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TRENDS IN INTEGRATED DESIGN OF MODERN COMBATANTS SHIP - CENTRIC TO NET-CENTRIC

Summary

Trends in the designs of future naval/combatants are being greatly affected by significant improvements in communication technologies and computing capabilities and the rise of global asymmetrical threat environments. As a consequence, the modern Naval ship design is moving more and more away from the ‘platform centric’ designs of the past to the modern ‘net-centric’) design philosophy. Considerations of enhanced ship-survivability, high power weaponry and flexibility in operation have led to new trends in combatant hull design and changes in propulsion systems. In light of construction and service cost constraints, coupled with the possibility of cheep-kill threats paralyzing a major asset, smaller, more flexible, and smarter platforms are expected to rule the future.

Key words: naval ship design, ship-survivability, operation flexibility, cost constraints.

PRAVCI U INTEGRIRANOM PROJEKTIRANJU SUVREMENIH RATNIH BRODOVA – OD SREDIŠNJE PLATFORME DO UMREŽENJA

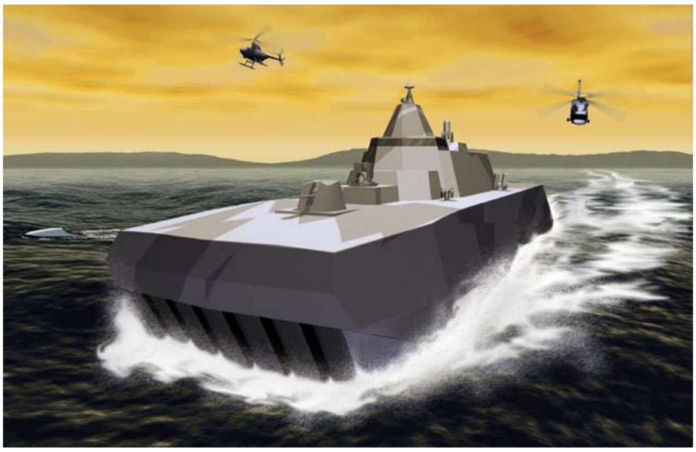
Sažetak

Na projektiranje budućih ratnih brodova uveliko utječu značajna poboljšanja u komunikacijskim tehnologijama, mogućnosti suvremene računalne tehnologije, kao i porast globalnih asimetričnih prijetnji. Zbog svih tih okolnosti, projekt suvremenog ratnog broda sve se više i više udaljava od tzv. projekta ”središnje platforme” prema filozofiji ”umreženja” gdje brod djeluje kao čvor velike mreže. Razmatranje poboljšavanja značajki preživljavanja broda i operativne fleksibilnosti te uvođenja sve snažnijeg naoružanja dovelo je do novih usmjerenja u projektiranju formi ratnih brodova i do promjena u propulzijskim sustavima. U svjetlu ograničavanja troškova gradnje te operativne službe, a povezano s mogućnošću onesposobljavanja temeljnih brodova ratne flote s jeftinim borbenim sredstvima u budućim flotama velikih ratnih mornarica očekuju se manje, puno fleksibilnije i pametnije borbene platforme.

Ključne riječi: projektiranje ratnih brodova, preživljavanje, fleksibilnost, troškovi.

1. Introduction

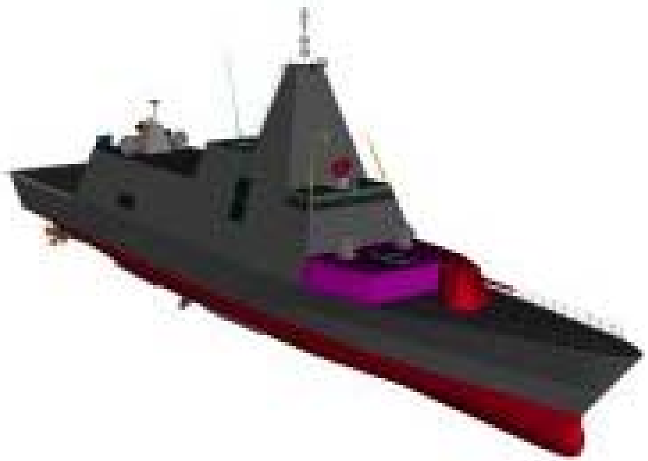
Trends in the designs of future naval/combatants are being greatly affected by significant improvements in communication technologies and computing capabilities and the rise of global asymmetrical threat environments. As a consequence, the modern Naval ship design is moving more and more away from the 'platform centric' designs of the past to the modern 'net-centric' (where the ship operates as node of a larger network) design philosophy. Considerations of enhanced ship-survivability, high power weaponry and flexibility in operation have led to new trends in combatant hull design and changes in propulsion systems.



Moreover, in light of construction and service cost constraints, coupled with the possibility of cheep-kill threats paralyzing a major asset, smaller, more flexible, and smarter platforms are expected to rule the future.

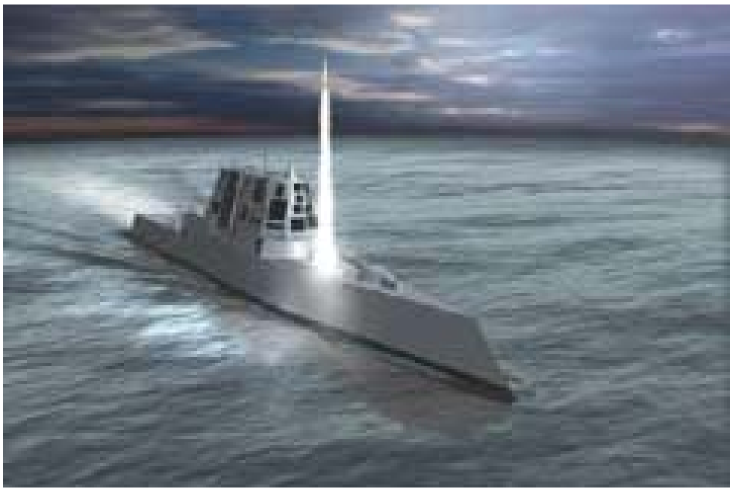
A number of recent US navy programs such as the Arsenal Ship, DD21-DD(X), LCS, unmanned aerial, surface and submerged vehicles, among others, are clear demonstrations of the adaptation of the new operational/design philosophies by US ship designers. The new ships are designed with significantly reduced manning, enhanced remote sensing and command structure, and superior survivability.

Moreover, the systems utilized in these ships increasingly rely on commercial technology manifesting itself by the extensive employment of Commercial Off The Shelf (COTS) equipment in conjunction with plug-and-play Open Architecture environments.



Total Ship Survivability has become an integrated, quantitative ingredient in most modern designs. Reduction of susceptibility is primarily being accomplished through quieting, shaping, camouflaging, and other stealth techniques and is widely evident in the design of ships for control of their signatures.

Vulnerability is being reduced through appropriate internal arrangement of vital components, redundant and proper routing of distribution networks and systems, use of distributed systems and controls, blast hardened bulkheads, and fragmentation protection characterized for the following of physics based statistical computer simulations. This is done for underwater detonations (UNDEX), above-water detonations, as well as, internal sympathetic explosions. Enhancement of recoverability from a fault or a hit, is again, quantified by dynamic computer simulations leading to reconfigurable system designs with automatic damage suppression, and reduction of cascading fault effects that are remotely detected.



The requirement for stealthy designs results in the shaping of the combatant's topside by the use of flat surfaces. Moreover, progress in Combat System technologies, in the US and the international arena, is leading to the use of large flat surfaces for carrying AEGIS type systems of embedded fixed phased array radars (e.g., Spanish, Norwegian and South Korean Navies), indigenous fixed phase array radars, as well as, a host of structurally embedded antennas and conformal satellite antennas. As a consequence, the relatively small topside surfaces are crowded with powerful transmitters and sensitive receiver antennas. This requires careful design and placement for EM interference-free co-existence. Other designs adopt a Modular Mission Systems approach, which enables quick changes in warfare capabilities in the field. This in turn, further stretches the design requirements due to the subsequent constraints that are placed on EMI/EMC of the combatants' topsides.

"Open Architecture," "net-centric", "modularity," "survivability" and "vulnerability" have all become factors in the design process. The presentation will discuss and demonstrate the defining characteristics and effects of these factors on the design resulting from operational requirements and environment for the modern combatant.

2. Classification of Trends

I will argue that three primary forces have affected the changes we have seen in naval design during recent years:

1. Technology driven advancements
2. Life-cycle cost reduction
3. Global-political changes

Perhaps surprisingly, the "traditional" areas within ship design and construction – such as ship hydrodynamic performance, exotic structural materials and building techniques, novel propulsion machinery, power distribution systems, propulsors – are *not* highlighted among my "primary forces." Although I will later mention a few notable advances in these traditional areas, I do *not* consider them as the forces that are currently driving trends in naval design into new directions. In today's naval environment, even significant advances in these traditional areas – and there are some very exciting ones – seem to me to facilitate rather than motivate the major design trends we are witnessing.

The primary forces, the trendsetters, are frequently accompanied by a vocabulary of "buzz words" if I may use that term without offense: phrases that have acquired fairly diffuse, but widely understood, meanings throughout the naval design communities. To illustrate, I would cite just three of the most powerful idioms, related as they are to my three primary forces:

"Net-Centric"

- Commercial “Plug and Play,” or in the naval spectrum, “Plug and Fight,” often accompanied by “Open Architecture”
- “Asymmetric Warfare”
- “Open system.” A system that implements sufficient open specifications for interfaces, services, and supporting formats to enable properly engineered components to be utilized across a wide range of systems with minimal changes, to interoperate with other components on local and remote systems, and to interact with users in a style that facilitates portability. Thus, Open Systems = Standard Interfaces + Defined Capability → Interoperability + Ease of Change

It is such ideas that can become the true determinants of trends in naval design.

3. Technology Driven Advancements

It is a classic understatement to say that the design of naval combatants has been strongly affected by improvements in communication technologies and computing capabilities. As a consequence of revolutionary advances in these technologies, the modern naval ship is moving progressively farther from the ‘platform centric’ designs of the past to the modern ‘net-centric’ design philosophy. Some essential elements of the change can be summarized as follows:

a. The combatant operates as a node of a larger network. The ships’s sensors and effectors are designed to utilize information resources from land, space, aircraft, and other ship assets, surface or undersea, and simultaneously to contribute to the over-all resources of the larger network. A composite situational picture can now be maintained by multiple entities. A gun or missile system at any node can be directed and operated by any authorized entity within the system of nodes. The topside of some modern combatants may carry a larger share (both in number of apertures, and possibly soon in aggregate aperture size) of communication apertures as well as radars. The architecture of the communication network is established, and topside arrangements are increasingly governed, by the need for hemispherical coverage to provide connectivity in real time. In some cases, hull features, and even ship proportions, are driven to assume secondary importance.
b. The unprecedented ability to miniaturize both sensors and computational power enable new generations of weapons to be guided passively, using the target’s visual image. New combatants must incorporate shaping and camouflaging in various parts of the spectrum, in order to reduce susceptibility in all signatures.
c. The role of off-board sensors and communication links that can be deployed from the ship (as unmanned air, surface, or underwater vehicles) demand design integration efforts that encompass portions of the ship which were previously less impacted by combat system functions.
d. To accommodate the increasing pace of advances in communication and computer technologies, modularity and ease of configuration changes are vital. This is discussed below, in connection with the control of life-cycle costs. However, the effects on ship arrangements are also profound. For example, in classic designs of a decade ago, it was standard console size that governed arrangements of computer and equipment spaces. Today, of course,

it is not only computers and electronic equipment that are packaged for ease of "technology refreshment," but even combat-system effectors, such as guns and launchers, are often incorporated as "plug-and-fight" modules. This development is a key driver for both topside and internal arrangements, and even structural concepts.

Given the increasing complexity of the combat environment, much of which stems from advances in communication and computation, it is fortunate for the design community that *design tools* have also benefited from faster computing capabilities and essentially limitless memory. As a result, the naval designer can now take advantage of the ability to perform affordable simulations of systems that would have been considered computationally intractable only a few years ago. Two examples may be particularly illustrative of this trend:

The study of non-linear dynamic stability, or more properly stability and control in extreme sea conditions, is emerging as a new sub-discipline within naval architecture, supplementing the classic static stability calculations that were previously assumed (largely as a matter of faith and empiricism) to adequately ensure resistance to large roll excursions in a seaway. Without this extension of computational capabilities, a tumblehome wave-piercing form for a combatant hull would probably not have proceeded.

- Statistical and physics-based simulations of total ship survivability elements, including susceptibility, vulnerability, and recoverability aspects, can now be investigated with a far higher degree of fidelity than was possible in the past. The ability to conduct sufficiently detailed investigations at a pace which can still prove helpful in reaching ship-design decisions, has already been shown to assist in establishing a set of rational designs and evaluating their merits in a quantitative, measurable, repeatable and verifiable way.

4. Life Cycle Cost Reductions

As the Cold War era came to an end, it was anticipated that defense budgets, at least those of the world's largest navies, would be subjected to increasingly critical scrutiny and stringent control of costs. This has indeed been the case. But at the same time, as we've noted above, there is also an increasing pace of advance in electronic technologies, mainly under pressure from the commercial rather than the military world.

Modularity (or more generally, reconfigurability) has become a central trend in naval design. This is obviously a key affordability issue, whether for world, regional, or coastal defense naval establishments. What is equally at issue, though, is the ability to maintain superiority over relevant threats. These, as we have seen, can evolve at the speed of markets in weapons, illicit as well as legitimate, and using improvised weapons along with "store-bought."

So-called "Plug and Play" systems, configured with a standard interface to the platform's "data backbone," or ship-wide area network, and to required support systems, such as electric power, cooling, and fluids, are at the heart of the "open architecture" concept. It is perhaps a sign of our times, more than in previous years, that even a stabilized gun system, for example, can (and should) be packaged so as to be upgraded within hours, and consequently with no changes in hard wiring. The required modules of software, too, are equally designed to exchange in the field.

The reality for many navies is that a primary contributor to operational costs is personnel: the human resources needed to operate and maintain the combatant ship and its systems. The trend is toward significant reductions in ship's complements (recent examples include manning reductions of two-thirds). Mechanization, remote monitoring, and automation of ship's functions during normal cruising operations follow trends that have long been exploited in merchant ships. The level of autonomy that has become possible for combat systems is a product of computational advances as much as anything else. The key remaining element, at the heart of several ongoing efforts, is the development of practical, affordable systems that can supplement or replace personnel in damage monitoring, localization of damage, and recoverability following a casualty.

Apart from investment in automated systems themselves, however, dramatic reductions in over-all manning are often reflected in a higher level of technical training (and cross-training) for the remaining complement. As a consequence, retention of personnel becomes more important as crew size is streamlined, and the counterbalance is the improvement in habitability standards in new combatants.

5. Global Political Changes

The balance of power between two major world groups resulted in opposing blue-water navies, fleets suited for operations covering enormous distances, extended periods away from a home port, and effectiveness in mid-ocean, under extremely severe conditions of weather and sea state. However, with the end of the Cold War, and even more in the post 9-11 period, it has become apparent that the objectives of sea power have changed dramatically. More than ever, the center of purpose is on the land. It seems clear that in conflicts waged against non-governmental organizations, rather than explicitly against sovereign states, any nation can find itself suddenly confronted with widespread and dangerous opposition on land, and in (or from) coastal areas as well. It is equally clear that geographic areas of interest may shift over time, and that the conflicts themselves will not be uniform processes, as they seemed to be during the Cold War. The conflicts will evolve persistently, and radically. Consequently, the tools of naval power will have to change, too.

The asymmetric threat is now surely the most ubiquitous, and possibly the most dynamic, threat in naval warfare. This is exemplified by the large, extremely expensive asset that is forced to defend itself against small, fast, and generally inexpensive craft, or land-based threats (in restricted waters), or to decline the engagement. The threats are perhaps more likely to have mission-kill rather than ship-killing weapons, although the latter are certainly possible as well.

To reduce asymmetry, a major change in size orientation has been reflected in the U.S. Navy's LCS program. Moderate size, shallow draft, high speed, agility, and reconfigurability have been placed at a premium for the first time in many years.

6. The Role of Survivability

Littoral combat capabilities require an unusually stringent demand for weight control. This need is only increased, of course, by the desire for higher speeds. Nevertheless, in spite of the desire to reduce asymmetry by focusing on small, agile, highly lethal and adaptable designs, there remains a need to ensure a certain level of total ship survivability.

The three components of total ship survivability, reduction in susceptibility, reduction in vulnerability, and improvement in recoverability, have become major considerations in combatant design.

Naturally, the most visible elements in ship designs for total survivability are those associated with reduction in susceptibility – the probability of being detected, classified, identified, engaged, and hit. Exterior shaping, with large, flat, and sloped (preferably in-sloped) surfaces has became typical – beginning with the Sa'ar 5 (designed in the mid 1980s), and continuing through the French Lafayette Class, and in quite extreme forms, the Alligator and DD(X).

The advancement in technology of passive systems, i.e., electro-optic sensors, promotes camouflage is a new hallmark of small littoral combatant designs. The use of visual and multi-spectral camouflage is highly background dependent, and therefore varies widely with mission, geographic area, and concept of operations.

Vulnerability reduction makes use of analytical tools and statistical analyses to produce optimal redundancy, separation, and enclaving schemes for arrangements of vital components and, in more recent work, distributive systems as well.

The automation of recoverability functions, using smart sensing and actuation devices are expected to be an element of new combatant designs, in accordance with reduced manning and weight control objectives.

7. Conclusion

As a final note, it seems that advances in composite materials may ultimately be able to support all three areas of survivability improvement, along with the over-all objective of light weight. This will be achieved by more accurate control of geometric features and surface flatness, by incorporation of the desired thermal properties into the material, and the possibility of embedding several types of signature treatments (and perhaps even distributed self-monitoring sensors), into the structural laminate itself. The advances that will permit this include the availability of improved analytical tools, leading to accurate assessments of structural and signature performance: as embodied in vessels such as the Swedish *Visby*, the Norwegian *Skjold*, and in the proposed surface-effect ship variant of the U.S. LCS design