Some of these can deliver benefits in the next decade. Others promise dramatic new capabilities after the turn of the century.

Ripe Technologies

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NEW military capabilities spring from several roots. One is the conventional, well-understood requirements process, in which the operational commands specify the features and characteristics they desire in weapon systems for the future. There is much to be said for this approach, but it tends mainly to seek improved variations on existing systems.

Another source of new capabilities is the push by zealous advocates for some technological opportunity, frequently in the face of a "show-me" attitude, or even a negative attitude, on the part of the operational community and approval authorities.

I worry that if we depend too much on the former "pull" process to the exclusion of the latter "push" stimulation, we will become trapped in incrementalism and fail to achieve important outflanking capabilities. It was pursuit of technological opportunity in the past that led to the development of ballistic missiles, space surveillance and communications systems, AWACS, cruise missiles, and stealth.

Despite the declining condition of the technology base *(see accompanying box),* opportunities today are ripe or ripening. For practical reasons, it is useful to divide them into two categories: technologies that can deliver benefits in the next decade and those that hold promise of dramatic new capabilities in the early twenty-first century.

The lengthy defense acquisition process probably precludes the fielding of any significant new weapon system capability in this century unless development has already begun. The defense budget outlook exacerbates that problem. Shorter lead times are still possible, though, in the case of lesser system capabilities or improvements to existing capabilities.

The Department of Defense and the Air Force are already committed to a substantial acquisition program for much of the next decade. In fact, it will be a major challenge to maintain support for all of these programs. At the same time, the services must assimilate the numerous new systems and capabilities they have acquired recently, plus those that will be coming out of development in the next few years.

It seems clear that there will be little room for additional major acquisitions. That being the case, my list of ripe technologies for the next decade emphasizes those that could aid with the assimilation of new weapon systems or those that might enhance their planned capabilities.

Improving O&M

First, consider how technology could improve the productivity of maintenance and training, achieve a substantial reduction in operations and maintenance costs, and ameliorate the budget problem.

The technology is at hand for big improvements in every aspect of maintenance. All maintenance requirements and diagnostic and repair procedures could be managed in a distributed digital network system. This system would be supported by a common distributed database containing all weapon system design and configuration information needed for Air Force purposes. It could also satisfy the data needs of contractors and suppliers.

The networks would extend all the way to the maintenance technician on the flight line. His tasks would be accomplished with the aid of a small interactive terminal by which he could obtain all necessary instructions and diagnostic assistance. This same system would be linked with the supply system to call up replacement parts. Paper would be eliminated. The system will also facilitate changes and improve responsiveness.

Training would be simplified and skill requirements would be reduced. I believe that new trainees could learn and adapt more readily to such a computer-based system than to our current paper-intensive maintenance system.

The long-term O&M savings potential is very great. The challenge is how to introduce such a change into our large, existing, multi-weapon-system, paper-dependent logistics environment.

Much of industry has already made such a transition. Some recent Air Force initiatives have taken a step in that direction, but widespread implementation still lies ahead. It is clear that the force will operate in this manner in the future. The only question is: How soon? The investment, although not inconsequential, could be amortized over a few years, after which large savings would result.

Technology is also available to ease the problems of rising costs and environmental constraints on realistic combat training. DARPA and the Army have made considerable progress in multiplayer exercise training, linking together many low-cost simulators by means of a high-data-rate digital network called SIMNET. They have proven that this system provides valuable individual and team training to tank and helicopter crews.

A similar approach could be useful in aircrew training. An easy first step could be taken in close air support and battlefield interdiction. Low-cost aircraft simulators might be linked not only to each other but also to Army simulators. In addition to its training value, the network would be a tactics development tool. The concept could be expanded into other air operations areas as users gain experience. Several companies, including McDonnell Douglas and British Aerospace, have already started "linked simulator" systems for air-to-air combat.

Still other simulation schemes are within sight, thanks to the availability of relatively low-cost, high-capacity digital data links and remarkable advances in digital scene generation and projection.

For example, with the avionics data bus architecture of our current-generation aircraft, it would be possible to link the cockpits of operational aircraft to a simulation module, enabling pilots to rehearse their planned mission. By linking several such cockpits together, a capability

Our Store of Technology Is Becoming Sparse

Today, we are reaping the fruits of wise technology investments made in the past. Our current generation of military systems and the even more capable ones now emerging would not have been possible had it not been for the technology base.

These systems are the outgrowth of tech base projects in such areas as inertial guidance; advanced turbine technology; fly-by-wire controls; terrain comparison and matching guidance; composite, high-temperature, and radar-absorbent materials; forward-looking infrared sensors; synthetic aperture radars; and multimicro detector focal plane arrays.

Now, however, there are disquieting indications that the health of our technology base is not what it should be and that the favorable development conditions we enjoyed in the past may not exist in the future. Air Force investment in the technology base in constant dollars has declined since the early 1960s. Except for a short period of modest growth—four percent a year—from 1982 through 1986, it is still declining.

The OSD annual assessment clearly shows that our lead over the USSR in a number of important military technology areas is dwindling. The more pronounced narrowing of our lead in comparison to many friendly nations in the world is equally disturbing. Although some might disagree with the evaluation of our current relative position in specific technology areas, none denies the dramatic decline of our lead over the short period of the last ten to twenty years.

As we embarked on design of a new capability in earlier years, we were seldom limited by technology in establishing such criteria as the accuracy, range, or combat margin required. In most cases, the challenge was to make cost-effective choices between competing technical approaches. Usually, there seemed to be plenty of technology on the shelf to construct a winning capability.

Increasingly in recent years we have had to precede our systems efforts with a technology maturation phase. We see it in the Advanced Tactical Fighter, the Strategic Defense Initiative, space-based radar, Joint STARS, the hypervelocity missile, the B-2, the National Aerospace Plane, and other programs. We refer to this effort by such names as pre-full-scale engineering development, risk reduction, demonstration/validation, and just plain technology maturation. But the purpose is the same: to mature the key technologies involved to a point where we have sufficient confidence to proceed with a reasonably low-risk, full-scale engineering and development program. These efforts are becoming more intense and are taking longer.

Some would argue that we are reaching further with today's systems and that technology maturation is needed for that reason. I say that our store of technology on the shelf is becoming sparse.

to develop and practice team tactics might be created. I am aware of the concern that increased use of simulators may threaten the essential flying training program, but I believe that it can and should be viewed as a supplement that helps offset the limited opportunities for realistic combat-crew and joint-exercise training.

Enhancing Communications

In another area, technology is available to close the intelligence/operations gap. Great strides in sensor development have produced an ever-increasing wealth of real-time threat information and precise target location data. Unfortunately, there has not been similar progress in the effective use of this information by the combat elements.

Despite past skepticism based on disappointing results of earlier efforts, I am now convinced that communication, artificial intelligence, and processing technology are adequate to synthesize this information and present it to decision-makers in useful form in near-real time. Equally important, technology will support affordable data communications from the command centers to elements of the strike force for real-time transmission of targeting and threat-awareness information. Means will soon exist in most aircraft to provide such information to crews on their multifunction displays.

The opportunity is near at hand to break out of the twenty-four-hour planning/execution cycle that we have been saddled with since World War II.

That leads to the broader area of command and control. No one doubts that there is plentiful technology to achieve major improvements. Despite the rhetoric, false starts, and the expenditures over the past decade or so, not much progress has been made. This is particularly true of tactical command and control. The problem is not the lack of enabling technology but a fault of the requirements and acquisition processes. Existing technology could provide each command and every operating level with appropriate access to current threat data, automated tools of high quality for planning and decision-making, and real-time information on friendly and enemy forces presented on a situation display suited to that operating level.

One could argue that the 1990s ought to be the "munitions decade." There is no area where ripe technology promises more leverage in the near term. Continuing progress in sensors, microelectronics, and microprocessing makes the goal of affordable "brilliant" weapons both possible and urgent. Admittedly, these new assured-kill weapons will cost much more than older "dumb" bombs, but their effectiveness, combined with the reduced exposure of the strike aircraft, warrant the investment. More important, weapons with increased killing power are the most effective means to offset constrained force structure.

Fortunately, now we can do it. Millimeter-wave technology is sufficiently advanced from both a technical and cost viewpoint to provide a highly effective night and adverse-weather, precision-guided munitions capability. Long-range tactical standoff weapons can be made every bit as effective as direct-attack guided weapons, since infrared, millimeter wave, laser radar, and synthetic aperture radar technologies make possible accurate waypoint-fixing in midcourse as well as high-value fixed target discrimination from natural background in the target area.

We know how to reduce the observability of weapons for compatibility with our stealthy aircraft and also how to reduce the weapons' vulnerability to countermeasures. We are acquiring a complete new stable of aircraft for all mission areas. Now we have the opportunity to multiply the effectiveness of that new force with far more capable weapons. The funding requirement for such an initiative is relatively small.

Now, let's shift our focus to the longer-term technologies that hold promise for use in systems of the next century and deserve careful nurturing and demonstration today.

An Eye On the Future

Since major new system starts will be few in the coming decade, it is likely that a number of pressing needs, requiring accelerated pursuit, will emerge once funds become available. Therefore, we should attempt to minimize the technology maturation phase so frequently required today. This dictates a strong science and technology program during the 1990s. It should include key technology demonstrations to lay a solid base for follow-on engineering development programs.

We cannot know with assurance which technologies will be critical to the capabilities we will be pursuing in the next century. A great deal can happen in ten years. For perspective, consider that a decade ago we had just begun the stealth programs, the birth of SDI was still three years away, parallel processing was in its infancy, 64K RAM had just emerged, and superconductivity was only achievable at liquid helium temperatures. Acknowledging that we cannot predict all of the technologies that will be important in the early twenty-first century, we can still identify a few now that we know will be important.

Given the long, unbroken pattern of the Soviets mirroring our new capabilities, it is only a matter of time before they present us with a low-observable threat. It is essential, therefore, that we develop means to cope with such a threat. We are in a good position to focus our broad stealth technological base and our advanced sensor technologies on means to detect, track, and intercept low-observable systems. We must not let enthusiasm and advocacy for our own stealth programs inhibit an aggressive quest of countermeasures. We should pursue a priority program to prepare for the time when—not if—countermeasures are required.

Next, we should strongly support the National Aerospace Plane. Although it is now apparent that the original vision of an "Orient Express"—or even of a low-cost, single-stage-to-orbit capability—is unachievable in this century, we must continue the effort to extend our aeronautical horizon into the hypersonic.

It is easy to imagine exciting possibilities. An aerospace plane would obviously compress the time required for operations. More important, though, the aerospace plane is one of those special multidiscipline programs that by its nature advances a large number of technologies as it moves forward. Propulsion will take a giant step with the development and flight-testing of the hydrogen-fueled scramjet. The program will extend and validate hypersonic computational fluid dynamics codes, the aircraft and propulsion designer's basic design tools. It will accelerate the development of higher-strength materials and new approaches to structural design. It will force the development of advanced integrated flight and propulsion control concepts and systems. It will require advanced cooling concepts and mechanisms. I can't think of another program that promises to open up more exciting opportunities.

Today, we acknowledge the great strategic value of DSP (Defense Support Program) satellites that monitor ballistic missile activity and provide warning of attack. A complementary capability for surveillance of airborne threats would be of great value. It appears that all of the requisite technologies—radar and infrared sensors, power generation, on-board signal processing, and spacecraft construction—to make that possible and practical are near at hand. They will be a reality early in the next century. This capability should be a high-priority candidate for technology development.

The increasing role of space systems in military operations makes it unconscionable that we are denied a means to destroy such systems during war. High-powered lasers, beam forming and control, adaptive optics, and power-generation technology will soon be available to construct a highly effective, ground-based antisatellite system out to geosynchronous altitude. Just a few sites would provide the necessary coverage.

Such a system would have much better altitude and coverage capability than was provided by the abandoned F-15 miniature homing vehicle system. It seems to be an ideal candidate for technology maturation and demonstration during the next decade. Our political leadership will surely come around to acknowledging its military necessity. It also seems apparent that this is an area where we should expect aggressive defensive countermeasures. Therefore, we should pursue a vigorous technology program to cope with that eventuality.

We have seen electronics take over the management and control of all the inner workings of our systems—the operation of the aircraft's flight control system, the control of the engine, the weapon delivery, the missile guidance and fuzing, and the processing and display of nearly all of our information. It's been happening as well in ships, helicopters, tanks, artillery, and even the individual soldier's equipment. There has been a relentless trend toward miniaturization of sensor elements, microcircuitry, solid-state RF devices, microprocessors, and micromemories. We see the same trends in Soviet and Soviet-bloc equipment.

Possible Programs

One of the most serious design challenges with microelectronics is protection against spurious, unwanted signals. This characteristic of enemy equipment—and ours—is one that technology enables us to exploit. Pulse power generation and microwave amplifier and transmission technology make a high-power microwave weapon a distinct possibility. A first step could be a capability to disrupt and upset critical electronic components, followed by a capability to burn out and destroy enemy systems. We should aggressively pursue this potential high-payoff technology to position ourselves for later full-scale development.

It is likewise obvious that we must develop means to reduce our own vulnerability to similar measures from the other side.

Given the improbability of new aircraft development starts in the next decade, it is especially important that we pursue an advanced technology air vehicle program. The ongoing turbine technology and materials programs promise to double the thrust-to-weight capability of turbine engines by the end of the next decade while reducing specific fuel consumption by fifty percent. I feel comfortable with that prediction.

Remarkable advances are being made in the use of advanced, lightweight composite materials in load-bearing aircraft structures. An all-composite high-performance aircraft is now close to reality. About fifty percent of an aircraft's weight today is in the fuel and engine system. Imagine the combined effect of doubled thrust-to-weight, halved specific fuel consumption, and all-lightweight-composite structure.

It could give us short takeoff and vertical landing in a supersonic airframe, an F-15-sized machine capable of sustained speeds greater than Mach 3—or a smaller fighter with truly spectacular performance. Such possibilities mandate one or more advanced technology demonstration programs during the next decade to advance and confirm the technology base to support the full-scale development programs that are sure to follow soon after the turn of the century.

Those are some, but not all, of the opportunities. There are others, including noncooperative target recognition, unmanned vehicle applications, and autonomous guided weapons. I have deliberately avoided the topic of ballistic missile defense because I see technology supporting only a limited terminal defense of questionable value in the next decade. I do, however, support the steady pursuit of technologies that could make possible a highly capable, cost-effective system after the turn of the century.

Nothing has been said here about superconductivity, extra-smart unmanned vehicles, highly maneuverable space vehicles, directed-energy weapons for combat aircraft, or superenergetic propellants and explosives. I feel sure that most of these are in our future, but they require further development in the technology base. I wonder, though, if they might have been on my list had the technology base received stronger support over the past decade or two. ■

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