Defense Science Board
Task Force

on

FUTURE OF THE AIRCRAFT CARRIER

October 2002

Office of the Undersecretary of Defense
For Acquisition, Technology, and Logistics
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DEFENSE SCIENCE
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MEMORANDUM FOR UNDER SECRETARY OF DEFENSE (ACQUISITION, TECHNOLOGY & LOGISTICS)

SUBJECT: Final Report of the Defense Science Board Task Force on Future of the Aircraft Carrier

I am pleased to forward the final report of the DSB Task Force on Future of the Aircraft Carrier. The Task Force was tasked to address how aircraft carriers should serve the nation's defense needs in the 21st century and beyond. The task force considered the aircraft carrier's role, status, technology and environment.

The report makes a strong case for the Navy to aggressively pursue new sea-based air system concepts as it replaces its aging carrier fleet. In their report the Task Force states that transforming today's carrier force into the most effective, affordable sea-based air system possible is mandatory as an indispensable component of future military capabilities.

I endorse all of the Task Force's recommendations and propose you forward the report to the Secretary of Defense.

William Schneider, Jr.
Chairman, Defense Science Board

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DEFENSE SCIENCE
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MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board Task Force on Future of the Aircraft Carrier

Naval air's deployability and its freedom from local basing restrictions make it a credible and viable force of choice in future conflicts and a mainstay of the nation's combat-credible forward presence. Aircraft, weapons and ISR advances have increased the effectiveness of sea-based air to the point where it can deliver sufficient forward combat capabilities to contribute to U.S. success in future conflicts. As future conflicts become more uncertain, there must be a transformation in sea-based air.

The Task Force was asked to review the role aircraft carriers will play in the nation's defense need in the 21st century and beyond. Specifically, they were asked to examine its applicability and potential for transformation in the future.

The Task Force believes that Navy should aggressively pursue new sea-based air system concepts to keep ahead of missions and threats.

Our recommendations focus on providing the Navy steps to focus spending on development of a new carrier design to keep in step with future missions.

1. ***The Navy's near term options are limited.*** There is a need for nuclear-powered carriers beyond the latest Nimitz (CVN-77). Carriers now in the fleet are aging. The current design has reached its limits. Thus, the Navy should build CVNX-1, as planned. It must be a prototype for important shipboard technologies, missions and operating cost reductions, but it does not address the essential ship concept. CVNX-1 is the only concept sufficiently well developed to meet the requirements for the next carrier

2. ***Provide More Choices in the Mid Term.*** Carrier designs CVNX-2 and beyond should not be forgone conclusions. A joint DARPA/Navy appraisal of available technologies should be completed before each new sea-based platform design is approved.

3. ***Kick Start a Process to Provide the Navy Long Term Options.*** Establish a Carrier Technology Oversight Council (CARTOC) modeled on the

submarine equivalent, SUBTOC, to seek out new sea-based air platform technologies, both shipboard and overall system of systems concepts.

4. ***Spread Carrier Design and Construction Funding Over Several Years.*** Establish a funding process, with Congressional help, that levels the construction cost of large ships. Such an approach would substantially contribute to the continued viability of the national capability to build such ships

Continued reliance on sea-based air demands a strong system of systems that allows for continued adaptation and transformation to account for changes in mission, threat, aircraft design and capabilities and technology. The recommendations listed above are intended to focus the Navy toward a new carrier design that provides the flexibility in adapting to change.

Dr. William Howard
Task Force Chairman

FUTURE OF THE AIRCRAFT CARRIER

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SUMMARY OF CONCLUSIONS

Air Superiority

- **In all future conflicts, United States military forces must have air superiority.**
  - This will require fighter aircraft for counter-air which are inherently short range in the absence of airborne refueling.
  - Fighter aircraft have also been effective against enemy surface-to-air missiles, although Tomahawk Land Attack Missiles (TLAMs), Conventional Air Launch Cruise Missiles (CALCMs) and Joint Air Stand-off Surface Missile (JASSM) will also meet a portion of this requirement.
  - Air superiority may require Unmanned Combat Air Vehicle (UCAVs) for Suppression of Enemy Air Defenses (SEAD), vehicles whose range is also likely to be short.
  - Access to contiguous bases can never be guaranteed
  - Therefore sea-based air will be an absolute necessity

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Intelligence, Surveillance and Reconnaissance (ISR)

- **Precise, persistent ISR from a mix of space and airborne systems is a must:**
  - Future airborne ISR will consist of a mix of manned (e.g., JSTARS) and unmanned systems
  - Manned ISR systems will be predominantly land-based and will reach the battlefield using airborne refueling
  - Today's unmanned ISR systems are a combination of short (e.g., Predator) and long (e.g., Global Hawk) range systems.
  - If the Navy is to provoke strike capability with minimal land-based support, it will need sea-based ISR Unmanned Air Vehicle (UAVs).

3

Fixed Target Servicing

- **A wide range of assets, both sea- and airborne, can service fixed targets**
  - TLAMs, Air Launched Cruise Missile (ALCMs), JASSM, Joint Service Stand-off Weapon (JSOW), strategic bombers or tactical air with Joint Direct Attack Munitions (JDAM)
- **Sea-based air offers the opportunity to attack fixed targets**
  - Less cost than TLAM and ALCM
  - Greater sortie frequency than strategic bombers or land-based attack aircraft based at greater distance than the sea-based air platforms.

4

Close Air Support

- **Rapid fire support will be fundamental for widely-dispersed ground forces** operating against a range of enemy formations (e.g., small units, massed forces, buried facilities)
  - Usually beyond range of naval and land-based artillery
  - Where enemy forces are relatively fixed, or pinned down by ground unit tactics, unguided, area, and GPS-guided bombs can do the mission.
    - Can be launched either from strategic bombers or by Tactical Aircraft (TACAIR)
  - Where targets are moving, only laser- or TV-guided munitions are available today and only tactical aircraft (plus Predator and some helicopters) are capable of employing such munitions.
- Thus, until there are effective, long-range, automated target recognition munitions, **there will be a need for short-range air to engage mobile targets, and hence a need for basing at sea.**

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Operations in the Littorals

- **The assumption that sea-based air platforms can operate close enough to shore to permit TACAIR operations at the distances where targets are located is open to question.**
  - At the moment, there is no carrier-based alternative for land-based ISR vehicles (Joint Surveillance and Targeting Attack (JSTARS), Predator, Global Hawk, various Electronic Intelligence (ELINT) aircraft)
  - The extent to which carriers can operate near shore is uncertain
  - Yet threats against carriers in the littoral have been more theoretical than real so far
    - No nation has effectively deployed submarines against the US naval forces
    - To date, mines have not been effective against carriers, although they have damaged lesser ships
    - On the other hand, capable equipment is in the forces or potential enemies
    - Views within DoD remain mixed on how vulnerable carriers would be against a capable and determined enemy (e.g., China)
- **Thus carriers cannot necessarily operate "alone and unafraid" in the littorals to provide useful tactical air support (i.e., ISR, tankage and weapons).**

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Nevertheless, the Task Force concludes that, in a wide range of operations, sea-based air provides a crucial contribution to warfighting in the littorals, especially when limited land-based ISR and tanker support is available.

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A Quick Summary of Study Recommendations

- **The current sea-based air system design is forty years old and has little margin for inserting new capabilities.**
- **CVNX-1 represents a crucial step in reducing carrier operating costs and providing opportunities to prototype new sea-based air capabilities.**
- **The Navy must establish a process and funding level for carrier improvement with oversight by a SUBTOC-like council for sea-based air. This process must provide future U.S. Navy carriers with the best available concepts, tools and techniques for military effectiveness, with continuous updates.**
- **The Navy must work with Congress to fund carriers on a multiyear basis to avoid budgetary and infrastructure difficulties inherent in the current system.**

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FOREWORD

The aircraft carriers are today's capital ships. Like the wooden ships of the pre-Civil War era and the battleships of World War I, they form the core of U.S. Naval power. The sea-based air capability they support is an indispensable component of the American way of war.

The mission of sea-based air has shifted from countering Cold War, blue water threats to supporting land forces dependent on air-delivered weapons, logistics and ISR for their survival and offensive punch. The Navy's role has shifted to the littoral, where the large deck carrier is potentially at risk from enemy weapons of increasing sophistication.

Yet aircraft carrier design has not substantially advanced during the past forty years. Despite major advances in ship design, shipboard technology, aircraft concepts and cost reduction schemes, major shifts in Navy missions, personnel shortages and the rise of joint CONOPS, the new Nimitz class carrier of today is essentially the same ship it was forty years ago. CVNX-1, the next carrier design, is essentially an extrapolation of this concept. The Navy, and those who oversee it, have not invested in a meaningful search for alternatives to the large deck, multifunction carrier since the Nimitz design was completed in the early 1960s.

Sea-based air platform design is a complex, long term "system of systems" undertaking with aircraft, weapons, personnel, logistics and ship considerations. Rapid development of new ships to meet urgent mission requirements (such as occurred during World War II) is no longer possible. Today's new platform must incorporate the best thinking about future CONOPS, threats, weapons systems and reduced cost if it is to remain effective in the unpredictable, rapidly changing world of the twenty-first century. A system that is unacceptably expensive, or incapable of effectively performing tasks required in future military operations, will fall of its own weight. The Navy should seek the best future sea-based air system to guard against the collapse that doomed capital ships of the past (e.g., wooden-hulled ships in the Civil War and battleships in World War II.)

Forty years have passed since the design of the Nimitz without substantial changes – almost as long as the entire life of the battleship concept. The Navy must aggressively seek new ideas for vehicles that support sea-based air

power. After study, it may turn out that the large deck, multifunction carrier is part of the answer to tomorrow's needs; it may also be that a force consisting of several types of ships, some small and some large, would provide the lower cost and flexibility needed. In any case, transforming today's carrier force into the most effective, most affordable sea-based air system possible is mandatory for the Navy.

This report examines the future of the aircraft carrier. The Task Force considered the aircraft carrier's role, status, technology and environment. It strongly recommends that the Navy aggressively pursue new sea-based air system concepts as it replaces its aging carrier fleet.

THE FUTURE OF AIRCRAFT CARRIERS – AN OVERVIEW

The United States, as the world's sole super power, will continue to have vital interests around the world. The 9/11 attacks on New York and Washington make it clear that foreign powers will intrude into the United States, whatever the nation's policy abroad. Yet with cessation of the Cold War, the United States has withdrawn from many of its overseas bases and called its forces home, limiting its ability to react quickly and powerfully with forward-deployed military power. Even where forward bases are available, host nations may have different priorities and limit access for the use of those bases.

Forward deployed naval forces help to fill the basing gap by projecting U.S. military power around the globe from U.S. sovereign bases at sea.

Sea-Based Air is Now, and Will Continue to be, Key to Projection of American Power

The past decade, since the ending of the Cold War, suggests that precision air power is a critical component in the projection of power in virtually every foreseeable scenario that might involve the use of America's military forces. Undoubtedly, strategic bombers flying out of the United States, or bases out of the theater of military operations, will be able to reach targets and thus will remain a substantial portion of the combat power the United States can project from North America. But it is also clear that the presence of U.S. maritime air forces in a crisis area, without exacerbating local tensions and sensibilities, carries significant deterrent power, as well as military punch. Land bases can be an important part of that equation, although in a world of spreading missile technologies, the fact that they are fixed to one geographic point carries obvious vulnerabilities. On the other hand ships possess less vulnerability, because of their maneuverability.

Early, sustained and powerful action lessens conflict length. Naval air's ready deployability and its freedom from local basing restrictions make it a force of choice in conflicts around a world that has become increasingly unpredictable. Aircraft, weapons and ISR advances have increased the effectiveness of sea-based air to the point where it can deliver sufficient forward combat capabilities to contribute to U.S. success in future conflicts.

The focus of naval action has shifted from blue water to the littorals. There remains no credible conventional naval threat to the United States. Thus, naval aviation has shifted its focus to support ground forces that now rely heavily on air power for protection, offensive power, ISR, and supply.

The operational requirements are already stiff. U.S. ground forces will require quick response to calls for fires - 8 minutes maximum from call to weapons on target. That reality requires that weapons be within 40 miles of potential targets. Increased radius of action and endurance are imperative for future combat aircraft while the Navy must give increased emphasis in both training and technological development in order to enhance close air support capabilities.

The United States needs both sea- and land-based combat air power. Naval air has ready access to and range for areas such as the "Asian Crescent," Latin America and Africa that are the likely loci of future combat. In future conflicts it will offer a substantial complement to in-theater land-based air. In some cases it will represent the only tactical, responsive air power in the theater. As such, with its forward presence, sea-based air provides considerable deterrence, while its combat power can provide immediate entry and strike capabilities.

Sea-Based Air Must Be Transformed

A revolution is underway in the weapons available to U.S. air forces. The Joint Strike Fighter (JSF), UAVs and UCAVs, precision weapons and the capability to project ubiquitous, persistent ISR will provide substantial new capabilities to U.S. maritime forces. However to take full advantage of these emerging capabilities, the Navy needs to address the problem of sea-based air platform design. The Nimitz class carrier design, is more than forty years old. It is at the end of its displacement, stability, and electric power margins; most significantly, it cannot be upgraded to address future threats and weapon systems. Moreover, Nimitz class ships are expensive to operate, since the crewing requirements are so large - a product of a time when Navy manpower was cheap.

Despite enormous changes in ship technology, aircraft, and mission, the Navy has invested minimally in new carrier concepts over the past forty years. As a result, at present, only evolutionary options are available for future sea-based air platforms, while the pressures generated by technological change, scarce manpower, and decreasing funding grow. However the need to support legacy aircraft, for which there are no replacement plans, constrains options for

revolutionary changes in both the sea-based air platform design and its aerial vehicles.

The sea-based air system of systems consists of many elements – aircraft, ship, battle group defenses, ISR, logistic and support systems, personnel, joint operations and support infrastructure. Changing one element in the system not only affects tactical and operational concepts, it can have profound effects on other elements in the system. Transformation, by its very nature, cannot be an easy process.

Sea-based Air Platform Alternative Concepts

The Task Force considered strengths and weaknesses of twelve notional platforms for sea-based air: the current Nimitz, the Navy's planned future carriers, CVNX-1 and CVNX-2, a "super" carrier, a carrier with a shorter service life (35 years) requiring no refueling, the current designs for British and French carriers, a smaller, faster carrier, a Mobile Offshore Base (MOB), the LHD, an arsenal ship, and specialized platforms. The Task Force concludes that the Navy's options at this time are limited to evolutionary changes in the Nimitz design as a result of the paucity of alternatives. No other system of systems is sufficiently developed.

Additionally, the Task Force considered a number of the technical elements of sea-based air platform system design. This report highlights crew reduction, propulsion, ship electrification, signature reduction and survivability. Carrier design and construction funding, infrastructure, and carrier utilization will also be discussed.

Findings

The Task Force finds:

Military Role:

Aviation is a key element in the American "way of war." Sea- and land-based air power each have unique and, in most cases complementary, capabilities. Both have significant roles to play in the projection of power for the foreseeable future.

Access:

Sea-basing is critical to the projection of responsive power into the theater of operations. Theater land bases can play an important role, but are also vulnerable to denial by host nations and enemy attacks.

Combat Area:

The Navy must address the proper balance between blue water and littoral combat capabilities. Some feel the balance today still emphasizes too heavily the Cold War's focus on blue water.

Supported Aircraft:

Future sea-based aviation platforms must support legacy as well as future piloted and unmanned aircraft.

Nimitz Design:

The Nimitz design is dated. It possesses limited weight, stability and electrical power margins as well as limited opportunities for new technology insertion.

Undeveloped Concepts:

The Navy has not sufficiently pursued new sea-based aviation or surface-to surface weapon capabilities to provide alternatives to the current evolutionary designs that, of necessity, assumes the preponderance of weapon delivery by piloted, sea-based aircraft.

Crew Size:

The Navy can significantly reduce crew size to lower carrier lifetime cost without sacrificing performance.

Propulsion:

Nuclear power is worth the extra investment in terms of military effectiveness.

Electrification:

Extensive electrification will simplify ship systems and increase mission flexibility. Initial costs will be worth the investment in terms of long-term savings.

Signatures:

With additional work, carrier signatures can be reduced to the point where decoys and defensive tactics can greatly complicate, and often frustrate, most detection and targeting.

Survivability:

Against current threats, carriers are robust. However given future threats, they require continuous refinements and realistic testing.

Infrastructure:

The U.S. infrastructure for carrier design and construction infrastructure is presently fragile. The Navy, with the help of the Department of Defense (DoD) and Congress, must adopt a funding schedule to assure its continued availability and competence.

Utilization Rate:

The Navy has sub-optimized the carrier deployment cycle, a misuse of an expensive resource. The Navy must innovate to increase ship utilization.

Funding Strategy:

The current single year funding obligation for carrier design and construction is disruptive to the Navy and DoD budgets, as well as the U.S. construction and design capability. An advanced appropriations process is essential to allowing a more coherent and less disruptive design and construction cycle.

Recommendations

The Navy's Near Term Options are Limited

There is a need for nuclear-powered carriers beyond the latest Nimitz (CVN-77). Carriers now in the fleet are aging. The current design has reached its limits. Thus the Navy should build CVNX-1, as planned. It must be a prototype for important shipboard technologies, missions and operating cost reductions, but it does not address the essential ship concept. CVNX-1 is the only concept sufficiently well developed to meet the requirements for the next carrier.

Provide Move Choices in the Mid Term

Carrier designs CVNX-2 and beyond should not be foregone conclusions. A joint Defense Advanced Research Projects Agency (DARPA)/Navy appraisal of available technologies should be completed before each new sea-based platform design is approved.

Because carrier authorization occurs every four to five years, the Navy must create a continuous design and technology development program for future carriers (which it has not done in the past) to push the design of carriers to the limits of what is technologically effective. It must identify technology packages and "on-ramps" associated with future and current ships.

Kick Start a Process to Provide the Navy Long Term Options

Establish a Carrier Technology Oversight Council (CARTOC) modeled on the submarine equivalent, Submarine Technology Oversight Council (SUBTOC),

to seek out new sea-based air platform technologies, both shipboard and overall system of systems concepts.

The Navy and DARPA should jointly sponsor competitive industry and Navy teams to develop a new Navy air capability system of systems, including ships, aircraft, weapons and ISR. The system should make the best use of network-centricity and look ahead to new naval combat environments.

The Navy and DARPA should brief the CARTOC at least annually on their progress and identify on-ramps for technology insertion onto new and existing ships.

Before each carrier authorization, convene an OSD/DARPA/Navy board, chaired by the Under Secretary of Defense For Acquisition, Logistics and Technology (USD[AT&L]), to review how the system of systems is developing and how the Navy is addressing and accomplishing technology insertion.

Spread Carrier Design and Construction Funding Over Several Years

Establish a funding process, with Congressional help, that levels the construction costs of large ships. Such an approach would substantially contribute to the continued viability of the nation's capability to build such ships.

Fully fund CVN procurement by advanced appropriations over a period not to exceed five years (advanced procurement as necessary for long lead items.)

Conclusion

This report develops, in detail, the Task Force's findings and recommendations for each consideration mentioned above. The report is in the form of an annotated briefing, with presentation charts and accompanying supporting text. Following a brief section on the Role and Environment of Sea-based Air Platforms (slides 9-18), the Task Force's considerations are grouped in five sections: Sea-based Air Platform Transformation (slides19-31), Notional Concepts Considered (slides 32-36), Factors Affecting New Sea-based Air platform Design (slides 37-55), Summary of Findings (slides 56-60) and Recommendations (slides 62-68). Additional material follows in Appendices.

Sea-based air is critical to the Nation's ability to project military power. Continued reliance on sea-based air demands a strong system of systems combat punch that must allow for continued adaptation and transformation to account for changes in mission, threat, aircraft design and capabilities, and

technology. The Navy *must* point toward a new carrier design that provides for maximum flexibility in adapting to change. The long lead time required to design and build new capital ships means that the Navy must keep ahead of missions and threats in its development of the future aircraft carrier. To fail to do so could result in expensive Navy investments that cannot meet future missions. It could also result in national disaster.

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Why Have Sea-Based Air?

- **The United States has and will continue to have vital interests around the world**
  - Forward deployed Naval expeditionary forces project influence and as well provide military capabilities
- **Carrier Battlegroups (CVBGs) / Amphibious Ready Groups (ARGs) provide U.S. sovereign bases off foreign shores**
  - Even where the United States possesses bases, it may not receive full access
  - Where access is granted, may not be permitted to launch weapons-carrying aircraft
  - Carriers: mobile, sustainable, flexible air bases that position military capabilities on U.S. territory near most of America's vital interests
- **Sea-based air and the platforms that support it will fill a critical need for the foreseeable future**

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The United States, as the sole remaining superpower will continue to have worldwide vital interests for the foreseeable future. Protecting those interests requires that the United States be able to exert military influence well beyond its borders. Sea power is the most supple way to project enduring American military power anywhere on the globe; it is one effective, flexible means through which to apply strong military force to those areas where conflict is likely.

One of the major strategic factors that has emerged since the end of the Cold War has been the return of U.S. military forces to bases in North America. During the Cold War the United States and its military forces had access to numerous bases abroad. The great majority of those bases have been closed. Given that many of the threats confronting the United States and its Allies are ambiguous, American access to those bases that it still maintains is not always certain. Our Allies may well define international threats in substantially different ways than do Americans. As the ongoing campaign in Afghanistan

has underlined, they may well deny U.S. military forces access to bases that lie on their territory. Yet as a global power, the United States must be in a position to project its military power into areas of the world that are of concern to the maintenance of its economic and military interests.

Moreover, bases on other nations' territory carry with them a number of dangers beyond that of denial of access. They have in the past, and will in the future, provide ready targets to U.S. enemies. The bombing of the Kobar Towers in Saudi Arabia underlined this vulnerability. Bases in volatile areas of the Middle East will also cause political friction with local cultures and political situations. As long as the threat of the Soviet Union persisted during the Cold War, it was relatively easy to overcome such frictions with the looming danger on the horizon. But in today's international environment, it is proving more difficult to overcome such frictions, which could, in some cases, fundamentally undermine the relationship between the United States and some of its Allies.

Sea-based air platforms are less susceptible to in-theater basing concerns than land-based air bases; they provide sustainable, flexible air support, on U.S. territory, that can be quickly deployed to conflict areas.

Strategic Picture for Carriers:

- **QDR + 9/11 => Unpredictable future military scenarios**
  - Political, religious, and economic conflict in the Asian crescent from North Korea to Southwest Asia, Latin America and Africa
  - Regional conflicts likely
  - Non-state threats evident
  - U.S. must dissuade threats by projecting combat-capable presence
- **Land bases not always available** – the Asian crescent is accessible from the sea
  - Air refueling, ISR issue
- **Sustained airpower critical in every foreseeable scenario**
  - Long-range standoff weapons for fixed targets and delivered weapons for mobile and fleeting targets
  - Early rapid air response is particularly critical in the early phases of conflicts
  - Sea-based air a critical capability

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The murderous attacks on the World Trade Center and the Pentagon made it clear that the United States no longer enjoys immunity from the troubles of the outside world. If the world is not to sink back into "a dark age, made darker by the light of perverted science," Americans will have to engage their military forces in protecting the immediate and long-range interests of the nation and its allies far from their shores. Those forces must carry political weight in peacetime as well as military effectiveness in war. There is no reason to believe that military power will be any less important in the twenty-first century than it has been since the dawn of time.

The Asian crescent (from North Korea to Southwest Asia), the expected area for most future conflicts, is accessible to air assault from the sea. However long-range support, such as Air Force refueling from its tanker force, flying from distant land bases will be needed.

Sustained airpower plays a pivotal role in every foreseeable scenario – both stand-off weapons for fixed targets and delivered weapons for fleeting and mobile targets such as tanks, mobile missile launchers and air defenses. Early, strong application of air warfare has been shown to shorten conflict length and lessen adversary offensive and defensive capabilities.

Air-based Weapon Delivery, Counter-air, and ISR are Key Elements in U.S. Way of War:

- **Early, powerful action lessens length and intensity of conflicts**
- **Precision guided munitions have changed air warfare**
- **Current surface-to-surface weapons are not and alternative to air-delivered weapons**
  - Cruise missiles are slow and suitable only for fixed targets
  - Existing tactical rockets have limited range
  - Conventional artillery lacks needed range
- **Until new surface-to-surface weapons are developed, the delivery of ordnance to remote targets will rely on aircraft**

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Air delivered weapons have proven to be critical to success in every conflict of the past decade. Modern precision weapons are capable of producing destructive effects to an adversary's forces and to his infrastructure that were unimaginable forty years ago. Weapons delivery aircraft possess the range, reaction time and human presence that are consistent with likely future military operations theaters and rules of engagement.

The most important components of the world's prosperity, now and for the foreseeable future, are the petroleum supplies that underlie the Middle East – a region of enormous instability. Like so many of the world's critical areas, the Middle East territory lies relatively close to the ocean. Carriers operating in the immediate area of the Persian Gulf, or readily deployable from outside the theater, offer both the deterrence of presence and the military punch to intervene in the area with devastating effect. The reach of carrier-based air, demonstrated at more than 600 miles in the Afghanistan conflict, exceeds, by a large margin, the range of conventional sea- and land-based artillery.

Studies of each of these conflicts clearly show that early, powerful application of air-delivered weapons is an important factor in lessening the intensity and duration of conflicts.

Air Operations in the Littorals

- **Ground combat relies heavily on air-based force protection, offense, ISR and supply**
  - Important element in every modern conflict – Desert Storm, Bosnia, Kosovo, and Afghanistan
- **Quick response times for close air support (about 8 minutes in Army combat commanders' judgment) will require weapons on station within 40 miles at all times**
- **Naval aviation has shifted from blue water targets to support of land forces**
  - Carriers operating in littoral waters are vulnerable to adversary threats and must be kept well offshore to be safe.
  - Increased combat radius and endurance are imperative for future tactical aircraft
  - Shift needed in training focus to increase emphasis on CAS and strike coordination support

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Future operational concepts for land forces, both Army and Marine, envision sizable detached groups operating within adversary territory. These forces will be mobile as well as lightly armed and supplied. They will be dependent upon airborne assets for logistics, situational awareness and force protection. This model is consistent with combat experience in the conflicts over the past thirty years.

For naval air, this represents a change in focus from operations against adversaries in a blue water environment to operations in the littoral regions that are the likely areas of conflict for the foreseeable future. It is unlikely that the United States Navy will confront a blue water threat in the foreseeable future.

Both Army and Marine briefers of the task force emphasize the need for quick response to calls for fires to protect ground forces. The consensus latency goal from call for close air support to weapons on target is eight minutes. If half that delay is taken up in resource assignment decision-making, four minutes remain for aircraft transit from loiter positions to attack. A vehicle traveling at Mach 1 covers approximately 10 miles in a minute, so weapons-carrying aircraft must be on station within 40 miles of the target and they must carry an

assortment of weapons to permit servicing many targets with different characteristics.

Future tactical aircraft and training need to emphasize this type of close air support and strike coordination and less anti-aircraft warfare.

Carriers operating in littoral waters are more vulnerable to adversary threats than they are in blue water. A carrier operating close to shore is easier to track in confined, shallower waters, is more vulnerable to mine and air attack, and targetable by land-based anti-ship cruise missiles.

A Mix of Sea- and Land-Based Air Capabilities Needed

- Sea-based air has quick response capabilities (arrives ready to fight in four days or less)
- Has access to the "Asian Crescent," Latin America, Africa - the locus of much of the world's troubles for the foreseeable future.
  - On the other hand, sea-based air platforms are vulnerable to future weapons.
- In-theater land-based air can have higher sortie rates, is better able to sustain prolonged operations and employ larger aircraft.
  - But air bases are also vulnerable to adversary attack
  - May have access issues

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The decade since the end of the Cold War has underlined the fact that precision air power, on a sustained basis, is a critical element in the projection of power in virtually every scenario that might involve the use of American military forces. Undoubtedly strategic bombers, flying from the United States or bases outside the theater of military operations, will be able to reach targets; they will remain a substantial portion of the combat power that the United States can project from afar. But it is also clear that the presence of U.S. maritime forces in a crisis area, without exacerbating local tensions and susceptibilities, carries deterrent power as well as military capabilities.

Land bases can also be important factors in that equation, although in a world of spreading missile technologies, the fact that they are fixed to one spot carries obvious vulnerabilities.

Air Capability is Undergoing Major Changes

- Joint Strike Fighter (three versions)
  - Enhanced range, stealth, and flexibility (Short Take-off, Vertical Landing [STOVL])
- UAVs and UCAVs coming
- F-22 and bombers in joint operations

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Combat aircraft are undergoing major changes from today's vehicles:

The Joint Strike Fighter (JSF) will replace current manned strike aircraft; it will have significantly improved range, payload, stealth and mission flexibility. The three versions specified by the Navy (designed for use with catapults and arresting gears), Marines (STOVL) and Air Force (land-based) each have different performance parameters but share much of the same technology and hardware.

Unmanned Aerial Vehicles (UAVs) and their combat siblings (UCAVs) are certain to join the inventory of sea-based air vehicles in the near future. These robotic aircraft approach the size of the F/A18 and will require much the same maintenance, technical and logistic support needed by manned aircraft.

Future air operations are certain to involve joint assets, as has been proven in Afghanistan.

But Legacy Aircraft will Continue to Play Critical Roles

- **B-52s still important**
- **USAF support (tankers, Airborne Warning and Control System (AWACS), JSTARS, ISR) critical to sea-based aviation**
- **Organic legacy systems (E2C, C2A, EA6B, F/A18) needed for foreseeable future**
  - Will be in the inventory for the next thirty years
  - These need large decks
  - Limits options for future sea-based air system
  - Replacement choices for current sea-based ECM / defense suppression / tanker platforms is a particularly serious need

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Despite advancements in combat air vehicles, future sea-based air platforms will have to support legacy aircraft. Just as the B-52 remains an important Air Force combat asset into its fiftieth year and beyond, support aircraft such as tankers, combat management aircraft (AWACS and JSTARS) and ISR assets (such as Rivet Joint) will remain in the operational inventory.

The Navy has no plans to replace its unique legacy support aircraft, such as the E2C, C2A, EA6B and F/A-18. The lack of a replacement for electronic countermeasures (ECM), tanking and airborne control platforms is a serious weakness. The lack of legacy replacement generates a need to continue to provide sea-basing for these aircraft, limiting the Navy's carrier options; as now envisioned, they will require large decks, catapults, arresting gear and maintenance support indefinitely.

Air-Delivered Weapons are also Changing:

- **JASSM, SLAM-ER, JSOW, JDAM enable precision attacks on fixed targets, safer standoff distances**
- **Greater precision allows smaller weapon sizes**
  - More targets addressed per aircraft
  - 250 pound precision weapons can replace 2,000 pound unguided bombs with greater effect and less collateral damage for many targets
  - Still smaller weapons may be feasible
- **Precision attacks on fleeting and mobile targets still limited to laser- or TV guided weapons**
- **Mixtures of smart and unguided weapons still required to address full spectrum of needs, including buried and area targets**
- **All the implications of the above apply equally to adversary weapons**

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Air-delivered weapons are also changing. The inaccuracies of unguided weapons dictate that these weapons be large and heavy, packed with explosives, to assure target destruction because of their large circular probabilities of error. Unguided weapons, however, are not as inaccurate as they once were – with GPS precision location of target and aircraft release points, dispersion of impact points of unguided weapons has improved. Nevertheless, with unguided weapons, strike is a matter of delivering weapons tonnage to the target.

Smart weapons such as JASSM, SLAM-ER, Joint Service Stand-off weapons (JSOW) and JDAM are far more precise. Follow-on weapons will continue to increase precision, allowing for smaller lighter weapons. Smaller, lighter weapons mean that future aircraft can carry more munitions and service more targets than was thinkable with unguided ordnance. The figure of merit for strike with smart weapons is changing from tonnage deliverable on target per sortie to number of targets (DMPIs - Designated Mean Points of Impact) serviceable per sortie.

The Afghanistan experience emphasizes, however, that there remain significant numbers of targets that require large, unguided bombs (e.g., buried

facilities and area targets), but much of the bomb load has shifted to smart weapons.

Weapon capabilities now available to U.S. forces will, in time, be available to adversaries. Precision guided standoff munitions and targeting sensors are certain to become widespread within the life of sea-based air platforms entering service in the early years of the twenty-first century and must be included in their threat profiles.

Sensor Packages and Information Flow Improvement

- **Mobile targets must be attacked in a timely fashion**
  - Weapons release authorization must be made quickly (<4 minutes) to be consistent with an 8 minute latency
- **A combination of national, joint theater, and organic ISR capabilities available; their data must be integrated to be effective**
- **UAVs present new possibilities**
- **UCAVs will be available within the lifetime of future sea-based air platforms**
- **Persistent,ubiquitous ISR necessary to detect, identify, and target unconventional foes**
- **Sensor capabilities to ID targets obscured in foliage and urban environments needed**
- **Enemy space-based ISR capabilities will improve**

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Warfare in the future requires improved ISR performance over that available to past combatants. Killing mobile and fleeting targets, as well as threats to U.S. ground forces in real time, requires persistent, ubiquitous situational awareness and fast response to calls for fire. Future intelligence, surveillance and reconnaissance systems must make the best possible use of data from national, joint and organic collection and analysis systems. A merged operational picture is a must for timely use of information.

UAVs, will be important contributors to this merged picture because of their ability to penetrate and loiter over the battlefield and their capacity to host future sensors capable of penetrating foliage and sensing in an urban environment. The persistence necessary to detect, identify and target unconventional targets is a hallmark of these new assets. Future sea-based air platforms must be able to support and manage them.

Space-based sensing and UAVs are also likely to be easily available capabilities to U.S. adversaries for detecting, identifying, and targeting U.S. ships.

The Future Configuration of the Sea-Based Air System Should:

- **Provide sufficient forward combat presence to deter adversaries**
- **Provide ISR early in a crisis**
- **Deliver precise ordnance against air, land and sea targets**
- **Possess robust capabilities against enemy attack - guided and ballistic missiles, torpedoes, mines**
- **Arrive ready to fight, be sustainable on station and support a broad spectrum of missions**
- **Be adaptable and flexible to future missions and threats as they develop.**

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The system of the future may focus on a single, multifunction platform supported and defended by a battle group, as is the case with today's aircraft carriers. But it could also be centered on a collection of special-purpose ships.

Need for Carrier Transformation

- **Nimitz Class is a ~ 40 year old design**
  - Product of an era when manpower was cheap
  - Labor intensive
- **The Nimitz design cannot support required enhancements to meet new threats / opportunities**
  - Insertion of future capabilities (Electro-Magnetic Air Launch System (EMALS), UAV/UCAVs, . . .)
  - Survivability improvements needed to meet emerging threats
- **Limited service life allowance (SLA) / margins**
  - Weight/volume (<2% margin remains)
    - Displacement/stability – cannot accept more weight
  - Electric generation capacity/distribution - little margin remaining

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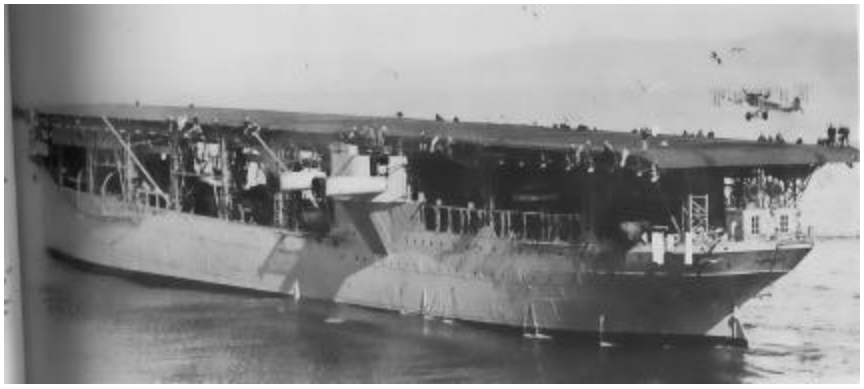
Nimitz class carriers have been overtaken by requirements and threats that were not foreseen by their original designers. Yet the Navy has invested essentially zero RDT&E funding to improve the Nimitz design over the thirty years preceding the CVNX program.

- Ships get heavier as they age. The Chief of Naval Operations (CNO) has prescribed a requirement for "Service Life Allowance" of aircraft carriers of 7.5 percent weight margin (displacement.) The newest Nimitz carriers have approximately 1 percent margin remaining. They cannot incorporate design changes without identifying offsetting weight and stability changes. Additionally, the existing low stability margins can result in operational complexities. Increasing weight has degraded speed; its distribution has also degraded stability and hence the ability to handle heavy seas and the sea conditions needed to launch and recover aircraft.
- Similarly, the Nimitz electric power margin is exhausted.
- Passive protection systems are inadequate to deal with future adversary threats.

These three issues are core to carrier design and extremely difficult and expensive to resolve on an in-service basis.

Reduction in the operating and support costs of Nimitz class carriers was a motivation for the CVNX program. The manning document for the current Nimitz class aircraft carriers prescribes over 3,400 enlisted personnel to man the ship with a wartime complement. This crew size, plus the manpower associated with the air wing, is the largest contributor to the Nimitz-class Total Operating Cost (TOC).

The same time has elapsed between the design of USS Langley (CV-1) --



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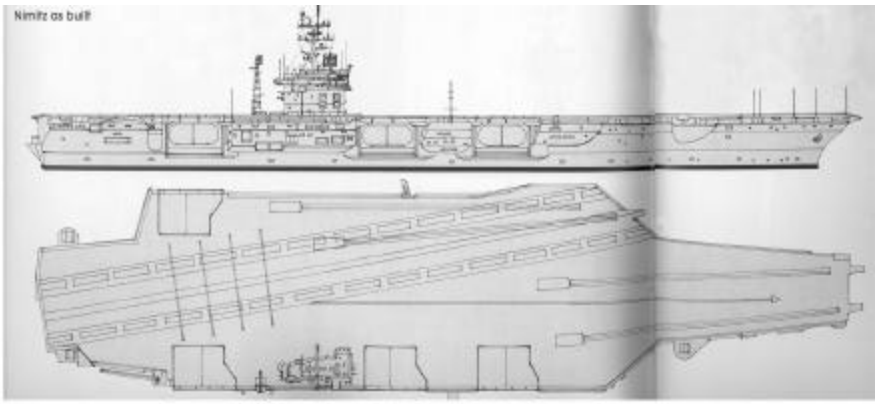
The USS Langley was the first U.S. aircraft carrier. Its concept was based on lessons learned by the British Navy in WW I. Commissioned in 1922, it was built on the hull of the collier, USS Jupiter, whose bunkers were turned into magazines, aviation fuel tanks and maintenance space. It had a displacement of 12,700 tons and a top speed of 14 knots. Its flight deck was 534 feet long; its crew consisted of 350 sailors.

and the design of USS Nimitz (CVN-68) --



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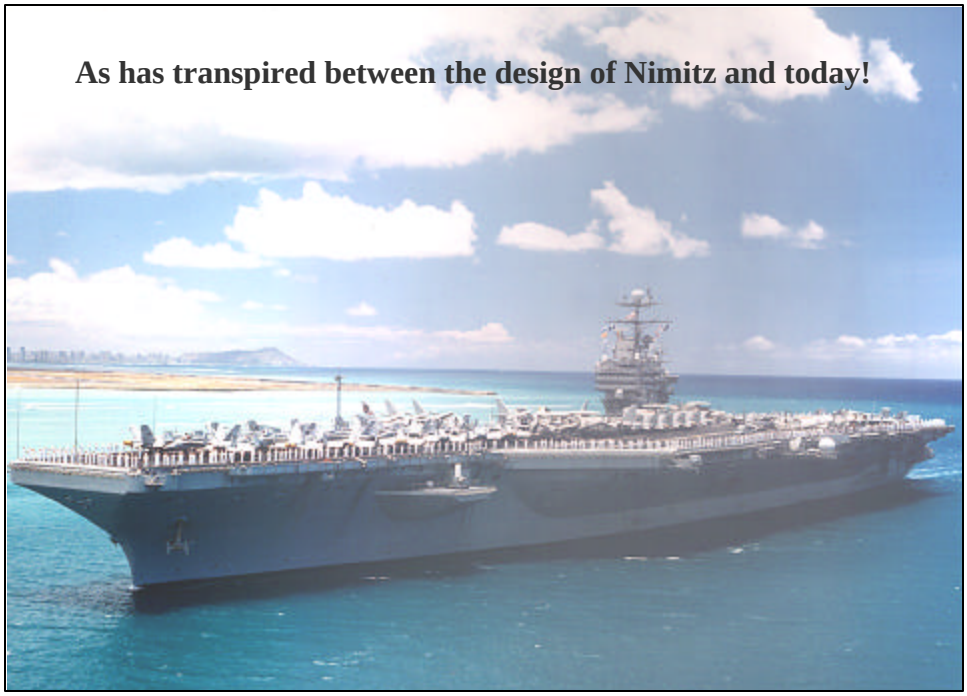
The Nimitz class of carriers was designed in the late 1950s and early 60s – forty years after the Langley. USS Nimitz, namesake for the class, was commissioned in 1975. The class, today's state of the art for aircraft carriers, is based on lessons learned from WW II, USS United States, and the Forrestal and Enterprise classes.

The original Nimitz had a displacement of 81,600 tons (now grown to 96,500 tons for the latest ships in the class) and a top speed of over 30 knots. Its flight deck was 1,076 feet long and it carried a crew of 6,400 sailors.



The changes between Langley and Nimitz took place over roughly a forty-year interval. During the subsequent forty years to the date of this report, there have been only evolutionary changes in the Nimitz and its systems. Nimitz-class carriers have steadily increased in displacement, crew size and electric power needs. Although the hull configuration has remained the same; the concept and basic design of the ship has not changed.

Changes in Non-Carrier Shipboard Technology in the Last 40 Years

- Transition to electric auxiliary systems (versus steam, hydraulic, pneumatic)
- Significant radar improvements
- Significant reductions in ship manning
- Improved crew habitability
- Roll stabilization systems
- Two generations of embarked aircraft - transition in sight for UAV/UCAV
- Several generations of nuclear propulsion improvements

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Shipboard technology has advanced significantly in the forty years since the Nimitz design.

The transition to electric power for auxiliary systems from steam, hydraulic and pneumatic power has improved the flexibility of a ship to adapt to new equipment and missions. For example, for aircraft carriers, the change to EMALS could reduce the ship's thermal signature and allow better control of catapult operation.

U.S. and British experience with new ships predicts that carrier crew size can be significantly reduced from Nimitz class levels. Since direct and indirect personnel expenses are a large part of carrier operating cost, crew size reduction will significantly decrease the lifetime carrier cost. Additionally, a smaller crew size would make possible improved living conditions and more interesting careers for sailors.

Shipboard radars have undergone two generations of improvement since the Nimitz radar was selected.

The impending entry of JSFs, UAVs and UCAVs into the operational inventory puts new support requirements on carriers.

Submarine nuclear reactor improvements have lengthened reactor life to over 30 years. While this is still less than the fifty year life of today's carriers, it raises the possibility that lower cost ships could be designed for a longer lifetime (~35 years) avoiding expensive mid-life refueling overhauls and time off-line.

Single-Step CVNX Non-Recurring Costs

		(TY$B)
Design		4.2
Feasibility Studies/Concept Design	0.1	
Functional/System Design	1.0	
Detailed Design	3.1	
Propulsion Plant Tech		0.5
IWS		0.3
EMALS		0.3
HM&E Tech		0.5
Aviation Tech		0.3
Survivability Tech		0.9
Total		**7.0**

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The design of new aircraft carriers is an expensive undertaking, made more costly by the Navy's lack of investment in carrier development since the Nimitz design. Until the CVNX design began, the carrier design force was Spartan, did not possess up-to-date design tools, and had no carrier-specific on-going technology development efforts. Because of the risk and cost of developing technology, a design workforce, and design tools in parallel with completing the CVNX design itself, the Navy has elected to fund the design costs in two steps, over two ships, CVNX-1 and CVNX-2.

New Sea-Based Aviation Platform Issues

- The Navy has not invested in new carrier design concepts since the first Nimitz
  - But extensively in new aircraft and other ship designs
  - New sea-based aviation capabilities and technology have not been resourced
- Cost is important in new carrier design but combat effectiveness is critical
  - Larger deck => more sorties, more capable aircraft
  - Flexibility / ability to support diverse missions

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Despite its extensive development of new aircraft and other surface combat ships, such as cruisers and destroyers, the Navy has invested little effort in investigating new sea-based aviation platform concepts beyond modest evolutionary improvements in current shipboard systems. Several revolutionary concepts (e.g., MOB, Sea Archer, new hull configurations, multiple ship replacements for carriers) have been proposed. None of these concepts have been sufficiently investigated to fully determine their usefulness as future carrier alternatives.

The Analysis of Alternatives for CVNX design places strong emphasis on efficiency as a figure of merit in shaping new designs. While the Task Force agrees that efficiency is an important consideration, it believes that military effectiveness (such as ability to arrive ready to fight or the ability to operate close to shore) should be the critical deciding factor in assessing design options.

Elements of the Sea-Based Air "System of Systems"

- Aircraft / weapons / ISR
- The ship
- Defensive systems in the battle group
- Targeting, C^4I, logistic and support systems
- Personnel and training
- Joint operations
- Basing, repair and dry dock facilities

A significant change in any one affects all others

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Sea-based air platforms are complex "systems of systems" developments. Mission support elements (aircraft, weapons and ISR), the ship itself, the defensive systems of the battle group, battle management, personnel and training, joint operations considerations, and the construction and repair infrastructure are all important factors in platform design. Significant changes in any one element affect all the others.

This complexity of interacting systems is reflected in the design costs for new aircraft carriers, which will total approximately $5B for CVNX.

Performance Metrics

- Strike target strike rate (peak, sustained)
- Survivability
- Life cycle cost
- Capable of air operations in high sea-states
- Flexibility (transformation potential)
- Efficiency
- Crew size (both ship's company and air group)
- Match to range of missions / effectiveness
- Mobility
- Sustainability
- Technology availability

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The Task Force considered many factors in its consideration of future aircraft carriers. A summary portrait of each of the alternatives considered follows later in this report.

"Tell me again how you 'forgot' to bring the Dramamine, Ensign"

Sea-worthiness remains an important consideration, even for ships a large as aircraft carriers. The Nimitz class is generally limited to flight operations for deck excursions normal for sea-states below 5.

Several Inevitable Trends

- **Technology will continue its advance**
  - Aircraft (JSF, UAV/UCAV, . . .)
  - Sensor systems (ISR)
  - Weapons (both ours and theirs) – more precise, smaller munitions, Automatic Target Recognition (ATR), new delivery
  - Ship electrification
  - Network-Centric Warfare based on Information Technology
- **Mounting pressures on manpower**
  - Recruiting and Retention
  - Opportunity Cost
  - Increasingly available automation
- **Future Budgetary Pressure**

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The continuing advance of technology affects all elements of the "system of systems" described earlier. In addition to the aircraft, ISR, weapons, and ship advancements listed above, improved network-centric warfare systems opens the possibility that command and control functions can be placed anywhere in the battle group.

Equally important, advances in weapons and ISR technology are taking place for adversaries as well as U.S. forces and allies. Sophisticated anti-ship missiles, wake-homing torpedoes and mines now available only to major technology-based armed forces, are gradually finding their ways into less-developed potential adversaries' armories. Future sea-based air platforms must be better able to contend with such sophisticated threats than today's carriers.

Conclusion

- **The United States will need sea-based air platforms for the foreseeable future**
- **Past Navy choices have been to optimize short-term uses of funds at the expense of carrier modernization and effectiveness**
- **Until major advances in concepts occur, future sea-based air platforms will remain limited to evolutionary changes**
- **Key technological developments could make revolutionary differences in sea-based air system design**

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The Task Force concludes that the United States will continue to need sea-based air platforms as elements in its military capability portfolio for the foreseeable future. Recent actions in Afghanistan only serve to reinforce that conclusion. The exact number of such platforms strongly depends upon the type of platforms available and the efficiency and effectiveness with which they are used.

Until CVNX, the Navy's choice was to invest minimal resources in new carrier concept development in order to have resources to develop near-term evolutionary modifications of the existing Nimitz design. As a result, major advancements in sea-based air platforms that potentially could improve efficiency (e.g., new ship configurations, crew size reduction) and effectiveness (e.g., signature reductions) have received little attention.

A consequence of this investment policy, given that the existing carrier fleet is becoming outdated, is that the Navy has no other choice than to select the CVNX-1 design as its next carrier. CVNX-1 will serve as an important step to improve carrier efficiency and effectiveness, but does not "push the envelope" to explore new carrier concepts for operational efficiency, effectiveness, new concepts of operations and survivability.

The Task Force concludes that there are technology improvements in aircraft, weapons, ISR and ship technology that could make significant changes in sea-based air platform concepts and use.

Promising Technologies that Could make a Difference in the Sea-Based Air System Design:

- Overall training: ship/air wing crew productivity improvements
- Automatic identification, targeting and destruction of fleeting and mobile targets (e.g., ATR that works)
- Small UCAVs
- Less expensive, easier to produce precision weapons
- An acquisition system to incorporate new concepts rapidly in the carrier system
- Space-based radar
- Reduced signatures
- Higher ship transit speeds
- Replacements for legacy support aircraft.
- Electromagnetic armor
- Advanced STOVL aircraft
- Assured (organic) ASW

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Some examples of promising technologies that could strongly affect the sea-based air system design are shown in this slide. Some are in development now.

Actual and Notional Platforms

- More “Standard” Nimitz-class carriers
- CVNX-1
- CVNX-2
- “Super” Carrier (150K tons)
- Carrier with nominal 35-year life (no refueling)
- British CVF
- French carrier design
- Sea Archer (High-speed, smaller ships to support sustained strike)
- MOB
- LHD
- Arsenal Ship
- Specialized platforms to support UAVs, UCAVs. STOVL-only wing

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The Task Force considered a dozen notional options for the sea-based air platform of the future. For reasons noted above, additional Nimitz class ships will be out of date and are not suitable to deal with future systems and threats. Additionally, the British and French overall designs are not appropriate since their design constraints (shipyard size) do not apply to U.S. ships. Each of the remaining notional platforms is briefly summarized on the next three slides.

Comparison of Alternatives Relative to Nimitz Design

CVNX-1:	Reduced Life-Cycle Costs (LCC) (smaller crew); new propulsion and electric plant design, increased sortie rate (EMALS, deck layout) and ability to more easily accommodate UAVs and UCAVs argues for an increase in effectiveness, restored service life margins
CVNX-2:	Same as CVNX-1 with added survivability features (e.g., dynamic armor) and increased sortie rate due to "pit stop" approach; restored service life margins, more effective than CVNX-1 second step in crew reduction, foundation for future upgrades

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Comparison of Alternatives Relative to Nimitz Design (Con't)

Super CVNX: (150K tons)	Increased sortie rate due to more efficient deck and increased seaworthiness and sustainability due to larger hull argues for substantive increase in effectiveness; CVNX-1 power plant in larger hull will result in slower top speed – would require new nuclear propulsion plant design. Unknown LCC impact as crew size/wing size not well defined. Requires extensive facilities upgrades
CVNX: (w/35 year nuclear core/no refueling)	Similar to CVNX-1 but planned retirement after 35 years. This could reduce some construction costs and will save refueling cost (potential total savings being examined by RAND); shorter life would result in normal mid-life upgrades being installed in new hull, more frequent opportunities for new technology insertion as ship replacement rate is higher

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Comparison of Alternatives Relative to Nimitz Design (Con't)
More Notional Alternatives

Sea Archer/Corsair: (13K ton air capable platform, 70 kts.)	Current technologies insufficient for power plant density required (fuel inefficient); small size of air group (7 a/c) requires at least 7 hulls to match striking power of a current carrier wing (using current aircraft configurations); not clear how flight ops are conducted at +70kts over the deck. Sortie rates, seaworthiness, and overall cost of multiple hulls to equal single carrier capability are other issues. Legacy aircraft not supported. Reduce survivability and sustainability but lower vulnerability due to higher speed. Closes faster.
Mobile Offshore Base (MOB): (3000'x300'; 6 modules)	Single runway will not allow simultaneous launch and recovery, resulting in lower sortie rate; the M in MOB is silent; will require organic or dedicated defense; Information Mission Area (IMA)/magazine protection/C^2 requirements could drive cost of 6 module MOB to well in excess of a Nimitz.

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Comparison of Alternatives Relative to Nimitz Design (Con't)
More Notional Alternatives

Arsenal Ship:	Inability to replenish at sea using current technology and lack of weapons for any targets other than fixed limit the utility of this platform. Its low acquisition cost and limited manning would produce a lower LCC but the utility would be limited to approximately 500 launches before going off-station to replenish.
STOVL-Only Platform (LHD):	With continued improvements in vertical lift technology, potential for additional strike platform to augment conventional carrier. Would require legacy aircraft support (E-2C, EA-6B, E-JSF), new sea-based support aircraft, or joint assets unless something like a Global Hawk-derivative could provide Airborne Early Warning (AEW) / defense suppression. Simpler deck could increase sortie rate and lower LCC. A 40,000 ton ship with less survivability than CVNX.

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Factors Affecting New Sea-Based Aviation Platform Designs

Factors Driven by Size:	Factors Driving Size:	Factors Indifferent to Size:
Propulsion Crew size Survivability Payload (aircraft, weapons, fuel) Tendency to concentrate command functions on a single ship Infrastructure	Air wing composition Sea keeping in high seas (displacement hull) Deck flexibility	Signature Long life vs. rapid technical change Where C2 functions reside in the battle group Specialized ships for unmanned aircraft Ship electrification Acquisition strategy Utilization rate

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The Task Force considered numerous factors affecting the design of future sea-based air platforms. Those not previously discussed are presented in the following slides.

Crew Size Reduction – Ship's Complement

- **Crew size (not including air wing complement) is a significant cost driver**
  - Nearly 50% of a ship's Total Operating Cost comes from direct and indirect manning.
- **CVN-74 baseline is 3460 people**
  - The current plans for CVN-77, CVNX-1 and CVNX-2 call for crew reductions (from CVN-74) of:
    - Smart Carrier and CVN-77 400-550
    - CVNX-1 700-900
    - CVNX-2 1200-1500
- **If met, the plan would reduce the manning portion of the CVNX-2 TOC by 40% from Nimitz class ships**
- **CVN-77 is the key to starting the crew size reduction initiative**
  - Indications are that near term cost constraints are already compromising the CVN-77's ability to achieve its TOC reduction goal

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Nearly 50 percent of a carrier's Total Operating Cost (TOC) resides in direct and indirect manning. The Navy has plans to reduce manning to lower this TOC figure, but has been moving slowly in implementing them.

As currently envisioned, a reduction in the manning portion of the TOC of 40 percent (about $5B savings) can be achieved for the CVNX-2 if the planned evolution from CVN-77 is followed. There are indications, however, that affordability is already impacting CVN-77's ability to achieve its established goal, adding doubt to the Navy's seriousness and aggressiveness in achieving major improvements in TOC.

The Navy must aggressively pursue work procedures and roles and technology improvements (from paint to damage control) if crew reduction goals are to be met.

People saved in these crew reductions must leave the Navy. Simply moving them ashore does not achieve the projected savings.

Crew Size Reduction – Air Wing

- **New aircraft designs have reduced repair and maintenance burdens**
  - The trend is to assign fewer maintenance people to squadrons
    - 40% to 50% maintenance reduction from F-4 to F/A-18
  - JSF, UAV and UCAV designs must continue this trend
    - Requirements documents already reflect this
- **Additional personnel savings can be achieved through organizational and procedural changes not currently being addressed**
  - While dedicated squadron maintenance is regarded as enhancing unit integrity, greater efficiency may result from consolidation into one Air Wing Maintenance Department
  - Additional savings may be achieved by placing record keeping ashore and improving information connectivity to perform burdensome logbook maintenance and other administrative actions

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The air wing crew is nearly as large as the ship's complement.

R&D investments made in the current generation of aircraft designs have improved reliability and maintenance and have resulted in fewer maintenance people assigned to squadrons. The JSF must further this trend – requirement documents reflect this. While it is recognized that dedicated maintenance departments enhance unit integrity, greater efficiency can be achieved by consolidating management into one Air Wing Maintenance Department and removing levels of intermediate maintenance. The Navy can achieve additional personnel savings by replacing time-consuming manual maintenance logging tasks. This entails moving record keeping ashore (copies could be readily available on the ship) and using greater information connectivity to perform logbook maintenance and other administrative activities.

Propulsion – Nuclear vs. Fossil Fuel

- **Nuclear propulsion offers highly desirable warfighting advantages at additional cost**
  - Arrive ready to engage
  - Maintenance of aviation qualification even in high-speed dash to station
  - Almost all fuel tankage dedicated to the air wing
  - Continuous high speed
- **Fossil fuel propulsion is an option but less desirable**
  - Fuel takes tankage, requires more frequent replenishment
  - Power density dictates gas turbines, which require extensive intake/exhaust ducting
    - Exhaust may affect deck operations
- **Nuclear - Direct conversion to electricity is a desirable goal**

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The advantages of nuclear propulsion in combat effectiveness are substantial. The ability of a carrier to operate continuously at maximum speed results in reduced time to arrive in theater and in increased time on station. Additionally, once there, the carrier is ready to fight immediately, since no ship refueling is needed before commencing operations. Air crews can continue to train while the ship is in transit. The only refueling the carrier requires is for the air wing (weekly in most cases).

Fossil fuel propulsion is also an option. However the impact on the combat availability of the carrier is considerable. The ship's ability to maintain maximum speed for sustained periods is sharply reduced. Refueling for fossil fuel-powered carriers must take place three times in transit between the U.S. West Coast and combat stations in Southwest Asia. While in theater, refueling is typically needed every two days.

The power density required for a fossil fueled aircraft carrier dictates the use of gas turbines. These require extensive intake and exhaust ducting. The exhaust can impair deck operations under some conditions.

Direct conversion from nuclear to electric power is a desirable goal as improved electric propulsors become available. Research on such reactors is underway.

Electrification of Ship Systems

- New reactor design in CVNX-1 will provide capacity for electrification of most auxiliary systems (replacing launch catapults, steam driven pumps, hydraulics, …)
- Electric main propulsion does not offer significant warfighting advantages with current technology.
  - Ducted propellers and water jets offer future possibilities
- New electrical generation and distribution systems:
  - Provide options for future warfighting capabilities
  - Increased survivability
  - Allows manpower / maintenance reductions

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The new reactor, generator and distribution system design in the CVNX-1 is capable of generating and transmitting 104 MW of electric power for use in ship auxiliary systems. A switch to electrical systems would make possible major reductions in the maintenance and operating crew required. Additionally, electric systems, such as catapults, can be easily programmed to provide optimum mechanical power for any aircraft loads.

For ships as large as aircraft carriers, electric propulsion does not offer operational, cost or weight advantages over steam. In the longer term, electrically driven, ducted propellers or water jets could be attractive since noise-producing cavitation can be significantly reduced.

Distribution of energy in electrical form through a ship is much easier and more reliable than traditional energy forms (steam, hydraulic and pneumatic power). Ability to quickly switch power to priority uses and to redirect power as needed in an emergency enhance ship survivability, provides new peak power options and significantly reduces crew needed for damage control.

Signature Related Vulnerabilities

- Current CVs has:
  - Large radar cross section (RCS) values
  - Significant levels of electromagnetic radiation
  - Large IR contrast with background
  - Large acoustic signatures
- As a function of the sensor and the sensor distance from the target, CVN signatures may permit:
  - Remote detection, ID, tracking and localization
  - Targeting and guidance control for standoff weapons
- Current tactics call for keeping carriers far out to sea early in a conflict to reduce possibility of adversary detection, tracking and location

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Although the average radar cross section (RCS) of a CVN is probably about 10^5 square meters, a polar plot of a CVN's RCS may have spikes equivalent to 10^7 square meters. At microwave frequencies, this implies that properly designed radars (on aircraft or spacecraft) that are within line of sight of a CVN can detect it, establish its radial range with great precision and establish its cross range location to within a beam width or better. Such radars can be used to establish the CVN's track and speed. In effect, a remote airborne radar can detect a carrier with sufficient accuracy to launch and guide a weapon to a location where the weapon's own sensor will support a terminal engagement. A remote land based high frequency (HF) radar can detect a carrier. Based on HF detection alone, the ID of the CV cannot be established and its location cannot be established with sufficient accuracy to support the successful launch of a weapon

Carriers must communicate and operate various radars and beacons. These radiations are sufficiently unique to allow ID and some degree of localization

Carriers radiate many kilowatts of IR energy and have a large IR contrast with the background environment. When atmospheric conditions permit, a carrier may be detected and imaged by an IR sensor on an orbiting satellite. Given adequate data links from such a sensor to a weapon in flight, a carrier may be attacked based on its IR signature.

Acoustically, carriers are extremely loud sources. In effect their screws always cavitate and, depending on environmental conditions, they may be detected and ID'd at ranges of several hundred miles. Localization adequate for torpedo attack can be established.

Carriers operate in an integrated defense system (the battle group). The resources of the battle group are available to mask the carrier.

Signature -- Reducing CVN RCS

- With careful attention to detail, shaping and the use of radar absorbing materials (RAM), RCS of future CVNs can be reduced from Nimitz values
- Although not enough to prevent detection by stand off radars, this RCS reduction makes protection by active and passive decoys feasible

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Although there may be structures and antennas on a CVN that are resonant at HF frequencies, the HF RCS of a CVN is basically determined by its projected geometric area. Little can be done to reduce the RCS value of a CVN at these frequencies. The probability of detection of a CVN by a remote sky wave HF radar can be degraded by jamming or by choice of a trajectory that provides minimum Doppler

On the other hand, at microwave frequencies, through attention to detail, shaping and use of RAM, the RCS of a CVN can be reduced from Nimitz values. Since most anti-ship missiles are radar guided, the value of achieving reductions of these magnitudes is substantial. Protection by decoys becomes more effective, Passive decoys (chaff) typically achieve RCS values of 10^3 to 10^4. A 20 to 30 dB reduction from the RCS values of the Nimitz begins to make CVN protection by chaff somewhat feasible. As the RCS of a CVN decreases, protection by active decoys becomes extremely effective and affordable.

Signature - Reducing Carrier Electromagnetic Emissions

- Although Emission Control (EMCON) operation of carriers is feasible for limited periods of time, carrier air operations are fundamentally dependent on electromagnetic radiation
  - Once ID'd, localized and targeted based on detection of EM radiation, the carrier's survival depends on success of decoys, the battle group's missile defense and ability to absorb damage

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One obvious way to avoid detection of a carrier's radiation is to operate in an Emission Control mode (EMCON). Although CVNs often transit in EMCON, flight operations require the use of radar, beacons and active communications.

The EM radiations from a CVN can be detected at extremely long ranges. Such detection is usually sufficient to permit unambiguous identification of a CVN. Depending on the sensor system, detection usually does not allow sufficiently precise geo-location to provide fire control accuracy for standoff weapons. The localization achieved by detection of EM can be used to cue other sensors so that fire control quality localization may be achieved.

Once an adversary has fired a standoff weapon based on the detection of radiation from a CVN and localization by some other sensor system, CVN survival depends on various layers of missile defense and the CVN's robustness in the face of damage.

Signature - Reducing Carrier IR Contrast with Background

- Seawater spray or piping under CVN skin could be used to minimize temperature contrast with ocean surface
  - Extraordinarily expensive to implement
  - Would not eliminate contrast with sky
- Best approach is to use missile defense supplemented by IR decoys

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The thermal contrast between a CVN and the ocean surface could be minimized if an extensive system of piping or water spray were installed under or on the skin of the CVN that allowed for a continuous flow of seawater. Such a system would be extraordinarily expensive to implement, and would undoubtedly be difficult to maintain. Although such a system might serve to minimize contrast with ocean surface, it would do nothing to reduce the contrast between the CVN and the sky background.

There is little that can be done to limit the ability of a remote IR imaging sensor to detect and ID a CVN when atmospheric propagation conditions permit long-range detections.

An anti-ship missile with an IR terminal seeker might be defeated by properly placed and configured decoys. The success of an IR decoy will be a function of how closely it negates the specific technology incorporated in the missile's seeker. Although IR seekers might be seduced to attack a decoy, a more robust approach would be to defeat the attacking IR missile with defensive weapons.

Signature – Reducing a Carrier's Radiated Acoustic Signature

- Inherently, little can be done to quiet a CVN
  - New propeller designs may raise the velocity for onset of cavitation, but for normal carrier operating speeds, cavitation will always occur
    - Water jet / ducted propeller propulsion could be quieter
  - The impulse sounds of landings and take offs can not be eliminated with legacy aircraft
    - EMALS will greatly reduce catapult noise
    - STOVL aircraft could be quieter
  - The expense of balancing and decoupling machinery is not warranted unless / until the propulsion system is modernized
  - Although decoys and anti-torpedo torpedoes are feasible, the best approach is to clear area of submarines and mines

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A CVN is an inherently noisy platform. The acoustic impulses of aircraft landings and take-offs can not be eliminated (except with STOVL aircraft). The propellers of a CVN operate at depths of between about 30 and 40 feet. At such relatively shallow depths cavitation will set in long before a CVN reaches its maximum speed. The propellers on CVNs are antique designs (more or less copies of propellers used on World War I battleships) and have a particularly low speed onset of cavitation. Although more modern propeller designs will raise the velocity for the onset of cavitation, they certainly will not stop cavitation from occurring. Water jets are believed to be capable of eliminating cavitation.

The propulsion and power generating machinery on CVNs is hard-mounted to the underlying platforms on which they sit. No attempt at acoustic isolation of machinery has been made, as it has been in the case of submarines. The price of doing so would be high. The range at which a CVN can be detected, ID'd, and tracked acoustically is a function of local propagation conditions. Under certain circumstances CVNs are subject to acoustic detection at ranges of several hundred miles.

Localization at such ranges is poor. However, a submarine (if not intercepted) can guide itself sufficiently close to a CVN to launch a torpedo attack. The

U.S. Navy has some acoustic decoys (Nixie) and has a concept for the use of an anti-torpedo-torpedo. The full implementation of an effective torpedo defense system is problematical. Although a Nimitz class CVN is designed to survive multiple (3 to 5) torpedo hits, even a single hit will probably result in mission-terminating damage. The best approach to mitigating the vulnerabilities related to a CVN's radiated acoustic noise is to find and sink enemy submarines.

Overall Carrier Signature Reduction

- Seek sensible cost ways to reduce carrier signatures to levels where decoys can be effective
  - Additional efforts in RCS reduction might pay off
  - Electromagnetic emissions reduction would seriously interfere with carrier operation
  - Reducing acoustic signature a difficult problem
  - IR signature can be reduced at significant cost
- **Raise the signatures of other vessels (integrated unmanned surface vehicles [USVs]?) to look like many carriers**

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Signature management for sea-based air platforms entails reductions to the point where decoys and tactics can be effective. No means currently exist to effectively eliminate signatures of ships this large. Their operation generates many electronic, thermal and acoustic signals to the point where signature reduction alone will not assure the security of the ship.

A design, which eliminates the island, could have significantly reduced microwave radar cross-section but an operational efficiency price. Such a design would not reduce HF, electromagnetic, acoustic or infrared signatures.

Extensive use of ship and battle group defense, decoys, and tactical maneuver will be required to assure the safety of sea-based air platforms.

Survivability

- Vulnerability
  - Current ship design is thought to be robust
  - Multiple hits required to sink a carrier (missiles/torpedoes)
  - Armor protection is adequate for today's threats but new technology offers improvements
  - Damage control automation is improving response and reducing manpower requirements
  - Survivability has not been tested under realistic conditions
- Recoverability (operating in a degraded condition)
  - A USN strength
  - Recovery (Fight Hurt) is a well developed blend of technology and training

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The modern carrier is the only surface ship now in the U.S. Navy designed and built to be survivable. The ship design encompasses many features (such as armored flight deck, double hull, magazine location, and shock-absorbing structures) intended to allow the ship to sustain multiple hits by missiles or torpedoes, yet survive. Automation is improving damage control effectiveness and response speed. The features now incorporated in carriers are effective against current threats but continuous improvement is necessary to keep up with advances in adversary weaponry.

While simulations, small-scale tests and estimates verify carrier survivability, there have been no live-fire tests on a large enough scale to determine damage and its consequences from attacks by modern adversary weapons. Live-fire testing on large sections of future sea-based air platforms is important to determine the real survivability of such critical components as the magazine and fuel tanks.

The U.S. Navy prides itself on its ability to carry out the mission despite damaged ships. This ability is a mixture of ship design and crew preparation. The Navy must assure that the ships such as carriers, are at the heart of Naval operations, are in fact survivable and must continue its emphasis on damage control training and continue the fight under degraded conditions.

Carrier Design and Construction Funding

Carrier design and construction funding extends over many years

Percentage of SCN Funding Authorized in One-Year
Expended in Following Years

Year	1	2	3	4	5	6	7*
	5%	13%	20%	17%	17%	17%	11%

*Current plan for CVNX-1 funding is over 8 years versus traditional SCN expenditure pattern of 7 years

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Construction and design costs for aircraft carriers are expended over a seven to eight year period, although current funding is principally allocated in a single year.

CVN Design and Construction Funding

- **Full funding of a CVN in the authorization year distorts the Navy's and Defense's procurement accounts for that year**
  - 83% of total SCN, 30% of total DoN procurement, and 11% of total DoD procurement
- **Funding over several years, appropriated at one time, called "Advanced Appropriations," is the scheme used by the federal government to fund large capital projects in the civil agencies**
  - Avoids major funding disruptions in the authorization year
  - Avoids temptation to incrementally fund CVNs through several years of "Advance Procurement" (AP) prior to the authorization year or "Shipbuilding Cost Adjustments" (SCA) subsequent to the authorization year

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The large amount of money required to design and build a nuclear carrier distorts the Navy and defense budgets in the year of authorization when funding takes place. A carrier amounts to over 80 percent of the Navy's annual ship building account, 30 percent of the Navy's annual budget and 11 percent of the total DoD annual budget. Thus, authorizing carrier design and construction funds in a single year distorts the budget.

Additionally, disruptions caused by shifts in actual funding years are costly and jeopardize the skill base required for special construction tasks, such as carriers.

The federal government uses "advanced appropriations" to fund large capital projects. Under the advanced appropriation process, the cost of a major project, such as a capital ship, is spread over several years to even the flow expenditures and allow for scheduling the design and construction process to reduce costs and preserve ship design and construction resources.

An "advanced appropriations" process would reduce the Navy's tendency to fund such projects incrementally.

Historical CVN Funding

(AY=Authorization Year)

Year	-6	-5	-4	-3	-2	-1	AY	+1	+2	+3	+4	+5
CVN-74/75							$6.2B				$200M	$200M
CVN-76					$800M		$3.4B				$100M	
CVN-77				$50M	$125M	$750M	$4.0B					
CVNX-1*	$25M	$140M	$245M	$1.3B	$400M	$420M	$2.5B	$2.5B				

* Current Plan which assumes incremental funding split between the authorization year and AY+1.

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Funding profiles for the last three CVN and the plans for the CVN-77 and CVNX-1 are shown here. CVNs 74 and 75 depart from the usual pattern in that both were authorized in a single year.

CVN Funding

- **With advanced appropriations, the government can obligate all of the funds provided for all years at one time, provided that the obligation takes effect in the year for which the funds are appropriated.**
- **No statutory or regulatory changes required to use advanced appropriations for capital ships.**

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Under advanced appropriations, the government can obligate all the funds required for a new ship, for the length of the project, in a single year, yet spread the appropriation over several years. No statutory or regulatory changes are required to institute an advanced appropriations funding process: mere agreement between the Navy, DoD and the Congress to institute the process is sufficient.

Infrastructure

- **Facilities**
  - Today's carriers can only be produced at Newport News (NGNN).
  - A decision to build larger carriers leads to continued use of a single builder: may require infrastructure investment to widen, lengthen and dredge the building ways.
  - Navy/DoD needs to manage carrier building and overhaul profiles to reduce shipyard workload fluctuations.
    - Given peaks and valleys, moving events by a few months can result in large cost / savings.
- **People**
  - Small, aging design community is jeopardized by workload fluctuations
- **Implications**
  - Need to replace conventional budget processes in favor of multi-year funding.
    - DoD must manage demands to lower costs and insure properly skilled industrial base.
  - DoD can only design new/improved carriers if it funds the maturation and sustainment of the science and engineering base.

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Only one U.S. shipyard is capable of producing a nuclear ship the size of a Nimitz class aircraft carrier – Newport News – and the Navy is its only customer. Commercial shipyards of the required size are available but they are not certified to construct nuclear-powered ships. A decision by the Navy to build future sea-based air platforms the same size or larger than the Nimitz will lead to continued reliance on this single facility. A decision to build a larger ship will require that the current facility be enlarged.

The Navy needs to pay close attention to scheduling carrier construction and overhauls to reduce the cost of shipyard fluctuations. The cost of slipping CVNX-1 one year is approximately $400M.

The community of designers for aircraft carriers is small and aging. Just as is the case with the ship construction facility, the availability of designers is jeopardized by workload fluctuations. The number of carrier designers is dwindling as those who possess the intellectual capital needed retire. The acquisition strategy must address how to recruit and mature new design teams.

The use of computer-aided design and drawing tools is planned to start with CVNX-1 and be complete with CVNX-2.

CVN Peacetime Utilization Rate

- Carriers are on 22-24 month peacetime cycle
  - Cycle restarts at end of each 6 month deployment
  - Driven by maintenance, personnel tempo, deployment needs, workup time
- "Long poles in the tent" are the air wing workup and air wing/ship interface
- Results in a deployed rate of less than 25 percent of ship life
  - Includes three year mid-life upgrade
- If total time ship is out of homeport is metric, utilization rate grows to just below 50 percent

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The aircraft carrier peacetime operational cycle lasts 22 to 24 months. The cycle begins at the end of the previous deployment with a maintenance period, followed by separate ship and air wing workups, the integration of the air wing with the ship, integration of the carrier into the battle group and, finally, deployment. Many factors contribute to the utilization rate – personnel and maintenance requirements are two of the most critical. The longest time in the carrier deployment cycle critical path is the air wing workup and integration onto the ship.

An aircraft carrier spends 25 percent of its life on deployment (including the midlife upgrade)– 50 percent of its time away from home. This is a poor utilization of an expensive capital asset, although other military systems are even worse.

CVN Peacetime Utilization Rate

- **Carrier utilization rate can be improved**
- **There are options to increase CVN peacetime utilization – but each has hidden costs**
  - Compress training timelines (current Navy plan)
  - Longer deployments
  - Increase carriers homeported overseas
- **SURFPAC Blue/Gold crewing experiment with Spruance class DDs may provide useful insights**
  - This concept would require non-deployed CVNs for workup
- **Effect on the number of carriers needs to be studied**

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Carrier utilization rates can be improved. The Navy is seeking ways to reduce training and workup times, ships could be kept on deployment longer, and more carriers can be home-ported overseas. Each of these options has serious drawbacks: Compressing training timelines runs the risk that the carrier and its accompanying battle group might not be trained to cover the full range of contingencies they may face. Longer deployments have a serious effect on morale and retention of members of the ship's crew and the air wing. Additional overseas home-porting carries with it major indirect costs.

SURFPAC is currently trying a blue/gold crewing system for Spruance class destroyers. Under this system, the ship remains on station for one year; at the end of six months, the initial (blue) crew is rotated home and a new (gold) crew is placed aboard the ship, on station. The utilization rate for the ship is significantly improved.

Additional study is required before such a system can be instituted for aircraft carriers. Spruance-class destroyers are uniform in many respects – moving from one ship to another does not entail major adjustments for the crew. Aircraft carriers are much less so. The destroyers used in the Navy's blue/gold trial program do not operate in battle group situations where close coordination among many ships is essential for mission success. To

implement a blue/gold system for sea-based air would require two battle groups reserved for training and workup for crews preparing for deployment – one in the Atlantic and one in the Pacific.

Task Force Findings Summary

- **Military Role:** Aviation is a key element in the American "way of war." Sea- and land-based air power have unique, and in many cases complementary capabilities. Both have significant roles to play in projection of power.

- **Access:** Sea-basing is critical to projection of responsive power into the theater of operations. Theater land bases can play an important role, but are vulnerable to denial by host nations and enemy attacks.

- **Combat Area:** The Navy must address the proper balance between blue water and littoral combat capabilities. Some feel the balance today is still too heavy on blue water.

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Task Force Findings Summary (cont'd)

- **Supported Aircraft:** Future sea-based aviation platforms must support legacy as well as future piloted and unmanned aircraft

- **Nimitz Design:** The Nimitz design is dated: it has limited weight, stability and electrical power margins and limited opportunities for new technology insertions

- **Undeveloped Concepts:** The Navy has not sufficiently pursued new sea-based aviation or surface-to surface weapon capabilities to provide alternatives to the current design that, of necessity assume the preponderance of weapon delivery by piloted, sea-based aircraft.

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Task Force Findings Summary (cont'd)

- **Crew Size:** The Navy can significantly reduce crew size to lower carrier lifetime cost without sacrificing performance
- **Propulsion:** Nuclear power is worth the extra investment
- **Electrification**: Extensive electrification will simplify ship systems and increase flexibility. Initial costs will be worth the investment in terms on long-term savings.

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Task Force Findings Summary (cont'd)

- **Signatures:** With additional work, the Navy can reduce carrier signatures to the point where decoys and defensive tactics can greatly complicate, and often frustrate, most detection and targeting
- **Survivability:** Against current threats, carriers are robust. However, given potential threats, they require continuous refinement and realistic testing
- **Infrastructure:** The U.S. infrastructure for carrier design and construction is presently fragile. The Navy, with the help of DoD and Congress, must adopt a funding schedule to improve the integrity of that infrastructure

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Task Force Findings Summary (cont'd)

- **Utilization Rate:** The Navy has sub-optimized the carrier deployment cycle, a misuse of an expensive resource. The Navy must innovate to increase ship utilization

- **Funding Strategy** The current single year funding obligation for carrier design and construction is disruptive to the Navy and DoD budgets, as well as the U.S. construction and design capability. An advanced appropriations process would allow a more coherent and less disruptive design and construction cycle.

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RECOMMENDATIONS

The Navy's near-term options are limited

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The Navy's Near Term Options are Limited

- **There is a need for nuclear powered carriers beyond the latest NIMITZ (CVN-77)**
- **Proceed to build CVNX-1 as planned –**
  - Must be a prototype vehicle for important new technologies (EMALS, enhanced survivability, new reactor design, . . .)
  - Major, must do, step in crew size reduction
  - An opportunity to design means to increase ship time on deployment
  - Provides opportunity to build in capabilities for UAVs / UCAVs
  - Maintains the U.S. carrier industrial base
  - Does not address changes in the essential ship concept. No other concept is mature enough within the needed timeframe to risk such a large investment

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The United States needs carriers to replace the aging Nimitz class. The 40-year old Nimitz design has reached its limits; it is not capable of addressing foreseeable mission requirements, will become vulnerable to adversary weapons, and is unnecessarily expensive to operate. Advances in ship, aircraft, weapons and ISR capability make possible new ships that require smaller crews, have improved survivability, and have lower lifetime costs. Additionally, carriers now in service will reach the end of their operating lives as a result of their designs, reactor lives, and dates of entry into service.

The Navy's options for new carriers are limited to the CVNX-1. It has not sufficiently developed additional concepts and their use to the point where there are viable alternatives to CVNX-1. Nevertheless, CVNX-1 is an important step in that it can serve as a prototype for many new shipboard technologies such as a new reactor design, extensive ship electrification, smaller crew size, reduced signatures, improved survivability, and a new deck design to handle future aircraft. Additionally, CVNX-1, constructed on its current schedule would keep the U.S. carrier building competence intact.

Provide More Choices in the Mid Term

- **CVNX-2 and future carriers designs should *not* be foregone conclusions**
  - A joint DARPA / Navy study of design options should be completed *before approval of each* new sea-based aviation platform design
- **Because carrier authorization occurs every four to five years, the Navy must create a continuous development program for future carriers to push the design of carriers to the limits of what is technologically effective. It must identify of technology packages and "on-ramps" associated with future and current ships**
  - Seek mission capability to handle a wider range of missions – Special Operation Forces, UAV, UCAV, heavy lift, joint ops
  - Seek ways to reduce crew (ship and air wing) by 50 percent from CVN-74
  - Examine need for including all leadership functions on the carrier – believe in network-centric warfare!
  - Seek common ship module designs for CVNs and LHs to improve economies of scale (per modern cruise ship construction techniques)
  - Provide capabilities for the carrier to fill in gaps in surge, contingency, and initial operations until other joint air assets become available

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More time is available to develop new carrier concepts and designs before commitment to the carriers following CVNX-1. CVNX-2 and future carriers should not be a foregone conclusion – the Navy must ensure that each new carrier incorporates the most effective design available to meet mission requirements and reduce operating costs.

Kick Start a Process to Provide the Navy Long Term Options

- **Establish a Carrier Technology Oversight Council (CARTOC) similar to SUBTOC to seek out new sea-based air platform technologies, both shipboard and overall system of systems concepts.**
- **Navy/DARPA joint sponsorship of competitive industry and Navy teams to develop a new Navy Air Capability system of systems, including as an integrated whole the ship, the aircraft and the weapons:**
  - Ship - consider:
    - Modifications to the current concept
    - Special platforms for UCAVs and/or JSFs in combination with modifications of the current concept
    - Ships with 25-35 year life (no refueling)
    - Ways to improve carrier utilization rates
    - Hull form, including propulsors

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A Carrier Technology Oversight Council (CARTOC) co-chaired by the Under Secretary of Defense (Acquisition, Technology & Logistics) and the Assistant Secretary of the Navy (Research, Development & Acquisition) should be established to focus the Department of the Navy's efforts toward steady funding for advanced carrier research and development and rapid incorporation of the most promising technologies. The Council should be made up of a board of directors that includes DARPA and other Navy and OSD science, technology and acquisition professionals. It should provide oversight of carrier technology management and assure continual refinement, assessment, and fielding of new and innovative technologies. The Council should foster strong links between DoD, industry and academia.

With the Council's guidance, Navy integrated product teams should assess, integrate, and prioritize the development and fielding of promising technologies. Teams of Navy experts in science and technology and carrier design and construction should survey relevant technologies that could meet performance and affordability goals, and develop plans for maturing the research and development for fleet applications. The teams of experts should report to a senior Navy management team that would integrate and prioritize inputs and recommend a technology investment plan to the Council. The

senior Navy management team should also improve the definition of requirements and objectives for the technology development community as well as balancing the performance schedule and cost for potential technology improvements.

Kick Start a Process to Provide the Navy Long Term Options (cont'd)

- Continued
  - Aircraft - consider:
    - UCAVs and UAVs on carriers as well as other shipd
    - New aircraft with high payload, long endurance, and flexibility to serve as the basis for a family of extended mission aircraft as well as to eventually replace all support aircraft (tankers, E2's E6's)
  - Weapons – consider:
    - Trends to smaller payloads, dial-a-warhead capability, higher precision weapons.
    - New weapons, common with other missions, that would make a major difference if available to this new air capability system.
    - Future developments in adversary weapons (with red teaming part of the process)

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Kick Start a Process to Provide the Navy Long Term Options (cont'd)

- Continued
  - Assume existence of, but define attributes of, net-centricity in this new system of systems.
  - Based on above, formulate a plan of development, experimentation, and demos. Associate specific technology bundles with specific hulls.
- **Brief CARTOC annually, as a minimum, on progress.**
- **Prior to each carrier authorization, convene an OSD/DARPA/Navy board chaired by the USD(AT&L) (i.e., the CARTOC principals) to review how the system of systems is developing and technology insertion is being accomplished.**

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Kick Start a Process to Provide the Navy Long Term Options (cont'd)

- **The goal must be to institute a rigorous on-going effort to improve the sea-based air systems of systems continuously**
  - Examine alternate concepts for most effective, sensible cost solutions (perhaps several different ship and aircraft types)
  - Develop ways to increase availability of continuous, quick response air support for ground forces (both Army and Marines)
  - Establish continuous, systematic examination of each phase in the enemy's "kill chain" to devise improvements in signature reduction, decoys, war reserve modes, fusing limitations, . . .
  - Realistically test survivability technology by destruction of large ship structural sections (e.g., the magazine)
  - Continuously look for new technologies capable of retrofitting to ships already in service

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Spread Carrier Design and Construction Funding Over Several Years

- **Establish a funding process, with Congressional help, that levels construction costs of large ships over several years. Such an approach would retain the viability of the U.S. capability to build such ships**
- **Fully fund CVNX procurement by advanced appropriations over a period not to exceed 5 years** (advanced procurement as necessary for long load items)
  - Full-funding maintains fiscal discipline and discourages "buy-in" of major programs
  - Allows level loading of CVN construction base and avoids significant reconstitution costs if the current fragile infrastructure is fractured by current funding scheme inside a constrained procurement budget

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APPENDIX A. TERMS OF REFERENCE

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Aircraft Carriers of the Future – TOR summary

You are directed to establish a Defense Science Board Task Force to:

- Assess how aircraft carriers should serve the nation's defense needs in the 21st century and beyond
- The 2001 QDR has reinforced the need to implement a shift in the Navy's focus from open water to littoral regions
  - –Explore the aircraft carrier's contribution to joint operations in the littoral.
- Concentrate on the increased need to fulfill the presence and warfighting missions that aircraft carriers perform.

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Cross reference of report to TOR **Slides Numbers**

Assess how carriers should serve the nation's defense needs 2-7,9

Operations in the littorals 12

Increased need to fulfill presence and warfighting missions 2-7

Aircraft Carriers of the Future – TOR summary Cont'd

•Examine the applicability and potential for transformation of the carrier battle group in the future.

•It is not expected that there will be sufficient funds to expand the carrier fleet significantly

–Examine the cost / capability tradeoffs in considering the design of carriers appropriate to the future environments in which naval warfare may occur.

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Cross reference of report to TOR **Slide Numbers**

Applicability and potential for transformation.....9-17, 19-30

Cost / capability tradeoffs 24, 31-55

Summary of findings 56-60

Recommendations 62-68

Aircraft Carriers of the Future – TOR summary Cont'd

- Be guided by the following questions:
  - What is the naval environment to be expected in the next 20 – 50 years?
  - What is the role of the Navy in the next 20 – 50 years?
  - What is the role of the carrier battle group in a joint environment in which technology has progressed for both the US and its potential adversaries? How does the existence of UCAVs affect the role of the carrier and the battle group?
  - How should the carrier evolve or be transformed to meet the mission requirements described above?
  - How might the role change for radically different aircraft carriers and what might their characteristics be to effect this change?
  - What are the technology improvement barriers that need to be overcome for a very significant improvement in the ability of the carrier to execute its mission?

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APPENDIX B. TASK FORCE MEMBERSHIP

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Task Force Members

Chairman:	
Dr. William Howard	Consultant
Vice-Chairman:	
ADM Donald Pilling USN (Ret.)	LMI
Members:	
ADM Stan Arthur USN (Ret.)	Lockheed Martin
Dr. Alan Berman	Consultant
Mr. Alan Ellinthorpe	Consultant
Gen Richard Hearney, USMC (Ret.)	Consultant
HON. Paul Kaminski	Technovation, Inc.
Dr. Williamson Murray	IDA
HON. Whit Peters	Williams & Connolly LLP
Mr. Frank Sullivan	Frank Sullivan & Associates

Task Force Advisors

Executive Secretary:	
Dr. Paris Genalis	USD(AT&L) Naval Warfare
DSB Representative:	
CDR Brian Hughes, USN	DSB
Government Advisors:	
VADM Dennis McGinn, USN	OPNAV, N7
RADM Isaac Richardson, USN	OPNAV, N785
LtGen W. L. Nyland, USMC	HQ USMC, Aviation
MajGen Michael Hough, USMC	HQ USMC, Aviation
MG John Curran, USA	U.S. Army Aviation Center (USAAVNC)
MajGen John Barry, USAF	USAF/XPX
Ms. Karen Owens	NAVSEA
Col Earl Wederbrook, USMC	J8
Col Peter Faber, USAF	
CAPT Mike McMahon, USN	NAVSEA
CAPT Steven Jacobsmeyer, USN	OPNAV
Col Doug Yurovich, USMC	HQ USMC, Aviation

CDR Kathy McGrath, USN	Joint Advanced Warfighting Program
Ms. Sharon Beermann-Curtin	ONR
Ms. Darlene Costello	OUSD(AT&L) Naval Warfare

APPENDIX C. PRESENTATIONS TO THE TASK FORCE

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September 26-27, 2001

Dr. Tom Welch	Office of Net Assessment
Mr. Bob Stoss	Standards of Conduct
RADM Joseph Sestak, USN	QDR
Mr. Dave Perin	Information from the CVNX Analysis of Alternatives (AOA)
VADM Dennis McGinn, USN	Overall Navy vision for the future
Dr. Ted Gold	Transformation and the Future Joint Force

October 22-23, 2001

Mr. Horman and Mr. Knisley	Dalhgren
Mr. Robert Merkel	CIA
Mr. Dennis Bushnell	Future Strategic Issues/Future Warfare [Circa 2025]
CAPT Jim Hart, USN	Support Aircraft
CDR Ron Unterreiner, USN	JSF
Mr. John Kinzer (ONR) and LtCol Roger Thrasher, USAF	Navy UCAV And DARPA/USAF UCAVs
Mr. Greg Catrambone	NAVY PEO Weapons and UAV Global Strike Task Force
VADM Blackham, RN	British perspective
Capt Michel de Monval	French perspective

November 6-7, 2001

Task Force visit to the USS John C. Stennis (CVN 74)

December 11-12, 2001

ADM Art Cebrowski, USN (Ret)	
Mr. Turk Maggi	Bureau Of Political-military Affairs
Dean Wayne P. Hughes, Jr. Capt USN (Ret)	Naval Postgraduate School
RADM Sprigg, USN	
Col Doug Yurovich, USMC	Marine Corps Perspective
Mr. John Schell	Ship Survivability

Dr. George Koleszar	1995 Heavy Bomber Study
MG Robert Scales, USA (Ret)	Army Perspective on Future Operations

January 16-17, 2002

Dr. John Birkler	RAND
RADM Roland Knapp, USN and CAPT Dudley Berthold, USN	PEO Carriers/PMS-378 Future Carriers Program
Mr. Joe Gist	Naval Reactors
CAPT Michael Vitale, USN and CAPT Ron Stites, USN (CCG4 Ops)	Battle Groups
Dick Bushway and Warren Baker	EMALs catapult and Flight deck changes on future carriers
Mr. Matt Mulherin	Northrup Grumman - Newport News Division
MG Mark Curran, USA	Army Requirements
CAPT James Winnefeld, USN	Enterprise Post Deployment

February 21-22, 2002

Mr. Paul Chatterton (NAVSEA O5T) CDR Steve Parks (NAVSEA PMS 378)	Future Aircraft Carrier (CVNX) and Signatures
Mr. Dwight Lyons	CNA brief on Maritime Prepositioning Force (Future) [MPF(F)] and LHA

March 13-14, 2002

CAPT Trip Barber, USN (Ret)	Assessing Naval Anti-Access Strategies and Systems

APPENDIX D. ONE POSSIBLE ALTERNATE SCENARIO TO CURRENT CARRIER SYSTEM CONCEPTS (A TRUCK-BASED OPTION)

Numerous concepts have been proposed as alternatives to the current Nimitz carrier concept. These alternatives have not undergone sufficient analysis to determine whether or not they merit consideration for future combat systems.

This appendix outlines one of many such possibilities based on assumptions and technology different from those in today's carrier system.

Overall Assessment in Priority Order of Concern

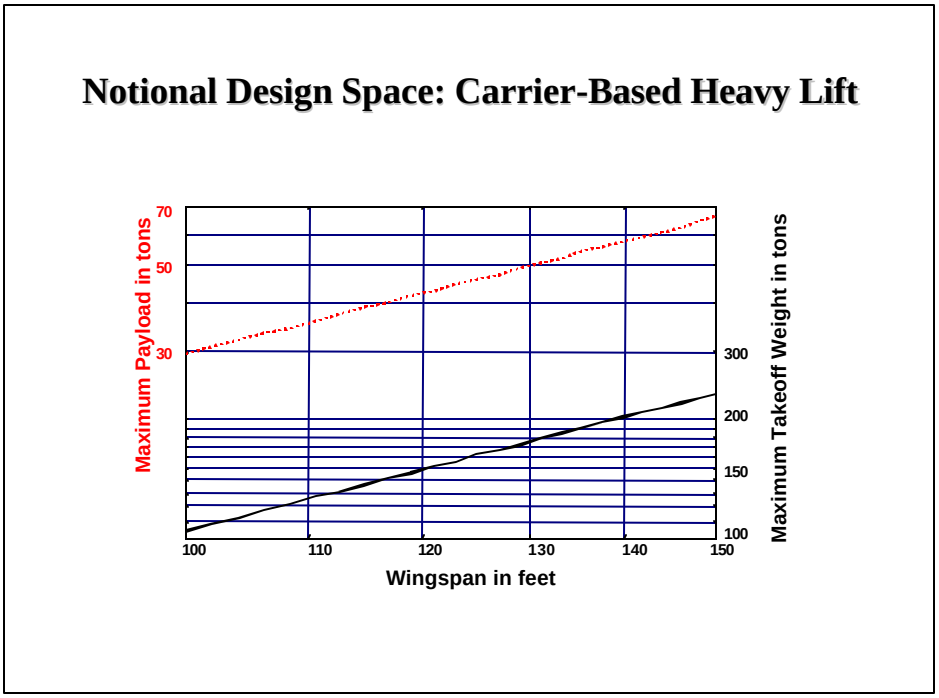
DRAWBACK		PROPOSED CURE	REQUIRED TECHNOLOGY	ART STATE
INSUFFICIENT RATE OF ORDNANCE DELIVERY		HEAVY-LIFT CAPABILITY	NEW PLANE (LIFT, EFFICIENCY)	MATURE
TOO VULNERABLE	TOO TEMPTING A TARGET	SMALLER, CHEAPER SHIP	RADICAL DESIGN; HIGH SPEED FOR AIR OPS & SUB EVASION	FAR TERM
	WEAK SUBMARINE DEFENSE	DOUBLE SHIP SPEED		
		ORGANIC ACTIVE SONAR	LOW-DRAG RADIATOR	ZERO
	WEAK MISSILE DEFENSE	RADAR ORBITING ABOVE	NEW PLANE (LIFT, ENDURANCE)	MATURE
	WEAK SUPP TRAIN DEFENSE	GET RID OF SUPPLY TRAIN	NEW PLANE (HEAVY LIFT + EFFICIENCY)	MATURE
INSUFFICIENTLY AUTONOMOUS		GET ORGANIC TANKERS		
TOO COSTLY		SMALLER, CHEAPER SHIP	RADICAL NEW DESIGN	FAR TERM
		LOW COST ORDNANCE DELIVERY	NEW PLANE (LIFT, EFFICIENCY)	MATURE

The future land attack: drones will do reconnaissance & targeting; ordnance will be launched from an airborne warehouse that must be within about 40 mile of the target(s) to satisfy call for fires latency requirements. Manned aircraft won't be put at risk competing with drones, and the warehouse role is one where fighter-type aircraft, designed for agility, can't compete in either range or payload.

Carriers are precious jewels; major status symbols. and thus appealing targets. They have to be made smaller and less expensive so we can have more and thus reduce the status investment in each.

Modern submarines, competently operated at low ship speeds, radiate so little noise that their detection by passive shipboard sonars can't occur until the range is less than the arming distance of a torpedo. Active detection is in principle viable, but only at low frequencies; there are no such systems suitable for use on combatant ships. High speed is a viable defense, but it's not available near-term.

The short legs intrinsic to fighter-type designs means that in-flight refuelings are required, and carriers are therefore dependent on land-based tankers -- a very serious flaw. It can be overcome by using long-range, combat aircraft and having an autonomous refueling capability.



This shows the result of scaling down a C-17 design to illustrate how heavy a payload could get off a carrier. The C-17's wing loading (154 lbs per ft2) and its aspect ratio (7.2) have been preserved.

The plots are thought to be conservative because the C-17 entered service almost 10 years ago, and technological advances have occurred in the interim; for example, the engines that power the Boeing 777 have over twice the thrust of those used on the C-17; thus a two-engine design would do the job -- at considerable cost saving.

The flight deck width in the way of the island is about 200 feet. There is at least anecdotal evidence that large aircraft can land and take off from a carrier – a C-130 (wing span 132 feet) has done so. On the basis of those numbers, it is plausible that a wingspan of at least 100 feet – possibly as much as 120 feet – could be used. From the slide's plot, that converts to a maximum payload of about 40 tons, and a maximum takeoff weight of about 150 tons.

If aircraft having these characteristics could be launched at the rate of eight a day, they could deliver a Kosovo day's ordnance, and the ship's magazine would be exhausted in a week. Such an aircraft could also mutate into a radar-carrying role, a tanker, a means of resupply.

Three Truck Models

	C-17	C-141B	C-130J
LENGTH (ft)	174	168	98
SPAN (ft)	170	160	132
Height (ft)	55	39	38
WING AREA (sq ft)	3800	?	1745
ASPECT RATIO	7.2	?	10.1
EMPTY WT (tons)	140	74	38
MAX PAYLOAD (tons)	85	35	22
MAX FUEL LOAD (tons)	90	50 (?)	23
MAX T.O. WT (tons)	300	160	78
MAX WING LOAD (lbs/sq ft)	154	?	89
RANGE (nmi) (max load)	2500	2500	2500
CEILING (kilofeet)	45	41	35
TOTAL ENG THRUST (tons)	20	10	?
ACQ. COST ('96 $M)	180	41	32
IOC	JUN 93	DEC 79	74

This table shows the performance of some modern military transport aircraft. The key morphological difference between this class of airframe and that of a fighter-type is in the wing aspect ratio – the ratio of the square of the span to the area. That number has to be large in order to hold down the "induced drag" – the loss of energy to air flowing around the wingtips from the high pressure on the wing's underside to the low pressure on its upper surface. The payload capacity depends on the wing area, and the combination of high aspect ratio and large area means a large wingspread.

A Sports Car
(the F-18)

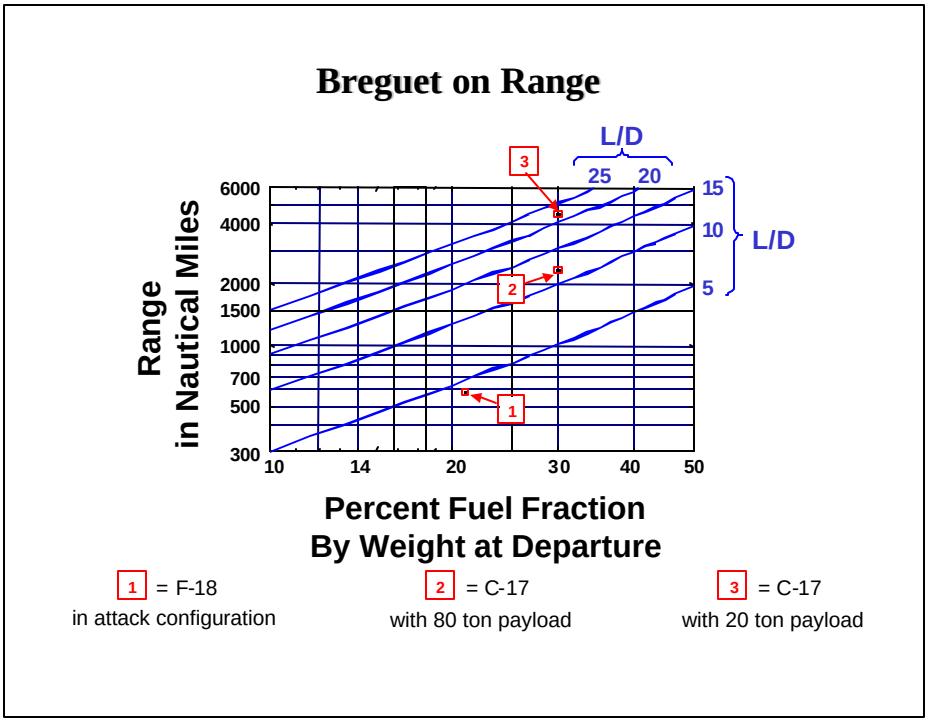
LENGTH (ft)	56
SPAN (ft)	40
HEIGHT (ft)	15
WING AREA (sq ft)	400
ASPECT RATIO	3.5
EMPTY WT (tons)	13
MAX PAYLOAD (tons)	8
MAX FUEL LOAD (tons)	5
MAX T.O. WT (tons)	28
MAX WING LOAD (lbs/sq ft)	140 (?)
RANGE (nmi) (max load)	580
CEILING (kilofeet)	50
ENG THRUST (tons)	?
ACQ. COST ('96 $M)	55 (?)
IOC	?

1/10 C-17's → 1/10 C-17's LIFT

1/2 C-17's → INDUCED DRAG >C-17's

6/10 C-17's % → RANGE < C-17's

In the case of a fighter aircraft, the desire for agility is a counter to this logic – long slender cantilevers are not good load-bearing members and can't be exposed to high g-forces.



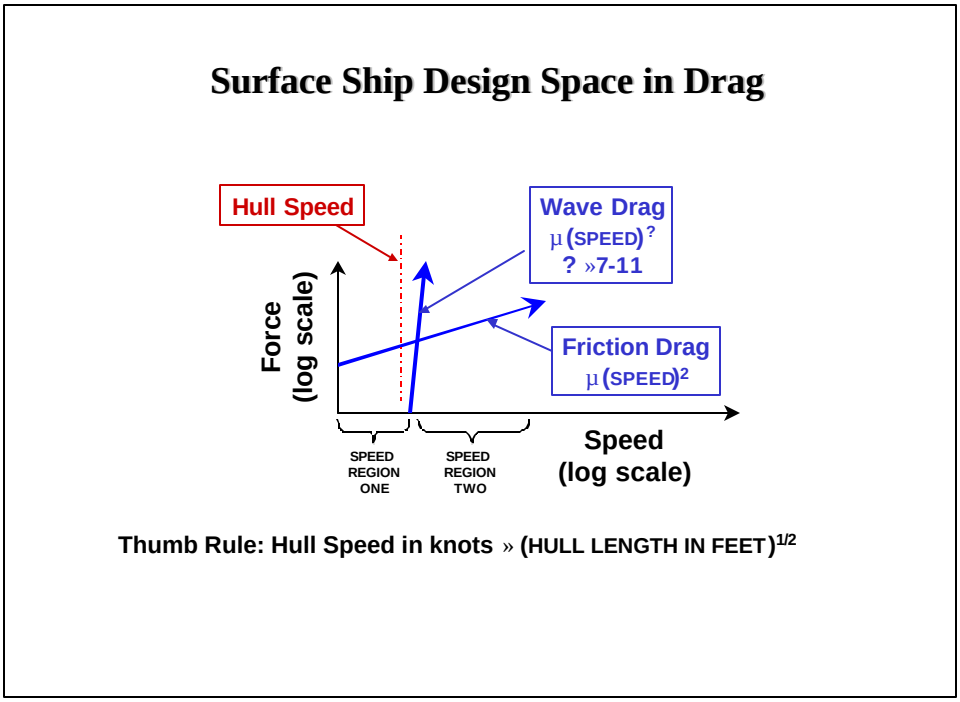
The relationship plotted here was derived about a century ago; it's fundamental and applies equally well to ships and to aircraft.

The "attack configuration" label on the F-18 point means it is equipped with externally-mounted "stores." They are a source of drag that's not experienced by transport-type aircraft or bombers whose payloads are carried inside the fuselage and not exposed to airflow. (The F-18 without stores has an L/D of about 8.)

To fix the scale of things, supertankers and container ships have L/Ds around 600 and 300 respectively. Thus, they can go about their business with only a few percent of their weight in fuel, a manifestation of their extraordinary transport efficiency.

Another "feel" for the significance of the parameter L/D is in work done in the early fifties by von Karman and Gabrielli. They sought to answer the question of how to measure the utility of speed. They didn't get an analytic solution, but they found that for an astonishingly wide range of examples – horses, humans, trains, ships, airplanes – changes in speed were viable (competitive)

if the product {L/D x speed} was held constant. If speed can be doubled, it is acceptable to halve L/D. Furthermore, they found an envelope along which lie the top performers, and it is {**L/D x speed in knots** ^{3} **5000**}. Supertankers have L/D ≈ 9,000, and so does the 747; container ships come in at about 7000.

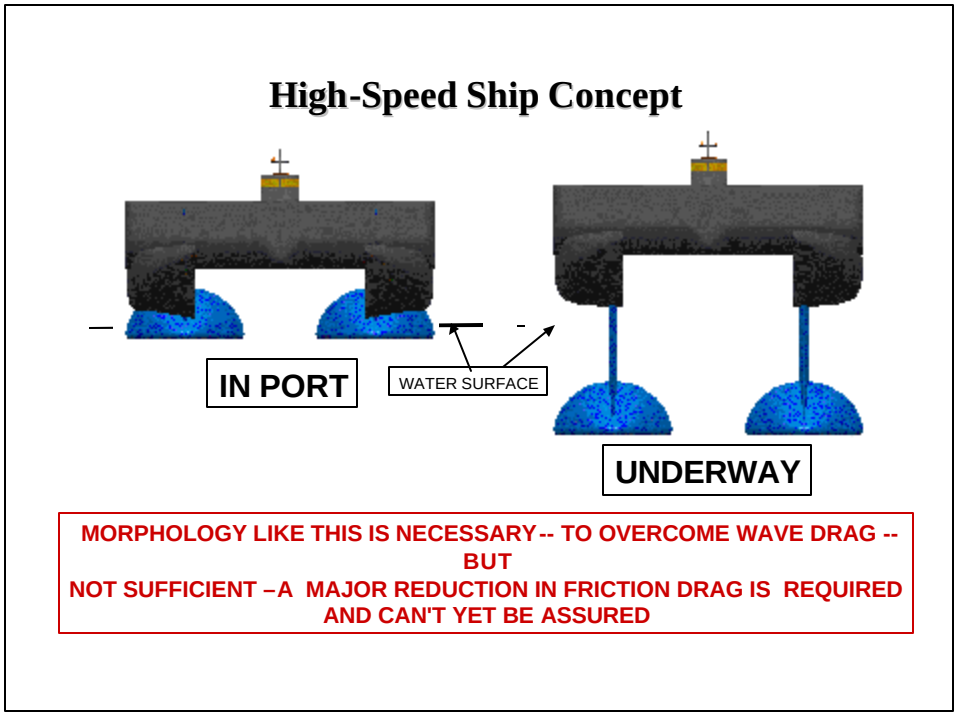


Wave drag in both aerodynamics and hydrodynamics is a manifestation of the loss of energy to radiation whenever the speed of the vehicle exceeds the speed of sound, or the speed of the relevant surface wave, respectively. In each case the onset of the phenomenon is abrupt and the rate of increase of loss with speed is so great as to constitute a wall. There are no cargo transporters, commercial or military, airborne or waterborne, that operate above the wave drag locus: the 747, the C-17, the B-52, container ships, are all nestled near but below that locus.

The maritime situation is different in that there is no single surface wave speed; each ocean wavelength has its own speed, and the notion of a "hull speed" stems from the fact that strong coupling occurs when the ship reaches the speed where the length of its hull matches the length of the surface wave of the same speed.

Wave drag can be reduced only by reducing the disturbance of the water – by reducing the beam of the ship, or by putting all the lift underwater (a hydrofoil or a submarine-like cylinder) and supporting the in-air hull on struts having a very small area at the waterplane.

Friction drag can in principle be reduced by adding a lubricant at the wetted surfaces. This has been shown to work, using polymers or air as lubricants, but only in laboratories at small scales and low speeds. There's no theoretical guidance; any advances will have to be by experiment, but at present there are no facilities anywhere in the world of a suitable size. (Although an effort to get such a capability is underway at ONR.)



Motivation for wanting a high-speed ship:

- Higher speed => shorter landings/takeoffs => smaller/cheaper ship => faster transits
- Twice sub speed => immunity from torpedo attack

Can't be done by throwing propulsion power at the problem: drag has to be reduced in both its manifestations – "wave" and "friction".

Wave drag = energy radiated away in surface waves. Fundamentally same as supersonic characteristics in aeronautics. Cure: put lift (dynamic or buoyant) away from – below – the surface.

Friction drag is in principle reducible by lubrication – a polymer or just air at the hull-water interface. Demonstrated to work in labs (small models, small speeds) but not in large scale. The physics is not understood, and several years of measurement work are required to determine feasibility. Intimidatingly huge reductions are required – about 10X – but achieving that -> a 40 kiloton ship (a 730 foot flight deck) capable of 70-knots using the existing power plant. (Its propulsion energy consumption per mile ≈ ½ current usage.)

Design Recommendations
IN PRIORITY ORDER

1. AN AIRPLANE TO PERFORM THE FOLLOWING ROLES AND BE RECONFIGURABLE AMONG THEM ABOARD SHIP:

- **FUEL-EFFICIENT HEAVY ORDNANCE DELIVERER**
- **ORBITING MISSILE DETECTION RADAR PLATFORM**
- **TANKER**
- **SUPPLY**
- **ECM PLATFORM**

2. UPDATES TO THE SHIP:

- **WATER JET PROPULSION (TO REDUCE RADIATED NOISE & IMPROVE EFFICIENCY)**
- **SQUATTING CURE (TO IMPROVE EFFICIENCY)**
- **BIGGER MAGAZINE (TO GAIN AUTONOMY)**
- **CREW REDUCTION (TO REDUCE COST)**
- **ISLAND REMOVAL (TO REDUCE RCS)**

3. LOCATE THE OPTIMUM OF THE SYSTEM {SHIP + AIRCRAFT + ORDNANCE} IN THE MODERN MISSION CONTEXT.

- **EVALUATE THE UTILITY AND PROSPECTS FOR A RADICAL HIGH-SPEED SHIP DESIGN**
- **MONITOR ANY DEVELOPMENTS IN ACTIVE SONAR**

Only design work is recommended; implementation decisions have to await clarification of the achievable performance characteristics.

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APPENDIX E. ACRONYMS

AEW	Airborne Early Warning
ALCM	Air Launched Cruise Missile
AP	Advanced Procurement
ARG	Amphibious Ready Group
ATR	Automatic Target Recognition
AWACS	Airborne Warning and Control System
CALCM	Conventional Air Launch Cruise Missile
CARTOC	Carrier Technology Oversight Council
CNO	Chief of Naval Operations
CONOPS	Concept of Operations
CVBG	Carrier Battlegroup
DARPA	Defense Advanced Research Projects Agency
DMPI	Designated Mean Points of Impact
DoD	Department of Defense
ECM	Electronic Countermeasures
ELINT	Electronic Intelligence
EMALS	Electro-Magnetic Air Launch Systems
EMCON	Emission Control
HF	High Frequency
ID	Identification
IMA	Information Mission Area
ISR	Intelligence, Surveillance, Reconnaissance
JASSM	Joint Air Stand-off Surface Missile
JDAM	Joint Direct Attack Munitions
JSF	Joint Strike Warfighter
JSOW	Joint Service Stand-off Weapon

JSTARS	Joint Surveillance and Targeting Attack Radar System
LCC	Life Cycle Costs
LHD	Amphibious Assault Ship
MOB	Mobile Offshore Base
NGNN	Newport News
OSD	Office of the Secretary of Defense
QDR	Quadrennial Defense Review
RAM	Radar Absorbing Materials
RCS	Radar Cross Section
SCA	Shipbuilding Cost Adjustments
SEAD	Suppression of Enemy Air Defenses
SLA	Service Life Allowance
SOF	Special Operations Forces
STOVL	Short Take-off, Vertical Landing
SUBTOC	Submarine Technology Oversight Council
TACAIR	Tactical Aircraft
TLAM	Tomahawk Land Attack Missile
TOC	Total Operating Costs
UAV	Unmanned Aerial Vehicles
UCAV	Unmanned combat air vehicle
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology and Logistics
USV	Unmanned Surface Vehicles