared Maverick. The case of the Wasp illustrates the two-sided seduction of promising more for less. We tolerate an imperfect present because we perceive a bright future.

It is also important to understand that the revolutionary capability of smart weapons (and high complexity weapons in general) is very narrowly defined. We are willing to pay the high cost per trigger squeeze because the predicted weapons lethality coupled with the predicted increase in the survivability of the launching vehicle promises to make these weapons cost-effective--i.e., under these assumptions, smart weapons are justified as the cheapest way to kill targets. Quoting again from the Business Week article (p. 76):

> "Fired from air, sea, or land, the new missiles should be able to spot and distinguish among targets with near-human perception, tracking them with speed and maneuverability from which there will be no escape, and destroying them with deadly, one-shot accuracy." (emphasis added)

This brings us to the second preconceived notion (i.e., the attrition mind-set) that shapes our view of capability. The attrition mind-set shapes our perceptions by assuming that meaningful differences in capability can be entirely distinguished through calculable differences in attrition. It encourages the view that war is a quantifiable interaction. We view capability through the perspective of mechanistic attrition models that require precise predictions of lethality, survivability, and patterns of combat interactions such as rules of encounter and shooting to compute outcomes that are measured by casualties or some derivative thereof. This deterministic perspective does not view "capability" as a quality of the "whole" because it does not consider the unpredictable human aspect of interaction.

The attrition mind-set views war as an inanimate interaction between two mechanical forces that act and react predictably. Even if one were willing to accept this severe limitation, it turns out that attrition is often a misleading indicator of capability. The following examples illustrate this point.

- In the Civil War, WWI, and WWII; the winners had more casualties than the losers. At the level of a war outcome, attrition measures would indicate the winners lost and the losers won.

- In WWII, the Germans considered the allied tactical fighter-bomber to be the best anti-tank weapon employed on the western front. The aircraft in question had very low lethality against tanks. However, the allies had presence--in the last eight months of WWII (including the famous European winter), the allies flew over 700,000 fight sorties against targets in France, Benelux, and Germany--over 250,000 sorties were air-to-ground. In contrast, during the same period the Germans flew less than 30,000 fighter sorties. The allied domination of the skies virtually guaranteed that the German panzer forces would be attacked if they tried to move during flyable weather. The fighters' effectiveness was not so much their lethality as their presence--their constant pressure destroyed and disrupted the German's mobility, and mobility is an essential element of armored warfare. There was not enough bad weather or night to make up for this German disadvantage in the air. High complexity aircraft and weapons give up presence (because high cost reduces numbers and supportability problems reduce sortie rates--i.e., numbers in the air) in an attempt to get lethality--a quality whose value is maximized in an attrition model.

- In 1939 and 1940, the German blitz through Poland and the West left the Germans with between 200,000 and 250,000 casualties--virtually all killed or wounded. In contrast, the allies suffered between 3,300,000 and 3,500,000 casualties--of which about 3,000,000 were prisoners. An attrition model would give no idea of the enormity of the German victory. The allies were utterly defeated and the huge prisoner of war bag was more of an indicator of this collapse than the dead bodies. Attrition models cannot calculate the "probability of capture"--the decision to surrender is a distinctly human intangible that no sane analyst would dare try to compute or predict. Even Clausewitz, who is often regarded as the leading theoretical exponent of attrition warfare, has written that prisoners and captured material are much better indicators of success than dead bodies. Captured live bodies are generally indicators of the enemy's declining moral strength.

- In the 1973 Arab-Israeli War, the Israelis decisively defeated the Egyptians (a victory that was not exploited for political reasons) when they captured the entire Egyptian 3rd Army and held them hostage. Again, live bodies were a more important indicator of success than dead bodies.

- Then there is Viet-Nam, we "managed" the Viet-Nam war according to the attrition model. Measures of effectiveness were the body count, truck kill, etc. The fact that we often thought we were winning indicates that these measures can be misleading. Viet-Nam started off as a guerrilla war and Mao has written that in the early stages of a guerrilla war, the guerrillas should avoid fixed battles. Only when the war is reaching victorious culmination does Mao advocate participation in conventional battles. When the guerrillas are willing to stand and fight, their body count is likely to increase; however, their overall strategy suggests the disturbing thought that this body count may be measuring their success, not their failure.

Although the deterministic attrition mind-set shapes our perceptions of revolutionary capability, we see that attrition is not the only indicator of a weapons quality. Attrition is at best a partial description, at worst it can be misleading.

Even if one were willing to accept the attrition view of effectiveness, attrition models are generally based upon unconfirmed assumptions concerning the combat interaction (e.g., rules of encounter and shooting) and weapons performance. The following subparagraphs consider these limitations.

First, we will consider assumptions concerning the form of interaction. For example, air-to-air models generally assume that visual identification is not required either because theater wide rules of engagement permit shooting at unidentified targets, or because of the existence of a high reliability noncooperative identification friend or foe (IFF) system--a system that has defied development for years and is still only projected to exist.

In general, attrition models do not account for human elements that can shape the form of the encounter--e.g., surprise, confusion, fear, etc. We will discuss the impact of this limitation in more detail during our discussion of force multipliers.

(Slide 70) Second, we will consider assumptions concerning weapon performance. By necessity, one of the most important weapon performance assumptions in the attrition model is weapon lethality--a quality that often is dependent upon the specific form of encounter and shooting as well as technical performance. A critical factor affecting performance and firing tactics is the assumed reliability of the missile. A 10% change in reliability changes the probability of kill by 10%. Recall from our definition of complexity and from our discussion of spares reliability (in the tac air material readiness section) that reliability is more difficult to predict for complex systems than for simple systems because increasing complexity increases uncertainty surrounding the interactions between components. Consequently, the best way to estimate reliability is through a live firing program conducted under realistic combat conditions. Moreover, as the complexity of a weapon increases, its number of failure modes increases. Therefore, a sound reliability verification program should increase the number of firings to maintain the same level of confidence in the reliability estimate.

However, if we look at the missile firing program shown in this slide (note: the projected program for FY 86 was selected to illustrate intentions when large inventories are available), we see that as cost and complexity increase, less missiles are projected to be fired--an observation implying cost is a major factor in shaping this program. This conclusion suggests that although the increased costs are justified in the attrition view by promised

increases in lethality; the increased costs lead to less confidence in predicted lethality because our plans do not absorb the increased total cost of the missile firing program. This is one more example of the short term tendency to hold down readiness costs.

This is a defense wide phenomena--as weapons get more expensive, we tend to fire them less--and less realistically--in training and testing. For example, the current front-line air-to-air missile that is fired the least is the AIM-54 Phoenix missile--i.e., the most complex and expensive air-to-air missile in our inventory. Although this missile and its parent aircraft were designed to have a multiple firing capability against a mass air attack with electronic jamming, it has never been tested this way against numerous targets.

(Slide 71) Summarizing the deterministic attrition mind-set, we see that it shapes a perception of capability that: (1) does not consider human elements; (2) is based upon an ambiguous or misleading measure of merit; and (3) embodies speculative or uncertain rules of engagement and performance. Quantitative attrition analyses suppress the visibility of these limitations. Precise, yet in reality uncertain and speculative assumptions are buried deep in the calculation. In addition, the appearance of scientific method combined with computational complexity discourages critical review. Consequently, debate and decisions tend to consider outputs only, and these outputs are what often underly perceptions of revolutionary increases in capability. The case of the AIM-82 missile illustrates this point. This slide was used in an Air Force briefing to describe the results of a quantitative attrition analysis predicting the effectiveness of the AIM-82 missile when fired from an F-15 fighter. At the time of this chart's construction, the AIM-82 was a paper missile and the purpose of the analysis was to determine whether or not to proceed with the program. The analysis "predicted" an exchange ratio of 955 to 1 in favor of the F-15. In other words, for every F-15 lost, this analysis predicted that we would shoot down 955 enemy fighters. Now recall that the F-4 achieved 2 to 1 in Viet Nam, so 955 to 1 represents a rather revolutionary improvement. What is significant about this result is that it reached the "four star" level of the Air Force before it was seriously questioned. The central point of this example is that speculative "evidence" of capability revealed through such attrition analyses can be intimidating and thus "persuasive," even to the initiated. What might normally be put into the category of pure hyperbole acquires the aura of scientific reasoning; "brilliant weapons" do seem plausible. As a footnote, the Air Force subsequently cancelled the AIM-82 on its own initiative.

(Slide 72) The mechanistic attrition mind-set encourages the third preconceived notion--i.e., the idea of war being a manipulatable deterministic process that can be centrally controlled. The focus is on lethality, and the enemy is treated as an inventory of inanimate targets to be processed at least cost. (Note: in Pentagonese this is known as "target servicing.") Complex attrition calculations amplify this view by lending

respectability to speculations about the "capability" of increasingly complex weapons. Since in this view, the only way to defeat the uncertain threats facing us is by fielding weapons having the increasing "capability" to service targets, long term growth in weapons complexity and cost is unavoidable and therefore low numbers must be accepted.

The principle physical dimension shaping our perception of the Soviet threat is its size. In the attrition perspective, this perception is magnified because it translates into a requirement to "service" a large number of targets. Moreover, this "servicing requirement" is perceived as all the more awesome because, as we have seen, rising cost (perceived as a necessary consequence of the increased capability to service targets) has led to force structure reductions. Consequently, we perceive a growing need to "optimally manage" our scarce attack assets when servicing this superior number of targets. To do this, it is argued, we need "force multipliers."

(Slide 73) Force multiplication, involves first identifying our enemies "critical nodes"--i.e., targets--and then concentrating attacks on these critical nodes. To do this, it is necessary to collect vast quantities of sensor data, analyse it, uncover an enemy activity pattern, and synthesize that pattern into an appreciation of enemy intentions that can be quickly digested by the human mind. Speed dictates that this process be mechanized as much as possible. The appreciation would then quickly be communicated to the centralized manager for high-speed target servicing decisions and these decisions would be quickly implemented through a detailed command, control, and communication system. A fundamental requirement is a survivable communications system with the qualities indicated in this slide. Such a system currently does not exist.

(Slide 74) Force multiplicaton in combat must be "well-oiled"--the complex interaction of sensors, data links, processing and fusion centers, geo-positioning systems, command guided weapons, etc.--and people--must work smoothly in the chaotic stresses of combat. This slide shows a very partial list of the types of systems used in force multiplication. Many of these systems are exceedingly complex and have virtually unknown downstream supportability implications. Military maintenance concepts have not even been specified for some systems. Force multipliers intend to solve a problem caused by complexity--i.e., low numbers--by pumping in more complexity, not only at the "bits and pieces" level; but more importantly, by pumping in complexity at the organizational level. Our emerging communication linkages illustrate this crucial point.

(Slide 75) This slide, taken from an official briefing, lays out the communications linkages perceived necessary in a modern force multiplication scheme. It is important to appreciate that this slide is the result of a serious analysis of the NATO Command, Control and Communications, and Intelligence (i.e., C^3I) system. Note the JTIDS (Joint Tactical Information Distribution System) links--often they are followed by an ambiguous "?" indicating a possible linkage. Lets look at the linkage capability of JTIDS a bit more closely.

(Slide 76) On paper, JTIDS has a phenomenal capability to transmit data. Whether such data can be turned into information and absorbed by the human brain during conditions of combat is another matter. This slide was taken from an analysis having the purpose of defining JTIDS' operational concept. The analysis was intended to support DSARC deliberations over the future course of the program so it also represents the results of a serious effort. Proliferating data communications such as JTIDS raise a question concerning our ability to absorb the information being communicated.

Thus, we see that in addition to increasing weapons complexity, the mechanistic attrition mind-set and the idea that war is a manipulatable determinstic process lead to increasing hardware and organizational complexity in command, control, and communications. However, we have also seen that the attrition perspective abstracts out unpredictable human actions. Since command and communications are meaningless concepts without people, we are forced to squarely face the intangible issue concerning the impact of this increasing technological complexity on soldiers in combat.

(Slide 77) One of Clausewtiz's enduring contributions is his study of human behavior in war. We can use his concept of friction to help crystalize this issue. This slide displays one of his most famous statements.

(Slide 78) Clausewitz's concept of friction describes why things naturally go wrong in war. Friction includes some of the factors underlying the material readiness patterns discussed earlier. Friction is bad weather during the Battle of the Bulge, contagious panic in France in 1940, an empty prison at Son Tay, and the dominant characteristic of the Iranian rescue mission. A famous response to friction is the WWII phrase: "Keep it simple, stupid." Clausewitz considered friction to be the central factor that distinguished real war from theoretical analyses. The existence of friction means that war is <u>not</u> a deterministic process. The clarifying question concerning the impact of complexity on the man-machine relationship in combat is: <u>Does increasing complexity increase or reduce friction?</u>

By necessity, we need to look at real war so this question can only be answered through historical research. Col John Boyd, USAF Ret., significantly enriches Clausewitz's concept of friction in his thought provoking briefing "Patterns of Conflict." This briefing summarizes Boyd's research on conflict from 400BC to the present. According to Boyd, Clausewitz had a limited one-sided view of friction. Clausewitz was concerned about reducing his own friction (a valid concern) but he failed to see the <u>opportunities</u> for increasing his enemy's friction. Boyd observes that the writings of the Chinese military theorist, Sun Tzu, stress these opportunities and that the extraordinarily successful operations of Genghis Khan and Tamerlane exploited these opportunities. Boyd then

synthesizes these two views with the operations of Genghis Khan, Napoleon, the successful German blitzkrieg commanders, and successful guerrilla commanders into a general theory of conflict--a theory that he supports with historical analysis and observations from real war. In sharp contrast to the deterministic view of the attrition mind-set, the central consideration in Boyd's theory is human behavior in conflict. In this context, he suggests that increasing complexity works on our mind and makes mental operations more difficult. It causes commanders and subordinates alike to be captured by their own internal dynamics--i.e., they must devote increasing mental and physical energy to maintain internal harmony--and hence they have less energy to shape, or adapt to, rapidly changing external conditions. In Boyd's perspective, the idea of decreasing complexity to diminish our friction and free up our operations gives us the opportunity to magnify our enemy's friction and impede his operations.

Force multipliers use emerging technology to centralize decision-making and control. There is precedent for a centrally directed war of attrition. Basically, WWI was a "big logistics" war of attrition requiring detailed coordination of large masses that moved over a limited transportation system. Centralization was perceived as desirable and communications technology--i.e., telephone--enabled the centralization of command and control in what quickly became a static war of attrition. All major beligerents evolved centrally directed forces.

Late in the war, the Germans began to appreciate that this centralization was a major source of weakness. The allies had exploited their communications and the centralized system had increased their rigidity. For reasons that are not relevent to our example, the Germans failed to break the stranglehold of centralization during the war. However, after the war a former signals (i.e., communications) officer named Heinz Guderian had a brilliant innovative conception to restore mobility and to get away from the effects of debilitating attrition.

Guderian's conception resulted in the blitzkrieg, and a central ingredient of his idea was to use emerging communications technology to decentralize command and communications. In this regard, his brilliant innovations were

- Put a radio in every tank
- Set up a division communications net so that the commander could command from any point in the division
- Commanders forward, always be at the decisive point of action. Result: on the spot decision-making is quicker and clearer, orders were radioed back to Chief of Staff who was empowered to over-rule his superior if necessary, and personal leadership set a superb moral example

- Verbal orders only, convey only general intentions, delegate authority to lowest possible level and give subordinants broad lattitude to devise their own means to achieve commander's intent. Subordinants restrict communications to upper echelons to general difficulties and progress. Result: clear, high speed, low volume communications.

These brilliantly simplifying ideas, as embodied in Blitzkrieg, "force multiplied" against the French in 1940--i.e., in addition to the Maginot Line, the French had a larger number of equal or better quality tanks than the Germans. When it was allowed to operate unfettered in the East, the blitzkrieg approach "force multiplied" successfully against Russian numerical superiority. We should not let the fact that the Germans lost WWII together with excesses and evils of the Nazi regime blind us to the lessons that can be learned from this impressive performance.

We have seen that attrition can be a misleading indicator of success or failure, we should also realize that the specific form of attrition assumed in force multiplier models--and quantitative attrition analyses in general--is a form that rarely occurs in combat. These models assume that attrition takes the general form described by Lanchester in his famous paper (circa 1914) analysing the material impact of modern weapons. Actually, Lanchester hypothesized two alternative forms of attrition; however, his "concentration of firepower" or "Square Law" is the most widely used form. The "Square Law" hypothesizes that the attrition rate for a Blue force is a constant (determined by Red's individual weapons effectiveness) multiplied by the surviving strength of the Red force. Red's attrition rate is calculated in an identical fashion.

(Slide 79) Given Lanchester's equations, the starting size of the opposing forces and their weapons lethality estimates determine the probability of battle outcomes. Unfortunately, real world combat data does not support the Square Law's hypothesis. The dashed "S" curve in the left hand chart of this slide plots the Lanchesterian probability of a Blue victory as a function of Blue to Red force ratios. The solid curve represents the results of a wide range of historical battle outcomes. Lanchesterian predictions are extremely sensitive to force ratios--hence, since we seem to be outnumbered, the belief in the need for force multipliers. Actual combat outcomes suggest that force ratios are far less influential--numbers are relevant but they are not the magic answer either.

One reason why Lanchesterian predictions fail is that they assume lethality is constant. Even if we ignore the speculative assumptions underlying weapons lethality discussed earlier, it turns out that lethality is determined, in large part, by external combat circumstances. Lethality is not constant in real war, the right hand chart plotting exchange ratios versus force ratios illustrates this point. Lanchester (i.e., the dashed line) predicts that lethality is independent of force ratios. Analysis of real war shows that exchange ratios (the relative lethality of the defenders' weapons to the attackers' weapons) change dramatically

(note the logarithmic vertical scale) with the attacker to defender force ratio. In other words, the more the defender is outnumbered by the attacker, the more lethal the defenders weapons are. The defender may still lose but he is going to take a lot of attackers with him. There are many plausible reasons for this pattern when human considerations are added. For example, when greatly outnumbered, the defender is likely to know he is in deep trouble and consequently he may be more willing to take risks, he may be resigned to "die like a man" taking as many of the enemy with him, and he doesn't have much of an IFF problem--he can shoot at just about anything that moves. On the other hand, the attacker may be confident of success--why take chances, and he may face a tougher IFF problem. Evidence and common sense suggest that the Lanchester "concentration of firepower" effect is swamped by other factors.

By assuming that individual weapons lethality is constant, the Lanchesterian perspective abstracts out the unpredictable human element, and tends to become preoccupied with weapons "capability" and force size. This directs attention away from the decisive contribution of human skill. For example, Lanchester ignores the impact of suprise (an effect that is by definition unpredictable). He assumes that if Blue fires the first shot and per chance misses, the probability of kill for the second shot is unchanged--i.e., Red is too stupid to duck behind cover. History is filled with examples of surprise being the major effect shaping outcomes. For example, since WWI, 60%-80% of the air-to-air kills in all wars have been against an enemy who was surprised. Lanchester also ignores the increased friction caused by the distinctly human effect of confusion. As engagements increase in numbers of participants, they become more difficult to understand and much harder to handle with automated systems. The AIMVAL/ACEVAL tests reveal that exchange ratios changed as complexity of the engagements increased--even when force ratios are held constant. As engagements went from 1V1 to 2V2 to 4V4, exchange ratios changed significantly. On a much grander scale, Boyd has uncovered extensive historical evidence suggesting that ambiguity and fear can be exploited to undermine the enemy's mental operations to the point of bringing about his collapse as a functioning military force.

(Slide 80) One final, and perhaps most important comment on the attrition mind-set. If we are going to allow the mechanistic attrition perspective to dominate procurement and operational planning, we should ask whether this is a sensible strategy for the US to use against the USSR. More than any nation in history, the USSR has demonstrated that it can take enormous attrition and win. Although a strategy of attrition plays right to a principle source of Soviet strength, the US has never experienced a level of attrition that even remotely compares to the Soviet experience. Our ability to play the game on the Soviet scale is not demonstrated. This chart depicts the combat deaths of the beligerents in WWII. By our measure of merit, we were minor combatants having less

casualties than the Rumanians. The bar at the far right depicts the total number of combat deaths since 1776 including both sides of the War Between the States. It is interesting to note that the Russians were completely defeated in WWI--to the point that society collapsed--yet they suffered less than one-third the casualties suffered in WWII.

Summarizing this section, we have discussed the excessive influence of three beliefs shaping our perceptions and decisions. The first is our faith that advancing technology will make the future different from the past. This faith is reinforced by the ambiguity surrounding perceptions of capability and the future performance of emerging technologies. The result is a subtle permissive influence stimulating the mismatch between our short-term and long-term budget behavior.

The second influence shaping our perceptions and decisions is the mechanistic attrition mind-set. The attrition mind-set shapes our perception of capability through its excessive focus on individual weapon lethality. Decisive elements of combat effectiveness are ignored, and its deterministic perspective encourages the belief that war is quantifiable via body count and number of targets destroyed. Weapons of increasing complexity and cost can be easily justified by predicting high lethality. Moreover, our faith that high technology weapons offer revolutionary capabilities (i.e., the first belief) amplifies these perceptions.

The third belief shaping our behavior is the idea that war is a manipulatable deterministic process that can be centrally controlled. This perception is amplified by our faith in revolutionary implications of emerging technology and by the attrition mind-set. By ignoring human elements and the concept of friction (in Col Boyd's sense), this notion of war leads naturally to the speculative concept of "force multipliers"--a bureaucratic buzzword that subtly implies one is getting something for nothing.

Observations and Conclusions

We have examined the realism of defense decision-making and planning by relating uncertainties and variations in the real world to our decisions and plans. Our discussion revealed the following interconnected impressions:

- The bureaucratic mechanism producing our financial plans establishes conditions for a mismatch between plans and reality by assuming certainty in future budgets and costs when in fact the real world is characterized by uncertain budgets and costs. Our country's economic problems suggest that the problem of budget uncertainty is likely to get worse over the coming decade and the increasing complexity of our hardware suggests that the problem of cost uncertainty will get worse. A sound planning system must recognize these uncertainties if a comprehensive strategy addressing the future

consequences of current decisions is to be produced. (Note: recently it has become fashionable to argue that the solution to the planning problem is to have eight-year planning instead of five-year planning. This recommendation misses the central issue of uncertainty and in all probability will make matters worse because then we would be saddled with producing eight-year plans one year at a time. Tying up more people by increasing debilitating out-year square filling exercises is not a solution. The central need is for a flexible planning system--you don't increase flexibility by lengthening the straight-jacket.)

- The historic mismatch between short-term and long-term budget behavior is evidence that we have not been able to convert our short-term desires (which continue to be reflected in our plans) into long-term reality. In the short-term, we try to hold down readiness expenditures and pump up modernization expenditures; however, despite long-term savings from quantity reductions in people and force structure, the rising cost of low readiness has squeezed modernization over the long term.

- The increasing complexity of our hardware is an inseparable part of this destructive pattern because it is the source of the long-term increases in the magnitude and the uncertainty of both investment and operating costs. The sharply increasing cost of replacement slows modernization and the rising cost of low readiness (i.e., operating costs that must be absorbed) squeezes the overall investment budget, in effect magnifying the process by leaving less money to modernize with more expensive equipment. Growing operating costs have overwhelmed the savings accrued from the significant long-term reductions in personnel and force structure.

- The case of AF Tac Air suggests that budget constraints are not the source of the problem. The problem is more one of a collective decision and planning process that does not consider the future consequences of its decisions. During the 1970s, Tac Air implemented a budget profile similar to that projected in current plans. The vigorous post-Viet Nam equipment investment in Tac Air was accomplished, in part, by readiness reductions and deferred investment in other areas. However, as we enter the 1980s, we find that Tac Air's investment requirements for the next five years and the rising cost of low readiness has made it, once again, too expensive to plan significant readiness improvements over the next five years. Notwithstanding these plans and the current low state of personnel and material readiness, this budget is justified by a War and Mobilization Plan that projects a near term readiness for an across-the-board surge to incredibly high sortie rates in a short-warning European war.

- In general, our current plans for high peacetime budget growth project the same historical tendency to pump up investment and hold down readiness. Investment plans change dramatically from year to year and the pattern of these changes indicates that these plans embody optimistically low esimates of future investment costs. Moreover, these investment plans are accompanied by unrealistically low projections of operating costs. In general, it appears that our plans do not account for the future consequences of current decisions.

- The amplification of three questionable beliefs seems to have put us into a mental straight-jacket. No alternative to increasing complexity can be conceived when perceptions are shaped by: (1) the perpetual faith that a technological revolution in cost and "capability" is right around the corner; (2) "capability" as defined by the attrition mind-set; and (3) the idea that war is a manipulatable deterministic process that can be actually controlled. By ignoring decisive human elements and the concept of friction, these perceptions stimulate decisions that accelerate the growth in complexity--i.e., increase our dependence on a strategy that is not working.

These general impressions enable us to make some statements about institutional factors impeding realistic planning.

(Slide 81) The planning process lacks overall discipline. The PPBS directs attention to the "bits and pieces" making up the "whole," and as a result, decision-makers are swamped with detail. The administrative complexity of the PPBS compounds the ambiguity, in effect, softening up the decision process to the excessive influence of narrow interests.

These narrow interests take the form of unbalanced investment advocacy pressures. We have seen that our plans are dominated by these pressures: planned overall investment budget growth is unrealistically high, predicted investment costs are understated, there is the tendency to add new investment programs when budget constraints are eased, and the operating accounts are underfunded.

Investment decision-making focuses attention on individual procurement programs. Since the general problem of the cost-budget squeeze cannot be ignored, it takes the form of arbitrary budget constraints and the sponsors of individual systems bureaucratically compete for limited funds. This competition is intensified by rewarding the program sponsor in accordance with how successfully he moves "his" program through the "bureaucratic wickets." The advocate depends, in part, on the contractor for cost information. The attrition mind-set measures capability in terms of the capacity to kill per dollar so the advocate is under continuous pressure to maximize the decision-maker's perception of this measure. The case of the AIM-82 is only an extreme example. Consequently, we have the ingredients for an incentive structure that is likely to be

biased towards being optimistic when predicting future costs and "capability." Increasing complexity magnifies the impact of any bias because the costs are more difficult to predict and the stakes are greater.

A system that is dominated by individual program advocacy cannot cope with these uncertainties. The impact of unplanned cost growth is viewed in terms of an individual weapon's cost rather than in terms of the impact to overall force effectiveness. Since the majority of investment programs exhibit cost growth and since we have a tendency to absorb cost growth in lieu of cancellation, short-term individual decisions to absorb incremental growth accummulate imperceptibly through gradual quantity reductions and readiness reductions. Unplanned budget variations contribute to this pattern, and also provide a convenient source of blame for the problem.

Fixed force structure planning directs attention away from the "whole" (why look at the "whole" since it is fixed?) and provides an arbitrary incentive to increase the complexity of the parts--i.e., to maximize their perceived "capability." The services should at least have the option (and incentive) to consider larger numbers of lower complexity, higher effectiveness systems.

Finally, the PPBS centralizes a highly visible, yet in reality weak, adversary process that provides the illusion of overall control and thus directs attention away from the problem of program discipline. The excessive influence of investment advocacy that is evident in our plans confirms the observation that there is little pressure to remove internal contradictions. For example, we advocate increased budgets because we perceive a growing threat, yet at the same time we project low readiness to meet the same growing threat.

Finally, the domination of plans by narrow interest leads to the fallacious belief that a growing budget will solve our problems. The problem of cost growth is erroneously attributed to arbitrary budget constraints. This is why the case of tac air is so important--Tac Air has the same general problems as the rest of the defense categories, the difference is that tac air has not been constrained like the other forces.

We believe the establishment of program discipline is fundamentally a leadership challenge. Management gimmicks have been tried and they do not work. Moreover, management gimmicks (e.g., zero based budgeting, Blue Ribbon Panels, Defense Resources Board, etc.) have the effect of a placebo rather than a cure--in effect they contribute to the problem by conveying the false impression of a solution. What is required is leadership that can make real national defense take precedence over the component interests involved in defense.

(Slide 82) The planning of individual investment programs is dominated by the absolute thinking of the formal requirements process. Uncertain future threats are precisely defined and this becomes the basis for a rigid specification of an operational need. Once these "needs" are bureaucratically blessed, they tend to become cast in concrete, and only rarely are they subsequently questioned. Finally, the implications of resource constraints are not addressed--requirements are viewed to be absolute entities, independent of actual cost and manpower constraints.

Theoretically, requirements are supposed to be independent of solutions; however, this rarely if ever, turns out to be the case. Since the operational requirement is a major factor affecting successful program advocacy, inevitably requirements become tied to and confused with specific systems. In reality, requirements are most often written with specific hardware systems in mind. Absolute requirements tied to specific systems that are competing for limited resources under the pressures of institutionalized program advocacy is a prescription for intolerance. The system is perceived to be absolutely needed, there are no alternatives to the preferred solution, organizational commitment must be mobilized to insure successful competition for limited funds. Result: an atmosphere that discourages critical review naturally evolves. For programs with a high degree of organizational identification, the atmosphere usually evolves to a point where objective criticism gets confused with disloyalty.

The symbiotic effect of the institutionalized program advocacy and formalized requirements process results in enormous resistance to change, particularly program cancellation, and one of continuous pressure to add new programs. Very few programs are cancelled and new programs tend to be added whenever budget constraints are eased. In the presence of rapidly growing unit costs, the net effect is one of across-the-board reductions in procurement rates, even when budget constraints are eased.

(Slide 83) Although we buy technology to support soldiers in war, plans and decisions do not use the criteria of actual combat to evaluate the potential contributions of emerging technology. Technology is evaluated within an artificial framework derived from the faith in technological revolution, the attrition mind-set, and the idea that war is a manipulatable deterministic process subject to central control. We have seen that this framework considers neither the decisive effect of the human elements nor the central characteristic of actual war--i.e., friction.

This pattern of decision-making is made easier by the institutional fact that there is no senior Pentagon staff organization chartered to study war--particularly, how soldiers act in war and how we can use emerging technology make these actions more effective. The criteria of actual combat can only be derived from the study of combat history and the tactics and strategy of real war. A fundamental value of Boyd's research in this area is that it demonstrates what is possible. He constructs and validates a frame of reference that can be used to evaluate the contributions of new technologies to the effectiveness of real soldiers in real wars.

We have seen that program decisions are supported by hypothesized mechanistic attrition models that ignore the friction of combat and are based upon unvalidated speculative assumptions. Further, it is rarely possible to even define combat data that could be used to test these theoretical models. This is the antithesis of the scientific method.

Although the study of history can be carried too far; history is the only "evidence" of real war, and to ignore it completely leads to a modern form of medieval scholasticism--i.e., the religion of miracle weapons. Hitler provides an ominous precedent for this unrealistic faith in technology--an observation suggesting a disturbing question: Was Hitler's faith in miracle weapons apparent between 1939 and 1941 when he was winning or was it apparent in 1944 and 1945 when he was losing?

By ignoring the real world, we have evolved a self-reinforcing--yet scientifically unsupportable--faith in the military usefulness of ever increasing technological complexity. We tend to think of military strength in terms of wonder weapons that are in reality mechanistic solutions--the concept of force multiplication being the latest example.

(Slide 84) In the real world of uncertain budgets and rising costs, we have seen that our decisions and plans have resulted in a force having the qualities listed on this slide. These are qualities of complexity and they take the form of costs. The costs of increasing complexity can be generalized into low readiness, slower modernization, and declining forces. The crucial question is: Are there positive qualities of complexity to outweigh these negative qualities?

(Slide 85) Our objective has been to determine the realism of our plans, this slide depicts our finding.

(Slide 86) Planning does not relate to future decisions; rather it relates to the future consequences of current decisions. In a nutshell, Pentagon economics discount the present and inflate the future.

(Slide 87) We do not see how we can avoid this painful realization. The across the board thrust towards ever increasing technological complexity just is not working. We need to change the way we do business, and in particular, we should use our superior technology in a positive way. Technology should and can increase readiness, not draw it down.

PURPOSE

EXAMINE DEFENSE PLANNING TO DETERMINE:

1. THE REALISM (OR LACK THEREOF) OF CURRENT PLANS

2. THE LEADERSHIP CHALLENGE FACING DECISION-MAKERS DURING THE COMING DECADE

SLIDE 1

OUTLINE

- NATURE OF THE PLANNING PROBLEM
- GENERAL VIEW OF CHANGE IN THE POST WWII ERA
- A CASE OF BUDGET GROWTH: AF TAC AIR
- UNCERTAINTY SURROUNDING INVESTMENT PLANS
- THE IMPACT OF TECHNOLOGICAL COMPLEXITY AND COST GROWTH ON PERCEPTIONS OF CAPABILITY
- OBSERVATIONS AND CONCLUSIONS

Slide 2

GOAL

PROVIDE A SUPERIOR FORCE

REALITY

DECISIONS AND PLANS MUST RECONCILE TENSION GENERATED BY

- PERCEIVED THREAT
- LIMITED RESOURCES

NOTE:

- PLANNING IS CONCERNED WITH THE FUTURE CONSEQUENCES OF TODAY'S DECISIONS
- JAN. FYDP IS THE AUTHORITATIVE STATEMENT OF DEFENSE POLICY

Slide 3

A SUPERIOR FORCE IS A SYNTHESIS OF:

- PEOPLE
- IDEAS
- MOTIVATION AND PSYCHOLOGY
- SKILLS
- MACHINES

NOTE: MACHINES DON'T FIGHT WARS – PEOPLE DO

Slide 4

"WHAT CONSTITUTES THE EFFECTIVENESS OF THE ARMED FORCES OUR COUNTRY PRODUCES?

I BELIEVE THERE ARE THREE FACTORS:

FIRST: THEIR STRENGTH, ARMS, EQUIPMENT, SUPPLIES AND TRANSPORTATION

SECOND: THEIR MORALE, ESPIRIT, TRAINING, LEADERSHIP, INFORMATION, MOTIVATION, COMMAND, AND CONFIDENCE IN THEIR MISSIONS

THIRD: THE ABILITY OF THEIR GOVERNMENT TO EMPLOY THEM WISELY AND EFFECTIVELY

THE SECOND AND THIRD FACTORS ARE FAR MORE IMPORTANT THAN THE FIRST"

Bruce C. Clarke
General, U.S. Army, Ret.

Slide 5

OPERATIONAL DEFINITION

COMPLEXITY IS A QUALITY OF THE WHOLE THAT

- RELATES THE NUMBER, ARRANGEMENT, AND COORDINATION OF THE PARTS

TO

- ONES ABILITY TO COMPREHEND THE WHOLE

Slide 6

THE PROBLEM

TENSION IS MAGNIFIED BY INCREASING COMPLEXITY

BECAUSE:

COSTS ARE RISING FASTER THAN INCOME

Slide 7

UNCERTAINTY COMPLICATES DECISIONS

TODAY'S DECISIONS IMPOSE RIGID BURDENS FAR INTO THE FUTURE

HOWEVER

IT IS DIFFICULT TO PREDICT:

- **FUTURE THREAT**
- **FUTURE INCOME**
- **FUTURE COSTS**

Slide 8

REAL WORLD OF BUDGET UNCERTAINITY

- OBSERVATION: PLANNED BUDGET GROWTH MUST BE FINANCED BY AN ECONOMY THAT IS GROWING MORE SLOWLY AND IS BECOMING LESS PREDICTABLE

  - BASIC PROBLEM: DECLINING PRODUCTIVITY REQUIRES LARGE INFUSION OF PRIVATE CAPITAL

    -- COMPLICATIONS: DECLINING SAVINGS RATE, PERSISTENT INFLATION, OPEC, TRADE DEFICIT, TAXPAYERS REVOLT, UNSTABLE INTERNATIONAL FINANCIAL SYSTEM, DEMOGRAPHICALLY AGING POPULATION, PERSISTENT FEDERAL DEFICIT .....

  - NEAR TERM: UNPREDICTABLE IMPLICATIONS OF EMERGING CONSENSUS TO REDUCE FEDERAL DEFICIT

    -- HOW DO WE ALLOCATE CONSTRAINTS ON SPENDING AMONG COMPETING NEEDS?

    -- HOW DO WE COPE WITH INCREASING PRESSURE TO "PORK BARREL" IN A POLITICAL APPROPRIATION PROCESS?

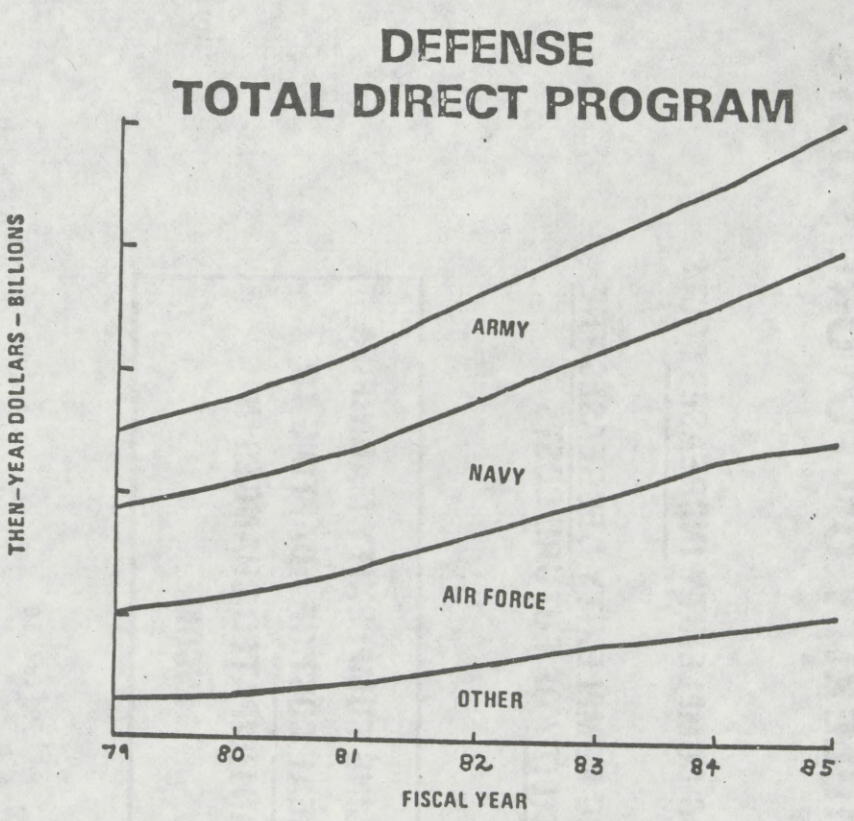
DECISIONS AND PLANS SHOULD REDUCE THE REAL COSTS OF ADAPTING TO UNANTICIPATED CHANGES IN THE BUDGET.

IMPACT OF COMPLEXITY ON FUTURE COSTS

- INCREASING COMPLEXITY INCREASES COSTS
- INCREASING COMPLEXITY DECREASES THE PREDICTABILITY OF FUTURE COSTS

INCREASING COMPLEXITY MAGNIFIES THE REAL COST OF ADAPTING TO UNANTICIPATED CHANGES IN INCOME

Slide 10


DEFENSE
TOTAL DIRECT PROGRAM
THEN-YEAR DOLLARS - BILLIONS
ARMY
NAVY
AIR FORCE
OTHER
79
80
81
82
83
84
85
FISCAL YEAR

Slide 11

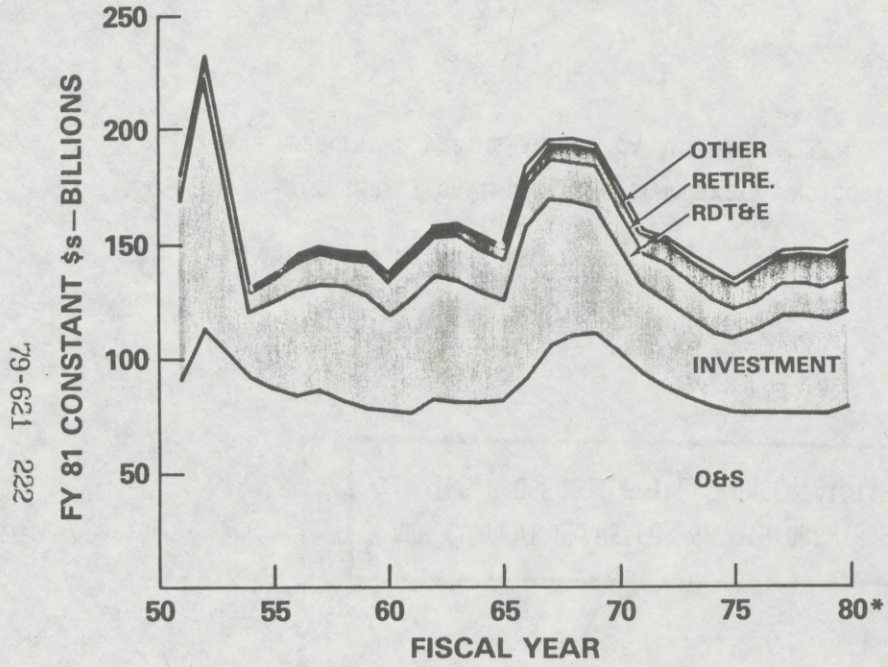
RAISES QUESTION

ARE CURRENT PLANS FOR SMOOTH GROWTH REALISTIC IN THE PRESENCE OF THESE UNCERTAINTIES?

- SIGNIFICANCE OF BUDGET UNCERTAINTY
- MEANING OF COST GROWTH
- THE IMPACT OF INCREASING COMPLEXITY AND COST UNCERTAINTY ON PERCEIVED VERSUS ACTUAL CAPABILITY

Slide 12

TOA HISTORY

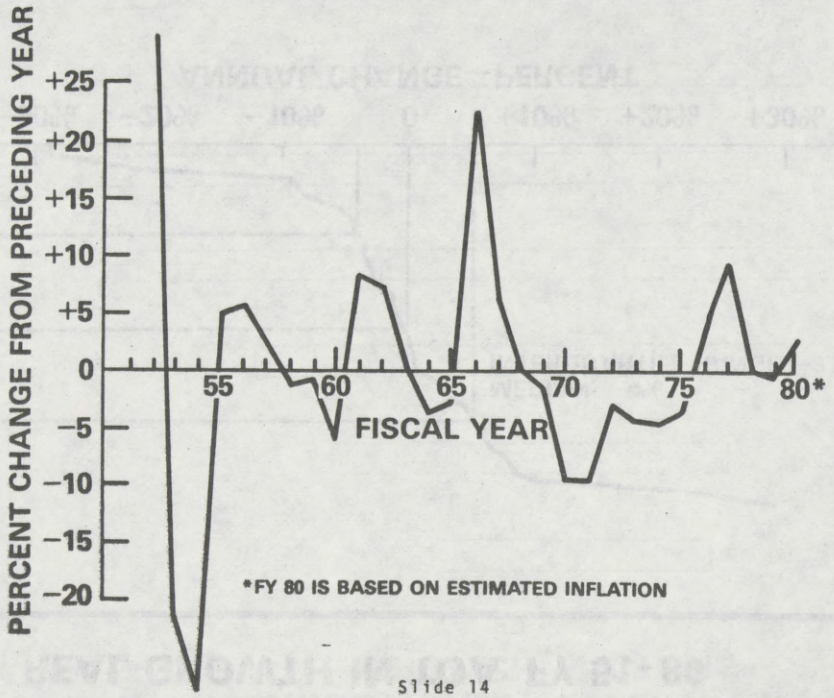


79-621 222

*FY 80 IS BASED ON ESTIMATED INFLATION

Slide 13

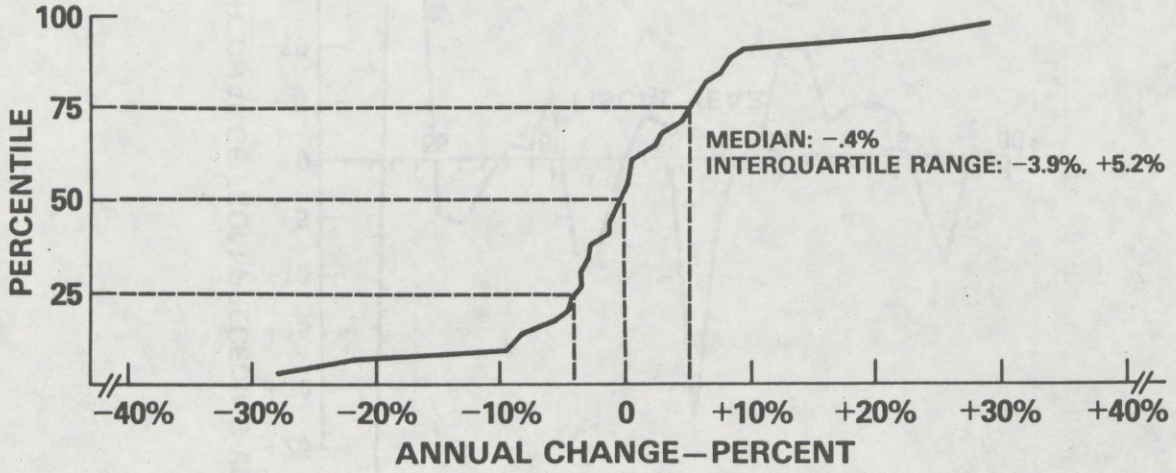
ANNUAL CHANGE IN DoD BUDGET
(CONSTANT $s)



Slide 14

79-621 O - 81 - 9

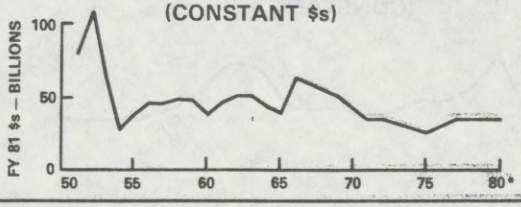
CUMULATIVE DISTRIBUTION: OVERALL DoD BUDGET REAL GROWTH IN TOA: FY 51-80



Slide 15

DoD INVESTMENT HISTORY (TOA)

(CONSTANT $s)



ANNUAL CHANGE IN DoD INVESTMENT TOA

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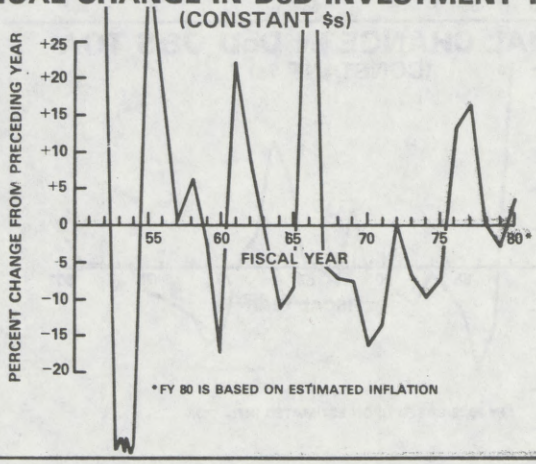
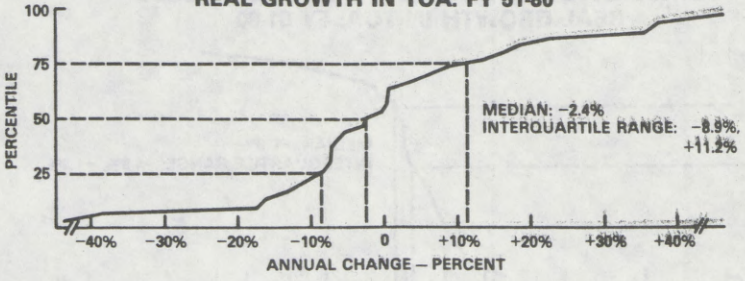
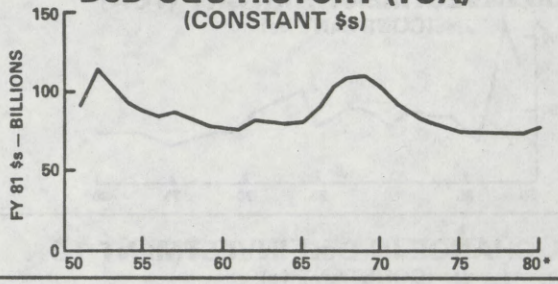


Slide 16

CUMULATIVE DISTRIBUTION: INVESTMENT BUDGET REAL GROWTH IN TOA: FY 51-80



DoD O&S HISTORY (TOA)
(CONSTANT $s)



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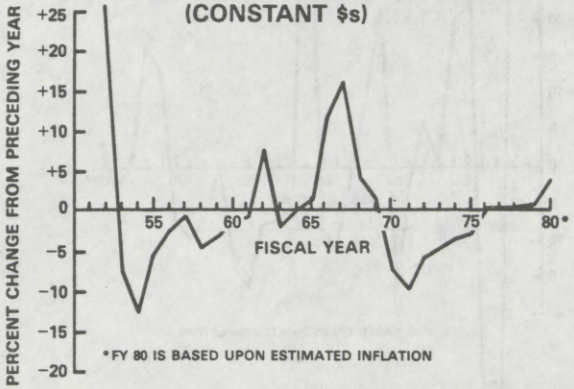
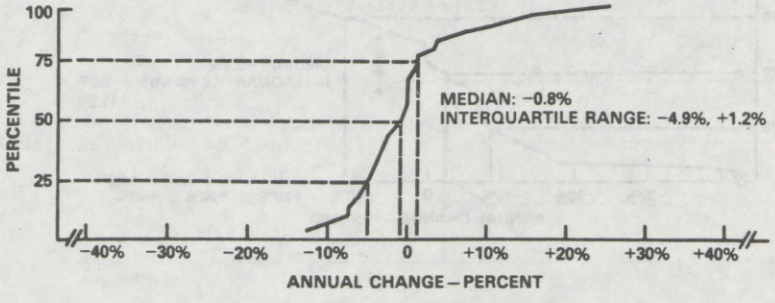
(CONSTANT $s)

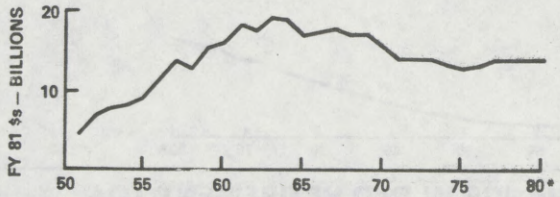


Slide 17

CUMULATIVE DISTRIBUTION: DoD O&S BUDGET
REAL GROWTH IN TOA: FY 51-80



DoD RDT&E HISTORY (TOA)
(CONSTANT $s)



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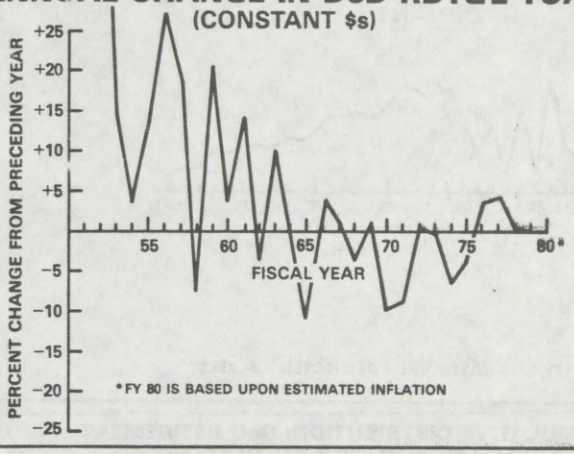
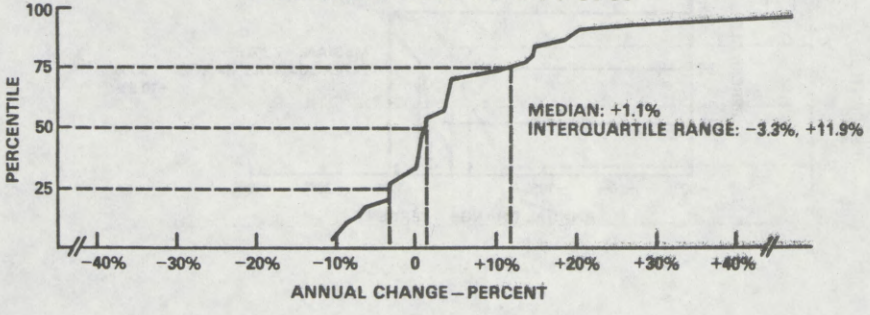
(CONSTANT $s)

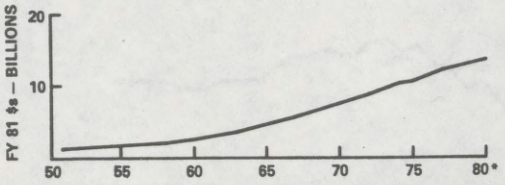


Slide 18

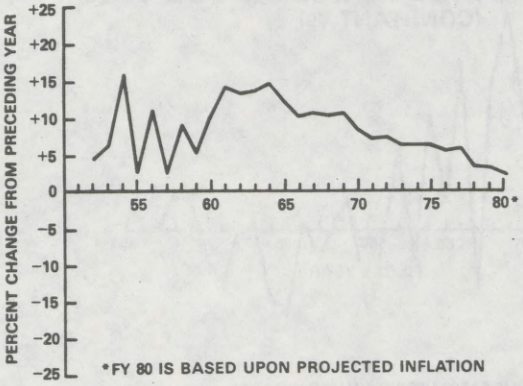
CUMULATIVE DISTRIBUTION: RDT&E BUDGET REAL GROWTH IN TOA: FY 51-80



DoD RETIREMENT HISTORY (TOA)
(CONSTANT $s)



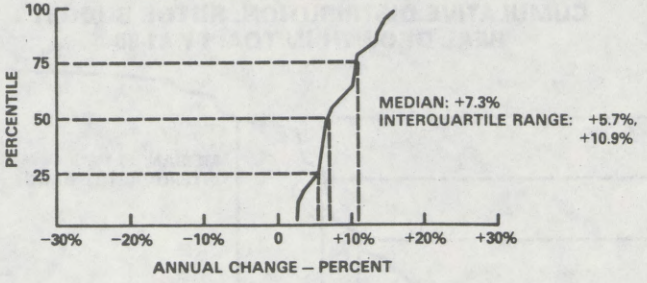
ANNUAL CHANGE IN DoD RETIREMENT TOA
(CONSTANT $s)



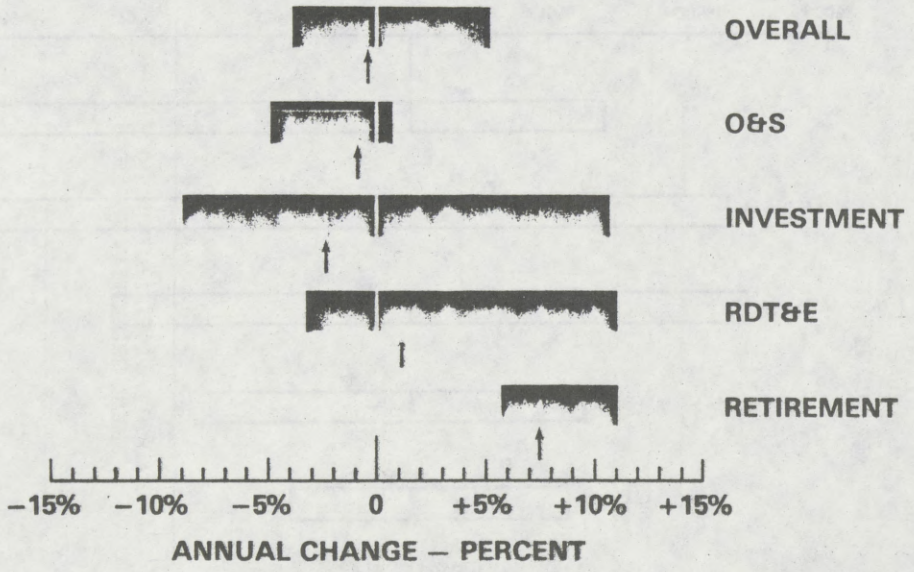
*FY 80 IS BASED UPON PROJECTED INFLATION

Slide 19

CUMULATIVE DISTRIBUTION: DoD RETIREMENT REAL GROWTH IN TOA: FY 51 - 80



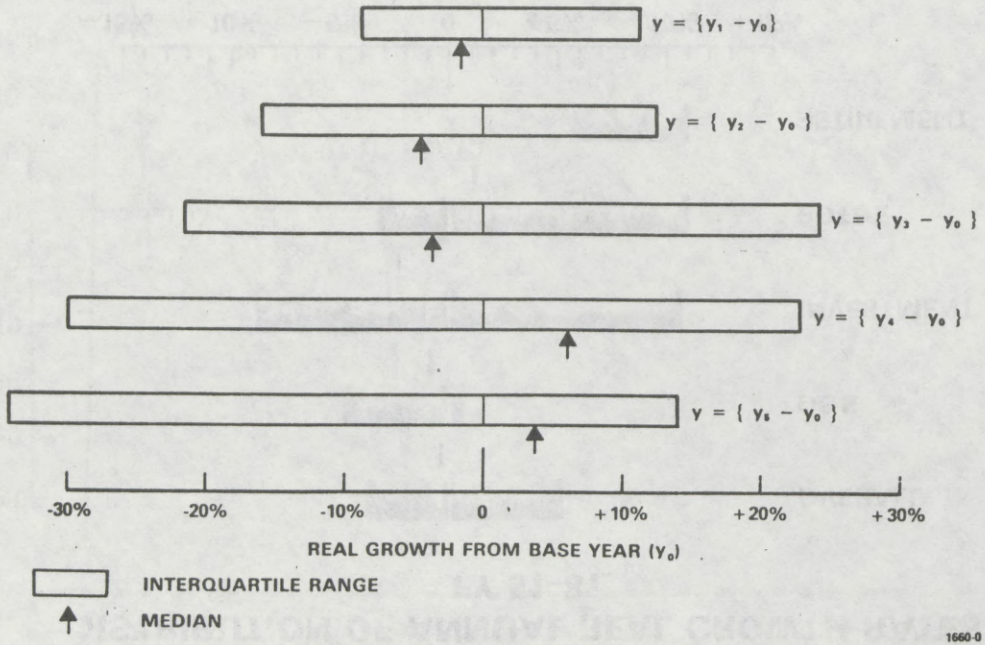
SUMMARY
DISTRIBUTION OF ANNUAL REAL GROWTH RATES
FY 51–81



Slide 20

DISTRIBUTION OF INVESTMENT TOA GROWTH FACTORS

FY 51-80



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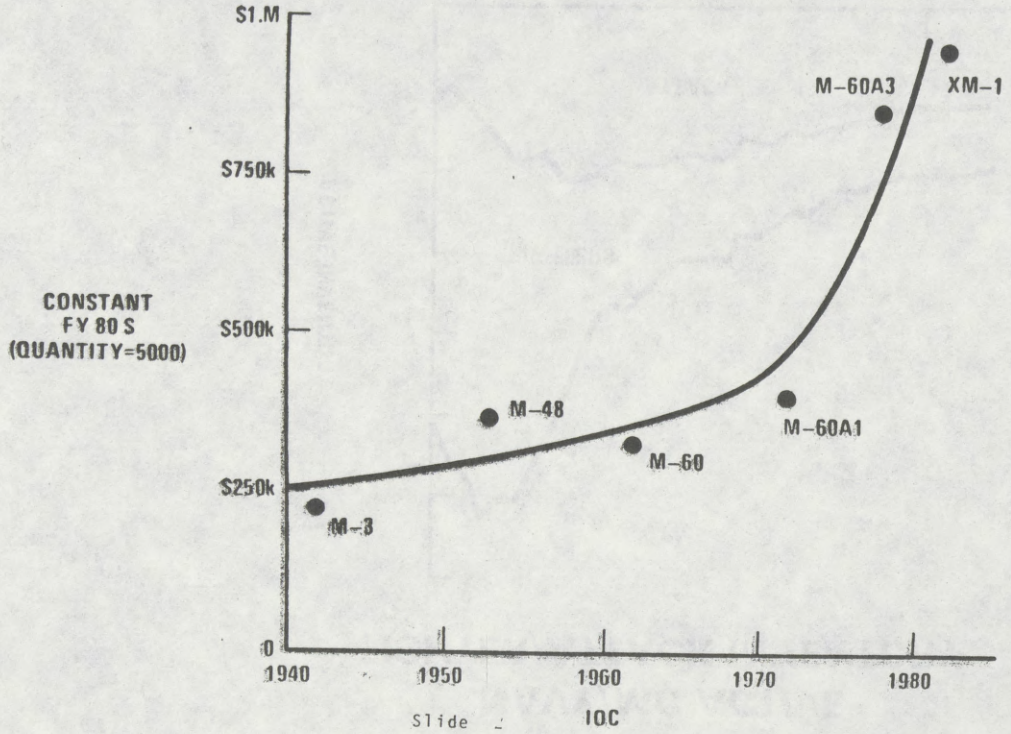
Slide 21

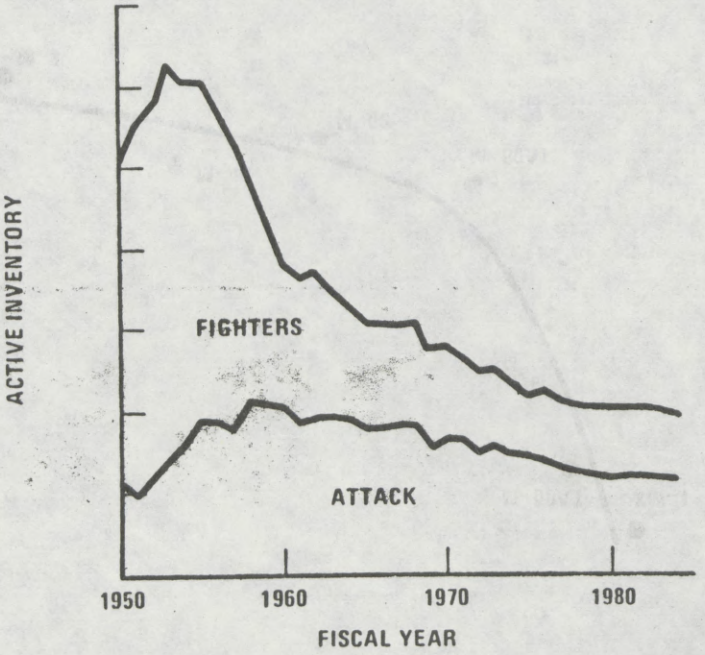
79-621 O - 81 - 10

SYMPTOM — COST OF THE TANK



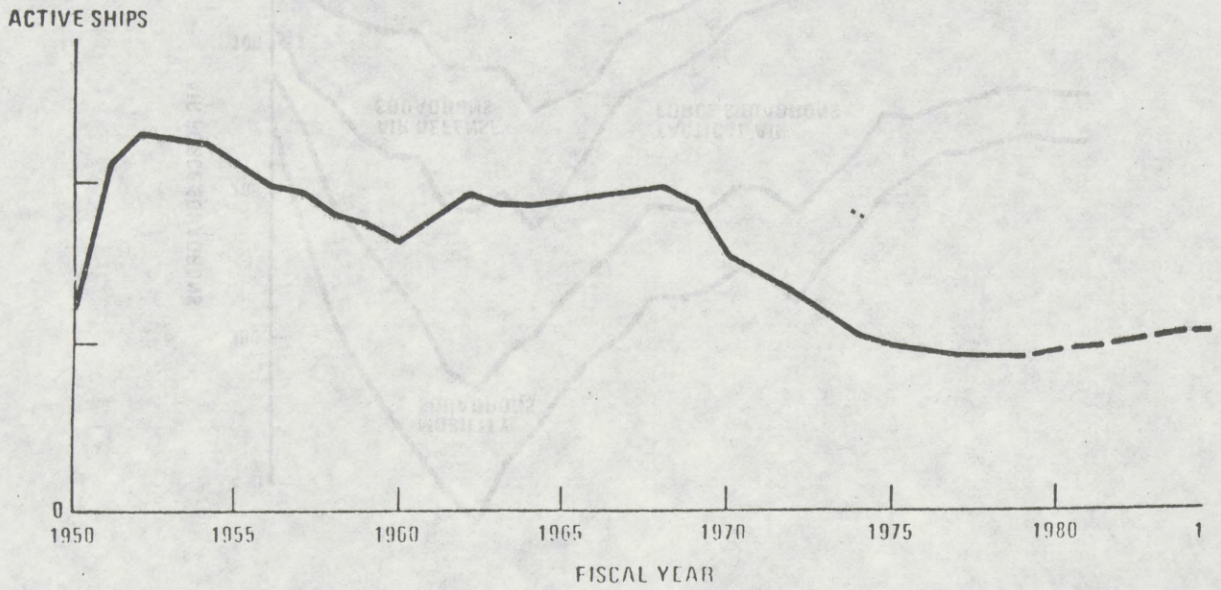
Slide

NAVY/MC ACTIVE FIGHTER/ATTACK INVENTORY



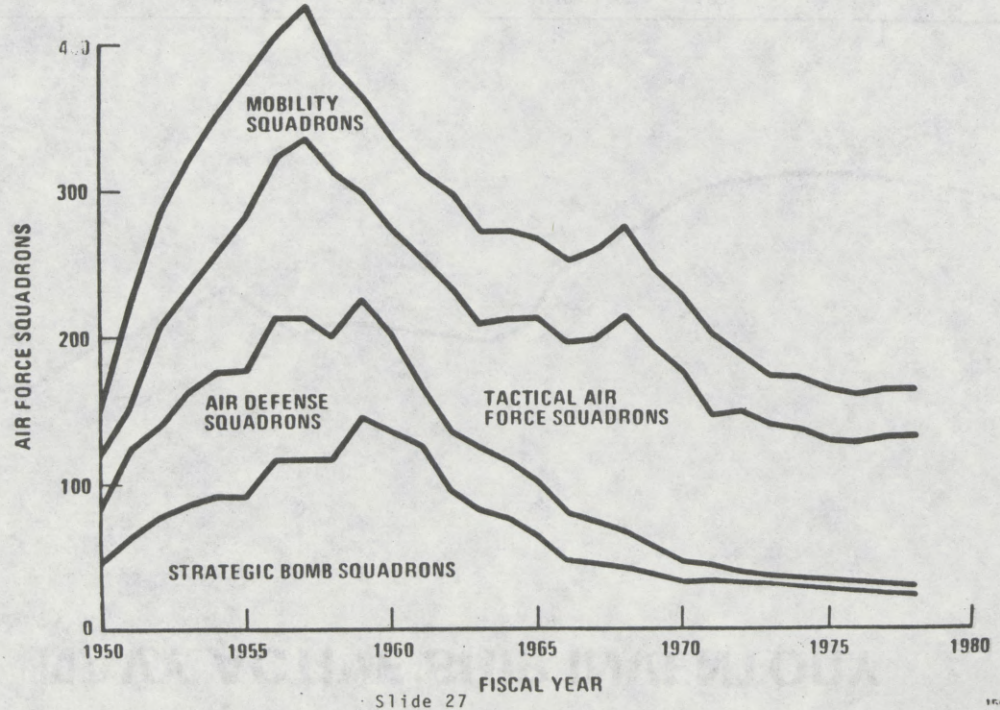
Slide 25

NAVY ACTIVE SHIP INVENTORY

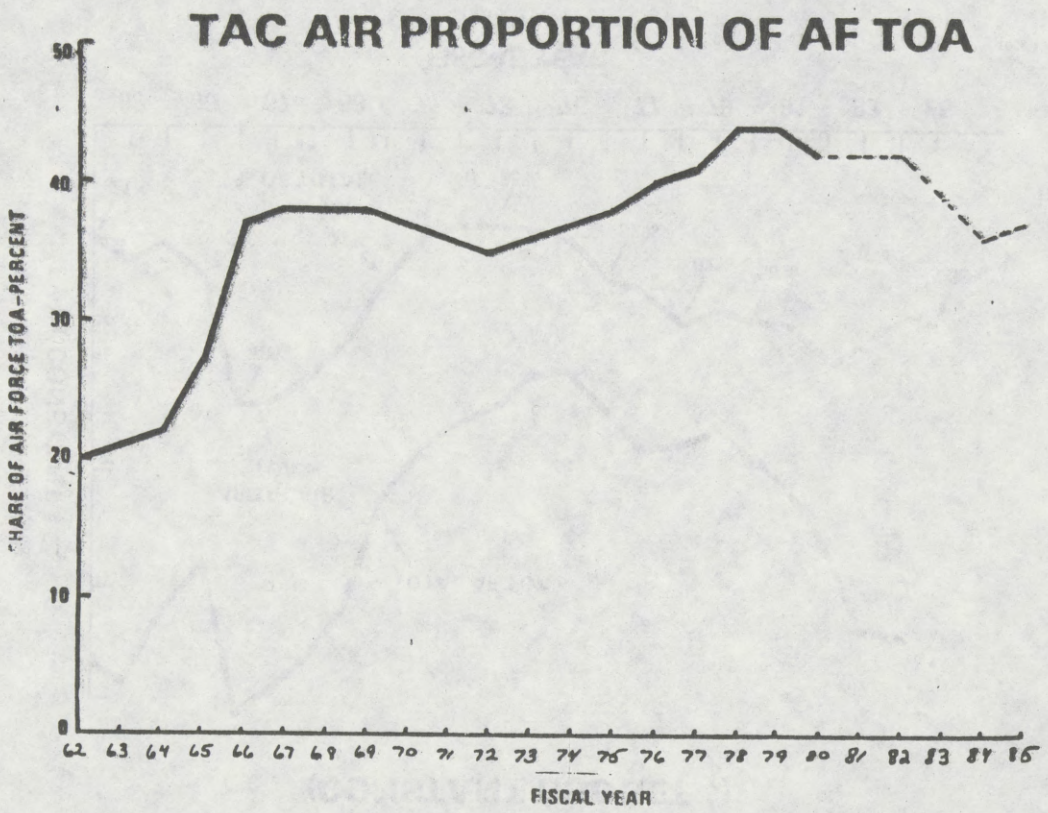


Slide 26

ACTIVE AIR FORCE MANNED AIRCRAFT SQUADRON STRUCTURE

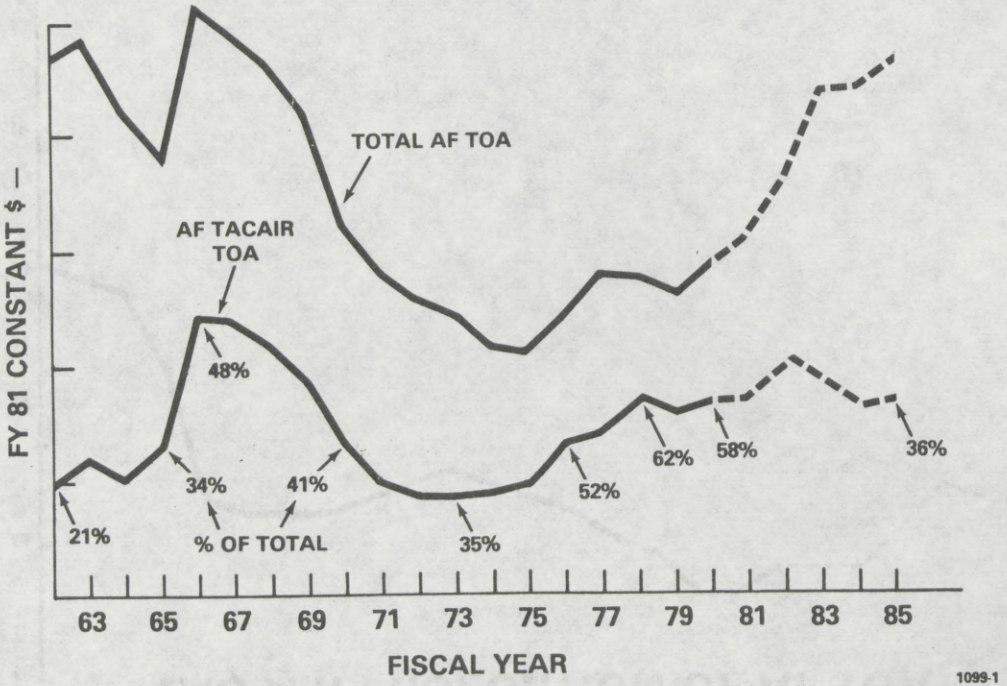


Slide 27


TAC AIR PROPORTION OF AF TOA
SHARE OF AIR FORCE TOA-PERCENT
50
40
30
20
10
0
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85
FISCAL YEAR

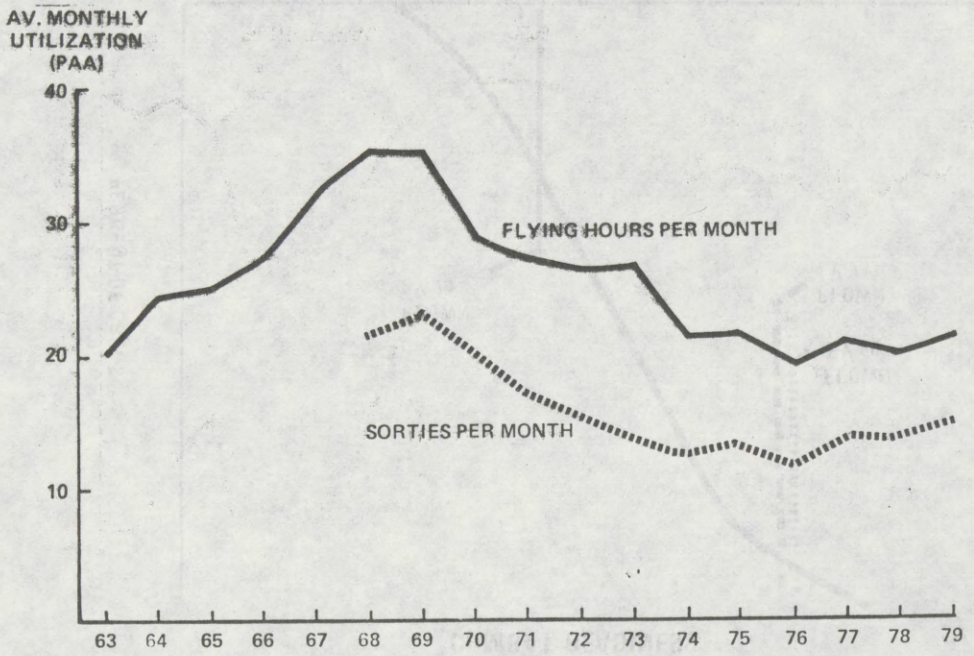
Slide 28

AIR FORCE INVESTMENT TOA
(CONSTANT BUDGET $)



Slide 29

AVERAGE AIRCRAFT UTILIZATION FIGHTER/ATTACK FORCE
(Active)



Slide 30

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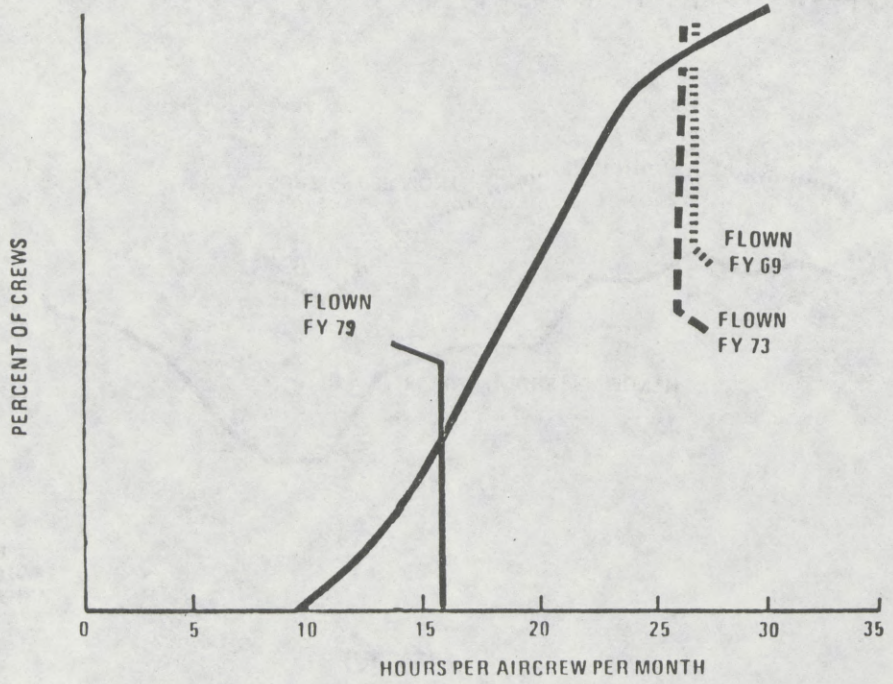
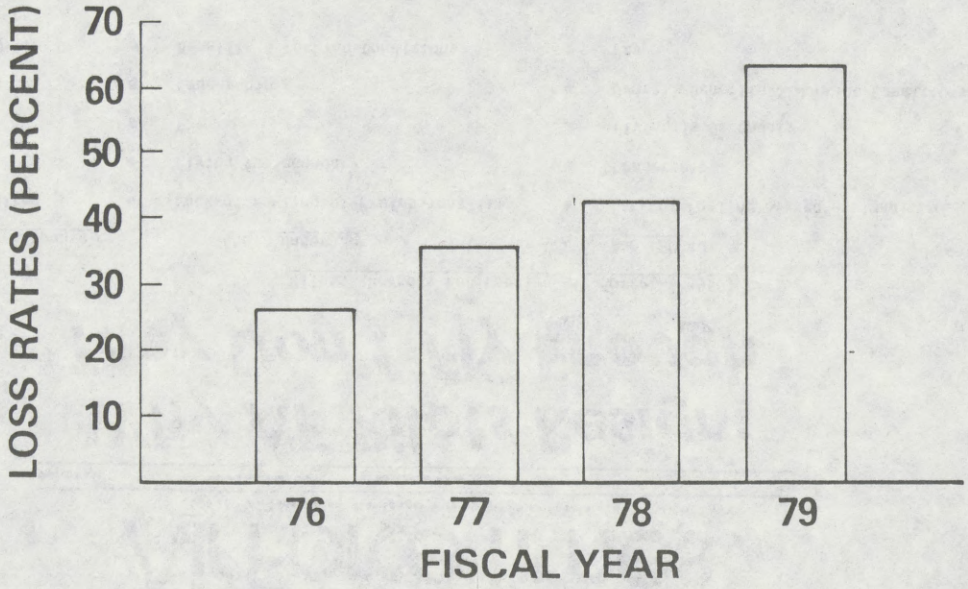
AIRCREW OPINION SURVEY

HOURS PER MONTH REQUIRED TO MAINTAIN COMBAT READINESS



Slide 31

USAF FIGHTER PILOT LOSS RATES
6-11 YEAR GROUP



Slide 32

2177-0

Air Force Times
An Independent Newspaper Serving Air Force People

Why AF Pilots Resign: They Don't Fly Enough

Pilots' Reasons For Leaving Air Force, (n=950)

Frequency of Response	Age: Under 30	Age: 30-40
Cited Most Often	• Lack of Feeling of Professionalism	• Lack of Feeling of Professionalism
	• Flying is Secondary	• Leadership
	• Pay	• Flying is Secondary
	• Leadership	• Overall Benefits & Working Conditions
Cited Less Often	• Benefits & Working Conditions	• Pay

Most Consistent Finding:

Pilots Like to Fly and Dislike Non-flying Aspects of Air Force

Slide 33

TACAIR MATERIAL READINESS INDICATORS

(FY 79)

A/C	Complex.	Sorties/Mo	NMC(%)	MFHBF	Maint. Events/Sortie	MMH/S	Cann-WR/100 Sorties	MM/Acft	Workload
Air Force									
A-10	Low	19.6	32.6	1.2	1.6	18.4	10.1	17.3	20.9
A-7D	Med.	16.4	38.6	0.9	1.9	23.8	11.9	19.2	20.3
F-4E	Med.	16.9	34.1	0.4	3.6	38.0	15.4	22.4	28.7
F-15	High	16.3	44.3	0.5	2.8	33.6	44.0	23.3	23.5
F-111F	High		36.9	0.3	9.2	74.7	42.1	24.8	26.5
F-111D	High	8.8	65.6	0.2	10.2	98.4	58.5	28.4	30.5
DON									
A-4M	Low	14.8	31.2	0.7	2.4	28.5	12.0	10.3	41.0
AV-8A	Low ?	16.8	40.0	0.4	4.3	62.4	13.4	14.2	46.1
A-7E	Med.	20.9	36.8	0.4	3.7	53.0	27.1	18.2	60.6
F-4J	Med.	15.4	33.4	0.3	5.9	82.7	22.2	17.3	77.4
A-6E	High	17.9	39.5	0.3	4.8	71.3	39.4	18.8	67.9
F-14A	High	14.0	47.5	0.3	6.0	97.8	69.6	18.9	74.5

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COMPLEXITY MAGNIFIES MAINTAINABILITY PROBLEMS

EXAMPLE: IMPACT OF BLACK BOXES AND AUTOMATIC TEST EQUIPMENT

		Monthly Rate: Dec, 79 - June 80		
		Lowest	Median	Highest
BASE LEVEL AIS:	F-15 CND RATE	25%	28%	41%
DEPOT LEVEL TEST EQUIPMENT:	F-15 RETOC RATE	24%	26%	29%

RESULT

- INCREASED SPARES REQUIREMENTS
- RISING CANNABILIZATION
- INCREASED MANPOWER AND SKILL REQUIREMENTS
- RRR WRSK CONCEPT
- INCREASED VULNERABILITY

1288 9

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COMPLEXITY DRIVES UP DEPOT REPAIR COSTS

EXAMPLE:

	F-100 UNIFIED FUEL CONTROL	*J-79 COMPARABLE CONTROLS
UNIT REPAIR COST	$ 9,956	$ 2,298
NR. INTERNAL COMPONENTS	4,541	999
NRTS-MTBF	386 HRS	3,049 HRS
STANDARD M/H TO REPAIR	328 HRS	47.8 HRS

* J-79 COMPONENTS (MAIN FUEL CONTROL, AFTERBURNER FUEL CONTROL ** & NOZZLE AREA CONTROL)

** AFTERBURNER FUEL CONTROL 100% BASE REPAIR

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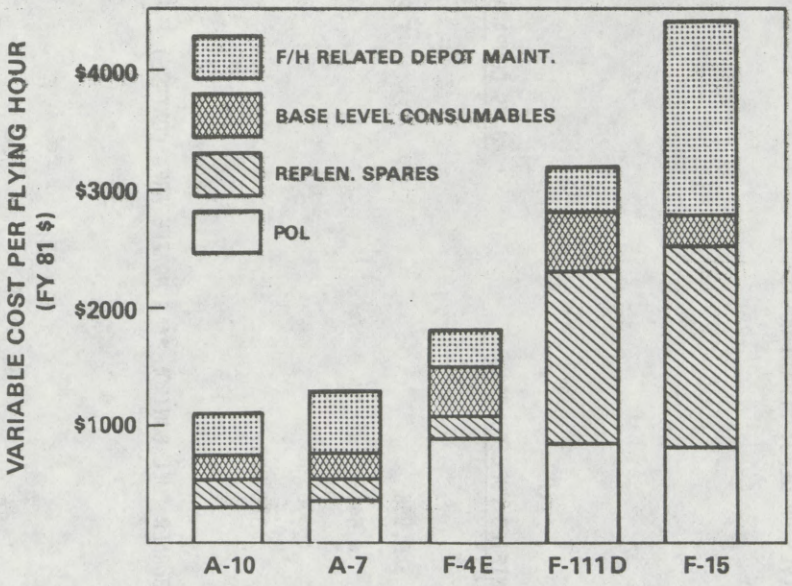
COMPLEXITY INCREASES OPERATING COSTS



Source: AFP 173-13, Feb 80

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FLYING HOUR COST FACTORS (CURRENT $)

	Fiscal Year							
	79	80	81	82	83	84	85	86
F-15 Depot Maintenance								
FY 79 POM:	267	300	306	313	321	-	-	-
FY 80 POM:	1431	1531	1616	1707	1803	1904	-	-
FY 81 POM:	-	914	954	985	1020	1058	1096	-
FY 82 POM:	-	-	1522	1609	1668	1731	1778	1827
A-10 Depot Maintenance								
FY 79 POM:	229	256	261	268	274	-	-	-
FY 80 POM:	309	330	349	368	389	411	-	-
FY 81 POM:	-	321	335	345	358	371	385	-
FY 82 POM:	-	-	355	375	389	404	415	426
F-15 Replenishment Spares								
FY 79 POM:	591	615	639	665	692	-	-	-
FY 80 POM	614	647	682	719	758	799	-	-
FY 81 POM:	-	1606	1693	1952	1636	1618	1483	-
FY 82 POM:	-	-	1290	1412	1506	1603	1701	1806
A-10 Replenishment Spares								
FY 79 POM:	398	415	337	293	244	-	-	-
FY 80 POM:	247	260	274	289	304	321	-	-
FY 81 POM:	-	207	218	230	243	256	270	-
FY 82 POM:	-	-	185	203	216	230	243	259

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FACT

- AF PLANS LIMITED AIRCRAFT BATTLE DAMAGE REPAIR CAPABILITY

  - AF POM-82

	$-MILLIONS					
	82	83	84	85	86	TOTAL
A-10 B/D REPAIR KIT:	21.6			75		96.6
ALL OTHER A/C:	3.0	3.0	3.0	3.0	3.0	15
						$111.6M

- INCREASING COMPLEXITY MAGNIFIES B/D REPAIR PROBLEM

- DAMAGED AIRCRAFT MAGNIFY REAL LOSSES

  - E.G., DURING VIET-NAM, F-4S REACHED A TWO-YEAR B/D REPAIR TURN AROUND TIME

  - E.G., DURING 1973 ARAB-ISRAELI WAR, FOR EVERY AIRCRAFT LOST, THREE WERE DAMAGED

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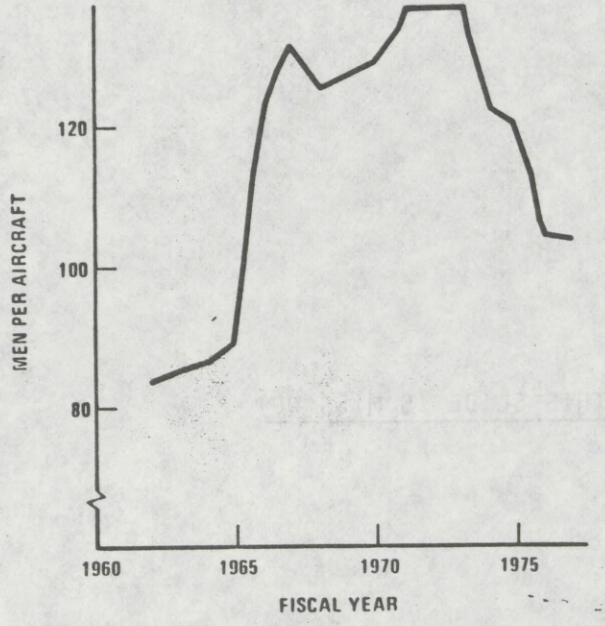
(THIS SLIDE IS MISSING)

SLIDE 39

AIR FORCE
DIRECT & INDIRECT MANNING
PER FIGHTER 1/



1/ INCLUDES: COMBAT CREWS, BASE AND DEPOT LEVEL MAINTENANCE, CENTRAL SUPPLY, TRAINING, ETC..

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INCREASING COMPLEXITY REQUIRES HIGHER SKILLS

BUT:

- FORMAL TRAINING TIMES HAVE DECLINED

CAREER FIELD	AVG COURSE LGTH (WKS)* FY 75	FY 80	CHANGE
31XXX Msl. Elec. Maint.	25	14	-44%
32XXX Avionics Systems	23	18	-22%
34XXX Training Devices	32	20	-38%
39XXX Maintenance Mgt.	7	7	-
42XXX Aircraft Systems	13	11	-15%
43XXX Aircraft Maint.	11	9	-18%
46XXX Mun./Wpn. Maint.	13	9	-31%

- FOCUS IS NOW ON PROVIDING SKILLS FOR FIRST JOB ONLY
- TRAINING IS MORE TASK ORIENTED WITH LESS GENERAL THEORY
- OJT HAS BEEN INCREASED

IMPRESSION

INTRODUCTION OF QUESTIONABLE ECONOMIES TO SLOW GROWTH OF TRAINING BUDGET

*NOTE: FY 75 WORKDAY: 6 CLASSROOM HOURS, 2 HOURS STUDY
FY 80 WORKDAY: 8 CLASSROOM HOURS

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CURRENT SITUATION - TAF MAINTENANCE MANNING

- DECLINING RETENTION INCREASES TRAINING QUOTAS (I.E., COST)
- SHORTAGES IN HIGH SKILL LEVELS

% OF AUTHORIZATIONS *

SKILL LEVEL	F-15	F-16	A-10
0	18% SHORT	-	6% OVER
9	22% SHORT	37% SHORT	19% SHORT
7	11% SHORT	22% SHORT	-
5	5% SHORT	22% SHORT	10% SHORT
3	10% OVER	22% OVER	17% OVER

- OUTLOOK: DECLINING RECRUITMENT BASE (18-26 YEAR-OLDS)

IMPLICATION

INCREASING SCARCITY WILL DRIVE UP MAINTENANCE COST

* MAY 1980

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TAF EXPERIENCE LEVELS ARE DECREASING

- MAINTENANCE MANPOWER AUTHORIZATIONS ARE INCREASING
- FIRST AND SECOND TERM REENLISTMENT RATES ARE DECLINING--FASTER THAN OVERALL AIR FORCE RATES

REELISTMENT RATES BY FISCAL YEAR

	Fiscal Year	Avionics Sys. (32XXX)	A/C Sys. (42XXX)	A/C Maint. (43XXX)	Mun/Wpns (46XXX)	TOTAL AF
First Term	75	42.9	35.7	49.9	38.0	40.1
	76	34.9	36.4	45.2	38.4	37.5
	77	26.5	38.9	39.7	34.3	39.0
	78	28.8	41.8	36.4	35.2	41.1
	79	32.6	35.8	31.2	28.9	38.0
Second Term	75	67.6	77.0	71.9	70.7	75.4
	76	66.6	71.1	66.5	70.3	67.8
	77	65.0	77.0	69.3	75.6	68.9
	78	55.2	68.5	63.3	74.0	64.7
	79	51.0	61.1	56.6	63.2	60.1

Source: AF/MPPP, April 1980

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SUMMARY

- FLYING HOURS AND SORTIE RATES ARE DOWN
- AIRCREWS FEEL CURRENT TRAINING RATES SHOULD BE INCREASED TO ACHIEVE COMBAT READINESS
- SPARES STOCK LEVELS APPEAR TO BE INADEQUATE
- COSTS OF ENGINES AND BLACK BOXES HAVE INCREASED
- MANNING PER AIRCRAFT HAS RISEN
- REQUIRED SKILL LEVELS HAVE INCREASED
- TACAIR FORCE STRUCTURE IS INCREASING

INCREASING COMBAT READINESS REQUIRES SIGNIFICANT INCREASES IN THE O&S BUDGET

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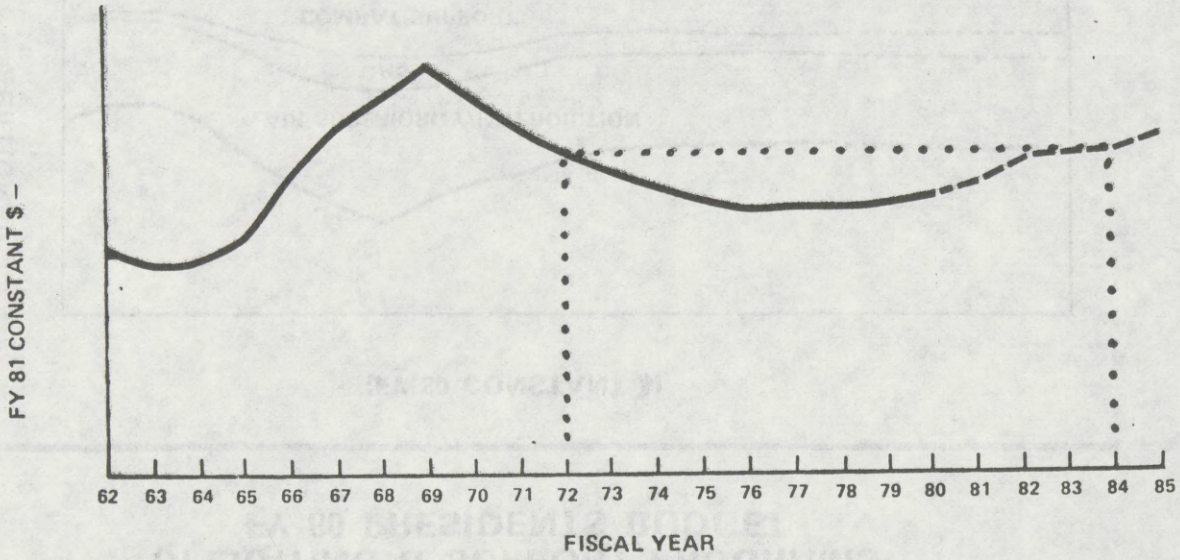
AF TACTICAL AIR OPERATING AND SUPPORT PROGRAMS

FY 81 President's Budget, January 1980

(Constant Budget $)



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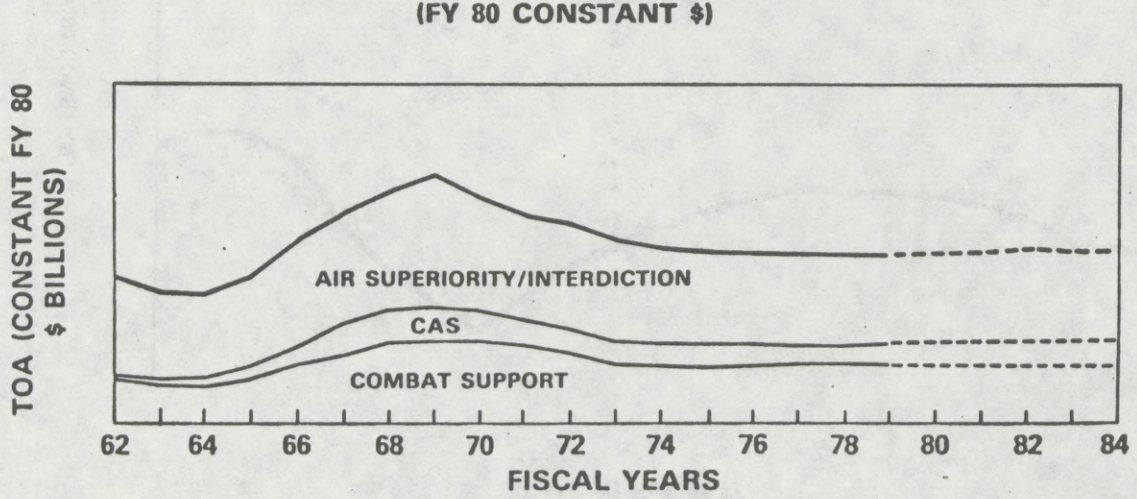
AIR FORCE TACTICAL AIR
OPERATING & SUPPORT PROGRAMS
FY 80 PRESIDENTS BUDGET



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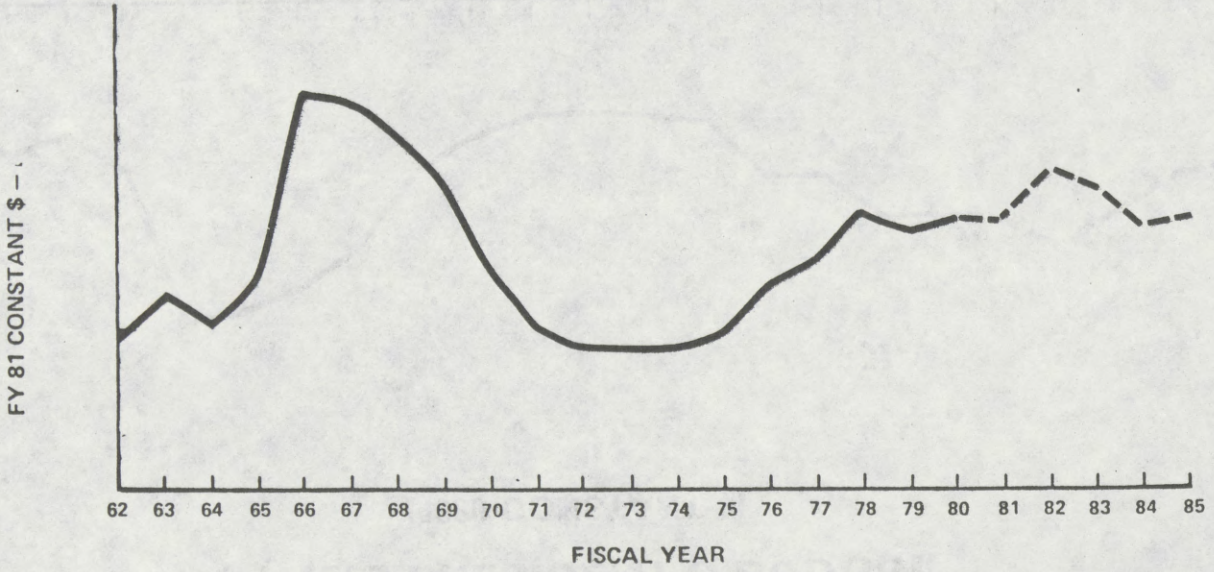
AIR FORCES TACTICAL AIR INVESTMENT PROGRAMS

FY 81 President's Budget, January 1980

(Constant Budget $)



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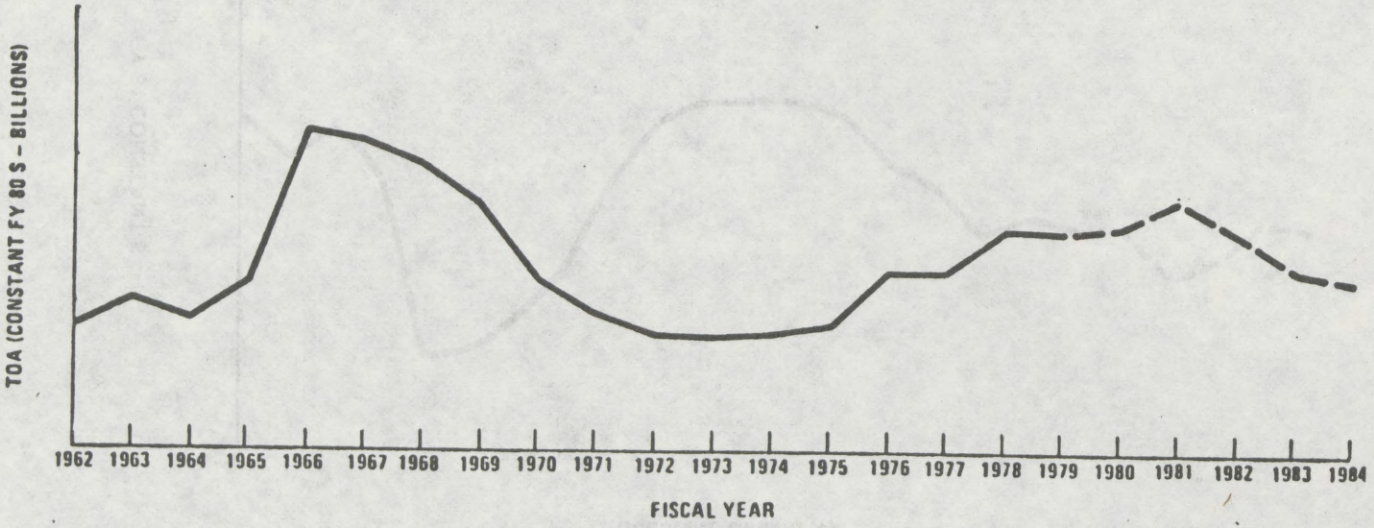
AF TACTICAL AIR INVESTMENT
FY 1980 PRESIDENT'S BUDGET

(1980 CONSTANT $)



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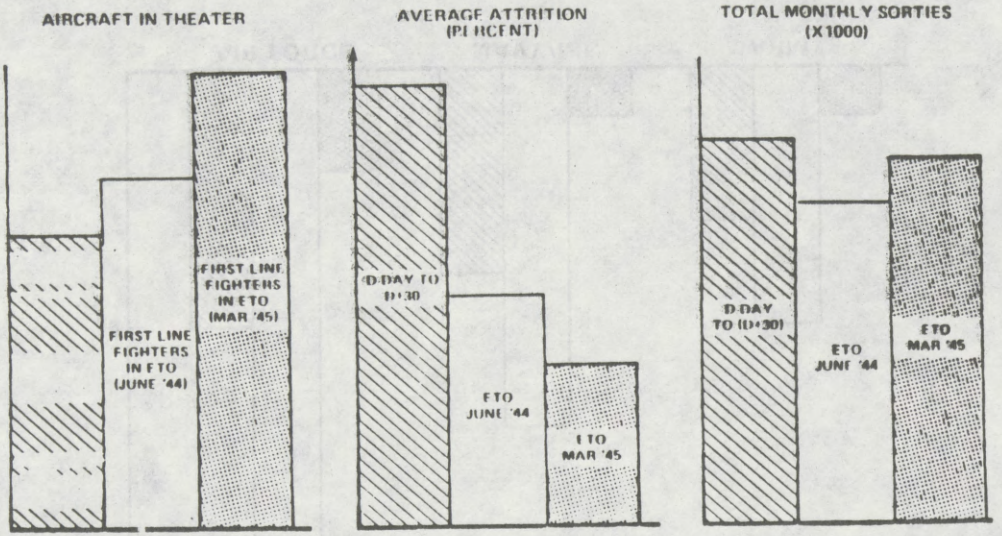
? CURRENT PLANNING ?



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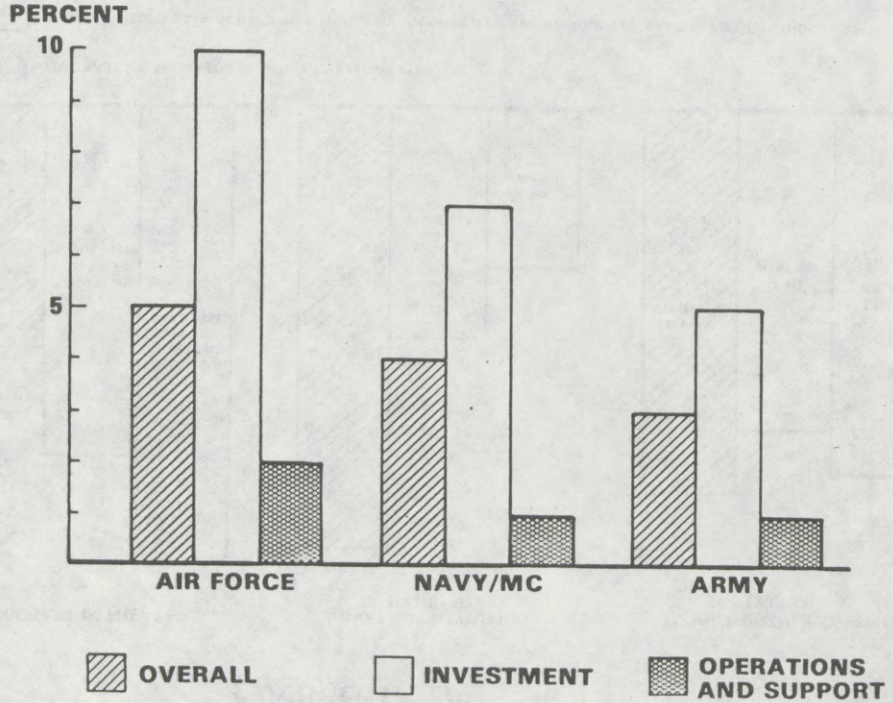
AVERAGE ANNUAL REAL GROWTH: FY 80-85
FY 81 Presidents Budget, January 1980



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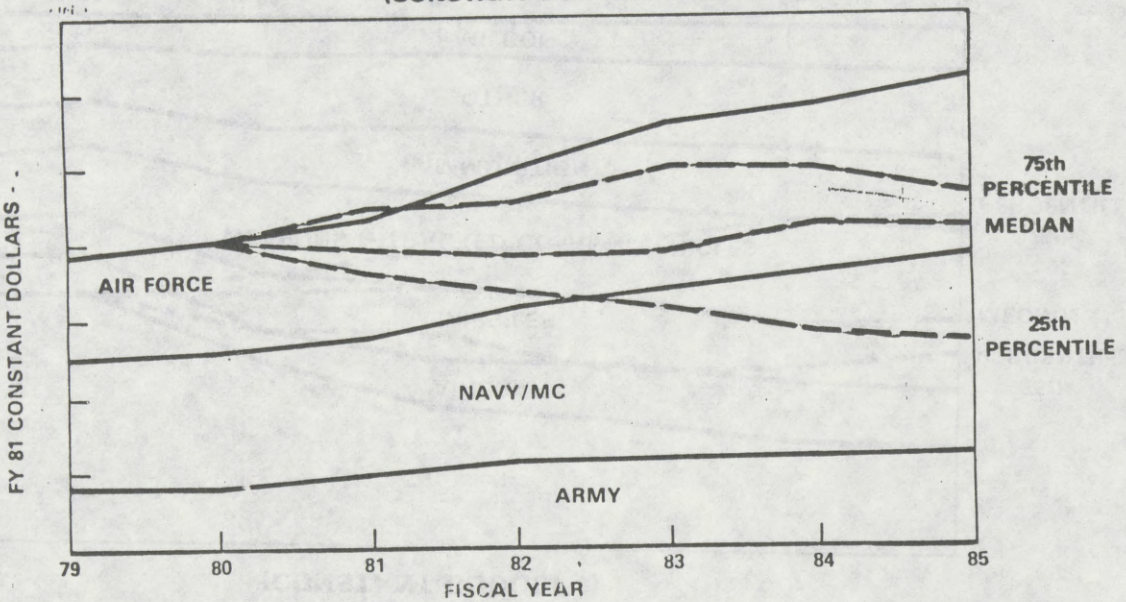
2011-0

DoD INVESTMENT PROGRAM

FY 81 PRESIDENT'S BUDGET, JANUARY 1980

(CONSTANT BUDGET $)



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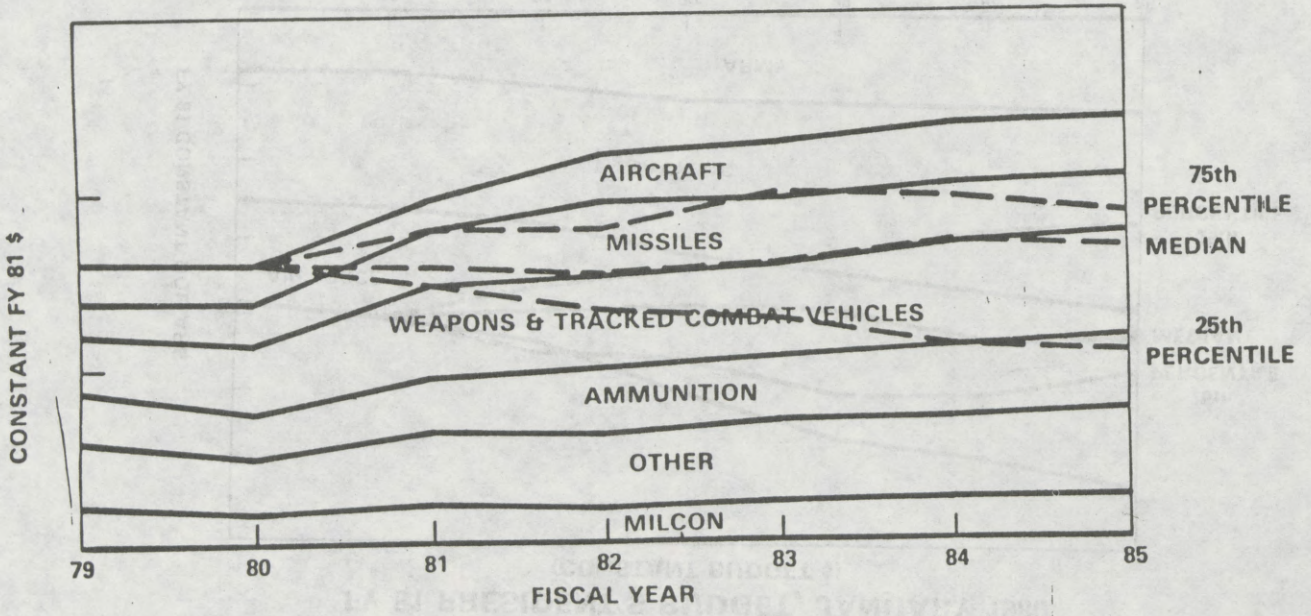
ARMY INVESTMENT PROGRAM

FY 81 PRESIDENT'S BUDGET, JANUARY 1980

(CONSTANT BUDGET $)



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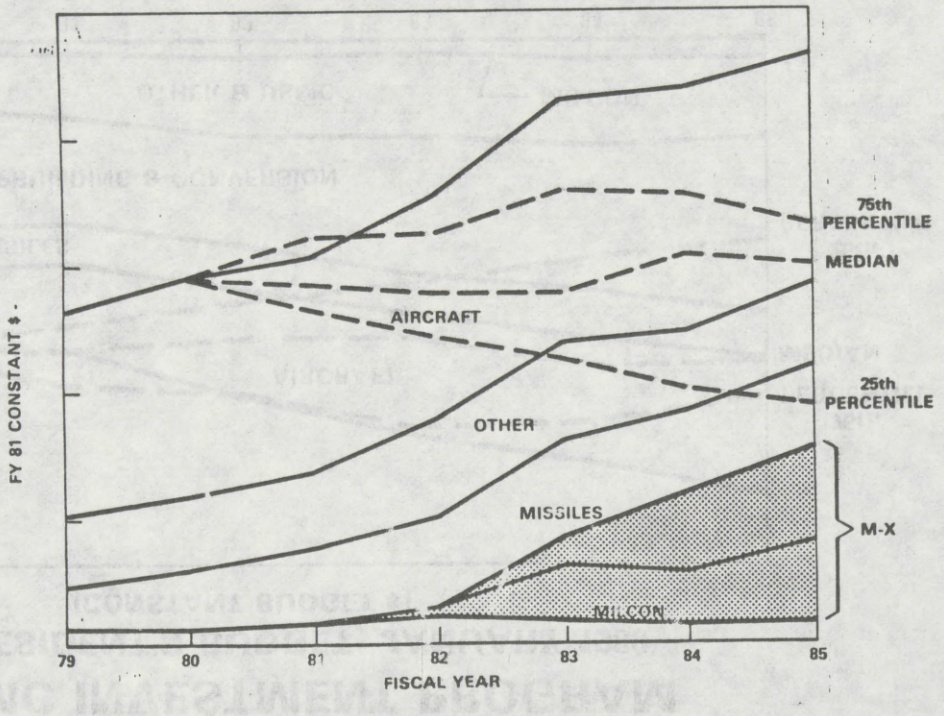
AIR FORCE INVESTMENT PROGRAM

FY 81 PRESIDENT'S BUDGET, JANUARY 1980

(CONSTANT BUDGET $)



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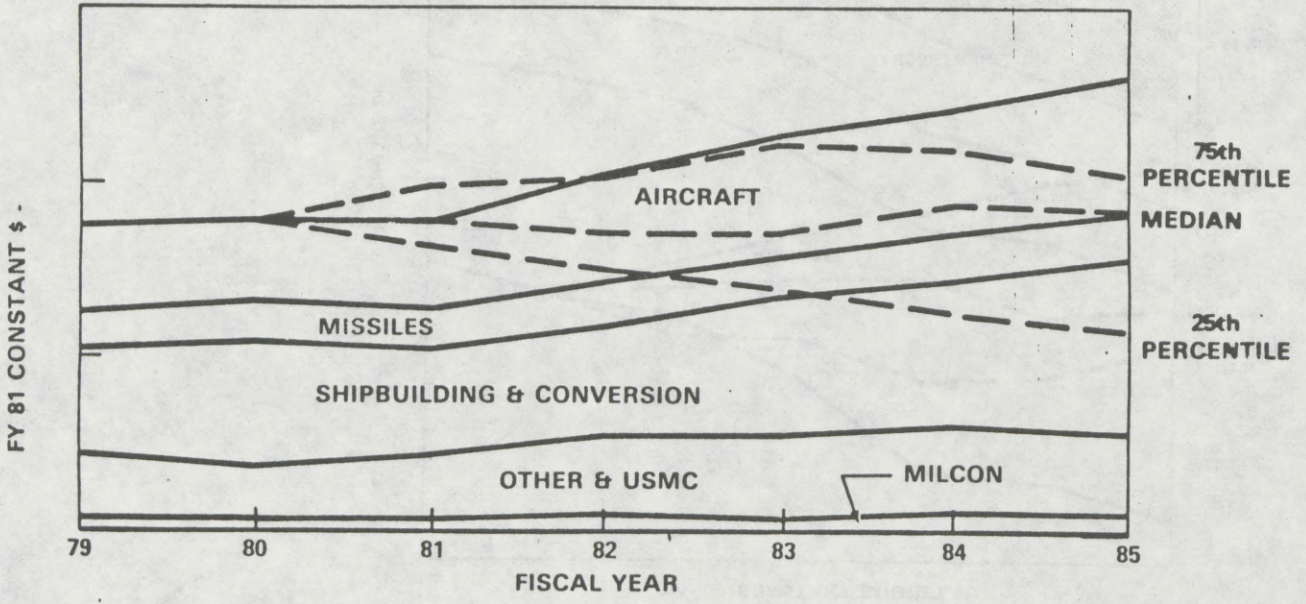
NAVY/MC INVESTMENT PROGRAM

FY 81 PRESIDENT'S BUDGET, JANUARY 1980

(CONSTANT BUDGET $)



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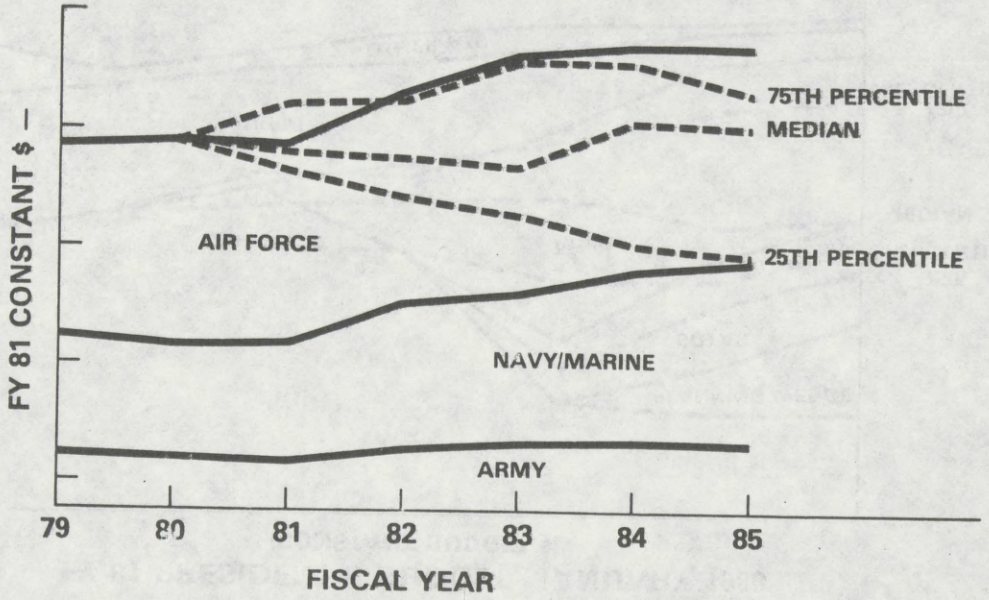
AIRCRAFT PROCUREMENT
FY 81 PRESIDENT'S BUDGET, JANUARY 1980
(CONSTANT BUDGET $)



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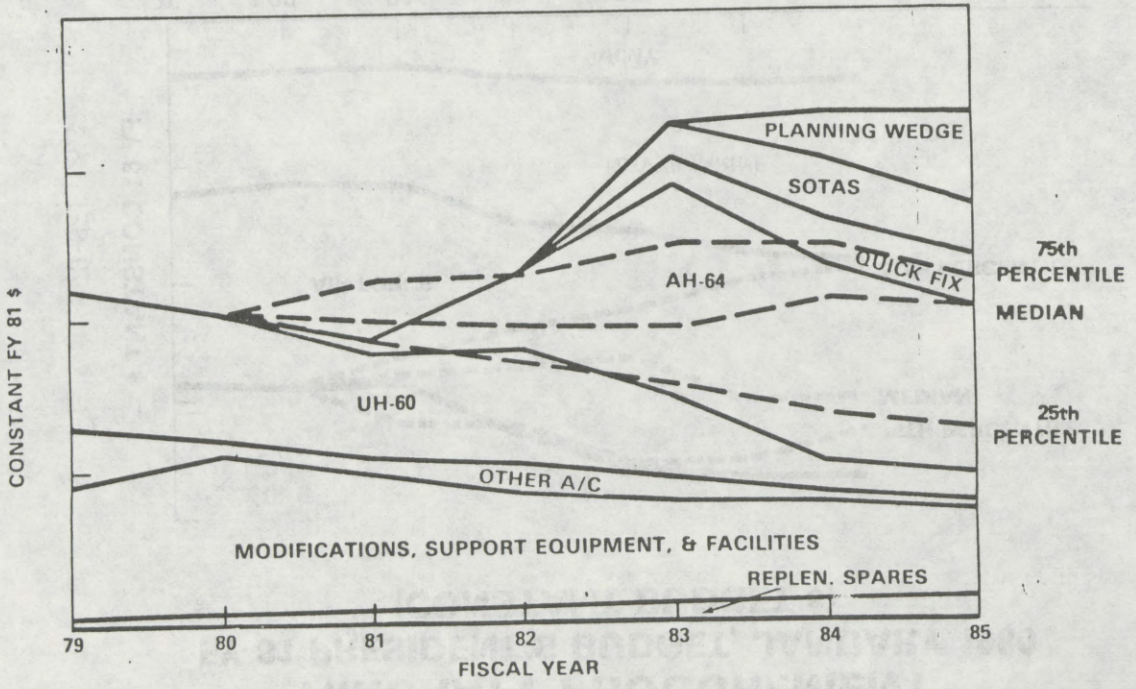
ARMY AIRCRAFT PROCUREMENT

FY 81 PRESIDENT'S BUDGET, JANUARY 1980

(CONSTANT BUDGET $)



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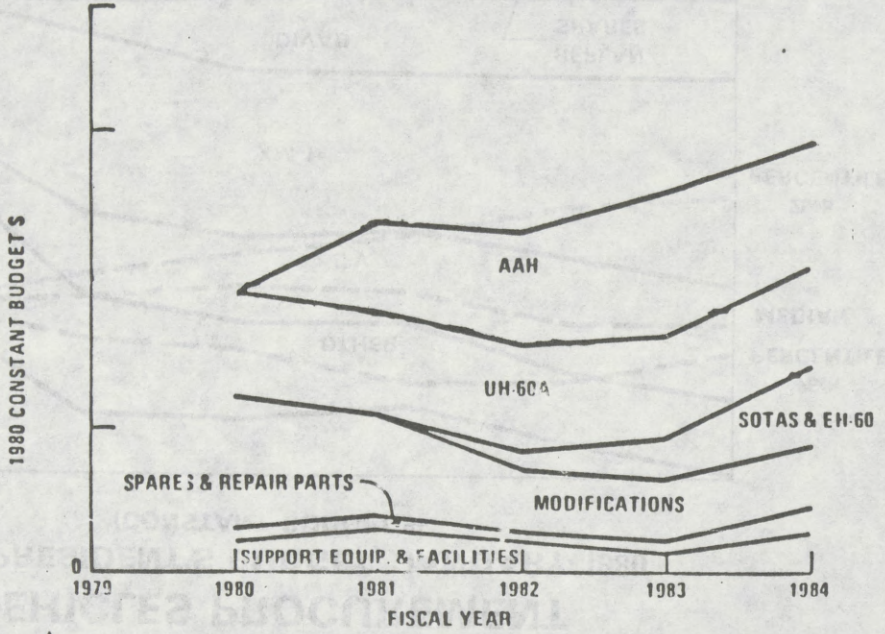
ARMY AIRCRAFT PROCUREMENT

FY80 PRESIDENT'S BUDGET, JAN 1979

(CONSTANT BUDGET $)



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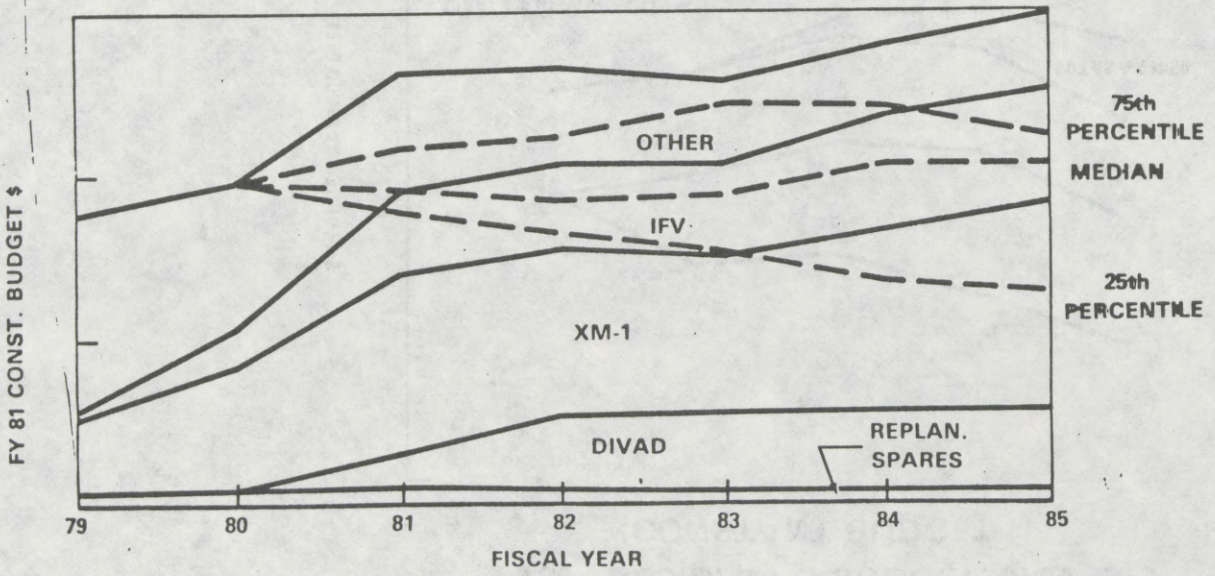
ARMY WEAPONS & TRACKED COMBAT VEHICLES PROCUREMENT

FY 81 PRESIDENT'S BUDGET, JANUARY 1980

(CONSTANT BUDGET $)



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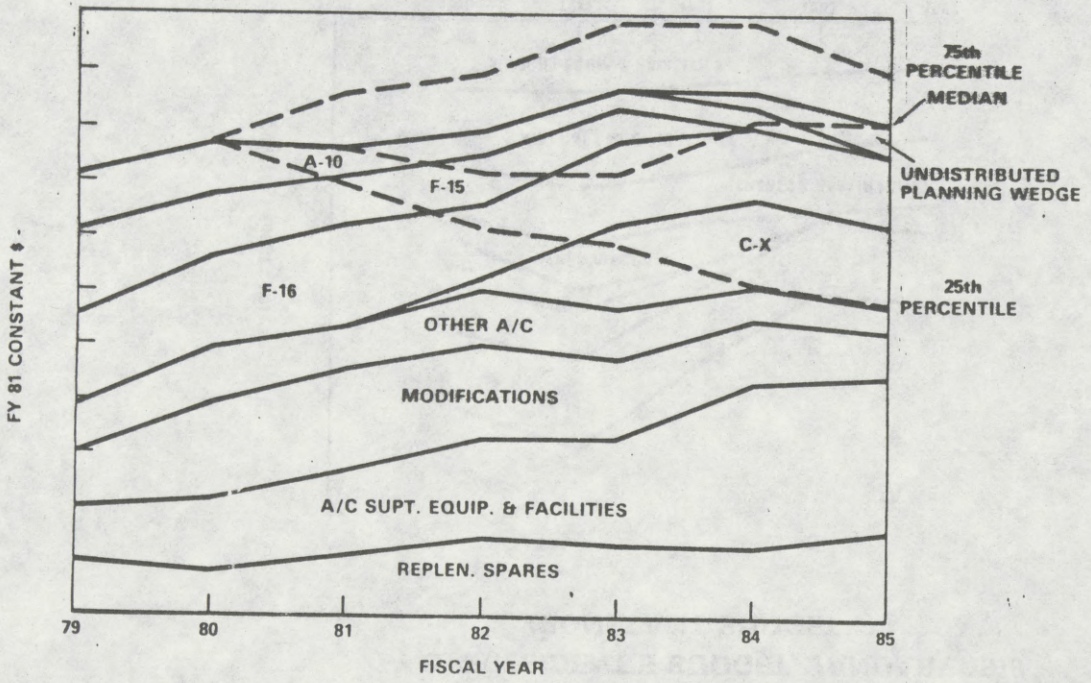
AIR FORCE AIRCRAFT PROCUREMENT

FY 81 PRESIDENT'S BUDGET, JANUARY 1980

(CONSTANT BUDGET $)



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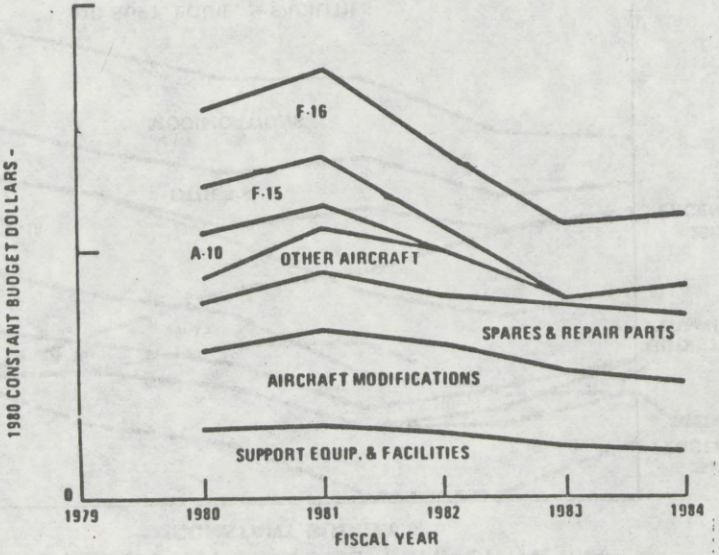
AIR FORCE AIRCRAFT PROCUREMENT

FY 80 PRESIDENT'S BUDGET, JANUARY 1979

(CONSTANT BUDGET $)



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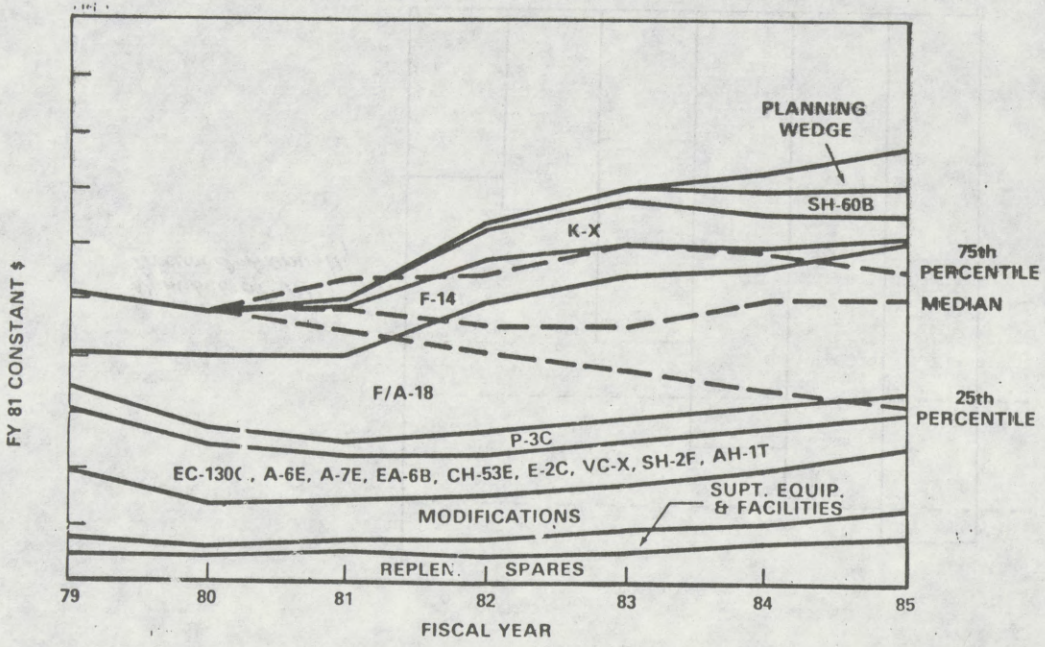
NAVY/MC AIRCRAFT PROCUREMENT

FY 81 PRESIDENT'S BUDGET, JANUARY 1980

(CONSTANT BUDGET $)



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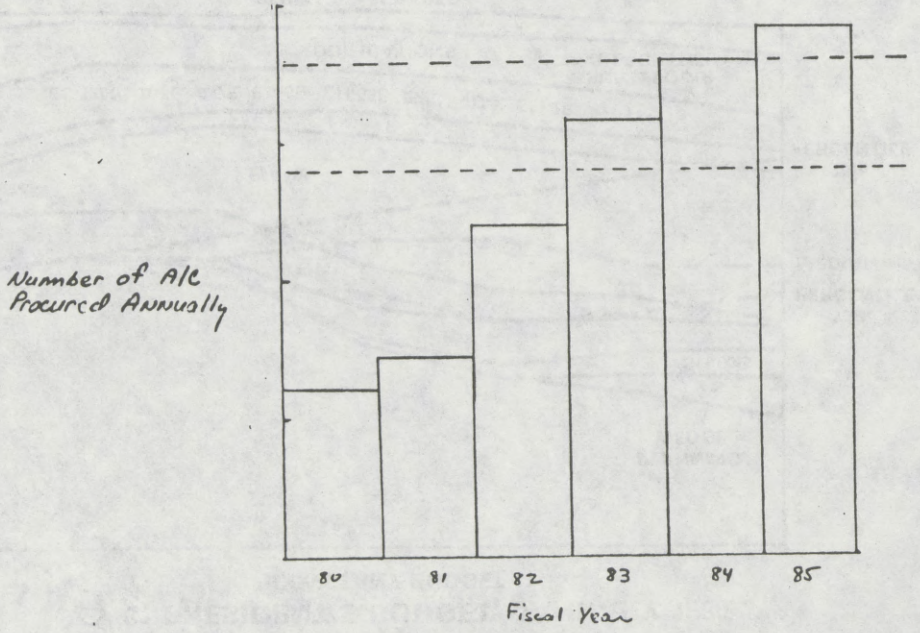
NAVY/MC FIGHTER/ATTACK PROGRAM

FY 81 President's Budget, January 1980

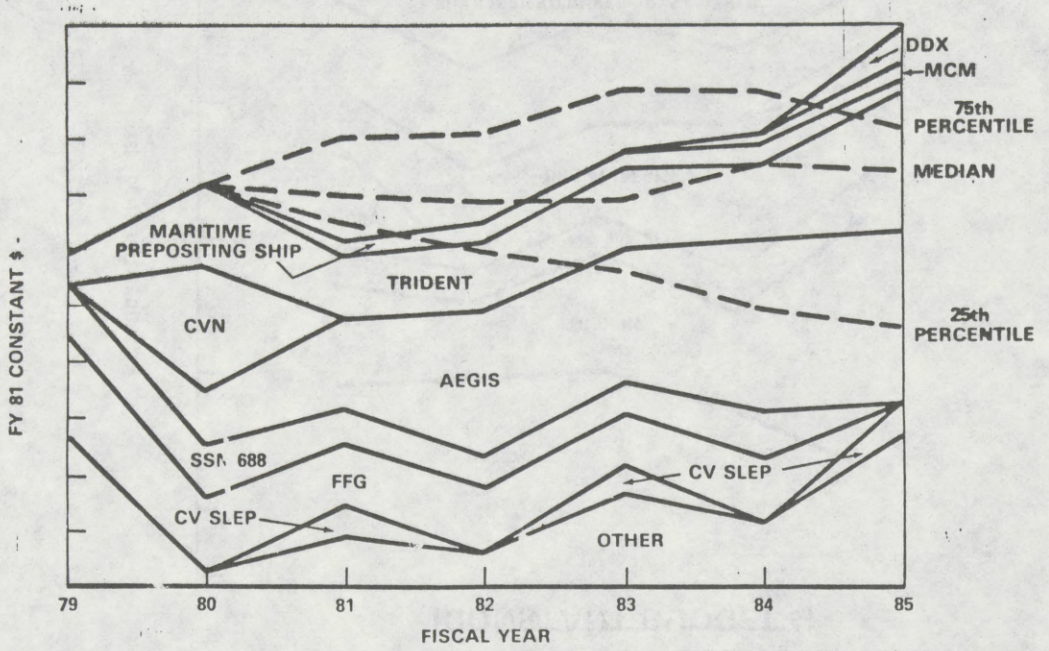


Slide 63

NAVY SHIPBUILDING AND CONVERSION

FY 81 PRESIDENT'S BUDGET, JANUARY 1980

(CONSTANT BUDGET $)



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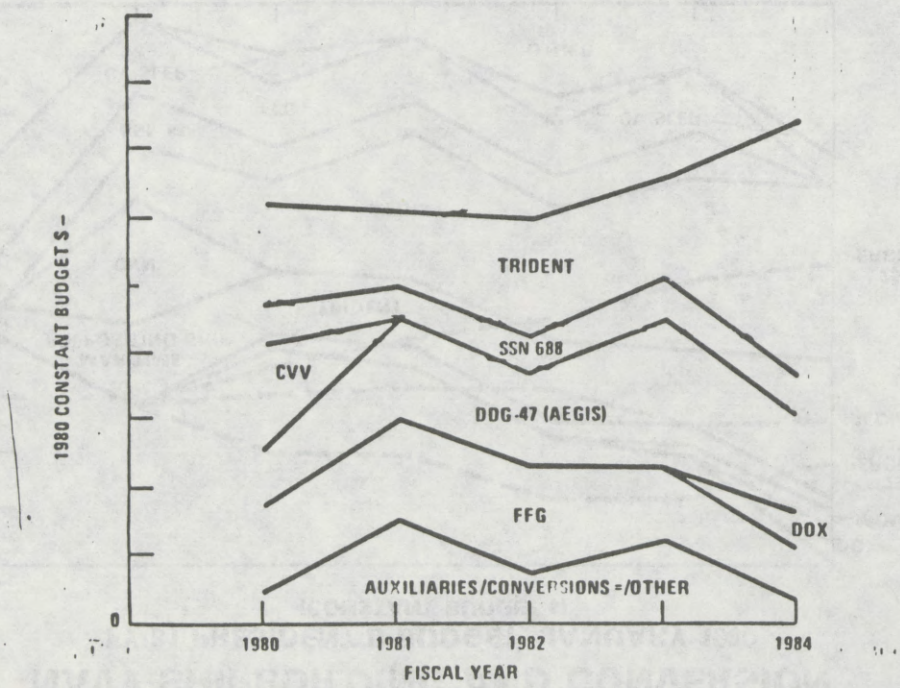
NAVY SHIPBUILDING & CONVERSION

FY80 PRESIDENT'S BUDGET, JAN 1979

(CONSTANT BUDGET $)



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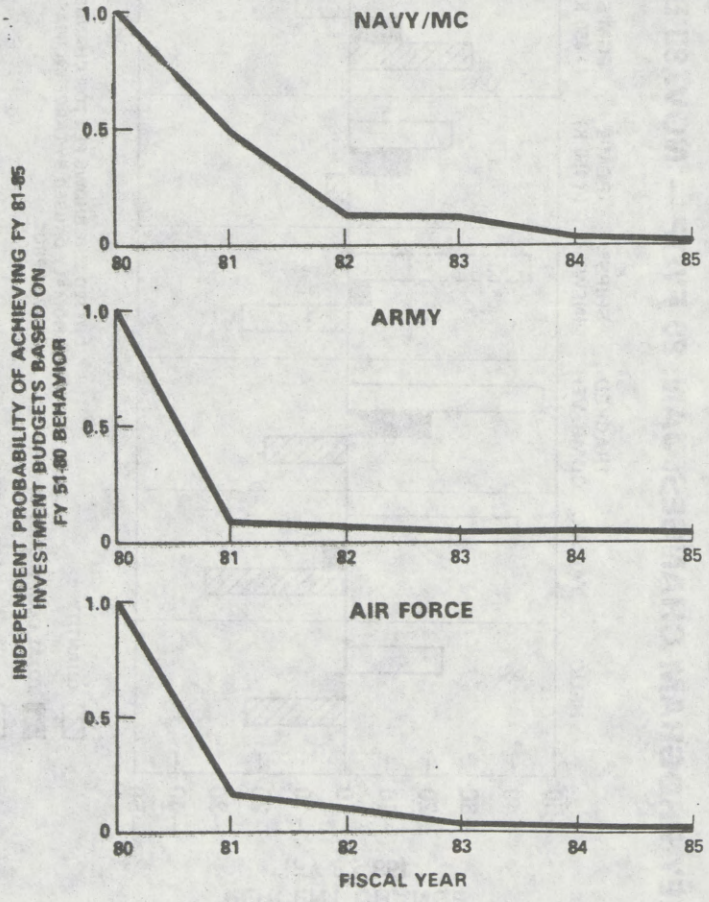
INVESTMENT PLANS:
HOW DO FUTURE DESIRES COMPARE TO PAST REALITY?



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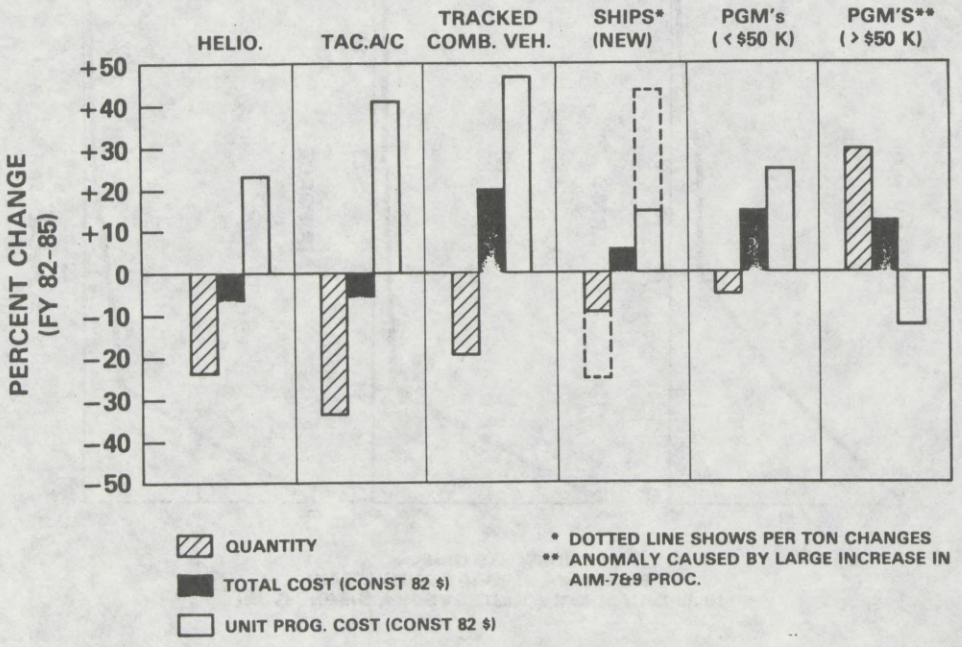
1660-0

UNIT COST GROWTH
MAGNIFIES COST OF CHANGE
(KEY PROGRAM CHANGES: JAN. 80 FYDP — NOV. 80 BES)



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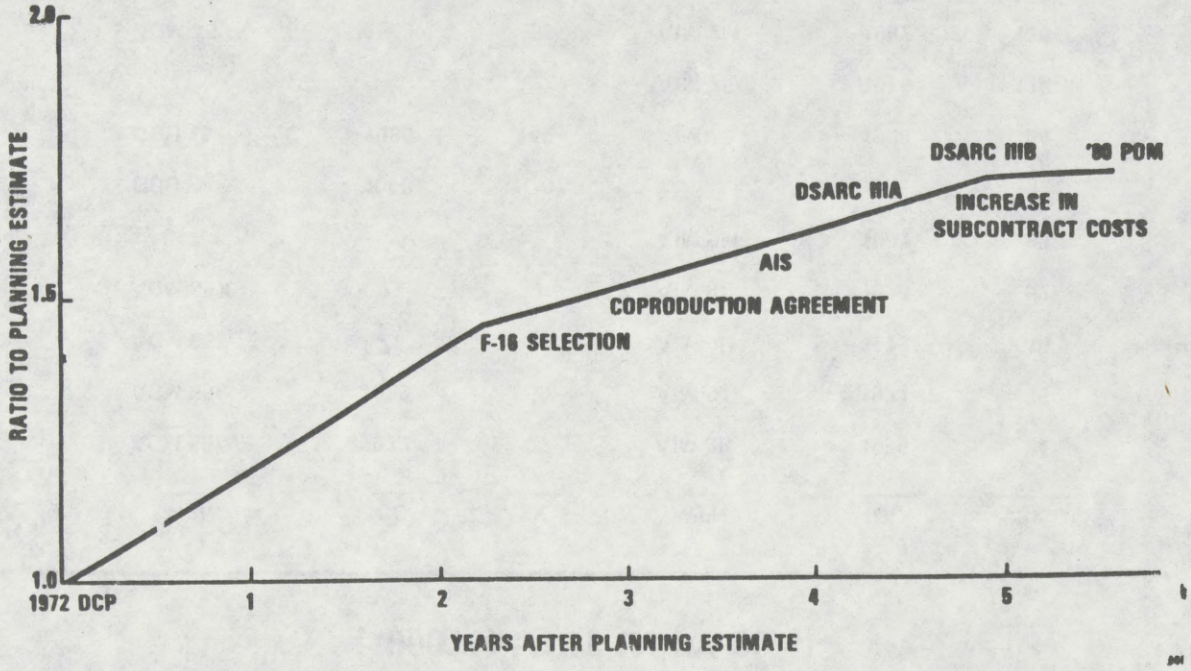
LWF/F-16 PROGRAM COST

(CONSTANT FY 75 DOLLARS, 650 AIRCRAFT PROGRAM)



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THE INCREASING COST OF AIR-DELIVERED ORDNANCE
(1000TH UNIT IN FY 80 $)

WPN	IOC	$K	WPN	IOC	$K
AGM-65A/B	1973	27	AIM-9B	1956	24
AGM-65C	1982	59	AIM-9J	1971	30
AGM-65D	?	77	AIM-9H	1973	44
AGM-65X	?	?	AIM-9L	1978	52
			AIM-9M	1981	83
GBU-8	1968	24			
GBU-15	1980	142	AIM-7E	1968	54
			AIM-7F	1976	118
AGM-45	1963	53	AIM-7M	1982	130
AGM-88	?	148	AMRAAM	?	154

1968 0

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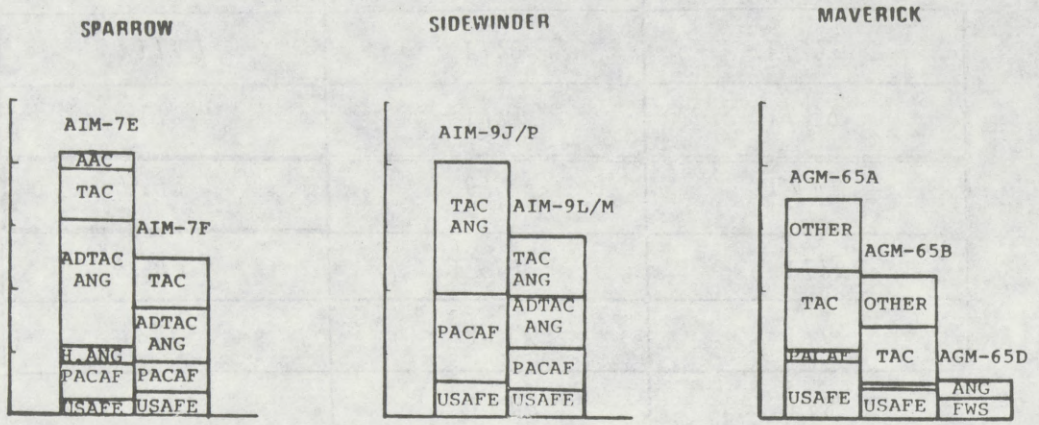
MISSILE FIRING PROGRAM

(FY 86)



SOURCE: PT82, USAF Program
Tactical Air Missiles
30 September 1980

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AIR COMBAT EFFECTIVENESS ANALYSIS (Cont'd)

EXCHANGE RATIOS

	THREAT MIG-21F, AIM-9J	THREAT MIG-21F, AIM-82/30°	THREAT MIG-21F, AIM-82/50°
F-15 AIM-9J	18/1	1/2.3	1/8
, AIM-9E (X)	22/1	1/1.6	1/6
, AIM-9K / 50°	245/1	1.7/1	1/2
, AIM-82 / 50°	955/1	6/1	1.4/1
F-4, AIM-9J	1/6	1/41	1/159
, AIM-9E (X)	1/4.7	1/20	1/39
, AIM-9K / 50°	1.2/1	1/2.3	1/5
, AIM-82 / 50°	5/1	1.8/1	1/1.4

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IMPACT

LONG TERM WEAPONS COST GROWTH PRECLUDES MAJOR INCREASES IN FORCE STRUCTURE

RESULT

WE PERCEIVE INCREASING PRESSURE TO DEVELOP A MECHANISM TO "EFFICIENTLY ALLOCATE SCARCE ATTACK ASSETS" AGAINST A NUMERICALLY SUPERIOR ENEMY

I.E., WE NEED FORCE MULTIPLIERS

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FORCE MULTIPLICATION

- NEED A THEATER SURVEILLANCE SYSTEM TO SEE BIG PICTURE
  - -- MUST ACQUIRE, PROCESS, AND INTERPRET VAST QUANTITIES OF SENSOR DATA
- NEED A BATTLE MANAGEMENT SYSTEM TO CENTRALIZE DECISION-MAKING
- NEED A DETAILED WEAPON ASSIGNMENT AND ENGAGEMENT SYSTEM

NECESSARY CONDITION:

SECURE, RELIABLE, JAM-RESISTANT, HIGH-CAPACITY COMMUNICATIONS SYSTEM

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FORCE MULTIPLICATION - (Continued)

TO FORCE MULTIPLY IN COMBAT WE WILL NEED A WELL OILED TECHNOLOGICALLY SOPHISTICATED COMPLEX INCLUDING --INTER ALIA--SENSORS, DATA LINKS, COMPUTERIZED PROCESSING AND FUSION CENTERS, PRECISE GEO-POSITIONING SYSTEMS, STAND-OFF COMMAND GUIDED WEAPONS.

SYSTEMS REQUIRED: PLSS, AWACS, QSR, JTIDS, PAVE MOVER, GPS, LORAN, BETA, TR-1, GBU-15 . . . . . .

SOLUTION: MORE COMPLEXITY

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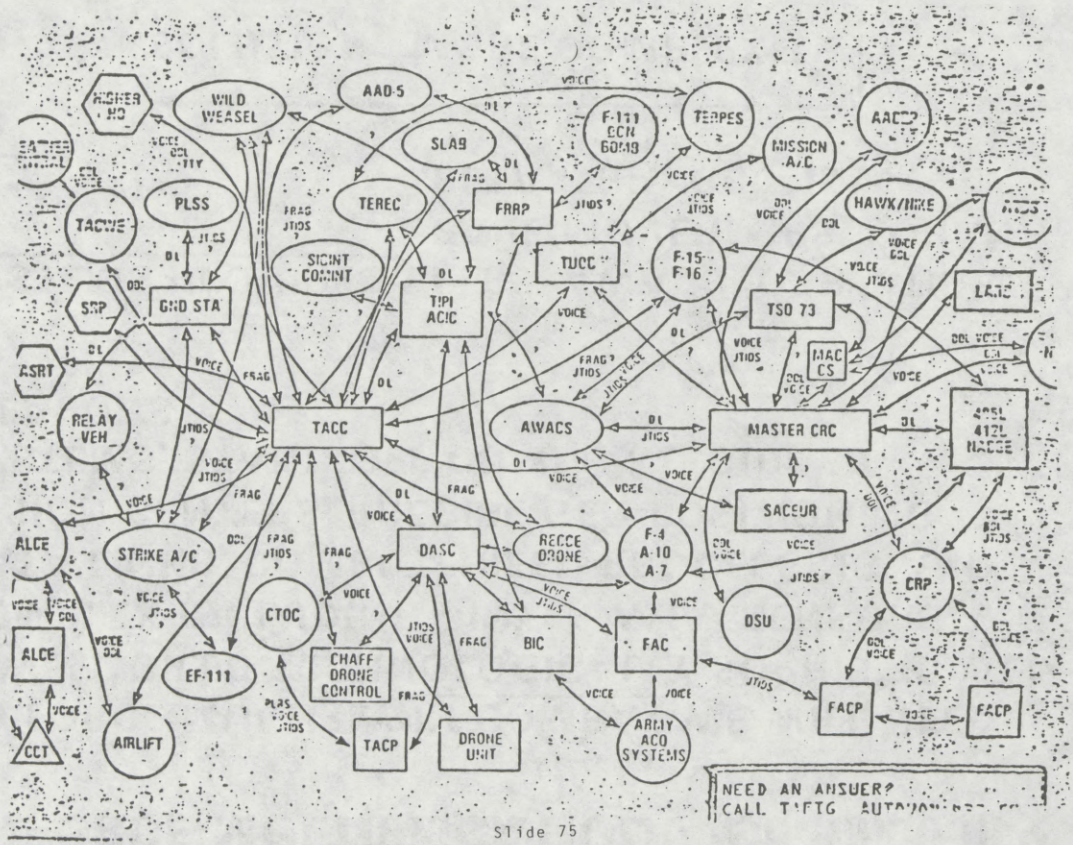
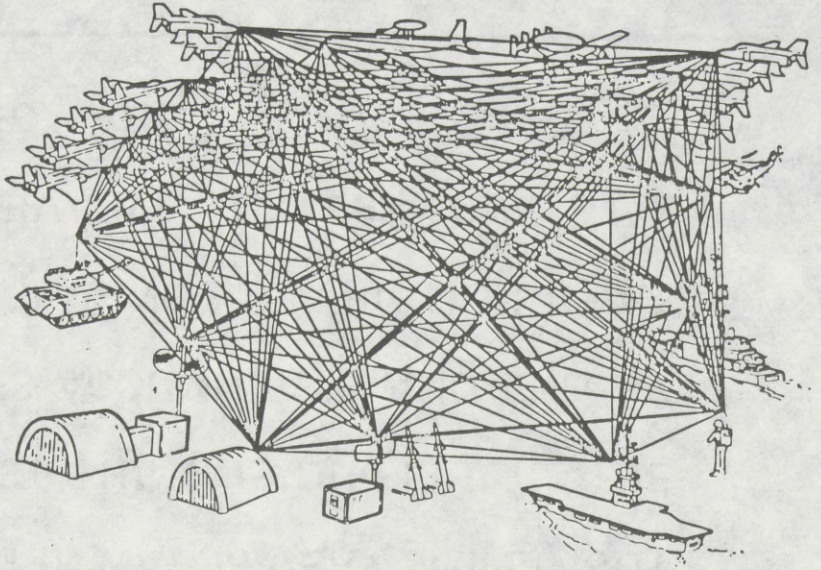

WILD WEASEL
AADS
SLAB
F-111 GCN GCMS
TERPES
MISSION A/C
AACP
HAWK/NIKE
PLSS
TEREC
FRRP
TACNE
SIGINT COMINT
TUCC
F-15 F-16
SRP
GND STA
TIPI ACIC
TSQ 73
MAC CS
ASRT
RELAY VEH
TACC
AWACS
MASTER CRC
SACEUR
ALCE
STRIKE A/C
DASC
RECCE DRONE
F-4 A-10 A-7
CRP
CTOC
OSU
BIC
FAC
CHAFF DRONE CONTROL
EF-111
FACP
TACP
DRONE UNIT
AIRLIFT
CCT
ARMY ACO SYSTEMS
NEED AN ANSWER?

Slide 75

JTIDS

INFORMED PILOTS KILL MORE AND LIVE LONGER



CONTRACT SPONSOR ESD
CONTRACT NO. F19628-78-C-0001
PROJECT NO. 5170
DEPT. D31

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EVERYTHING IN WAR IS VERY SIMPLE, BUT THE SIMPLEST THING IS DIFFICULT. THE DIFFICULTIES ACCUMULATE AND END BY PRODUCING A KIND OF FRICTION THAT IS INCONCEIVABLE UNLESS ONE HAS EXPERIENCED WAR.

CARL VON CLAUSEWITZ

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CLAUSEWITZ ON FRICTION IN WAR

- FRICTION IMPEDES THE SMOOTH FUNCTIONING OF THE MILITARY MACHINE
- FRICTION IN WAR INCLUDES:
  - FOG OF WAR: DECISIONS MUST BE BASED ON IMPERFECT INFORMATION
  - PSYCHOLOGICAL PRESSURE
  - PHYSICAL STRESS ON MEN AND MACHINES
  - THE UNEXPECTED

FRICTION DISTINGUISHES REAL WAR FROM WAR ON PAPER

ONLY ONE LUBRICANT REDUCES FRICTION:

COMBAT EXPERIENCE

- QUESTION: DOES INCREASING COMPLEXITY INCREASE OR REDUCE FRICTION?

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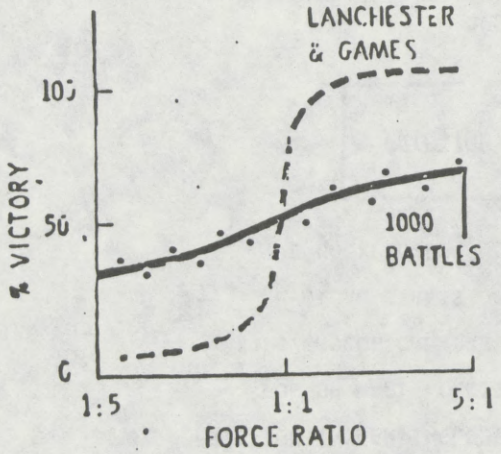
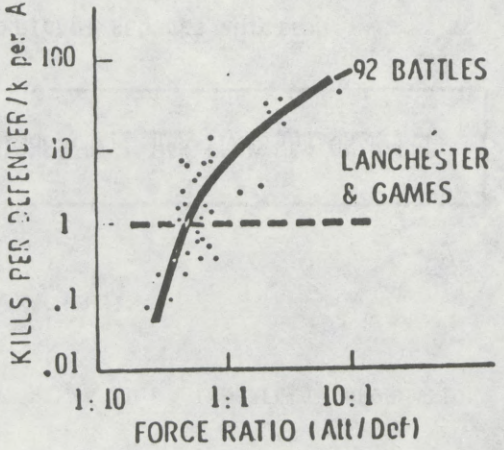
Example:

FAILURE OF BATTLE OUTCOMES TO CONFIRM MODELS



REF: D. WILLIARD (ORSA)



REF: R. HELMBOLD (NATO)

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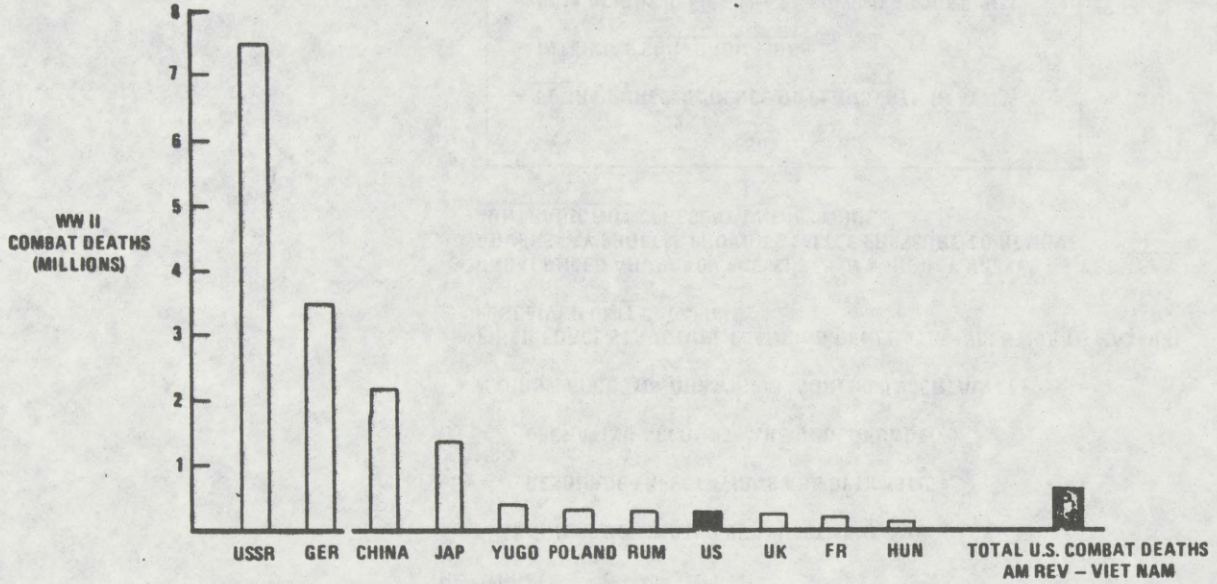
THE STRATEGY OF ATTRITION

QUESTION: CAN THE U.S. ENDURE THE PAIN? 1/



1/ PARTICULARLY – IS THIS STRATEGY REALISTIC AGAINST RUSSIANS?

84 8

Slide 80

OBSERVATION

- DECISIONS AND PLANS LACK DISCIPLINE: FOCUS IS ON "BITS AND PIECES", NOT THE "WHOLE"
  - PLANNING IS DOMINATED BY INVESTMENT ADVOCACY
    - -- RESOURCE EXPECTATIONS ARE OPTIMISTIC
    - -- OPERATING ACCOUNTS ARE UNDERFUNDED
  - NARROW FOCUS IGNORES "REAL WORLD" UNCERTAINTY
  - FIXED FORCE STRUCTURE PLANNING GENERATES INCENTIVE TO MAXMIZE PERCEIVED UNIT CAPABILITY
  - UNBALANCED ADVOCACY PRESSURES IN A HIGHLY VISIBLE -- YET WEAK -- ADVERSARY PROCESS PROVIDES LITTLE PRESSURE TO REMOVE CONTRADICTIONS PRESENT IN THE "WHOLE"

RESULT

- POOR CORRESPONDENCE OF PLANS WITH REALITY
- INTERNAL CONTRADICTIONS
- FALLACIOUS BELIEF THAT GROWING BUDGET WILL SOLVE PROBLEMS

3485 9

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OBSERVATION

INVESTMENT PLANNING IS DOMINATED BY A REQUIREMENTS PROCESS THAT:

- CLEARLY DEFINES AN UNCERTAIN FUTURE THREAT
- RIGIDLY SPECIFIES THE OPERATIONAL NEED
- DOES NOT ADDRESS IMPLICATIONS OF RESOURCE CONSTRAINTS

RESULT: ABSOLUTE THINKING LEADS TO INTOLERANCE

- ALTERNATIVES ARE ELIMINATED
- COMMITMENT TO PREFERRED SOLUTION IS STRICTLY ENFORCED
- OBJECTIVITY, CREATIVITY, AND CRITICISM ARE DISCOURAGED

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OBSERVATION

- REAL WORLD CRITERIA FOR JUDGING THE TECHNOLOGY TO SUPPORT HUMAN ACTIVITY IN WAR IS NOT CONSIDERED IN DECISIONMAKING AND PLANNING
  - THERE IS NO ORGANIZATION CHARGED WITH UNCOVERING THE PATTERNS UNDERLYING HUMAN CONFLICT AND HOW THESE CAN BE EXPLOITED BY EMERGING TECHNOLOGIES
  - DECISIONS ARE SUPPORTED BY THEORETICAL MODELS, NOT HISTORICAL ANALYSES
  - THERE IS A LACK OF COMBAT DATA TO VALIDATE MODELS AND TESTING

RESULT: THE NEW RELIGION

- A SELF-REINFORCING -- YET SCIENTIFICALLY UNSUPPORTABLE -- FAITH IN THE MILITARY USEFULLNESS OF EVER INCREASING TECHNOLOGICAL COMPLEXITY
- MECHANISTIC SOLUTIONS THAT PRESUME MILITARY UTILITY CAN BE EQUATED TO PRECISE ENGINEERING SPECIFICATIONS

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3485 9

INCREASING WEAPONS COMPLEXITY REDUCES COMBAT READINESS

- DEGRADES COMBAT SKILLS BY CAUSING INADEQUATE AND UNREALISTIC TRAINING
- INCREASES RELIABILITY AND MAINTAINABILITY PROBLEMS
- INCREASES COST OF MAINTENANCE
- INCREASES DEPENDENCE ON LARGE VULNERABLE SUPPORT BASE
- INCREASES ECONOMIC INEFFICIENCY OF PLANS
- SLOWS MODERNIZATION BY INCREASING DEVELOPMENT/PROCUREMENT LEAD TIMES
- MULTIPLIES MAGNITUDE AND LIKELIHOOD OF DISASTER
- INCREASES VULNERABILITY TO COUNTERMEASURES
- CUTS FORCES, SUPPLIES, AND MUNITIONS TO INADEQUATE NUMBERS

QUESTION

DO THE DISTINCTIVE CHARACTERISTICS GENERATED BY WEAPONS COMPLEXITY COMPENSATE FOR THESE NEGATIVE QUALITIES?

3451 9

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FINDING

PLANNING APPEARS TO BE INDEPENDENT OF:

- THREAT
- BUDGET

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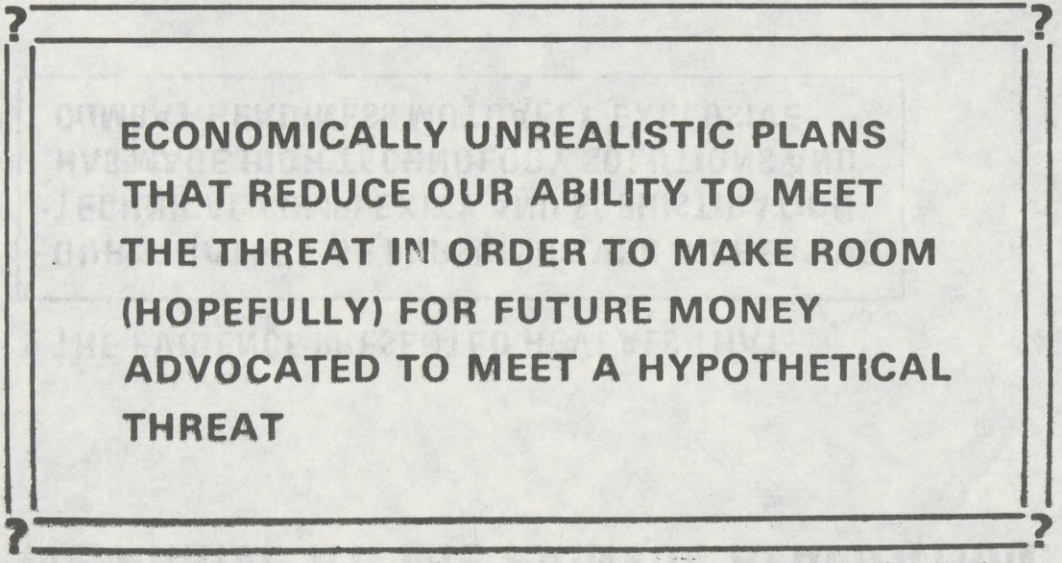
...OR PUT ANOTHER WAY, THE FUTURE CONSEQUENCES OF TODAY'S DECISIONS ARE:



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THUS WE ARRIVE AT THE PAINFUL REALIZATION:

THE EVIDENCE PRESENTED REVEALS THAT:

OUR STRATEGY OF PURSUING EVER INCREASING TECHNICAL COMPLEXITY AND SOPHISTICATION HAS MADE HIGH TECHNOLOGY SOLUTIONS AND COMBAT READINESS MUTUALLY EXCLUSIVE.

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