Naval War College Review

Volume 32
Number 1 *Winter*

Article 5

1979

Technology and Warship Design: Capturing the Benefits

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The Admiral Richard G. Colbert Memorial Prize is awarded each year to the Naval War College student author of the best of the professionally worthy essays submitted in competition for the prize. The 1978 winner argues herein for an understanding and exploitation of the benefits technology can lend to the design and production of warships.

TECHNOLOGY AND WARSHIP DESIGN:

CAPTURING THE BENEFITS

by

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One need not dwell on the wonders or the progress of modern technology; moon landings, hand-held computers, and microwave cooking are part of the everyday vocabulary of today's elementary school pupil. Even more advanced concepts are well within the understanding and common use of high school and undergraduate students: microcircuitry, nuclear fission, Venus probes, solar energy cells.

The most striking characteristic of technology, however, is not its present level but the rate at which it is evolving. Civilization's rate of technological growth, which for several thousand years had been immeasurably ponderous, is now exponential. The reason for this is that technology feeds on itself. Advanced technology makes even more advanced technology possible, and the cycle of invention, innovation, exploitation, and diffusion becomes shorter and shorter, eventually overlapping itself. The development of microcircuitry and silicon chips, for example, has been described as having the same force and significance as that of the development of handtools or the discovery of the steam engine.[1]

Today's naval warships can and do claim benefits from this technological explosion: missiles instead of guns, electronic sonar signal processing, the computerized Naval Tactical Data System, nuclear propulsion (in some cases), "smart" bombs. In today's smaller Navy it is claimed that technological quality is the replacement for quantity and recruiting posters imply that a tour of duty in the Navy will provide a young man or woman with the equivalent of an advanced scientific degree.

The application of technology to today's warships is indeed praiseworthy, but it is not unreasonable to ask whether maximum application of technology is being made. Are our warships getting as much out of today's technology as they should? Will future warships be as technologically advanced as they could be?

Before addressing these questions, it is appropriate to provide some perspective by examining a few projections of the future. Predicting the future is admittedly a risky business because of gross uncertainties in the speed and direction in which we are moving. Military technology, in particular, is difficult to forecast because so many nontechnological uncertainties (the budget, politics, national strategy) affect the speed and direction of movement. Nevertheless, it is safe to say that, as in the past, our wildest expectations may be exceeded.

Kahn and Wiener[2] have prepared long lists of innovations that may appear in the last third of the 20th century. In order to illustrate where warship design could be headed, I have chosen several items from these lists. In reviewing these items, one should keep in mind that the Kahn-Wiener projections address the period 1967-1999, a relatively *short*-range view:

Multiple applications of lasers and masers (sensing, measuring, communications, welding, power transmission, weapons).

–Extreme high-strength and/or high-temperature materials (ship construction, defensive shielding, propulsion plant materials, projectile launchers).

–Widespread use of nuclear reactors for power (propulsion).

–Superperformance fabrics (insulation, fireproofing, protection).

–New and improved material for (shipboard) interiors (variable transmission glass, heating and cooling by thermoelectric effect, electroluminescent lighting).

–Ultrareliable, high-resolution, high-capacity communications by light pipes and lasers.

Admittedly these projections do not stretch the mind (or imagination) too far; Kahn and Wiener may in fact have been too conservative. The Foreign Policy Association[3] has ventured a projection to the year 2018, not too far beyond Kahn and Wiener:

–Antigravity machines.

–Computers with a capacity on the general order of the human brain that could be carried in a shoebox.

–Infrared laser radar using holographic techniques, providing a major breakthrough in radar performance.

–Underwater surveillance systems using sound and lasers, making the ocean "transparent."

Remembering that the two lists above represent relatively short-range and conservative projections of from 22 to 40 years, we realize that as we discuss the technology of the future we are also discussing the warships of today, for naval ships are expected to have a service life on the order of 30 years. Thus when we consider laser technology, transparent oceans, or superperformance fabrics, we provide a framework within which to evaluate our new *Spruance*-class destroyers, *Perry*-class frigates, or *Nimitz*-class aircraft carriers. If we apply these same projections to our decade-old DDGs or *Knox*-class frigates, we realize that the ships we are operating today may be considered to be technological neanderthals. Within the perspective of accelerative technological growth, our present warships fall near the bottom of the technology scale.

The claim is made that these ships, as they come off the ways, contain the best that technology can offer. Engineering plants are safer and more efficient, guns are automated, sonars reach farther, and computers link ships in a task group. Some advances are indeed technological gains. But close observation will show that most of the improvements made are simply incremental advances in *engineering*, not technological leaps forward.

Technology is more than just machines and equipment; it includes *techniques* as well. No matter how efficient, clean, and powerful a modern ship's steam engineering plant may be, it still involves the ancient technique of boiling water to make steam to turn a windmill. Sonar, which involves the technique of "yodeling and waiting for an echo," has extended its range not by changing the technique but by "yodeling" louder.

A true technological advance, however, is represented by the introduction of the gas turbine engine to surface ship propulsion. The gas turbine represents not only new, improved machinery, but a new methodology, a new technique. Nevertheless, in the year 2008, "boiling water" will be the predominant method of propelling our warships.

Furthermore, a close look at warships being launched today will show that they make very little use of the levels of technology that have already been widely diffused throughout modern society:

–In a day when housewives can routinely cook with microwaves, food is (and, for the next 30 years, will be) cooked in giant cauldrons and ovens aboard ship.

–Today, small hand-held computers are routinely used by school children to solve fairly complex math problems; for the next 30 years officers and sailors aboard most of our ships will labor with pencil and paper to solve maneuvering board, navigation, and other simple problems.

–Stockbrokers routinely communicate among each other and share complicated data by electronic display techniques using microwave links, telephone, cathode ray tubes, and computer terminals. Today (and for the foreseeable future) our ships will communicate by voice radio and that wondrous mechanical marvel of a thousand moving parts, the teletype.

–Although high-impact plastics, exotic protective coatings, sonic cleaning devices, and superstrength epoxies and bonding materials are available and in use commercially, sailors are today (and will be for the next 30 years) engaged in the brutalizing manual labor of chipping and painting aboard ship.

–Over a decade ago, a surface-to-surface missile sank an Israeli destroyer. Today our ships still do not have an effective antimissile defense. Indeed, without air support provided by an aircraft carrier, an amphibious task group today would be helpless if challenged by the Ecuadorian Navy (EXOCET missiles) or the Trinidad and Tobago Coast Guard (PENGUIN missiles). The American nonresponse to the whole revolutionary technological change in naval warfare introduced by the surface-to-surface missile is inexplicable in rational terms.

The above examples range from the barely important to the crucial, but it is plain to see that our warships have failed to make full use of the technology already available and in use in commerce and industry. This gap must necessarily grow throughout the life of ships being launched today; as technological advances surge on, the ship remains relatively static as there is no way to introduce truly major advances in technology into a ship once the construction is complete. This is an *application gap:* much of the available technology is not applied during the construction of a ship, and cannot be applied once the ship is built.

In those areas where advanced technology *has* been applied, it appears that there are uncertainties regarding its use. The HARPOON missile, for instance, cannot be used to its full potential because we have not yet solved the problem of over-the-horizon targeting. Despite almost 20 years of operational use, recent fleet exercises have shown that the computerized Naval Tactical Data System provides a commander with so much erroneous information that his own ships are in almost as much danger of being attacked by his forces as are the enemy's. Despite the introduction of surface-to-surface missiles into naval warfare, there are no schools that teach a task group' commander how to fight his missile forces (or defend against missiles) nor are there any radically new tactics or doctrine available. This is *doctrinal lag:* even in those cases in which technology has been applied, the understanding of its use lags many years behind its physical application.

A century ago, Victor Hugo observed that nothing is so powerful as a new idea whose time has come. That technological innovation is a powerful idea whose time has come is undeniable. But some organizations and individuals find the idea so powerful that they are unable to cope with it. Bureaucracies, in particular, are ill-suited to deal with change and uncertainty. The Defense Department's (and within it, the Navy's) programming process, for example, emphasizes marginal program adjustments in the near future, and therefore tends to promote evolutionary rather than revolutionary increases in military capabilities.[4] Accelerative technology, however, is revolutionary in nature, and cannot be managed—or capitalized on—on an "incremental improvement" basis.

The most important step in capturing the benefits that technology offers is to gain an understanding of what technology *is*, and what its economic implications are. This may seem to be an oversimplification until we realize that in all the literature about technology *per se* (one bibliography contains a listing of almost 300 books) there is no military compendium. At no military school is there to be found a course on pure technology and how to deal with it. The simple fact is that we really do not understand what technology is, nor how to avoid its pitfalls or capture and apply its benefits to warship design and construction.

Technology is man's way of doing things easier or faster, or of doing things (like flying) that he could not do otherwise. It is also man's way of extending himself. Thus the microscope and telescope are extensions of his eyes; the bicycle and car extensions of his feet; and computers are extensions of his brains.[5] It should also be clear that, as pointed out earlier, technology is not just hardware, it is also technique. Put in the most simple terms, John Kenneth Galbraith states that technology means the systematic application of scientific or other organized knowledge to practical tasks.[6]

Technology is expensive. An increasing span of time separates the beginning from the completion of a task to which the frontiers of technology are being applied, and there is an increase in capital investment, especially the "front-end load" of research and development. This commitment in time and money tends to deter change or, in other words, to increase inflexibility. Specialized manpower, with its attendant high cost, is required, and the job of organizing the total effort is extremely complex. Yet, despite these high costs, technology roars ahead. Obviously the benefits obtained must be (or seem to be) greater than the costs. Whether or not the cost of technology is too high is, in fact, the subject of some debate. Nevertheless, the sum of technological benefits during the past few decades is staggering: radar, computers, transistors, space flight, supersonic transport, antibiotics, mass communications; the list goes on and on. Analysts agree that major advances will continue to be needed in food and energy technology just to keep abreast of Earth's burgeoning population, and that continued development in military technology is a necessary condition of maintaining the international balance of power. On the whole, our society perceives the benefits as outweighing the costs.

Therefore, it appears that the cost of technology will continue to be paid by a willing society at large. Basic research continues, industrialization spreads, travel and communications speed up, farms become more productive, energy sources become more efficient, knowledge grows. In a macroeconomic sense, the nation is willing to pay for these technological developments, and the Military Establishment (and the Navy within it) is paying a share of that cost. While the Navy's direct costs are highly visible (budget dollars), the indirect costs are too often ignored: higher training and education costs, more taxes paid by Navy personnel, costs to preserve the environment, higher telephone bills at the Pentagon, more expensive travel, more expensive office equipment, subsidized mass education, ad infinitum. These additional, albeit invisible, costs represent the Navy's share in paying for the nation's technological and industrial growth.

If this is the case, the Navy's goal should be to maximize the benefits to be derived. Indeed, the practice of paying for something and then not using the product purchased (technology) can only be characterized as waste, not good management. Thus the claim that closing the application gap is "too expensive" is not valid. With the proper strategy, we should be able to design and purchase technologically up-to-date warships at reasonable cost.

In designing ships, there is a tendency to focus on the wrong measure of effectiveness. The *Spruance* class, for instance, is hailed as satisfying the needs of the Navy into the 21st century. But the technology of today will not be the technology of the year 2001; *Spruance* may not be obsolete if age is a measure of effectiveness, but it may be useless if combat effectiveness is the measure of effectiveness (as it should be). What we should be concerned with is not the chronological age of a ship, but whether it is able to perform its mission in the face of the expected threat, that is, whether it is "tactically obsolete."

Some may respond that *Spruance* is designed for periodic updates as weapons systems evolve, and that she can be modernized to keep up with technology. Unfortunately, a subset of the "technology-is-hardware" philosophy is the "technology-is-weapons" philosophy. Even if it were possible to keep abreast of weapons technology by frequent updates, the remainder of the ship—the basic platform, fuel, engineering, interior communications, habitability, etc.—will remain as it was built in the mid-1970s. Millions of man-hours will be expended on maintenance, upkeep, repairs; the crew will still live in metal below-deck caverns; the antennas, masts, and bridge will remain exposed and vulnerable to weather and whatever weapons an adversary can devise; the ship will never travel faster than her 1975 speed; and rust, electrolitic action and age will take their toll. All of these factors must render the ship largely, if not totally, ineffective after the turn of the century. Worst of all, the stupendous costs of attempting to maintain *Spruance* "on the line" after 15 or 20 years of service will preclude purchasing more technologically advanced ships!

This consideration leads directly to one of the main characteristics of technology: impermanence. In particular, technology requires that the economics of permanence be replaced with the economics of transience.

First, advancing technology tends to lower the costs of manufacture much more than the cost of repair. It is often cheaper to replace than to repair, and in this situation it is economically sensible to build cheap, unrepairable, throwaway objects even though they may not last as long as repairable objects. Second, advancing technology makes it possible to improve the object as time goes by. The second generation computer is better than the first, and the third is better than the second. (A computer "generation" is generally recognized as 7 years; the computers installed in

Spruance may be aboard for 30.) Because we can anticipate further rapid technological advance, it makes hard economic sense to build for the short run rather than the long. Third, as change accelerates and reaches into more and more remote conceptual corners, uncertainty about future requirements increases. Recognizing this, we should hesitate to commit large resources for unchangeable objects or equipments intended to serve unchanging purposes. Products should be built for the short run, or alternatively, built to be highly adaptable.

It appears that these economic fundamentals of technology are being ignored when we build large, expensive, relatively permanent and unchangeable warships. Our ship design does not capitalize on technology, and we need a new ship design and construction strategy.

A strategy that would capitalize on technology will be one that recognizes the following imperatives:

–Technology is a *change* agent, not just an improvement agent. As such, technology requires new and innovative approaches to problem-solving.

–Technology, although expensive, is already being paid for. That is, the hidden costs of a technological society are already built in, unavoidable, and should be capitalized on.

–Technology requires specialized manpower, specialized training and education, and specialized skills.

–Technology has its own economics, the economics of impermanence, rather than permanence.

–Technology involves uncertainty, which requires maximum flexibility.

A strategy that recognizes the nature and economic implications of technology suggests radically different concepts of designing and building warships. It is evident that, in order to capture the benefits of technology, we must accept, rather than resist, the concepts of impermanence, disposability, diversity, uncertainty, and accelerative growth. In particular, we should move in the same direction as high-technology private industry: research and development funds and technological advances are used to reduce cost and increase reliability while performance gradually improves (as design matures) and technology and components become available at reasonable cost.

Ships which would meet these technological imperatives would probably be smaller, high-technology ships designed for an extremely short (5 years?) lifespan. Production runs of these ships would be shorter but more frequent, thus allowing for more frequent updates to close the application gap. At the end of their useful life, such ships could be sold to lower-technology navies, or sold for scrap, since their scrap value would still be relatively high.

Soviet warships are often criticized (by the U.S. Navy) for their poor watertight integrity, inadequate damage control equipment, and lack of weapon reload capability. They are denigrated as "one-shot" ships. Yet it must be admitted that they carry more weapons that are, in many cases, more sophisticated than the weapons carried by our own ships. It would appear that these Soviet ships have capitalized on the economics of impermanence to obtain the benefits of technology. Not only are they highly sophisticated where it counts—in weapons systems—but there seems to be a growing number of them, indicating that capitalizing on the economic imperatives of technology may permit buying more ships for the money, despite an economic base that is smaller than our own.

Alternative to (or concurrent with) a concept of "throwaway" ships, a concept of "building block" ships would capitalize on another economic imperative of technology: uncertainty. Basic hull forms could be designed to accommodate a diversity of major self-contained modules, including weapons systems, communications, ammunition, command and control spaces, engineering plants, and habitability modules.[7] In this manner truly significant technological updates would be possible by replacing obsolete modules. Repairs could be facilitated, ships could be specifically mission-configured, training could be conducted in "out-of-ship" modules, and modules could be updated without a necessity for the entire ship to be withdrawn from service while modernization is accomplished.

Once again, private industry has already learned to capture the benefits of technology by adapting to, rather than resisting, the economic imperative of flexibility to deal with technological uncertainty. U.S. industry is pioneering in the successful development of modular design and construction techniques, ranging from interchangeable electronic "black boxes" to huge containerships.

And the Soviets seem to be dealing with technological uncertainty by applying their own brand of flexibility: their new aircraft carriers are really aircraft carrier/cruisers, with a multiplicity of combat roles and weapons systems. At the very least, we could learn from the Soviet approach and build truly multipurpose ships. At best, we could learn from our own private industry and build truly flexible modularized ships.

Admittedly, the ideas of "throwaway" or "building block" ships are shocking. Yet, within the technological perspective, they are no more shocking than walking on the moon, "smart" bombs, liquid-crystal diode wristwatches, or cooking with microwaves. This is not, however, an exercise in advocacy for any particular ship design; rather it is to demonstrate that warship design requires greater breadth and understanding of technology. I use these examples to demonstrate that there are aspects, ramifications, and unique characteristics of technology that appear to be little understood and even less applied in designing a warship. It seems obvious that merely continuing past approaches will not provide the needed solutions. Indeed, to continue the present course may well lead to spending more to achieve less.

Developing a new ship design strategy based on an understanding of technology's economic imperatives will not be an easy task. But it is technology, not an inexhaustible fund of money, that gives us our lead in naval warfare capabilities. Given the facts that no single country can put unlimited resources into armaments and that there are urgent social uses to which our national wealth must be applied, efforts to exploit technology must continue to expand if our dual national goals of peace (safety) and prosperity are not to become mutually exclusive.

Goethe said: "What a man doesn't understand, he doesn't have." The Navy cannot design a rational strategy for exploiting technology to the fullest until we understand what technology is. Unfortunately, we have an organization which confuses technology with R & D, with weapons systems, with engineering, or electronics, or computers. This will not do. There are, however, certain fundamental steps that could be taken at little or no cost to introduce an understanding of technology into our thinking.

BIOGRAPHIC SUMMARY

Captain William Fahey is a 1978 graduate of the College of Naval Warfare, Naval War College. His undergraduate work was at the U.S. Merchant Marine Academy and his career has been in operational and intelligence billets. He is now assigned to the Office of the Joint Chiefs of Staff.

First, we need a mechanism, an organization, within the uniformed Navy itself to trigger studies on the application of technology, in a systematic way, at the earliest stages in the process of development and diffusion; to explore means of deciding whether a given set of events does indeed represent an early stage in a significant technological trend; to inject the possible ramifications of technology into the decision-making process itself.

Second, in our War College, Postgraduate School, and Naval Academy, we need courses that will teach what technology is and how to exploit it.

Third, we need seminars, retreats, and refresher courses where senior officers with operational experience are exposed to intellectually challenging ideas and discussions on what technology is, where its leading edge is, and what it means—and could mean—to the Navy.

In short, we need to institutionalize an effort to understand and capitalize on technology.

The Navy is a bureaucracy, with all the strengths and weaknesses of an old, honorable, and very conservative bureaucratic structure, and there will be drawbacks to institutionalization: resistance to change, careerism, bureaucratic inertia. But the rewards to be reaped are so great that they must not be foregone.

An institutionalized search for understanding, then, would represent the first step toward developing a ship design strategy that captures the benefits of technology. Where that strategy will lead us is, like technology itself, largely uncertain. But as it takes us deeper into the Age of Technology, we may find that the concept of the "throwaway" ship is not new after all, and that the greatness of the American Fleet in the mid-1800s was grounded in recognition of the principle of technological impermanence:

> . . . I accost an American sailor, and I inquire why the ships of his country are built so as to last but for a short time; he answers without hesitation that the art of navigation is every day making such rapid progress that the finest vessel would become almost useless if it lasted beyond a certain number of years. In these words, which fall accidentally and on a particular subject from a man of rude attainments, I recognize the general and systematic idea upon which a great people directs all its concerns.
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> —Alexis De Tocqueville, 1840

NOTES

1. "The Age of Miracle Chips," *Time*, 20 February 1978, p. 44.
2. Herman Kahn and Anthony J. Wiener, *The Year 2000* (New York: Macmillan, 1967), pp. 51-57.
3. The Foreign Policy Association, *Toward the Year 2018* (New York: Cowles Education Corporation, 1968), pp. 9, 10, 171.
4. CNO Policy and Planning Guidance, 1978. SECRET
5. Hal Ellerman, *Technophobia* (New York: Evans, 1967), p. 72.
6. John Kenneth Galbraith, *The New Industrial State* (Boston: Houghton Mifflin, 1967), p. 12.
7. See George H. Miller, "Crisis and Commitment," *Seapower*, January 1978, pp. 20-26, for an excellent discussion of Modular Ships.