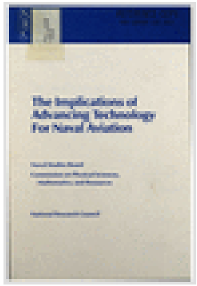

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The Implications of Advancing Technology For Naval Aviation

Panel on the Implications of Advancing Technology for Naval Aviation

NAVAL STUDIES BOARD

Commission on Physical Sciences, Mathematics, and Resources
National Research Council

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The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Executive Summary

INTRODUCTION

The Panel on the Implications of Advancing Technology for Naval Aviation was established at the request of the Chief of Naval Operations (CNO) on January 16, 1980. The task of the Panel was to consider the Navy's current patterns of naval warfare involving naval aviation together with evolving relevant technology, and to derive from this:

- Recommendations concerning the most important technical trends to assist the Navy in developing its future R&D programs,
- Suggestions for new systems concepts made possible by expected technological advances that would enhance the effectiveness of the Navy.

The Panel confined itself to the extrapolation of ideas and capabilities now known, and refrained from forecasting future scientific discoveries or inventions.

The CNO also asked the Panel to address three more specific questions:

- What should be the future forms of the carrier?
- What might be the impact of V/STOL on the carrier and the form of the Navy?
- What might be the impact of cruise missiles on the Navy?

In spite of the fact that nuclear, biological and chemical warfare technologies are not normally considered in "aeronautics," the impact of such technologies on aeronautical systems was of such importance that the Panel probed this field as well.

In approaching the general and specific questions the Panel has not attempted rigorous analysis, but rather has concentrated on developing and examining the technological trends it believes are sound, and on describing system implications so that the Navy can better focus its future, more rigorous studies and investigations.* In addition to analysis efforts the Panel believes that there are important, experimental development programs that are essential to carry these new concepts further and to put them into practice.

NAVAL AVIATION MISSIONS

The missions of naval aviation which were addressed are those already defined and accepted: to assist in the U.S. and allied use of the seas, control of the seas in wartime, and the projection of military power ashore. These broad mission areas include the following specific military tasks in which aviation participates: acquisition and distribution of intelligence; attacking enemy surface ships and submarines; attacking targets on land; defending friendly assets (of all kinds) at sea; landing ground and air forces from the sea; and defending friendly forces and related assets ashore or over enemy territory.

These military tasks may be carried out against a spectrum of opposition varying from third countries to Soviet forces. Thus, although the Navy may operate against lesser threats, it must be designed with the maximum threat in view.

THE THREAT

The main, and growing, threat to the Navy at sea is from missiles. Missiles can be launched from the air, from the surface, and from under the sea. Future missiles can be expected to have longer ranges and to approach their targets from unexpected angles, at high speeds with short intercept times, utilizing saturation tactics. The Soviet Navy is now supported by a worldwide information and tar-

*This report represents a summary of the findings produced by some five task groups. For those who are interested, the working documents are available in the office of the Naval Studies Board.

geting system, which will inevitably improve in the future. Delivery platforms will be able to approach U.S. ships from 360° azimuth, wherever they are. The long reach of the threat and the short time available to react will mean that our current long-range defenses, such as F-14/PHOENIX, will no longer be able to reach the launch platforms, and shorter range defenses in heavy ECM environments can potentially be saturated. Longer defense reach and shorter response time are essential.

The Panel believes that the present missile threat has already forced the Navy to bias its aeronautical resources toward defense of the battle group to the detriment of its offensive capability. If new technologies and the resulting systems concepts can assist the defense of the fleet and free more aviation assets for offensive missions, a major contribution to Navy effectiveness will have been achieved.

Ashore, attack aircraft will face increasingly capable missile-firing air defenses that, if undefeated, will cause more attrition of attacking aircraft than is tolerable. These defenses may be Soviet, or furnished by the USSR, or even by the U.S. or its allies, to third countries. Thus, any land-attack mission concept must include elements to find and defeat defenses in the target area.

WHERE COULD AVIATION TECHNOLOGIES LEAD THE NAVY?

To fulfill its task the Panel found it necessary to consider technologies and operational functions beyond "naval aviation" as strictly defined. The strong systems nature of evolving technology makes it impossible to consider aviation without examining the ways in which it is embedded in the larger Navy. Indeed, the Panel concludes that it is the nature of the embedding that best defines the technologies that will shape the future Navy.

Naval aviation is, by its very nature, a dispersable force. Advances in nearly all traditional aeronautical technologies now require a system structure that takes better advantage of its dispersability than current Navy systems do. The evolving threat makes this dispersal essential; it is propitious that evolving network and supporting technologies make it possible.

Implicit in success of such a dispersed force of ships, aircraft, and missiles is the effective flow of signals within and from without the battle group and the ability of this command structure to be disguised and made more difficult to find and attack effectively.

R&D in those technologies which promise significant advances in naval aircraft is important and should be continued. However, the major contributions of technology to "naval aviation" in the broad sense will not be in the traditional technologies of aircraft, airframe, propulsion, etc. Existing and planned naval tactical aviation airframes, the F-14, A-6, and F/A-18, continue to provide adequate platforms for the tasks envisioned. The leverage of technology will accrue in the application to surveillance, sensors, communications, computation capability, new and improved weapon systems and weapons guidance and control. Even more essential will be the demand for total system integration and control which will require advanced data handling and presentation for effective command. Thus the key technologies are in electronics and electronic systems rather than the traditional fields supporting engine and airframe development.

There is, however, an important caveat. The Panel fully expects the emergence of airframe and engine advances which from time to time will permit significant advances in existing airborne assets. This same technology may be applied to offensive and defensive missiles to produce operational ranges of hundreds rather than tens of miles. Similar traditional technology growth will make feasible sensor-carrying aircraft that can stay aloft for days. Finally, the operating radii and payload capability of V/STOL aircraft will continue to increase.

To support both missiles and specialized aircraft, the Panel is convinced that substantially smaller surface ships can be built with rough-water stability and speed comparable to a big-deck carrier. The ship concept which appears most suitable for support to the carrier battle group appears to the Panel to be the Small Waterplane Area Twin Hull (SWATH) ship. The surface effect ship (SES) also appears to have capabilities that could augment independent Surface Action Groups or over-the-beach effectiveness including capabilities as a launch platform for V/STOL assets in support of landing operations.

Thus, the Panel found it impossible to think about the core of naval aviation--the carrier and its aircraft--without also thinking about the missiles that are becoming the primary warhead delivery vehicles, the platforms they are launched from, the information network that ties all these components into a functioning whole, and the aircraft, spacecraft, sensors, and communications links that make up the physical components of that network. All these were treated as parts of naval aviation in the study, and they are so treated in this report.

THE BROAD CONCEPTS

The Panel is convinced that technology is available, and the developing threat makes it imperative that the Navy pursue operational concepts in which there is a wider dispersal of carrier battle group assets than would be feasible with currently planned surface and airborne elements. The directions for development that will both control this evolution and capitalize on the opportunities it offers are listed here.

1. Most important is the information network, including intelligence, on which the entire naval structure will depend. This includes sensors, communications, command structure, data handling and presentation to the command (with emphasis on real-time presentation), and provision for denial of information or confusion of enemy forces. This is the "nervous system" of the naval "corpus," without which it will not be able to function.

   The Panel further emphasizes that deception, jamming, third-party communications links, and other means of foiling enemy targeting and guidance will be an essential part of this information network. Maintaining a decisive information advantage is as important as obtaining and using information per se.
2. Next in importance is the design and development of families of missiles of much longer range than presently planned systems. There should be longer range missiles for all purposes (AAW, ASW, ASUW, and land target attack). Because of the extended range of these missiles, a "forward-pass" mode of guidance should be utilized in which target localization information and even fire control signals can be passed to a missile by a "third party," probably airborne or spaceborne, regardless of the launch platform for the missile. The potential third-party sources for control or update of these weapons can be widely distributed over the force engaged in any action.

3. Given the above systems, provision is needed for a heavy ammunition (missile) load, distributed among many surface and subsurface elements of a task force. These missiles would be called up and controlled by the "nervous system," through various airborne systems utilizing a multiplicity of target intelligence sources in the C^3I loop. The missiles themselves, of course, should be capable of precision delivery. Simply adding to the number of any inaccurate weapon is of little value.
4. In addition to missile complements on existing carrier battle group ships, there is both need and opportunity for provision of diverse new platforms that can be small enough to be economical, yet maneuver with the carrier in heavy weather. These include:

   a. SWATH, missile-carrying ships, some of which may be air capable.
   b. SES ships to act as air-capable auxiliary ships suitable for rapid over-the-beach and roll-on-roll-off deployment and other support operations.
   c. V/STOL aircraft able to operate as sensor and missile control platforms from the above ships, and others suitable for combat and transport missions in amphibious operations.
   d. Long-endurance sensor-carrying aircraft, which may or may not be manned or even ship-based, to comprise a part of the Navy's total information and control network, along with other airborne and space-based assets.

From the above developments, naval task force structure (and the aviation within it) is visualized as evolving not only toward greater distribution of information and combat assets over all elements of the fleet, but also toward covering much larger geographic areas, including ocean and land, than has previously been operationally feasible. Force size and ship spacing will be highly variable with the circumstances of the battle and the character of the opposition. The force spacing should be determined by the information umbrella, the reach of the offensive and defensive weapons, and the span of control over these weapons and their launch platforms. The technology is and will be available to disperse the task forces as far as appears to be optimum for fleet effectiveness.

ANSWERS TO THE ORIGINAL SET OF QUESTIONS

The preceding outline of technical developments and opportunities leads to the following answers to the more specific CNO questions:

- What will be the future form of the Navy, especially with regard to aviation? It will have many of the same components we know about today. For the forseeable future the carriers themselves and the tactical aircraft (F-14's, A-6's and F/A-18's) they are programmed to carry will remain essentially the same. However, as described above, technological ideas on the verge of exploitation are likely to add new components and to make it possible for "the Navy" as a collection of ships, aircraft, missiles, sensors, and connecting links to function quite differently, in an operational sense, than it does today. In effect, a carrier battle group will increasingly operate as an integrated, distributed weapon system supported by major C^3I assets, some organic and some external, and can have a substantially larger radius of effectiveness for approximately the same number of surface elements that now constitute a carrier battle group.
- What of the large carrier? We have concluded that it need not change much, if at all. Under the dispersed concept we have described, the carrier concentrates, as it should, more on its classic function as a floating airbase for high sortie rate offensive aviation operations in areas where land-based tactical aviation is not available, tasks for which the large-deck carrier and its multi-role airwing are especially efficient. The most marked change in naval ships that we see would occur in combat ships other than carriers. These ships would be primarily missile carriers that can keep up with the big decks in heavy seas--an essential requirement if the carrier battle group is to survive high-speed transit while under threat. Some of these ships could be air-capable to launch sensor-carrying aircraft for target localization and forward control of long-range missiles. New ship design concepts, particularly SWATH, can provide this capability. Similarly, ship concepts such as the improved high length-to-beam ratio SES

will be able to provide fast-deployment, air-capable amphibious assault and combat air support more effectively than current conventional designs.

- What of V/STOL? This capability will not drive the form of the naval aviation system, but the evolving technology offers an opportunity, in combination with other developments in information, ships, and weapons, to fulfill an expanded tactical role.

  The ability of a V/STOL-capable aircraft to fly off various battle group combatants in either a based or a staging mode, higher, faster and farther than helicopters, could provide a carrier-independent surveillance, targeting, and fire control capability for AAW, ASW, ASUW, and overland targeting applications. The capability to base such aircraft on new SWATH or SES ships enhances the offensive power of large aircraft carriers by reducing the traffic demands of support aircraft on the scarce deck facilities and space. These advantages should be aggressively explored and quantified in the near term to provide the basis for long-term planning.

- The impact of cruise missiles. The impact of precisely guided cruise missiles in attack on ships by both sides demands U.S. defensive reaction against submarine and BACKFIRE launch threats. Range improvements in air defense, ASW missiles, and land and ship attack missiles lead to the dispersed and distributed operational concepts described. Missiles for land attack permit destruction of defenses and high-value fixed targets so that manned aircraft can seek out and attack mobile land forces that may be the main elements of concern in a conflict. The possibility of using such missiles enhances interest in the performance potential of new ship types. The resulting long reach adds emphasis to the need for the expanded information network described. Thus, in many ways, cruise missiles prove to be one of the main agents of change in the Navy and specifically in naval aviation--indeed, the cruise missile concept is the reason the Panel had to define "naval aviation" as broadly as it did.

  The Panel also notes that conventional-warhead ballistic missiles may become similar agents of change and concern in the latter part of the period we are considering. The Navy should closely monitor developments in this area, particularly with an eye toward earlier introduction.

NBC AND DIRECTED ENERGY WARFARE

Soviet doctrine lays great stress on these areas of warfare, and the Navy, for deterrence and for survival if deterrence fails, must prepare to meet the Soviet threat. The "information war," especially including information denial and confusion, appears to us to offer the best defense against nuclear attack since the chance is high that at least one attacking weapon can reach a major ship whose location, movement and activity are known. Beyond this, the following measures are strongly indicated:

- Assess and correct as appropriate or required the EMP vulnerability of naval aircraft, combat systems, and vital C^3.
- Ensure the existence of an appropriate nuclear and binary chemical retaliatory capability.
- Ensure that electro-optical/optical systems are provided with protection against directed-energy weapons.
- Develop and provide appropriate personal protection gear and decontamination equipment to permit flight-deck operations subsequent to CW contaminating attack.
- Provide flight crews with protection against flash-blindness.
- Provide for chemical protection of other ships by such measures as scrub-down and positive-pressure ventilation, to the extent feasible.
- Incorporate such protection measures fully in any new ships to be considered. The cost of complete retrofit is recognized as prohibitive, but incorporation of such features in new designs is believed to be both essential and affordable.

IMPORTANT APPLICATIONS OF NEW TECHNOLOGY

This review of naval aviation needs and prospects has highlighted many areas of technology application requiring attention or offering opportunities for future exploitation. The Panel has tried to select the most effective of these broad concepts and has listed them in the order of importance to the future Navy.

Each of these concepts, if successfully pursued, will depend on basic programs of system and subsystem studies and development that should be an essential part of the Navy's continuing R&D effort along with basic research and engineering exploration to build the total technical base. The Panel's suggestions for emphasis in supporting system programs and R&D follow this priority listing of applications.

1. A network of diverse sensor/information sources and interconnecting communications, to maintain full knowledge of enemy forces' whereabouts and activities and to send guidance and fire control signals to long-range missiles, should be built. ITSS is already in the planning stages and could provide a basis for this network. Of special importance are the following:

   - Sea-, air-, space-, and land-based sensors, platforms, and integration/processing centers.
   - Low-probability-of-intercept among those communications nodes.
   - Reduction of vulnerability to enemy jamming and exploitation, increased attention to hiding/spoofing/masking signatures, i.e., electronic warfare in the broadest sense.
   - Reduction of sensor and seeker vulnerability to directed-energy weapons from space, airborne, or surface systems.
   - The same attention to surveillance and target-acquisition systems for land attack and ASW as is given to air defense and surface attack.

   Particular emphasis should be placed on methods of target acquisition and communication that will not disclose the presence of platforms that may be otherwise shielded from observation. For this reason, as well as the advantages of closer approach to the targets for localization, the forward-pass mode of targeting and guidance of long-range missiles is indicated.

2. Implicit in the successful creation of such a C^3I network is the availability of suitable platforms for acquisition and relay instrumentation. Military satellite systems will be important and per-

haps primary elements, but airborne systems will continue to provide platforms to support these functions. Airborne platforms, particularly those which are organic to or under the control of the carrier battle group are generally more readily available to task force command. High-altitude, long-duration aircraft, either land- or fleet-based, also appear to the Panel to be essential. Land-launched platforms with days-of-flight endurance appear feasible.

3. New kinds of ships other than carriers, to function primarily as missile ships able to keep up with carriers in heavy seas, and designed to expand the combat radius of the carrier battle group (AAW, ASUW, ASW, and some land attack).

   - The Panel believes that SWATH designs offer the best combination of characteristics for this purpose.

4. Surface-launched, air-targeted (SLAT) missile systems of several hundred miles range should be designed for installation on these ships for anti-air warfare and for ASW, extending the range of fleet defense.

   - The SLAT concept for missile guidance can also apply to subsurface-launched weapons. It is, therefore, recommended that such missiles be capable of submarine and subsurface launch.

5. Long-range (e.g., 300 to 1000 mi, depending on payload) cruise missiles for attacking sea targets, land-based tactical air defenses, and other land targets should be developed that are smarter (i.e., more effective in a countermeasures environment), cheaper, and more numerous than currently planned systems for these purposes, integrated with the above information and control network, and capable of launch from diverse Navy ships. These long-range missiles will also benefit from target information from both airborne and space platforms and should be capable of accepting third-party target inputs or guidance.

6. Long-length, narrow-beam SES ships appear to offer major gains in capabilities for roll-on-roll-off and other assault duties. Such ships appear to

offer substantial improvements in support of air elements for across-the-beach support.

ESSENTIAL PROGRAMS TO SUPPORT APPLICATIONS

1. Operational concepts, tactics, and strategy for using these new systems should be developed and tested. This implies a new look at operational concept evaluation utilizing modern analytical methods coupled with operational simulation of new weapons and systems.
2. The Navy must be concerned about nonnuclear ballistic missile attack on our ships and about special risks of NBC warfare, with collateral or even primary effects such as EMP, and begin planning to meet these threats with special emphasis on incorporating countermeasures in new ships, aircraft, and systems.
3. Emerging technology for greatly increased--in fact, a whole new concept of--reliability must be consciously developed and used. The cost of doing so will be more than returned by the gains in decreased logistics tail, manpower, reduced system failures, and actual lowered cost of individual weapons if adequate control of initial specifications is included as an essential part of the Navy's search for reliability.
4. The same technologies that make possible the network suggested as "priority one" offer new practical opportunities to develop advanced control systems, and automation for drastic reduction of manpower in operating new ships and combat systems.
5. Advanced electric propulsion (drive) subsystems for ships offer design advantages that can capitalize on item 4, above, and provide other inherent efficiencies.
6. Exotic fuels for extra-long-endurance aircraft and ships, e.g., liquid hydrogen.
7. Ballistic missiles designed to attack enemy ships and other targets should be continually studied to seek advantageous applications and clues to defense systems should the potential enemy deploy them. The concept of MIRV'd warheads for such missiles must not be overlooked.

BASELINE TECHNOLOGIES

The system concepts and supporting programs enumerated above are all based on an adequate and sound foundation of supporting R&D. This must be continued at a consistent pace in order to make these new concepts feasible and should be done as necessary R&D even if current circumstances indicate delay in procurement. Specifically:

1. General weapon guidance R&D, including mid-course and terminal guidance for sea, undersea, and land attack, must be continued along with technology development to support some form of the forward-pass concept explicitly recommended.
2. The basic aeronautical technologies, aerodynamics, control-stability, structures, and propulsion which now make advances in V/STOL feasible and which would permit increases in the endurance of high altitude aircraft must be fully supported.
3. More effective warheads for all purposes.
4. Guidance concepts for direct aircraft-to-aircraft combat.
5. Better ship and ship system design for damage control and secondary damage amelioration.
6. Progressive improvement in ship design concepts for vessels smaller than current carriers to improve rough-water stability at carrier escort speeds, thus providing reasonable-cost missile and aircraft basing for specific missions.
7. Sturdiness and adaptability of all electronic elements and systems to achieve "iron box" reliability and "hands off" long life and constant readiness.

THE TRANSITION FROM HERE TO THERE

Technology will show strong indicators but will not, of itself, cause the major changes in naval aviation envisioned by the Panel. The Navy must decide to follow those indicators and go that way. The Panel believes that if naval aviation does not evolve to take advantage of its inherent capability for a broader dispersal of force it will not be serving the nation as well as it could. The Panel does not suggest that it is possible to design a system such as the one described in one step: procure it all, field it all simultaneously, and expect to have it work. Such a total system must be approached as a planned evolution, using exploratory operations in which elements of these concepts are introduced, tested in the operational field, and then incorporated, where reasonable, into existing assets or new system designs. The Navy should reevaluate its capability and organization to experiment and explore system possibilities to develop advanced requirements, and test their utility by the operators in an operational environment. Once satisfied that the technologies will be available and the operational concepts rational, a final commitment can be made for new systems and approaches. It will be especially important to develop, by experiment, the sturdiness of the information and control network and the potential effectiveness of deceptive techniques and tactics, to make certain that the ultimate system concept can withstand severe hostile action. Graceful degradation of the network under stress is a vital design consideration.

This exploration can be done at a reasonable cost. Full ITSS capability, SWATH ships, and V/STOL or days-of-endurance aircraft are not essential for exploring some of the concepts for forward-pass operations; simulations with E-2C's, helicopters, and temporary electronics installations are possible. A few missiles can be devised for use with separate control aircraft for simulation and trials. By this process the Navy can begin to see the promise and the difficulties and experiment with possible solutions, thus refining the concepts while building rational requirements. A parallel program can explore superreliability concepts and evaluate possible logistics, production, dollar and manpower savings.

It must be emphasized that the entire evolution cannot be accomplished with simulation alone. It will be necessary to build and operate some new conceptual equipment as part of the operational fleet in order to gain experience and build confidence in the Navy and supporting communities. This element of the evolution will necessarily take time and money but it should be initiated soon or the total system will be delayed even further than the decades it will take under the best of circumstances.

Elaboration of Main Concepts

CONCEPTUAL OVERVIEW

The emerging technologies summarized in the Executive Summary have clear and significant implications for the way the future Navy can look and operate. We see an increasing capability and usefulness to the physical separation of functions such as target acquisition, launch of weapons, guidance of weapons, final targeting, and command decisions. This separation demands the connection by an information transfer net so that the total system becomes much more dominated by what the Panel has come to call the "information war." This war is a contest to acquire and distribute information while denying such information to the enemy. It requires acquisition of surveillance and targeting information from a variety of systems, made available in the proper form, to the commanders of a multiplicity of attack and defense systems.

Once the integrity, value, and durability of the information network are established and maintained, weapons may be deployed aboard and launched from any platform, based on target information available in the network from any reliable source. Weapon control may be in the weapon itself or from a person, computer, or even robot controller somewhere in the network. Aircraft can function as surveillance and communications platforms, as weapons launchers, as weapons controllers for weapons that are launched from ships, as target designators, and as attack and fighter aircraft. The operators of aircraft may be in them or elsewhere, depending largely on where the human capability for decision can have the maximum impact. The best location for decisions to strike changing or fleeting targets in a chaotic environment is likely to remain in the aircraft. In many other situations, man can be more effective aboard ship or ashore depending on availability of data for decision and operation.

Advancing aerodynamic, structures, and propulsion technology is improving the performance potential of aircraft designed for basing on smaller ships remote from the big-deck carriers, or from land bases at very long ranges. This implies that very long-endurance aircraft and various forms of V/STOL capability for specialized purposes can now be considered in combination with new ship concepts (i.e., SWATH or SES) for dispersed basing or for staging to perform expanded range missions. Some of these missions could provide essential or emergency lines of information sources for the "information war." These new ship forms, besides providing stable decks for aircraft, promise carrier-compatible speeds in rough seas. They also offer efficient packing of missiles for stationing and use at the outer periphery of the combat formations.

This concept of using multiple air- or missile-capable small ships is not that of a lot of little carriers, but rather a capability to disperse support aviation tasks away from the big-deck carriers, making their "real estate" available for high-performance aircraft to expand classical offensive aviation missions. It should be noted that smaller air- and missile-capable ships make possible a wide variety of task group configurations including relatively simple integrated forces, in which the local net could use V/STOL aircraft or possibly RPV's to provide the same elements of information acquisition and control as larger complex forces. These smaller systems could provide an effective lower-cost capability for tasks not requiring a major carrier force, such as local protection of sea lines of supply. Incorporation of such elements in a major task force would also provide for graceful degradation in the event of successful enemy action.

This pattern of naval force evolution is not revolutionary in the Panel's view. It is a rational use of evolving system technologies which provide a communications and information network for ships, aircraft, and weapons using source information from national, regional, space, and locally controlled data-gathering systems. Once the expanded intelligence and command network is established, the creative distribution of people, computers, and the ship, missile and aircraft elements of the fleet is essential to maximize the efficiency, flexibility, effectiveness, and retained capability of the force in the face of inevitable enemy penetration and disruption. With these tools at the Navy's command, the opportunities for deception of the enemy by a "battle group plus" are legion, and the systems flexibility provides a fertile arena into which the newest deception, countermeasures, and masking technology can be selectively introduced.

THE INFORMATION NETWORK

The information network is not only a "support system," it is also the essential core of any combat force and, in some phases of combat, can become the primary element of the battle.

The USSR is implementing space-, air-, and sea-based information systems and is expected to continue to develop such systems. In some important respects it currently leads the United States.

The Navy, with its ITSS concepts coupled with MILSAT, is planning to develop and deploy a large-scale, wide-area, space-assisted information system connecting many decision makers, data bases, sensors, and weapons systems, thereby providing high-quality information in real time. Developing the U.S. "naval information system" properly, assuring its survivability, endurance, and graceful degradation during wartime, exploiting its potential, and providing for information denial to and deception of the enemy are of utmost importance to the future of naval aviation. The technologies supporting these developments deserve first priority in the application of resources to the evolution of naval aviation. It is expected that future information subsystems of ITSS will cover extremely large areas--oceans, or essentially the globe, when that is needed--and will provide information close to targeting quality on aircraft and ships of interest to any point around the globe in near real time. ITSS would also provide data on friendly air and surface activity for purposes of command and control of combat.

The augmentation needed to complete the information and control network should include the following:

- o Surveillance assets providing fine detail for reacquiring and localizing the threat for direct attack by aircraft or missile systems, including elements of guidance associated with SLAT (surface, etc.) and analogous mid-course correction concepts.
- o A similar system for detection, tracking, acquisition, and weapon delivery against submarines.

Much of this system exists, but must be expanded and renewed. Detailed study in this area was beyond our scope, but the link with aviation systems as we have defined them is apparent since enemy submarines can fire long-range missiles, but can also be attacked by them.

- A system for acquiring targets in land attack, especially air defenses, and helping to guide either land-attack cruise missiles or carrier-based aviation with standoff weapons to them.
- The appropriate, multiple redundant interconnections among all these systems.

Once these systems have been added, the Navy will be able to use current weapon systems much more efficiently and effectively; e.g., the F-14/PHOENIX, the A-6, the F/A-18, AMRAAM, and TOMAHAWK.

The detection (potentially identification), tracking, and targeting data provided by future space or high-altitude aircraft supported information systems will eventually demand the development of new missile systems of ranges much greater than the current systems. These may be either cruise or ballistic missiles, and they may be based on land or at sea using aircraft, surface ships, or submarines as launching platforms.

Deception, EMCON, jamming, third-party communications links, and other means of foiling enemy targeting and guidance will be an essential part of this information war. The development and deployment of systems designed to degrade, disrupt, destroy, or exploit the naval information systems being developed by the USSR are thus equally important and must be considered part of the U.S. Navy's overall information network. Maintaining a decisive information advantage is as important as obtaining and using information per se.

WEAPONS

The Panel believes that nearly all future aviation-related weapons will be "intelligent," i.e., guided. Most of the guidance systems requiring new development and application are needed for long-range weapons which reach beyond enemy attack weapon launch points or to penetrate enemy defenses from beyond their reach. Because of this long reach and the efficiency of carrying such weapons on surface ships, the concepts almost all involve lock-on-after-launch.

Achieving this capability may require mid-course guidance into a self-recognizable "basket" from which area-type warheads without terminal guidance can be effective (useful against aircraft, ships, or ground targets); coarse, third-party mid-course guidance with further, near-target, third-party correction; or terminal guidance for warheads with either of the above mid-course schemes. In the sense considered here, an attack aircraft with a bombing/navigation system similar in concept to that now carried by the A-6 or the F/A-18 launching either ROCKEYE or MAVERICK is consistent with these guidance principles, but such a system concept can extend to long-range surface- or subsurface-launched interceptor missiles or long-range ship or ground attack cruise missiles. Obviously, a fully operational Global Positioning System (GPS) will be a valuable aid to weapon delivery accuracy.

Two kinds of weapons are conceived to be of primary importance for the future. Since weapon and launch platform constitute the system, it is impossible to discuss them entirely independently.

"FORWARD PASS" TECHNIQUES

The expanded defensive and offensive radius of the threat and of the task force will demand range augmentation of both attack and defensive missiles. It would appear that interceptor missiles, even if based on ships at the edge of the battle group, should be designed for ranges of 400 to 600 mi and that cruise missiles for offensive use should be capable of at least an 800- to 1000-mi range, although range-payload tradeoffs are possible and ranges as low as 300 mi for the latter will be useful. The guidance technologies for making such long-range missiles effective will be well demonstrated within the next decade.

Capability to target and control weaponry launched from remote platforms, be they surface or airborne, will yield major enhancements in both defensive and offensive effectiveness and flexibility. The SLAT concept is representative of the air defense and ASUW case, whereas the AWSACS, PAVE MOVER (now JSTARS), and PLSS approaches are air-to-ground analogues.

The SLAT concept permits aircraft from the carrier or air-capable ship to serve as target-track/weapon-guidance/fire-control assets with essentially unlimited firepower. F-14's and F-18's carry fire-control systems which might (perhaps in combination with AEW) be adapted to handle eight or more anti-air missiles simultaneously, and to continue to target additional missiles as long as the aircraft can remain on station. They are limited in the current concept of operation to the firepower they can carry under their wings (~4 radar missiles). By launching the missiles from a surface ship, the airborne carriage capacity becomes less critical and the endurance of the aircraft can be maximized by substituting fuel for missiles. In a variant of this technique, air-to-air or air-to-surface missiles could be carried by fighter or attack aircraft serving as weapons "trucks" and launch platforms, with guidance provided by the surveillance/targeting SLAT aircraft. In either case, the opportunity is gained to reduce complexity and cost of the (disposable) missile by locating the bulk of the complicated avionics--the intelligence of the system--in the targeting aircraft.

Furthermore, the carrier magazine would then not have to contain large numbers of large, long-range PHOENIX-type missiles. The SLAT missiles can be carried in vertical launchers on a large variety of auxiliary surface combatants. While existing ships could accommodate these missiles, the Panel focused on the desirability of the SWATH type. SWATH would provide a platform which could maintain its station in all sea states at carrier cruising speeds. SLAT missile ships could be located considerable distances away from the carrier battle group center to provide a forward launch point for a 400 nmi SAM, with guidance correction (localization) provided by the targeting aircraft.

A similar SLAT concept appears feasible and desirable for ASW. It could employ a long-range, vertical-launched ASW missile to be guided and targeted by helicopters or other V/STOL aircraft from the air-capable ship. The weapon guidance platform could be the LAMPS III or some future ASW localization platform. This relieves the localizing platform from carrying the firepower necessary to reliably sink submarines. This is particularly important as Soviet submarines become harder, deeper-diving targets which may require a number of large weapons to achieve a high probability of kill. This SLAT ASW concept of operations can also overcome increasing standoff of submarine-launched anti-ship cruise missiles.

For attack operations against ship or land targets, introduction of remote targeting and guidance capability as typified by the AWSACS/PAVE MOVER/JSTARS/PLSS approaches will yield unprecedented flexibility, as well as fulfill the pressing requirement for standoff capability with weapons more affordable than ultra-sophisticated cruise missiles. It would also open the possibility of employing multiple airborne "trucks" with a few "smart" airborne platforms at standoff ranges.

CRUISE MISSILES IN THE ATTACK MISSION

There is a spectrum of scenarios and attack missions in which cruise missiles can and would be used differently, depending on level of defenses and costs. Assuming that the nuclear-nonnuclear ambiguity with the Soviet Union can be solved, or that the combat environment is clearly nonnuclear, the Panel sees these primary targets:

1. High-value targets on land and at sea tend to be heavily defended targets. They warrant the use of effective, expensive cruise missiles because they are "high value," and once such targets are destroyed they tend not to have to be struck again (e.g., major ships, unique tunnel through rugged mountains, major bridge). High-value, fixed targets on land can be prelocated prior to any conflict; those that must become active to warrant attack can be observed and highlighted when appropriate by the information network.
2. Some "high-value" targets, such as armies on the move, may be distributed and time-critical. They can best be struck by manned aircraft carrying suitable weapons. They could be attacked with cruise missiles with appropriate, probably local, last-minute targeting. The target acquisition system and missile cost problems need careful analysis and tradeoff in terms of numbers and guidance complexity (e.g., a carrier air wing at low attrition can deliver a few thousand warheads in a week). If it is the case that cruise missile unit cost cannot be reduced below $500,000 to $700,000 (in 1982 dollars) per missile, the probable preferred use of the cruise missiles would be to reduce the defenses so that carrier-based attack aviation with shorter-range, less-expensive weapons can reach and hit these targets with acceptable attrition. Many fewer missiles would thus be required than if they were used to attack primary

distributed targets such as maneuvering land forces.

Any of the above applications for cruise missiles in the attack require missile-launching capability for thousands rather than hundreds. This, plus a prudent standoff for a carrier, suggests the use of ships other than carriers. Provision of launchers to fulfill a total campaign could be accomplished by a combination of refitted conventional "escorts" and a few tens of ships and submarines newly designed for the purpose. If planned properly, this should be both physically and economically feasible.

AIRCRAFT CARRIERS OF CV/CVN TYPE— "LARGE-DECK CARRIERS"

After reviewing the various alternatives, the Panel concluded that the large aircraft carrier, and particularly the nuclear-powered aircraft carrier with its air group, will continue to be the Navy's most versatile and powerful surface warfare force element. The large aircraft carrier provides economy of scale, employs enough aircraft for sustained strike operations, and considerably enhances safety of operation for high-performance aircraft. Evolving technologies will lead to changes in embarked aircraft, weapons, distribution of functions, and particularly C^3I capabilities. However, it would be difficult to suggest a more apt system with refuel, refurbish, rearm, and damage control for the same number of aircraft, and to achieve the same responsiveness and time on station. The battle group centered on the large carrier will have greatest leverage for conventional limited wars, including the leading edge of threat scenarios with the Soviet Union.

However, the Panel also recognized the growing impossibility of operating a total offensive or defensive mission where all the essential "network" functions are supplied by carrier-based assets, in view of the changing capability of the opposing forces. Also, it was obvious that such limitations have forced the Navy into an extensive assignment of its carrier assets to a defensive role.

The main purpose of attack carriers should be to act as floating airbases for launching aircraft on offensive missions, particularly in geographic locations where there are no usable airbases on land within striking distance of important opposing forces that may be on land or at sea. Carrier-based aircraft have grown in size, capability, and diversity for target acquisition, attack, escort, and defense in parallel and in interaction with the size of the carrier. The carrier's onboard ASW and AAW defenses, and the defensive nature of its accompanying ships, have grown as the opposition, mainly Soviet, has become more capable. The consequence of having to provide defenses for such threat potentials is a reduction in the offensive power of the carrier's aviation assets in relation to their cost. This is even more dramatic if the cost of accompanying defensive ships is included. The growth of land-based and shipboard defenses at and around targets has further diminished the capability of the offensive air power that remains on the carrier.

In concrete terms, the battle group cost is now spent to bring approximately 70 attack airplanes within range of targets. The target complex includes naval forces, land armies, supporting enemy air forces, including those attacking the carrier force, and all supporting infrastructure and logistics assets. In any but the most minor conflict, 30 to 40 attack airplanes per carrier, using the simple ballistic weapons that currently constitute the bulk of our air-delivered weapon inventory, can do little damage to the opposing target complex unless they revisit it many times, with cumulative attrition that could be fatal in the case of adequate enemy defenses. In present circumstances the carrier is therefore at risk for periods that are too long, the attack aircraft are likely to be lost to target-area defenses before their mission is completed, and the political consequences of long war and collateral non-tactical damage are likely to be severe.

It appeared rational to the Panel that attention be paid to relieving the carrier of as much of the burden as possible of performing its own defensive role and freeing its assets for offense. No new concepts of the carrier itself were persuasive in the course of the study. The technology that is and will be available makes it possible to change these adverse and inefficient trends in two ways: by offloading defensive "overhead" from the carrier to increase the size of its offensive air arm; and by increasing the offensive power of that air arm. The carrier and its attack aircraft do not have to change to use this technology. Therefore, we believe that the large-deck, conventional carrier will continue to be the principal ship for offensive naval aviation, and because of carrier costs and ship life there probably will not be a significantly larger number of them than there are today. The size and configuration of the carrier do not appear to be driven by the potential of V/STOL or any of the other possible new systems being described.

COMBAT SHIPS OTHER THAN CARRIERS

Recognizing the advantages of a more dispersed and flexible task force and the promise of a major advance in the surveillance horizons, the Panel gave extensive attention to the task force support ships. A revised distribution of tactical responsibilities can relieve the carrier of many of its support missions in order to provide leeway for expanding its offensive capabilities.

Combat ships other than carriers have evolved as escorts to provide sensing, screening, and forward defense of capital (i.e., highest-firepower) ships. They have also undertaken independent missions where the firepower of capital ships was not needed. They have continued as conventional-design combat ships because that has been the known technology, it was convenient, and there was no compelling reason for modifying habitual operations. As the carrier has become the main capital ship, the other ships have become mainly sensor and defense missile carriers. They have also attempted to become aviation-capable to the extent of operating helicopters, thus modestly extending the reach of their sensors, primarily for ASW. This evolution has left the carrier as both the primary target and the center for defense, with the advent of the bomber, submarine and surface ship with standoff guided weapons as the prime threats.

Currently, these conventional support ships suffer the disadvantage that even in modest sea states (3 or 4) they cannot keep up with the carriers they support. Those that have the capability are often precluded from operating their aviation complement for ASW missions in either the carrier-escort mode or for independent assignments. Moreover, the reach of opposing forces using cruise missiles now makes these ships sufficiently vulnerable to attack from land or by submarines that independent operation outside the radius of carrier based aircraft becomes questionable--largely due to the lack of over-the-horizon surveillance. The Panel recognized that the possibilities of designing very long-range missiles for attack and defense, and the advantages of separating sensors from weapon launchers by using the information network, might expand the missions of ships other than carriers and might suggest renewed interest in other design concepts for such ships. The Panel pursued several promising new ship concepts and commends the following for major early attention by the Navy:

1. Addition of the very long-range missiles to present conventional escort ships. These may be air defense SLAT missiles, long-range ASW missiles, or land- and sea-attack cruise missiles. These ships would obtain information needed and command for weapon launch from organic aircraft assets or the information network.
2. Present ASW support ships might still operate helicopters as they do today. However, the radius of effectiveness could be extended by third-party targeting and the installation of longer-range ASW weapons. The third-party platforms could be RPV's, or aircraft from new-concept air-capable ships, or from land-based air assets. The extent of missile carriage on these ships may be limited, but because the main ship construction cost is "sunk," the cost per missile may not be high. A 61-missile VLS bay would represent reasonable firepower if reloadable after engagements. Some current escort ships may be too small for even this modest load.
3. New ships of conventional design specialized for the long-range missile carriage/launch role could be built. If of monohull design, they might suffer operational limitations in moving with the carrier in rough seas. They could be designed to carry many more missiles than the refitted, conventional escorts--e.g., some amphibious-type ships could carry many standard VLS bays.
4. For seakeeping and stability at carrier speeds, new designs such as SWATH or SES could be built for these expanded missions. The Panel was impressed by the original work done by the David W. Taylor Naval Ship R&D Center, Naval Ocean Systems Center, and the Naval Sea Systems Command in exploring new hull concepts that show promise of providing stable platforms in high sea states, capable of speeds compatible with carrier task force operations, but at substantially smaller tonnages than modern destroyers. The configurations of these ships offer more than adequate space for internal stowage of missiles and launching systems for ASW, sea and land surface attack, and

AAW missions. They also offer the potential for the use of helicopters and other V/STOL and STOL aircraft. Their relative properties are described in Table 1. Some of these ship designs also offer special advantages in terms of reduced vulnerability to certain kinds of attack. The need for air capability may derive from the requirement for servicing ASW helicopters, RPV's for "scouting" purposes, or for basing and servicing of aircraft to carry sensors and help guide SLAT interceptor or land-attack missiles if for some reason the long-range, long-endurance land- or carrier-based aviation is unavailable or unacceptable for this task. Ship complexity, size, and cost will obviously increase as aviation capability increases, so that careful system design would be needed to choose configuration, number of ships, and relationship to the carrier.

On balance, with all factors taken into account, the SWATH design appears clearly preferable for the missile-ship and ASW surface sensor carrier missions and aircraft-capable support missions (STOL). The SES design may lend itself better to missions such as amphibious assault where the densities of the loads, the potential for launching support aircraft and the shallow draft all contribute to potential mission success.

In all concepts where ships other than carriers operate far from other ships (including carriers), they would become vulnerable to "rollback" by saturation attacks. This would be less true for air attack if the ships were designed for AAW in coordination with the information network, but vulnerability to submarines might be increased. Such ships, in their "independent" or task force "periphery" role might then operate in groups of two or more for mutual support. With proper overhead intelligence, a single ship could carry both AAW and ASW SLAT missiles. Attention to denial of information about their presence through various techniques, some of which have been discussed, becomes increasingly important as their operation becomes more independent.

SHIP SELF DEFENSE

Not under development, but needed, is a new concept of self-defense weapon system for the defense of major fleet

TABLE 1

Characteristic	SHIP TYPE: Conventional Monohull	SHIP TYPE: SES Moderate-Speed (high length/beam)	SHIP TYPE: SWATH
Speed in Smooth Sea	Intermediate	Highest (50-60)	Lowest
Speed at Sea State 5	Worst (15 kt maximum practical)	Intermediate (Rough "Ride")	Best
Range (nmi)	All comparable if SES at comparable speed (order of 4000-8000 nmi, depending on conditions)		
Maneuverability for station-keeping in dispersed CBG	Least for speed in high seas; best for turns	Comparable overall; different in detail	
Volume Utilization for Missile Load	Worst if destroyer hull; best if amphibious assault ship hull	COMPARABLE	
Aviation-capable (if so designed)	1 helo, if destroyer hull; helo/V/STOL if amphibious assault ship hull	helo/V/STOL; CTOL at high speed	helo/V/STOL
Vulnerability: Missiles	ALL COMPARABLE		
Vulnerability: Torpedoes	Vulnerable	Less Vulnerable in near term	Vulnerable
Cost/Ton for Basic Hull and Machinery	Least	Most (cost comparison with monohull confused by introduction of new ship type)	Intermediate

elements; i.e., carriers and particularly major combat ships other than carriers. The targets in this defense mode are "leakers"--those weapons that have been launched, have avoided or penetrated the long-range defenses, and are closing the target. Since these may include submarine-launched ballistic weapons, much complexity can enter the overall defense concept from this source. The Panel believes that technology will be available to solve this problem, but the ship self-defense systems available today bear little resemblance to what will be required. Expansion of these new technologies should be supported. It is recognized, however, that priorities and economy of resources may first dictate the development of expanded long-range defenses against the platforms launching such weapons. Defense against the under-keel torpedo--not specifically considered in this report--falls in this category.

AIRCRAFT PLATFORMS

In general, the first-line combat naval aircraft as they are today, are likely, within the concepts examined, to continue in the same or quite similar forms for the foreseeable future. These include attack aircraft, fighters, and sensor-carrying aircraft such as the E-3, E-2, P-3, and S-3. As described above, some of the onboard subsystems, payloads, and functions of these aircraft are likely to change as new system components, weapons, and operational concepts evolve. A few novel aircraft types, some of them derived directly from aircraft known today and some wholly new, will be of interest, and they merit special mention.

1. It has always been useful to have "scout" aircraft aboard ships for specific reconnaissance. Recent events in the South Atlantic have again served to dramatize the indispensability of high-quality air and sea surveillance; preferably organic to the force. The float planes of World War II have been replaced by helicopters on ships other than carriers. For such ships, RPV's might serve this purpose--e.g., the range/payload/response-time characteristics of such a craft may well justify the additional expense and operational problems of launching and recovering such aircraft. The mission would be a "gap filler" for uncertainties in

the main information network resulting from spot failures or enemy action.

2. New V/STOL aircraft analogous to helicopters promise range/payload/speed characteristics that warrant considering them as helicopter replacements for such diverse missions as ASW localization, ASW SLAT, amphibious assault, and COD. To be truly useful, such concepts should be mated with new stable-deck ship concepts such as the SWATH (or SES for assault).

3. Technology potentially available in the near future would appear to make feasible aircraft with operating altitudes in the vicinity of 70,000 ft and durations on station from two to three days over most of the ocean areas of interest, using land bases accessible to the United States. The advent of such aircraft could have a major impact on fleet effectiveness if used as sensor and relay carriers, to augment and provide redundant (failure-resistant) capability for ITSS and MILSAT and related missions of target localization (e.g., as PLSS-type platforms for attacking air defenses on land or on enemy ships). Such aircraft could become links to the combat fleet for convoy command, carrying instruments and communications for target sensing and location and weapons call-up, and assistance in third-party guidance. These functions, along with direction of the platform, can be automated or commanded from the surface, requiring minimal or no onboard crew. They would not carry weapons.

The characteristics of these aircraft (low speed, light structure, outsize dimensions) make them generally unsuitable for carrier operations. The time to reach station in operations from land could be an undesirable "force multiplier" where over-ocean distances are large. It may well be desirable to configure some suitable ships, such as SWATH's or SES's with clean decks, to launch and recover these aircraft as staging bases.

As part of its review of future technologies the Panel addressed the potential of fuels other than synthetic JP-5. One fuel that promises major performance advantages is liquid hydrogen (LH_2). It can enhance the altitude and duration performance of the high-altitude platform in a major way, and, since this system is conceived as mainly ground based and needs few bases worldwide, it may be profitable to devise a program of research and demonstration to confirm the promise of this application. It appears that high-altitude duration on station could be increased up to 50 percent by the use of LH_2 due to its high energy density per pound and the potential of achieving laminar flow over major areas of the airplane by surface cooling. The use of cryogenic temperatures for electronic elements was not explored but would also be possible and beneficial.

4. Continuation of "conventional" V/STOL combat aircraft developments such as the AV-8B for supporting amphibious operations will also offer fleet operational flexibility for such things as independent operation of ships other than carriers, and should not be neglected.

NBC AND DIRECTED ENERGY

The naval advantage in a nuclear, biological, or chemical (NBC) war at sea goes to the side whose aim is sea denial, rather than sea control. Because the United States and its allies must rely on sea control to support specific interests and objectives while the interior lines of the USSR make pure sea denial a viable strategy for them, preventing Soviet success in NBC war at sea becomes a vital task of the Navy in accomplishing its wartime mission of sea control. If we are to prevent NBC war or, indeed, any war at sea, we must employ technologies that ensure a credible deterrence in the tactical as well as the strategic arena.

One can speculate on the possibility of purely tactical employment of nuclear weapons; i.e., employed only against targets at sea of recognized military importance with minimal collateral damage to land areas. It is also quite possible that chemical weapons could be directed toward American forces at sea. The circumstances under which a biological agent might be employed against U.S. naval forces are less clear, but intelligence estimates recognize biological warfare as a very real threat. Our present posture of vulnerability to the NBC environment does not support credible deterrence, but rather may tend to invite the situation our policy wishes to deter.

It is also very clear that the Soviets are making every effort to achieve an operational capability with a first-generation, space-based, high-energy laser weapon system able to destroy satellites that may be key to the survival of ITSS and Navy communications. Intelligence estimates give the Soviets the capability of deploying directed-energy satellite weapons in space by the 1990's. These could put U.S. satellites at risk and potentially pose a threat to aircraft. At lower levels, airborne and ship-borne laser weapons of modest power can destroy sensors and seekers on missiles and aircraft unless protective countermeasures become part of the system designs. (The Defense Science Board has recently studied this problem for land warfare, with results that are directly applicable to Navy systems.)

On the other side of the coin, one of the most important requirements of the next major war--and certainly one of paramount importance to the Navy--will be to selectively destroy enemy surveillance and communications satellites.

It is appropriate to note that an increase in the level of conflict is accompanied by an increase in the probability of employment of nuclear, biological, or chemical weapons. Intentions cannot be determined, but capabilities can frequently be assessed. The Soviet Union has a relatively greater capability to operate in an NBC environment and to wage offensive nuclear or chemical warfare (CW). Consequently, we must do what is reasonable and feasible to reduce the vulnerabilities of the surface platforms, aircraft, and personnel. Ships, like all other "targets," cannot survive a direct hit from a nuclear weapon. However, success in the information war, as we have defined it, can go a long way in reducing the probability of such a direct hit on any ship. In addition, actions can be taken to improve ships' hardness to the "cheap kill" (near misses and area-wide effects such as EMP). Likewise, it is difficult to protect the ships and men in the fleet today from the effects of direct hits of chemical or biological projectiles. Steps can be taken, however, to mitigate the effects of chemical warfare and, to a large extent, to reduce the danger of near misses or indirect attacks. The development of at least minimum protective measures, including positive-pressure ventilation systems for new ships, decontamination techniques, tactics, and training, is important.

Of particular importance to naval aviation, the Navy must:

- o Assess and correct as appropriate or required the EMP vulnerability of weapons, naval aircraft, combat systems, and vital C^3.

- Ensure the existence of an appropriate nuclear and chemical retaliatory capability.
- Ensure that electro-optical/optical systems are provided with protection against low/medium-energy directed-energy weapons.
- Develop and provide appropriate personal protection gear and decontamination equipment to permit flight-deck operations subsequent to CW contaminating attack.
- Provide flight crews with protection against flash-blindness.
- Take other defensive measures in retrofit or new ship design, such as positive-pressure ventilation systems and decontamination techniques, that will help ship survival in a radioactive or chemical-release environment.

BALLISTIC MISSILES IN NAVAL WARFARE

The capability obviously exists today to launch ballistic missiles from surface ships and submarines against tactical targets having reasonably predictable locations. CEP's for unguided trajectories are still sufficiently large that a unitary ballistic warhead with conventional explosives is unlikely to hit and damage a ship. Bomblet warheads may achieve hits, but with few enough bomblets from the pattern that damage may be minimal. The problem becomes even more difficult for the attack if the target moves and can maneuver when a launch is detected. For example, a ship at 28 kt can move a mile in an essentially random direction in about two minutes. Given the limited missile loads on ships, expenditure of those loads in this manner would not be viable.

This picture changes, of course, if the warhead can be guided so that each of one or two missiles is likely to hit the target. Then the attack will have the advantage of short response time, complicating the defense, and the combination of high explosive (which can be distributed in submunitions against targets like carriers) and kinetic energy can be especially destructive. The USSR is known to rely on command guidance for many of its missile systems. For terminal guidance of TBM warheads at sea, the guidance vehicle--aircraft, ship, or submarine--would have to approach close enough to the carrier battle group to come under its defensive air umbrella, which would not be practical. (Terminal guidance by satellite would, of course, avoid this problem.) However, it appears reasonable that over the next 10 to 20 years both the U.S. and the USSR could develop radar or electro-optical terminal homing systems that could withstand the reentry environment. In that case, ballistic missile attacks against high-value surface ships could become a more realistic threat. The defensive systems described here for use against cruise missiles could be adapted to meet such attacks--e.g., success in the information war would provide early warning of launch, deny target information, and confuse terminal guidance. It may also be found desirable to give an ATM intercept capability to ship self-defense missiles, a capability which is achievable today.

The main point is that for these defenses to work the Navy must be alert for signs that they are needed so that they can be brought into being. It will also be worth assessing the ballistic missile technological opportunities periodically to ascertain when weapon capability and economics justify adoption of the technology into weapon systems.

RELIABILITY

An important technology, emerging particularly from integrated circuit computer technology, is the increasing ability to make complicated systems work, and to continue to work with little or no attention, in severe environments, for long operating periods. The combination of carefully designed and built systems incorporating redundancy, automatic fault detection and self correction, and methods for the management of system diversity in case of degradation will make it possible to operate the kinds of systems described here with high states of readiness and effectiveness. This will not happen accidentally; the technology for reliability management must be developed further and must be used. The high costs of unreliability (logistics costs, manpower costs, and mission failure) must consciously be faced in the light of potential savings and operational enhancement accruing from superreliability. The necessary costs in design and manufacturing time, effort, and money will, of course, have to be paid to ensure superreliable ("welded shut") systems. The choices between reliability and maintainability must be made in terms of operating system costs, and must be tested not only to prove that the goals have been achieved, but to develop confidence in the constant readiness of such systems. This confidence is essential to the commander depending on such systems and it is also essential to prevent normal but costly logistics and maintenance planning and handling.

MANPOWER REDUCTION

The developing technologies of electronics, sensors, computer control, and robotics can be used to reduce drastically the need for continuous human monitoring and intervention in operation and maintenance of naval machinery in engine rooms and elsewhere aboard ship.

Many continuous watch-standing operations can be replaced by automatic control and alarm machinery. Such systems can be more reliable, and can cope more effectively with damage, than those with human intervention. Designs which remove the necessity for frequent human intervention also reduce operating costs substantially. Regular maintenance and monitoring of the need for maintenance can be done by instrumentation, and, thus pinpointed, the maintenance can be done with few people of high skills. Relieved of the necessity for onerous watchstanding, these jobs will attract the interest of skilled specialists and each individual can handle many more systems. The objective should be very little attention to machinery, with light major overhaul for those systems which instrumentation indicates are approaching failure. Human monitoring can rarely predict incipient failure where instrumentation can.

The damage control problem should be reexamined in terms of modern materials and design for failure and maintenance technology, with analysis of modes of damage and failure. Careful design and prepositioned materials and replacement system elements can cope with likely failure and damage events. Designs for damage techniques are well developed. Redundancy, alternate cable routing paths, fire control measures, robotics, etc., will reduce the possibility of major degradation from minor damage, and can maintain essential functions in the face of major damage.

Combat systems are becoming more automatic and computer managed; this trend should be encouraged so that the maximum of combat operations can be run with the minimum number of people. The modes of operation under degraded conditions, whether from battle damage or other failure, should, to the extent possible, be designed in. If carefully done, as the system degrades it should be capable of being operated by fewer and fewer people, so that the reduced crew remains adequate for the decreased capability of the combat systems. Automatic operation and understandable warnings of potential malfunction can cut down the necessity for 24-hr watches, thus further reducing manpower.

SHIP PROPULSION ELECTRIC MACHINERY

Even though most of the U.S. Navy's fleet of surface warships will be, in the near future, gas turbine propelled, the advantages inherent in using gas turbines in the design of warships have yet to be fully exploited.

New power transmission technologies could free the ship's most desirable real estate--the midships area--from having to be reserved almost exclusively for machinery spaces, intakes, and uptakes. Today, the need to have the propulsion plant's prime mover in line with the shaft and propellor means that the prime mover itself must be positioned fairly low in the ship. Because the underwater hull form of a typical warship has to be slender and gently rising from the keel amidships to the stern, the power plant also requires a location fairly forward in the hull. These two requirements combined mean the power plant of today must be both low in the ship and considerably forward of the stern. That combination was considered acceptable with steam propulsion plants because their weight and space demands forced location amidship, and low for proper weight distribution. Gas turbines are light by traditional power plant standards. The LM 2500, for example, weighs only 11,000 lb. Because of the habitual power plant location, today's gas turbine is further penalized because the enormous quantities of air it consumes must be brought in, and later exhausted, through large ducts that use up valuable hull volume and cause the decks of a warship to look like Swiss cheese where the structural integrity should be maintained.

It seems clear that, to take full advantage of the inherent characteristics of aircraft-derivative gas turbines, technologies that are known should be applied to decouple gas turbines from the traditional shaft drive line, and locate these units where volume for intake and exhaust is minimized and noise suppression simplified. One promising possibility is the development of electric generators and drive units which exploit the efficiency and near-zero electrical resistance of systems cooled to extremely low temperatures.

Because of the increased efficiency of superconductive systems, the weights and volumes of plants incorporating such systems need to be only 20 to 25 percent the weight of conventional electrical machinery, and their use would allow gas turbines to reach their full potential as naval ship propulsion prime movers.

Development of such plants would undoubtedly lead to major beneficial changes in naval ship configuration. The reduction gear, most of the propulsion shafting, and a significant portion of the air intake and uptake duct-work could be eliminated. Present CRP (controllable reversible pitch) propellors could be replaced with fixed pitch propellors. Main propulsion gas turbines would no longer have to be in line with the propellor, but could be moved to the ship's stern, making the midships area available for bigger, and more conveniently positioned, electronic and weapon payloads. It should be noted that the separation of the prime driver (turbine) from the driven machinery (shaft and propeller) is ideally suited for new concept ships like the SWATH or SES.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The Panel commends the Navy, the other military services, DOD, and NASA for the steady support over the years of a basic research, development, and demonstration program providing steady improvements in aerodynamics, ship design, analytical methods, controls and control systems, materials, structures, and propulsion systems. This program makes it possible to realize the vision of the future Navy we have presented. It must continue and should be augmented in the demonstration of new sensing, communication, guidance, and control techniques, structural materials, the use of alternate fuels, the techniques for VTOL, and new ship designs for redefined naval aviation missions. The Navy is urged to seek joint programs within DOD and with NASA in support of these technologies, and to make maximum use of developments by our allies.

More specifically, the Panel recommends that the Navy initiate these efforts:

1. Explore and gradually develop, building on the ITSS concept, total network designs for C^3I

utilizing space and aircraft links in support of major task forces for sea control, land attack, convoy missions, and land-based Navy systems designed for surveillance or ASW, strategic communications, and task force support. R&D should be initiated for the elements of such systems that are not in current programs. Particular emphasis should be placed on methods of target acquisition and communication that will not identify the presence of otherwise hard-to-find platforms. This latter effort combined with over-the-horizon targeting needs suggests emphasis on third-party targeting concepts and the forward-pass handling of longer-range guided weapons.

2. Major concept definition efforts should be initiated to define the aeronautical subsystems that will match the expanded horizon made possible by total network concepts. The Panel believes that the following platforms and weapons will emerge:

   a. A subsonic V/STOL aircraft to provide organic air surveillance and targeting of missiles in the "forward pass" mode. Such aircraft should also have autonomous air-to-air missile capability and might carry alternative electronic complements for electronic warfare or possibly ASW (SLAT) missions.
   b. A long-duration, land-based, minimum (or no) crew, high-altitude C^3I platform to supplement space systems and act as a target localization and guidance element for smart weapons launched from other platforms and as a communications link to other units of the force. Such a platform should also be useful in land-based ASW missions and for communications with submersibles. This platform would be an appropriate vehicle for experimentation with exotic, high-energy fuels such as liquid hydrogen.
   c. Long-range surface-to-air and surface-to-subsurface missiles (400 nmi and much longer as necessary and possible) for use from ships other than carriers, distributed over the area dominated by the task force, called up by command through, and guided by, information acquired by diverse airborne platforms.
   d. A long-range "intelligent" cruise missile (perhaps up to 1000 nmi range, depending on

payload), also for launch from surface ships other than carriers. This weapon, too, will be targeted and partially guided through airborne or spaceborne platforms. This missile is for anti-surface ship targets and for high-value land targets, probably with a variety of terminal guidance systems and warheads.

e. Other applications that have been mentioned in the preceding discussion, such as the use of conventional fighter or V/STOL aircraft to guide missiles in the SLAT mode, and RPVs for spot reconnaissance and filling of information gaps.

3. It appeared to the Panel that new ship concepts in the offing can greatly enhance the performance of the network/forward-pass modes of attack and defense now made possible by expected technologies. These programs appeared to be feasible to define now and are recommended:

a. A SWATH ship for carrying and launching the weapons of items 2c and 2d above. Such a ship platform could also be useful as an ASW sensor-operating element of the battle group ASW effort. The SWATH hull form also appears to be the ideal approach to modest-size air-capable ships. It is suggested that such ships could be bases for ASW airborne assets and could serve as a refueling staging base for the aircraft described in item 2a above.

b. The surface effect ship state of the art also appears ready to support conceptual and probably large-scale test and demonstration programs. It appeared to the Panel that application of this hull form with its low draft requirement is nearly ideal for assault roles where V/STOL aircraft are needed and perhaps roll-on-roll-off duties where V/STOL aircraft support could also be useful.

c. To obtain planning data to help design for the most efficient aviation applications of the SWATH hull forms, a concept definition effort should be initiated to determine their utility as staging ships or bases for V/STOL and pilotless aircraft. Such decks within the task force would relieve the carriers of some support and defense duties and allow an increased carrier complement of combat aircraft. This is independent of the application of the SWATH as a platform for long-range missiles, which the Panel firmly recommends.

4. Attention is needed to strengthen ship self defense within the overall network/long-range defense umbrella, to meet the threat of hostile weapons leaking through.
5. The system complexity implicit in the "network" concept will require special "make it work" programs for system hardware elements and to assist in a smooth transition from today's Navy to the one we have visualized. For the first purpose, the Navy can, for example, select components and subsystems from present or newly designed electronic and computer units to redesign into "welded shut iron box" form, where the concept is to design, test, install, and never touch again--a system element requiring no more attention than basic structure. Such an experimental program could point the way to future system programs. It is not intended to limit this welded shut iron box to C^3I elements of the overall system.

   More generally, the Panel suggests that the transition to the new system designs can be aided, and their chances of successful implementation greatly enhanced, if the Navy begins early experimentation with various concepts using existing components, for parts of the information network and to test system concepts such as forward control of weapons to over-the-horizon targets. Ultimately, it will be necessary to build operational versions of the information, missile, and ship systems to gain real experience in actual fleet trials and operations. As we have indicated throughout, there is great flexibility in the use of platforms for sensors, communications, and long-range missiles, so that gradual and reasonable incorporation of the more efficient and effective ships and aircraft we have described is possible in parallel with adaptation of existing ships and aircraft to the new modes of operation.

Additional comments on selective application of other classified technologies are contained in an appropriately classified annex to this report.

Attachments

Terms of Reference

PANEL ON THE IMPLICATIONS OF ADVANCING TECHNOLOGY FOR NAVAL AVIATION

Current Navy plans include a prominent role for carrier-based aircraft extending well into the next century. These plans are accompanied by a recognition that developments along a variety of technological lines may significantly influence the operational viability of the platform and its aircraft. In order better to understand these developments and their implications, to identify means by which the performance of the carrier and the effectiveness of its aircraft can be enhanced, and to assess those technical trends which individually or in combination will serve to define naval aviation of the 21st Century, the Naval Studies Board proposes to conduct a study beginning in the early fall of this year.

Specifically, the Board proposes to establish a Panel on the Implications of Advancing Technology for Naval Aviation to conduct an evaluation of those technologies likely to define or influence the characteristics of naval aviation in the period beyond the year 2000. The study will focus on those technologies affecting aviation based at sea, and will concentrate on the following areas of concern:

- Existing or emerging technologies which hold promise of improving the operational viability and utility of the carrier and its aircraft, or providing alternatives. The operational environment to be considered will include the presence and possible use of theatre nuclear weapons.
- An assessment of those scientific and technical trends which may contribute to a definition of the generation of naval aviation which will follow present and developing ship and aircraft designs.
- The role of command, control, and communications (C^3), and its potential for enhancing the operational performance of naval aviation.

The study will adopt a systems approach in which the reinforcing effect of combinations of elements (e.g., satellite surveillance in conjunction with tactical aircraft and/or tactical cruise missiles) are considered.

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