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Naval Aviation, Information, and the Future

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THERE IS MUCH CONFUSION about the difference between evolution and revolution in the security context. Evolution is the logical progression of an existing system or framework, while revolution connotes a fundamental break with precedent. Oftentimes the problem is one of level of analysis. Performance improvements which signal tactical revolutions very rarely justify revolution at the operational or strategic level. A truly revolutionary strategic development alters perceptions of the relationship of means to ends and, most importantly, dictates a reformulation of warfighting doctrine—the codified precepts that govern operations.

Today, naval aviation must cope with a development with revolutionary ramifications at all levels: the Information Age. Although the navy emphasizes technological sophistication, the service has failed to appreciate the primacy of information (the management and exploitation of data through intellectual processes) in both the generation and employment of military power. Just as an infant grasps with its hand without self-conscious knowledge of its workings or full utility, so the navy uses information without realizing its sweeping applicability or understanding its import.

This article analyzes the implications of information for future naval aviation doctrine, beginning with an explanation of current doctrinal choices within a Clausewitzian framework. Next the Information Revolution is examined, with attention to recent Soviet writings and Desert Storm experience.[1] An assessment of current naval doctrine and the carrier battle group then follows. The article concludes with a plan for naval aviation.

The Clausewitzian View

The Clausewitzian conception of war posits a duel enacted on a large scale. Each duelist's aim is to compel the opponent to do his will. This he accomplishes

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by disarming the opponent, the theory being that once rendered unable or unwilling to offer forcible resistance, the disarmed party will submit. Since the power to resist combines the mental faculty to plan and coordinate with the physical ability to act forcibly, two disarming strategies are readily apparent: the opponent may be deprived of either the capability to control, or the capacity to resist. Similarly, military doctrines may be divided into those which aim to deny an enemy, through disruption, the ability to organize effective resistance, and those which aim to deny him, through destruction, the physical capability. The former may be loosely termed "maneuver" doctrines and the latter "attrition" doctrines. Clausewitz clearly preferred the latter, claiming, "What do we mean by the defeat of the enemy? Simply the destruction of his forces, whether by death, injury, or any other means. . . . The complete or partial destruction of the enemy must be regarded as the sole object of all engagements."[2]

Historically the industrially powerful United States has adopted attrition doctrines. It fought the Civil War, both world wars, and Vietnam with the aim of grinding down the enemy's inferior military force. Battle is actively sought and losses are accepted under the premise that the enemy will capitulate when either costs become unbearable or his force is exhausted.

In a doctrinal sense, naval aviation has not experienced a lasting "revolutionary" change since the Battles of the Coral Sea and Midway in 1942. The emphasis has been and continues to be on efficiently generating a large and sustained combat effort; the central paradigm has been the carrier battle group (CVBG). This naval attrition doctrine has appreciated and accommodated many evolutionary technological changes, such as jet engines, radar, and nuclear power. However, I contend that the influence of sophisticated automation—of the "Information Age" *revolution*—should not be interpreted with respect to the existing doctrine. Rather, it justifies a new doctrine with implicit consequences for naval aviation.

The Information Revolution

The term "Information Age" is used here to characterize the increasing degree to which systems and operations are constrained by the ability to gather, process, and use facts. Information, both its management and its exploitation, has been involved previously in the technology of war, but never before as the binding, predominant consideration.[3] For the bulk of war's history the information necessary for combat was assimilable by the human mind; a single man could control the elements of battle because he could survey the entire battle scene. Weapons, correspondingly, depended for their operation on the active intervention of human intelligence.

Industrialization and the mechanization of war made available material and manpower that expanded the scope of war beyond one man's control, elevating

the importance of organization, systemization, and command and control. The advent of automation, advanced electronics, worldwide communications, modern sensors, and the order-of-magnitude increases in complexity and capability that arrive with these have added the management and exploitation of information to the equation. According to military historian Martin van Creveld, "The cardinal result of the invention of invention [as a systematized endeavor in itself after 1945], and the accelerated pace of technological innovation, was a vast increase in the amount of information needed to 'run' any military unit, make any decision, carry out any mission, conduct any operation, campaign or war."[4] Just as attrition doctrine posits the paramountcy of combat forces, and maneuver doctrine that of command, control, and communications, modern doctrine must recognize the centrality of information in both the generation and control of military force. This prospective doctrine will obviously owe much to maneuver concepts, but will expand upon them to attack the adversary's information management and exploitation capabilities while minimizing our own vulnerability in this realm.

Stealth technology is a prime example. The F-117 protects itself by denying the enemy the opportunity to target it; if targeted, it is imminently vulnerable. It uses its relative immunity to fly at higher altitudes so that its pilot has time to employ the information-gathering capabilities of its weapon system to target an objective precisely. Creating and exploiting such an informational asymmetry would be at the heart of an information-centered doctrine.

Soviet Interpretations. The Soviets refer to the growing domination of the military aspects of doctrine by informational considerations as the "intellectualization" of warfare.[5] The term emphasizes the degree to which the ability to discern and use information for precision attack and coordination, and the consequent imperative to prevent the enemy from doing so, have come to define professional armed conflict. "According to representatives of the General Staff Academy," Hudson Institute Research Fellow Mary C. FitzGerald observes, "the Gulf war was a clash between two concepts of warfare: the Iraqis lost because their concept was based on fighting in the past, whereas the coalition forces' strategy was oriented towards the future. Proceeding from the anticipated effect of advanced conventional munitions (ACMs), directed-energy weapons, and space-based systems, the Soviet General Staff had already developed a revolutionary vision of a future 'aero-space war' long before the Gulf conflict. . . . The 'intellectualization' of all weaponry [is] said to be revolutionizing warfare in all spheres. Highly effective ground, air, and space-based reconnaissance, surveillance, and target acquisition systems linked in real time to powerful global strike capabilities [will] make the Soviet vision of an 'aerospace war' a reality."[6]

The Soviets believe that the growing sophistication of aerial attack weapons is superseding the historical importance of seizure and possession doctrines,

which implicitly rely on the attrition of enemy forces. "Soviet experts argue that all of this [technological advancement] is changing the nature of future war. Large groupings of ground troops will not be employed. Massed strikes will be delivered by remotely-piloted, precision-guided weapons and by reconnaissance-strike systems capable of automatically finding and destroying the target. . . . First priority targets will be state and military command-and-control points, energy sources, and military targets—especially means capable of delivering retaliatory strikes. . . . Soviet military theorists envisage a future war whose political and military objectives are to be achieved not by seizing and occupying territory but by destroying the enemy's military capabilities and military infrastructure."[7] This view foresees the elimination of the traditional concept of attrition as a decisive element in war and its replacement as such by the decimation, through precision attack, of political-military control and military infrastructure. Importantly, it would not be the incapacity to resist that would lead the defeated party to submit, but the loss of the ability to exercise political control and ensure order. These concepts are futuristic, but recent combat experience shows evidence of the increasing importance, both tactically and strategically, of information.

Desert Storm. Desert Storm was a transitional point in the development of informational warfare, combining advanced maneuver concepts with attrition. Tactically, this war was dominated by the technological sophistication of coalition attack capabilities, and strategically by the use of those capabilities to deprive the Iraqis of the lines of communication necessary to support and control their forces. However, these capabilities were not sufficient to destroy Iraqi infrastructure so completely as to threaten Saddam Hussein's ability to exercise political control and perhaps induce surrender. An invasion was necessary to disarm the enemy. Consequently, after the initial thrust to achieve air superiority and isolate Iraqi command and control, the air campaign constituted a traditional attrition operation.

Doctrinal lessons useful to naval aviation center around the tactical efficacy of maneuver (information-disruptive) concepts. The swift success of the land campaign can be attributed to the soundness of U.S. Army and Marine Corps maneuver doctrines. General Mundy, the new marine commandant, explains: "Maneuver, by definition, is the application of both movement and firepower against the enemy to achieve a decision. More than that, however, the philosophy of maneuver doctrine is to out-think, out-act, and plainly out-smart an opponent—defeating him using speed, surprise, and disorientation rather than annihilation."[8] Concentrations of force, save at points of attack and break-through, are avoided since they expose friendly forces to the devastating effects of advanced conventional munitions. Survivability is heightened by dispersion, deception, and redundancy. Dispersion and deception also serve as passive forms of information denial. Killing power, focused on the enemy's ability to

coordinate, is mustered through precision, not weight. In a parallel manner, one's own command, control, and communications (C^3) are critical if the force is to operate in a coordinated manner, concentrating to attack and then immediately redispersing for protection.

Naval Doctrine and the Carrier Battle Group

Postwar naval aviation doctrine, after a brief flirtation with the strategic nuclear strike role in the fifties, has, as noted, emphasized the traditional attrition doctrine and embodied the carrier battle group paradigm. The battle group concept provides efficiently produced aviation firepower concentrated in large-deck carriers, protected by a coterie of ever more sophisticated escorts and layered defenses. The navy has come in for a great deal of criticism over this defensive emphasis, but under the precepts current when it was established there was no choice. The singular conventional strike capabilities of the carrier had to be protected. The unparalleled capability of the large-deck carrier for sustained power projection was and remains essential in the framework of attrition doctrine.

But the information revolution suggests the question: "Has the attrition doctrine become outmoded?" The answer depends on the impact of information on the central assumption of the doctrine, namely, that the object of war is to inflict maximum physical damage on the enemy's means of forcible resistance.

Information's Impact. "Intellectualization" has changed the security environment in two important regards, of which one is newly apparent and the other has been assiduously ignored. First, the pivotal strike element is now the ability to neutralize the military potential of an adversary by destroying precisely his ability to manage information. Secondly, all targetable systems are vulnerable.

As to the first proposition, warfare is now governed by machines ("smart weapons") which have the ability to detect changes in their environment and react to them without the intervention of human intelligence. Effective use of them requires the detection, classification, localization, and assessment (pre and post strike) of suitable targets.[9] The whole endeavor depends on the management of information. Information is the crux, heart, and linchpin of militarily useful force. Therefore, by depriving the enemy of the ability to manage and exploit information, one destroys his ability to generate as well as coordinate military force.

The second conclusion follows inductively from the first. If the pivotal capability is informational management of precision destruction, then any system which is targetable must also be susceptible to attack and destruction (or, more specifically, "mission kill"). The increased lethality of precision weapons means that there is an almost perfect correlation between a system's detectability and

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its vulnerability. The USS *Stark*, *Samuel B. Roberts*, *Princeton*, and *Tripoli* are (since mines fit my definition of smart weapons) recent U.S. examples. The sobering truth is that *all* surface ships are vulnerable.[10] They are especially vulnerable when these smart weapons are teamed with stealth platforms, e.g., submarines firing torpedoes. The National Academy of Science's authoritative study of twenty-first century requirements concluded, "The driving factors in this [twenty-first century] environment that will press the Navy to change its current systems and operations include *increased vulnerability*, in times and areas of crisis, of all surface and air assets to early detection and attack with weapons of increasing effectiveness."[11] Vulnerability, however, is not a synonym for obsolescence or uselessness but an injunction to recognize the need for resilience or redundancy. The best remedies are deception and dispersal, not greater protection.

This judgment is dictated by the spread of intellectualized processes to the level of the individual weapon. The relative merits of "hard" and "soft" kill capabilities are central. The former involves either destroying the incoming weapon or surviving its damage; the latter denies or misleads the weapon's targeting function. "Hard" kill has been emphasized in attrition-based U.S. strategies. Protection of an asset by "hard" kill capability, however, necessarily leads to layering as opposing weapons become more lethal. The result is main battle tanks become mammoth due to armoring, or battle groups with a preponderance of escorts. A more productive approach is to oppose the weapon system's information processing system actively (with deception) or passively (with dispersion). At the level of the weapon, as at the strategic level, dependence on intellectual processes raises the choice between disruption or destruction. Choosing disruption plays to the U.S. technological advantage, provides the much sought-after "force multiplier" effect, and allows lighter, more mobile weapons and formations.

At this point it is important to reiterate that this "intellectualization" is at present an incomplete revolution and that Desert Storm is a transitional example. Reconnaissance, intelligence, C^3, and the weapons themselves must be further refined before advanced conventional warfare will consist totally of precision destruction. The trend, however, is in that direction, and this capability already exerts a dominating influence.

Implications of Information. Coping with this revolution and with the certainty that they would fight outnumbered on Nato's Central Front, the U.S. Army and Marine Corps have adopted maneuver-based doctrines, doctrines that shield their vulnerabilities to advanced weapons by dispersion, deception, and redundancy. At the operational level the object is to disrupt the enemy's orderly command and control by depriving him of the ability to manage information. Comparatively, the navy's dependence on the battle group, centered around a

capital ship, is outmoded. It is an enclave strategy suggestive of Maginot Line mentality.

The notion of the capital ship is completely foreign to the modern situation. In the past, capital ships were "capital" because only another of their kind could stand up to one of them. Other ships screened them and scouted to find them targets, but sea control was decided by the confrontation of these uniquely powerful ships. The carrier does not fit this definition; it is vulnerable to many other kinds of ships and threats. The modern sea control problem has three dimensions, and no single platform is dominant across all of them—hence there is today no capital ship. When every unit is vulnerable, albeit to varying degrees, it is unsound to hinge a major battle group capability—tactical air—at a single point.

A Plan for the Navy

The navy must be prepared both to defend against and execute informational warfare in the future. In particular, naval aviation must shift from outmoded concepts of reinforced citadels generating maximum attritive force, to dispersed assets delivering coordinated multi-axis strikes aimed at an opponent's informational capacity.

A plan of adjustment for naval aviation has three prongs: coordination of aircraft capabilities with the other communities, coping with the platform vulnerability issue, and the modification of our aircraft long-range procurement program. The plan should recognize the obsolescence of the carrier battle group paradigm (the capital ship complex) and aim rather to disperse the fleet's aviation assets and make them germane in an information-dominated environment.

The Role of Aircraft. Rationalization of aircraft capabilities in congruence with other fleet assets is long overdue. In the halcyon days of naval aviation following World War II, the air wing dominated all phases of surface fleet offensive capabilities. Manned aircraft were the primary strike and anti-ship weapon system. Airborne decision makers were required to assess situations which were unknown at launch and provide intelligence for unsophisticated weapons. Today, intelligence, navigational, and computational capabilities are better by orders of magnitude, and the "overhead" of manned systems (increased signatures, danger to crew, training costs) are increasingly insupportable in missions where reusability and having a decision maker on board would be only marginal improvements.

In the future, aircraft will fulfill four primary functions. They are, in descending order of importance: reconnaissance and information gathering, fleet defense, support of shore operations, and stand-off strike. The deep strike mission, which has been central to previous carrier doctrine, is deleted.[12]

Penetration of enemy airspace is better handled by advanced cruise and tactical ballistic missiles.[13] With regard to deep strike, manned aircraft should develop capabilities as stand-off launch and control platforms (recall the vivid stand-off land attack missile imagery from Desert Storm).

Missile development efforts should center on providing the fleet a successor to the Tomahawk incorporating long range (at least 1,500 nautical miles), stealthiness, dual navigational ability (Global Positioning System and inertial backup), warhead flexibility (for hardened and area targets and ships), and an imaging sensor (for flexibility, and attack on mobile targets).[14] Procuring a missile with these capabilities would allow deletion of deep-strike aircraft from the air wing.

The new primary role for aircraft is to gather, process, and disseminate information of all kinds (reconnaissance, intelligence, surveillance, and targeting) to other fleet units and to the fleet command center. The flexibility and range of aircraft suit them to this role. As strike assets have been spread to other surface and submarine units, correlated information necessary to enable a long-range strike has become the critical need. Aircraft can provide the information and communications paths for effective target detection, localization, and command and control. Technology should soon be available for a high-altitude long-endurance aircraft carrying sensors and passive electronic warfare equipment. This aircraft will be capable of anti-air, anti-submarine, and anti-surface warfare, long-range communications relay, and other continuous electronic support as either an adjunct or backup to space-based systems.[15]

Fleet anti-air and anti-surface defense, and also support of shore operations (overland air superiority, close air support, and battlefield area interdiction), can be carried out by a single strike-fighter airframe. These roles presently require manned aircraft, albeit lighter and less sophisticated ones than for penetrating strikes. Also, in both instances sustained sortie rate—a measure by which manned aircraft excel—is important. In the future the fleet defense mission may move to greater automation with the introduction of ultra-long-range and sophisticated missiles (e.g., the advanced anti-air missile and the advanced anti-ship Tomahawk) and techniques (the "forward pass").

Platform Vulnerability. By eliminating strike aircraft and moving many support functions off the carrier, fleet vulnerability to a crippling strike is reduced, its important aviation assets (for which protection could not be assured) having been dispersed. However, for maximum efficiency those capabilities still residing in the carrier should be distributed among the greatest possible number of hulls. In the current budgetary environment there is no possibility of procuring sufficient large-deck platforms to provide for dispersal of fleet aviation assets. Rather, dispersal must come through procuring more less-expensive platforms. The small versus large-carrier debate has been going on for decades;[16] assuming

the need for an *attrition* platform, the large carrier is indisputably superior. The revolution we have described in maritime warfare, however, would change the role of the carrier from that of capital ship to an aviation platform. It is with this new paradigm in mind that one must examine the alternatives.

Dispersal of aircraft presents a tremendous problem given the U.S. Navy's preference for catapult and arresting gear operations (conventional takeoff and landing, or CTOL). Modern carrier aircraft are large and heavily built, both in order to carry sufficient fuel for long ranges and extended loitering and also to be able to withstand the wear and tear of CTOL operations. A standing requirement to be able to conduct simultaneous takeoffs and landings means that the 700-foot angled deck must be clear of the 300-foot-long forward catapults. This factor plus seakeeping requirements result in a ship which currently displaces over 100,000 tons and is 1,100 feet long. The tremendous investment such a ship represents and the uniqueness of its ability to operate high performance aircraft necessitate caution in its tactical employment.[17]

A shift to short takeoff and vertical landing, or STOVL, technology offers an alternative method for basing air power at sea.[18] STOVL offers a number of benefits:

- For an air wing of a given size, STOVL aircraft can be on the order of thirty percent larger since most of the angled recovery area is usable for parking during recovery.
- Given equal costs, STOVL aircraft provide better mission performance with fewer aircraft.[19]
- STOVL designs are compatible with existing carriers.

The deletion of catapults and arresting gear reduces the chance of a mission kill through battle damage or malfunction. Course changes into the wind are minimized since STOVL aircraft need only align with the relative wind while landing. Deck respotting is reduced since the deck is always ready to recover aircraft. The needs for carrier-specific landing techniques and aircraft design are deleted. Furthermore, STOVL technology is rapidly closing the gap versus CTOL aircraft. Composite structures and higher thrust-to-weight engines are boosting range-payload specifications. The AV-8B Harrier already has range-payload performance comparable to the F/A-18C/D when both are operated from shipboard. Incorporation of a radar into the AV-8B Plus gives it the capability of an F/A-18 (except the fuel-prohibitive supersonic dash capability). Next-generation designs promise stealth and supersonic capability.

Long-Range Planning. Planning to implement these changes must address platform and aircraft concerns. Ideally, a program should allow naval aviation's capabilities to grow with technology as the latter provides the tools—communications, real-time reconnaissance, surveillance, battle management, and

precision strike—that will move maritime warfare fully into the realm of the Information Age.

The urgent platform need is for a relatively inexpensive hull upon which the fleet's aviation assets may be dispersed. It is obvious that no CTOL platform will be both capable enough and inexpensive enough. The choice I recommend is to reduce the types of aircraft in the air wing by moving electronic support off the carrier (and into larger, more capable, land-based and space-based systems), deleting deep strike aircraft and consolidating the remaining strike and fighter functions into a single airframe compatible with small decks.[20] This makes possible a small to mid-sized platform (30,000-50,000 tons) able to operate a reasonable number of STOVL strike, fighter, and antisubmarine aircraft.[21] Such a ship, in addition to being an aircraft platform, would serve as a command center and a clearinghouse for information gathered from all sources. It would serve not as a capital ship but as an air platform, able by virtue of its comparative austerity to be deployed forward when necessary. In general, however, it would stay safely beyond the range of shore-based threats and depend on cruise missile platforms, including its own aircraft, to suppress those threats before closing the shore.

The situation in the current carrier fleet provides a golden opportunity to procure an alternative to the *Nimitz* class. Eight *Nimitz*es are in the fleet, building, or authorized. These ships guarantee a nucleus of aviation capability till approximately 2020, assuming service-life extensions. A number of alternative platforms could be deployed alongside them beginning early in the next century; in this way, the navy would have a window of perhaps ten years in which to validate the concepts of STOVL operations and non-capital-ship fleet operations. If these concepts prove unworkable, the successors to the *Nimitz* can be another generation of large decks. If not, suitable numbers of alternative aviation platforms can be procured instead.

Today's air wing is dominated by the strike element: F-14s for air superiority, F/A-18s for light attack, suppression, and fighter missions, and A-6s for medium attack. An oft-stated goal of the navy has been the reduction of aircraft types on the carrier deck. The F/A-18E/F is to replace the F-14 and earlier model F/A-18s, and augment the A-6, in the latter half of this decade; this will reduce aircraft types from three to two.[22] If deep strike is abandoned, the money currently being expended on the AX could be transferred to development of a STOVL successor to the F/A-18E/F and to cruise missile research and procurement.[23] With the STOVL aircraft replacing the F/A-18E/Fs and A6s, aircraft types in the fleet defense and shore support element are reduced to one. If alternative platforms are produced as the foregoing suggests, navy AV-8B Pluses (perhaps augmented by marine assets) can be procured to fill those decks until the advanced STOVL aircraft is available. Research and development should continue into high-altitude long-endurance aircraft, space-based systems, and

communications technology in order to continue the development of sophisticated C^3 and intelligence capabilities.

Conclusion

Modern warfare is dominated by information. The ability to gather, process, disseminate, and use facts is the most important consideration in modern war. Not only does the ability to coordinate action depend upon information, but the very ability to generate force is increasingly determined by informational considerations. Accordingly, modern doctrines of offense and defense must regard the preservation of one's own information-related capabilities and denial of the enemy's as the fundamental tasks of warfare.

Naval aviation has lagged in its adjustments to the Information Age. Unwilling to revise its doctrine, the service has all its tactical aviation assets concentrated on large-deck carriers and emphasizes attrition in its warfighting strategies. Large-deck carrier "capital ships" should be supplanted by more numerous aviation platforms which allow the valuable air assets to be more readily dispersed. The preeminent position of information should be recognized doctrinally so that available power projection assets are used to direct precision strikes at the enemy's ability to manage and exploit information.

Notes

1. For a recent examination of Soviet views of Desert Storm see Mary C. Fitzgerald, "The Soviet Military and the New 'Technological Operation' in the Gulf," *Naval War College Review*, Autumn 1991, pp. 16-45.

2. Carl von Clausewitz, *On War*, Michael Howard and Peter Paret, eds. and comps. (Princeton: Princeton Univ. Press, 1984), p. 227.

3. Several excellent surveys of the relationship of technology to war are available, among them: Martin van Creveld, *Technology and War: From 2000 B.C. to the Present* (New York: The Free Press, 1989); Bernard Brodie and Fawn M. Brodie, *From Crossbow to H-Bomb*, rev. and enlarged ed. (Bloomington: Indiana Univ. Press, 1973), orig. ed. Laurel Science series (New York: Dell, 1962); and William H. McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000*, (Chicago: Univ. of Chicago Press, 1982).

4. Van Creveld, pp. 235-236.

5. Mary C. Fitzgerald, "Soviet Armed Forces after the Gulf War: Demise of the Defensive Doctrine?" *Report on the USSR*, 19 April 1991, p. 2.

6. *Ibid.*

7. V. Slipchenko, "Impending Changes Resulting from Reform Plans for the Employment of the Soviet Armed Forces," presentation made at National Defense University, Washington, D.C., on 15 and 20 March 1991, in Mary C. Fitzgerald, "Soviet Armed Forces after the Gulf War," p. 2.

8. The response of Gen. Carl E. Mundy, Jr., Commandant of the Marine Corps, to confirmation questioning by the Senate Armed Services Committee. Carl E. Mundy, Jr., "The Transition of Leadership/Perspective on the Corps," *Marine Corps Gazette*, August 1991, p. 78. For a more general and theoretical explanation of U.S. maneuver concepts see *U.S. Army Field Manual 100-5: Blueprint for the AirLand Battle* (New York: Brassey's (US), 1991), pp. 91-111, 173-182. The influential interwar concepts of Marshal Tukhachevskii are explained in Richard Simpkin, *Deep Battle* (New York: Brassey's Defence Publishers, 1987). The classic work of maneuver warfare remains Sun Tzu, *Sun Tzu: The Art of War*, Samuel B. Griffith, trans. (New York: Oxford Univ. Press, 1963).

9. For a clear explanation of the evolution, importance, and implications of guided weapons and the coordinated use of information that allows their capabilities to be exploited, see Karl Lautenschlager, "Technology and the Evolution of Naval Warfare," *Naval Strategy and National Security*, Steven E. Miller and Stephen Van Evera, eds. (Princeton: Princeton Univ. Press), pp. 208-221.

10. For a current explanation of the magnitude of the ship signature problem, refer to William D. O'Neill, "Don't Give Up On the Ship," U.S. Naval Institute *Proceedings*, 9 January 1991, pp. 46-51.

11. Naval Studies Board, Commission on Physical Sciences, Mathematics, and Resources, National Research Council, *Overview*, v. 1 of *Navy 21: Implications of Advancing Technology for Naval Operations in the Twenty-First Century* (Washington: National Academy Press, 1988), p. 7 (Emphasis added). A primary contributor to increasing weapon effectiveness is technology diffusion through international trade. For an overview see U.S. Congress, Office of Technology Assessment, *Global Arms Trade*, OTA-ISC-460 (Washington: Govt. Printing Office, June 1991). A succinct description of the dynamics of technology diffusion is provided by B. David Mussington, *Weapons-related Technology Diffusion in the New World Order: Problems and Prospects*, Canada Dept. of National Defence, Operational Research and Analysis Establishment, Directorate of Strategic Analysis, ORAE Project Report No. PR 560 (Ottawa: ORAE, August 1991).

12. A very persuasive argument to this effect appears in Charles E. Myers, Jr., "Time to Fold 'em," U.S. Naval Institute *Proceedings*, July 1991, pp. 37-41.

13. *Ibid.*, p. 41, and Naval Studies Board, pp. 49-51.

14. Development along these lines has already started. The Precision Strike Initiative (PSI), spanning the years 1991-96 and budgeted at a mere $2.5 million per year, aims to integrate imaging sensors aboard cruise missiles. Future studies are aimed at enhancing the warheads, communications, and stealthiness of cruise missiles. See Robert Holzer, "Navy Explores Advanced Technology for Future Cruise Missile," *Defense News*, 3 June 1991, p. 5.

15. Naval Studies Board, p. 15.

16. None of these battles raged more fiercely than the mid-1970s debate between the navy, the defense department, Congress, and analysts about the procurement of CVN 71, the CVNX, a mid-sized CVV, or various VSTOL options. For details see Office of the Chief of Naval Operations, *Report of the Findings of the CVNX Characteristics Study Group's Development of Alternative Nuclear Powered Aircraft Carrier Conceptual Models Suitable for Procurement in FY 1979* (Washington: January 1976), pp. IV-1, IV-2; Congressional Budget Office, *Planning U.S. General Purpose Forces: The Navy* (Washington: Govt. Printing Office, December 1976), p. 66; A.M. Bowen, *A Critical Analysis of the CVNX Characteristics Study Group Report of January 1976* (Washington: Library of Congress Congressional Research Service, 20 February 1976), p. CRS-3; U.S. Congress, House, Committee on Armed Services, *Authorizing Appropriations, FY 1978, for Military Procurement*, Report 95-194, 95th Cong., 1st Sess., p. 23; U.S. Congress, Senate, Committee on Armed Services, *Authorizing Appropriations for FY 1978, for Military Procurement*, Report 95-129, 95th Cong., 1st Sess., pp. 53-55; *Sea Plan 2000: Naval Force Planning Study* (Executive Summary) (Washington: Dept. of the Navy, 28 March 1978); "Brown's Shipbuilding Plan Undercuts Top Two Options in Navy Plan," *Aerospace Daily*, 29 March 1978, pp. 160-161; "Administration, Navy Shipbuilding Plans Compared," *Aerospace Daily*, 30 March 1978, pp. 168-169; U.S. Congress, House, Committee on Appropriations, *Department of Defense Appropriations for 1979*, Hearings before a Subcommittee on the Department of Defense, 95th Cong., 2nd Sess. Part 1, p. 642; "Veto Message," *Congressional Quarterly*, 26 August 1978, p. 2285; "President Carter's Veto Message," *Aerospace Daily*, 22 August 1978, pp. 230-231; and "Weapons Bill Vetoed," *The Washington Post*, 18 August 1978, p. A5.

17. This tactical caution has consistently hampered the effectiveness of naval airpower. The USS *Vincennes* shootdown would have been prevented had an aircraft carrier been on station in the Persian Gulf in July 1988. Although there was a critical tactical need for aircraft for fleet defense, the USS *Forrestal* was stationed outside the Gulf in order to reduce its exposure to Iranian assets. In Desert Shield the USS *Independence*, the first carrier on station, was similarly held outside the Gulf by platform vulnerability considerations, with the result that its combat power was hampered (see Michael C. Braunbeck, " 'Desert Shield': The First Lessons Learned," U.S. Naval Institute *Proceedings*, January 1991, p. 18). Indeed, it was only under the protective umbrella of the coalition's land-based air armada that carriers were allowed into the Gulf.

18. For a comprehensive appraisal of V/STOL and STOVL technologies by an accomplished and experienced aerospace engineer, see John W. Fozard, "Espousing the Vertical, Evolution or Revolution," *Interavia Aerospace Review*, June 1991, p. 497.

19. N. Vignevic and W. Riviera, "CTOL/VTOL Comparison: A View From the Deck," Naval Air Engineering Center, Lakehurst, N.J., paper (AIAA-80-1812) delivered at the AIAA aircraft systems meeting, 4-6 August 1980, Anaheim, Calif.

20. Integral to the strike and fighter functions is a significant electronic warfare capability to include defense suppression, electronic countermeasures, electronic support measures, and reconnaissance capability sufficient for damage assessment. As an example, the Tornado airframe, albeit in three versions (GR.1A, F.3, and ECR), currently handles these missions.

21. For example, the *Wasp*-class LHDs are credited with a capacity of twenty-six aircraft at 40,000 tons, but have only a half-length hangar deck. *Jane's Fighting Ships, 1990-91.*

22. For a description of the F/A-18E/F aircraft see "McDonnell F/A-18E/F Offers Increased Range, Endurance," *Aviation Week and Space Technology*, 25 March 1991, p. 25. The navy's procurement planning in the aftermath of the A-12 cancellations is outlined in "Navy Seeks 228 more F/A-18C/Ds, Rewinging

Additional A6Es," *Aviation Week and Space Technology*, 25 March 1991, p. 24; the proposal to Congress is reported in Eric Schmitt, "Navy submits plan for carrier Jets," *The New York Times*, 27 April 1991, col. 1, p. 10 (L).

23. The navy's efforts to procure an A-6 replacement suffered a major setback with the cancellation of its intended replacement, the A-12; see Eric Schmitt, "Pentagon scraps $57 billion order for attack plane," *The New York Times*, 8 January 1991, col. 6, p. A1(L). A description of the cancelled long-range, high-payload stealthy aircraft is given in Bill Sweetman, "The A-12 Avenger: Stealth for Tactical Strike," *International Defense Review*, October 1990, p. 1157. The program to produce a more moderately performing successor, the AX, is described in Bill Sweetman, "AX rises from the Ashes," *International Defense Review*, October 1991, p. 1082.

Ψ

There is no expedient to which a man will not resort to avoid the real labor of thinking.

Sir Joshua Reynolds

(This quotation was displayed in the office of Thomas A. Edison.)

Science discovers and teaches truths which it has no power to change; Art, out of materials which it finds about it, creates new forms in endless variety.

A.T. Mahan
Naval Strategy (1911)