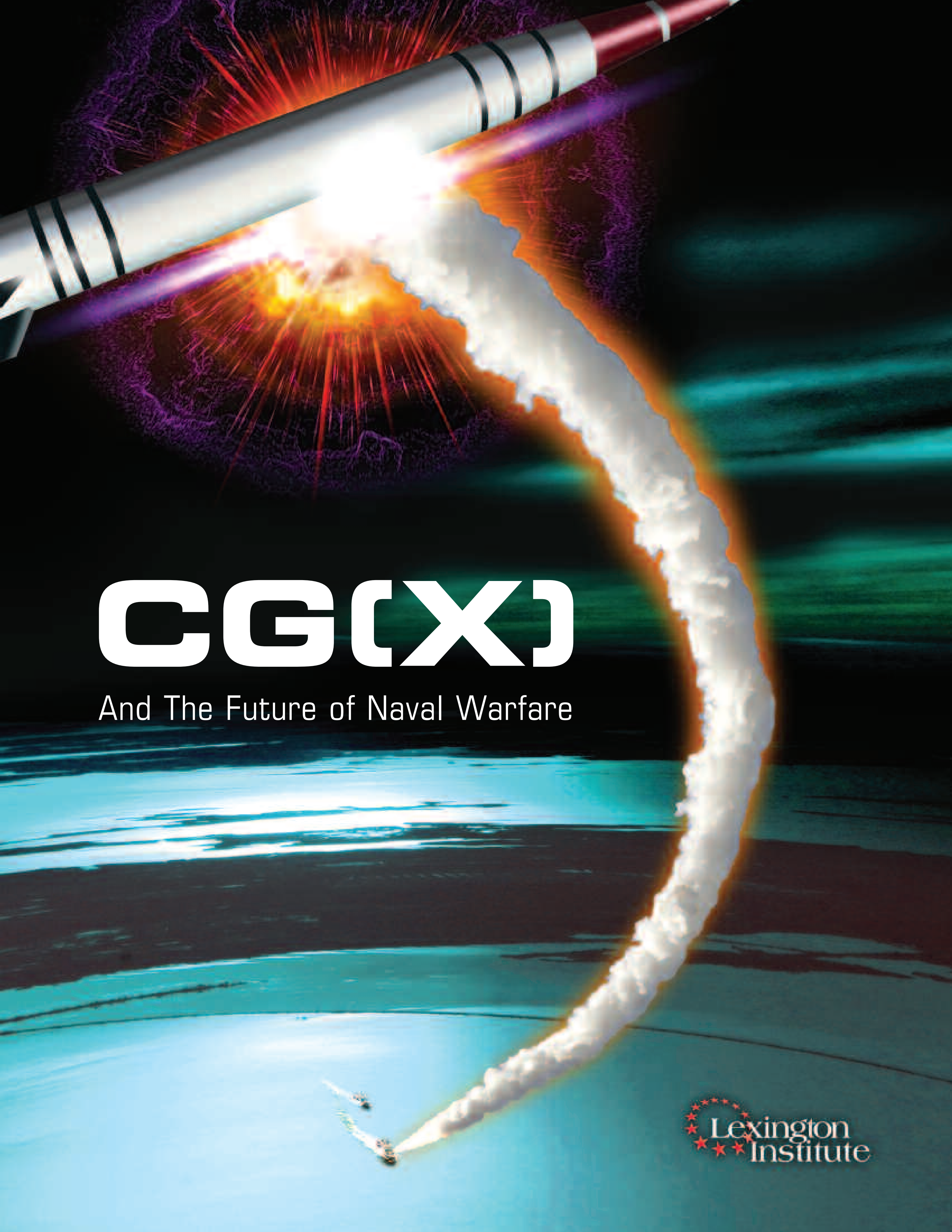
CG(X)

And The Future of Naval Warfare



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FINDINGS IN BRIEF

The U.S. Navy plans to acquire a next-generation cruiser that can defend its fleet, the rest of the joint force, and overseas allies against emerging airborne and ballistic-missile threats. These threats include stealthy strike aircraft, ground-hugging cruise missiles, and theater-range ballistic missiles equipped with maneuvering warheads. The challenge of coping with such threats is made worse by the fact that the Navy of the future will be operating in littoral regions where enemies are hard to distinguish from friends and neutrals. The primary mission of the new cruiser, designated CG(X), will be to promptly detect, track and engage airborne and ballistic threats before they can inflict harm on U.S. forces or interests.

Five basic performance requirements drive the design of the CG(X). First, it must be able to destroy hostile ballistic missiles during the midcourse of their trajectories, when they are hurtling through space. Second, it must be able to intercept a diverse collection of airborne threats, both manned and unmanned, which employ advanced technology and tactics to avoid detection. Third, it must be continually networked with the rest of the fleet, the joint force, and allies to assure that all relevant capabilities are brought to bear against airborne and ballistic threats. Fourth, it must be able to conduct other missions such as sea control and force projection while successfully performing its primary defensive missions. Finally, it must be scalable and adaptable to new threats that emerge during the 30 or more years it is operational.

The Navy has conducted a detailed analysis of alternatives identifying its options for developing the CG(X). It expects to build 19 warships, with the first such vessel reaching operational status at the end of the next decade. In order to facilitate timely development, the service will probably elect to use structural, mechanical and electrical elements already developed for the DDG-1000 class of land-attack destroyers. However, three key on-board systems will have to be substantially improved beyond what is available from the DDG-1000 in order to accomplish CG(X) defensive missions. The ship's radar will need to be much more powerful and sensitive than any radar previously deployed at sea; the weapons used to engage future airborne and ballistic threats will need to be extremely agile and accurate; and the ship's integrated electrical system will need to generate and condition very high levels of power for diverse applications.

Even if all of the supporting technologies necessary to make the CG(X) work are developed in a timely fashion, it will still be dependent on off-board systems such as carrier-based E-2D radar planes and Space-Based Infrared System missile-warning satellites to overcome the surveillance constraints inherent in being a surface vessel. Beyond that, the basic architecture of the warship must be designed to accommodate regular upgrades of all capabilities as new threats emerge and new technologies become available. This requirement for continuous improvement dictates a design that it scalable, flexible and modular, making maximum use of open architectures to assimilate new innovations. It is neither feasible nor affordable to design a ship today that anticipates all the relevant developments through 2050, but the ship can incorporate principles of scalability that maximize the options available to future warfighters.

This report was written by Dr. Loren Thompson of the Lexington Institute staff in consultation with other participants in the Naval Strike Forum.

CG(X) AND THE FUTURE OF NAVAL WARFARE

On November 1, 2001 the U.S. Navy unveiled a plan for the modernization of its surface combatants. Surface combatants are the most common type of warship in the fleet, and currently are constructed in three sizes: cruisers, destroyers and frigates. The 2001 modernization plan preserved the notion of three distinct sizes, but proposed a radical redesign of each class of combatant to cope with emerging threats and missions. There would be a new cruiser focused on defense against stealthy cruise missiles and maneuvering ballistic warheads, a new destroyer designed mainly for attacking targets on land, and a successor to frigates dubbed the "Littoral Combat Ship" that could conduct diverse shallow-water operations. The new destroyer, designated DDG-1000, is now in advanced development, as is the Littoral Combat Ship. The future cruiser is little more than a concept, but that is about to change.

Aegis warships currently host the most capable maritime air-defense systems in the world.

This report is about the future cruiser, which is referred to in naval nomenclature as CG(X) — "C" for cruiser, "G" for guided missile, "X" for experimental. In other words, CG(X) is the next generation of guided-missile cruisers, conceived to replace the *Ticonderoga* class of cold-war cruisers. Like the 22 *Ticonderogas* in today's fleet, the 19 CG(X) warships in the Navy's modernization plan will be designed primarily to protect the joint force and allies against airborne and ballistic-missile threats. But they will also have the capacity to perform a range of other missions such as sea control, and their suite of defensive technologies will be far superior to the Aegis combat system carried on current cruisers. In addition to hosting the most agile air-defense radars and surface-to-air missiles in the world, CG(X) will be thoroughly connected to the other war-fighting assets of the joint force, enabling a new approach to warfare called network-centric operations. These features, combined with an integrated power system and open information architecture, are supposed to facilitate adaptation to virtually any threat likely to emerge between now and mid-century.

Although the planned 19 CG(X) cruisers will only comprise six percent of the ships in the Navy's proposed future fleet of 313 ships, they are likely to be crucial to the viability of the entire naval force posture. Without them, the sea services would be hard pressed to defend other war-fighting assets against a variety of emerging threats. Therefore, it is important to develop the new cruiser expeditiously, and to utilize design concepts that enable the warship to evolve easily in response to nascent dangers. With the first CG(X) not expected to join the fleet until late in the next decade and each vessel likely to serve at sea for 30 years, flexibility for dealing with future challenges must be built into the warship.

The Navy has recently completed a detailed analysis of alternatives assessing the tradeoffs that must be made in developing CG(X). The purpose of the present report is to introduce key considerations in the cruiser's design to a broad audience by concisely covering five topics:

- Emerging threats and missions that the future fleet must address.
- Performance requirements driving the capabilities of a next-generation cruiser.
- Key design features and concepts that will shape the configuration of the vessel.
- Other joint-force programs critical to the success of CG(X) in its primary mission.
- The optimum path forward to assure a timely and affordable acquisition effort.

EMERGING THREATS AND MISSIONS


An Aegis warship launches a Standard surface-to-air missile.

The emerging threat environment in which the U.S. Navy must operate is different from the one that shaped the current fleet. During the 20th Century, national security was threatened by three successive waves of danger — imperialism, which caused World War One; fascism, which caused World War Two; and communism, which caused the cold war. Whatever the pretensions of these challenges may have been, they were at bottom the bid of non-democratic great powers for global supremacy. The war-fighting capabilities that the Navy acquired to counter such challenges reflected their state-based, highly industrialized character, and therefore the fleet was focused mainly on preparations for intense conventional combat.

There is a high likelihood that the joint force will face similar threats in the future from countries such as China. However, the landscape of global security challenges looks more complicated today than it did in the last century, because a diverse range of lesser threats has materialized that adds to the danger posed by other industrialized powers, including backward dictatorships armed with weapons of mass destruction, stateless terrorists pursuing fanatical agendas, and elusive traffickers in every conceivable illicit commodity — from arms to drugs to slaves. The appearance of these non-traditional threats has blurred the distinction between wartime and peacetime by populating the world with potential aggressors whose behavior cannot be predicted with any degree of confidence. All of the prospective adversaries share the goal of reducing U.S. access to their areas of influence at a time when America is more dependent on overseas trade and markets than ever before.

From the viewpoint of the U.S. Navy, the most troubling trend in this emerging threat environment is the proliferation of advanced military technology to previously weak troublemakers. In particular, airborne and ballistic systems with considerable anti-ship potential have spread rapidly among the littoral nations of Asia, Africa and Latin America. Among the most troubling overhead threats with which the future Navy will have to cope are:

- Stealthy cruise missiles that can approach maritime traffic using ground-hugging, circuitous routes across cluttered landscapes.

- Very fast ballistic missiles with maneuvering warheads and sophisticated countermeasures to aid penetration of defensive screens.

- Sea-skimming anti-ship missiles that can attack warships from any direction very quickly while eluding detection by surface sensors.

- High-flying, long-endurance unmanned aerial vehicles that can host surveillance systems for pinpointing the location of naval forces.

- Orbital reconnaissance and intelligence-gathering satellites that enable emerging powers to greatly enhance maritime situational awareness.

When these new technologies are combined with the highly networked communications infrastructure of the information age, they present the Navy with a complex set of operational challenges. The challenges are amplified by the need to operate in littoral regions rather than the open seas, where surface and airborne traffic is much denser. At the same time potential adversaries are being empowered by new technologies, the Navy is being constrained by the ambiguities of operating in close proximity to concentrations of civil and commercial activity. Against this backdrop, the service must carry out its traditional missions of forward presence, deterrence, sea control and force projection while also participating in newer missions such as counter-insurgency, counter-terrorism, stability operations and humanitarian assistance. All of these missions,

Future surface combatants will be designed to minimize radar reflections.

new and old, would be impaired by mistakes that claim the lives of local civilians, yet the speed and lethality of enemy weapons leave little time to sort out friend from foe.

The primary mission of the CG(X) in this environment is to defend the fleet, the rest of the joint force, and local allies without making such mistakes. It therefore must deliver a quantum leap forward in situational awareness and precision targeting of airborne and ballistic threats. Existing seaborne air defenses such as the Aegis combat system were not designed to cope with the complex littoral operating environment of today, not to mention the more challenging environments of the future. Even in the open seas, today's weapons would be largely impotent against stealthy cruise missiles and maneuvering ballistic warheads. If the U.S. Navy is to successfully fulfill its responsibilities in the years ahead, it requires a much more agile and sensitive solution for overhead threats — one that can adapt readily as threats change.

CG(X) PERFORMANCE REQUIREMENTS

The U.S. Navy completed a two-year assessment of CG(X) performance requirements and design tradeoffs in autumn of 2007, officially known as the Maritime Air and Missile Defense of Joint Forces Analysis of Alternatives. The analysis identified a range of options for the configuration of a future cruiser, but tended to favor re-use of hull, electrical and propulsion concepts developed for the DDG-1000 destroyer in designing CG(X). Within that framework, five overarching performance requirements drive the cost and capabilities of the cruiser.

Missile defense. The CG(X) must be able to provide ballistic missile defense against theater-range missiles equipped with maneuvering warheads. The Navy has never faced such a challenge before, but the intelligence community has forecast that China and other potential adversaries will begin acquiring maneuvering ballistic-missile warheads in the next decade, along with the overhead reconnaissance capabilities necessary to accurately target the warheads against U.S. naval vessels. Chinese military writings have repeatedly stated that theater ballistic missiles equipped with maneuvering warheads are the most cost-effective solution for securing the nation's "eastern maritime flank," and there are clear signs that these weapons are being developed. Over time, the accuracy of Chinese reconnaissance systems and warheads is likely to improve, while the range and mobility of Chinese ballistic missiles increases. The most important new performance requirement of CG(X) is to negate this emerging threat through a combination of on-board sensors and interceptors linked to off-board systems that can quickly detect and characterize ballistic threats against the U.S. fleet, the joint force and allied nations. The resulting area defense would need to extend hundreds of miles distant from each cruiser, including over land, in order to cope with the full range of potential ballistic threats.

Air defense. The CG(X) must be able to detect, track and engage hostile aircraft with low radar cross-sections, also known as stealthy aircraft. Potential adversaries are developing a variety of elusive airborne systems that will be difficult to track using conventional radars, from stealthy manned aircraft to unmanned surveillance drones to ground-hugging cruise missiles. The air-defense radar and other sensors on the CG(X) must have sufficient range, power and sensitivity to identify all potential airborne threats within a few hundred miles of the warship, and to differentiate them from non-threatening aircraft operating in the dense airspace characterizing many littoral regions. The air-defense missiles carried by the CG(X) must have sufficient range, speed and precision to successfully intercept all such threats before they can harm the joint force or allied assets. Developing radars, sensors, and battle management systems that can accomplish both the demanding missile-defense and air-defense missions of the CG(X) is the central design challenge of the entire program, especially in light of the need to build sufficient scalability (growth margin) into the defensive architecture so that it can adapt readily to further refinements in the threat over a period of several decades.

Networked operations. The CG(X) cannot accomplish its core defensive missions unless it is continuously linked to other war-fighting assets of the joint force. It will have to rely on orbital reconnaissance satellites such as the Space Based Infrared System to provide early warning of missile launches, and airborne surveillance systems such as the E-2D Advanced Hawkeye radar plane to track hostile aircraft beyond its radar horizon. These off-board sensors cannot handoff target tracks or cue defensive missiles aboard the CG(X) unless they are all part of a robust, resilient network that unifies all relevant war-fighting assets. Even when the CG(X) radar is the first sensor to detect and

The E-2C Hawkeye will be upgraded to support future defensive missions.

track an attacker, it will often make more sense to intercept that attacker from a different location because of more favorable positioning. More broadly, the future concept of operations for the entire U.S. Navy and the rest of the joint force assumes an unprecedented degree of connectivity so that scarce war-fighting capabilities can be applied in the most integrated and collaborative fashion. Therefore, CG(X) must have all the information and communication capabilities necessary to operate as a vital node in a global security network that encompasses the joint force, coalition partners, and various civil agencies of the federal government.

Multi-mission versatility. With a future fleet of barely 300 warships to cover the world, the Navy must wring as much war-fighting flexibility out of each vessel as is possible. Although airborne and ballistic-missile threats are increasing steadily in the Western Pacific, Persian Gulf and other key regions, it would not be desirable to invest in a next-generation cruiser that can only perform a narrow range of defensive missions. CG(X) must be designed as a multi-mission, versatile warship that can participate in other naval missions such as forward presence, force projection, sea control and counter-terrorism. It also must be able to defend itself against a variety of dangers in addition to the airborne and ballistic threats that are its primary focus. Thus, the final configuration of the cruiser should include both offensive and defensive weapons in sufficient number to make a major contribution to complex military campaigns, and the provisions for on-board surveillance, battle management and communications gear must assure relevance across the various phases of war.

Future adaptability. Whatever the mix of capabilities ultimately integrated on CG(X), the overall system architecture of the warship must provide considerable growth margin for addressing threats not existing at the time the baseline vessel is built. The emerging global threat environment is so diverse and unpredictable that the Navy cannot afford to incorporate every capability that might conceivably be useful over the 30-year life of the warship simply because there is a possibility that certain threats will materialize. However, it can develop a cruiser that is equal to the challenges of the near-to-medium term while providing the adaptability to scale up on-board systems to whatever new dangers do appear. This is a complex performance requirement dictating design features such as scalability, modularity and open-source software code, but without the necessary margin for future modifications, CG(X) could easily be rendered obsolete early in its life by unforeseen threat developments.

CG(X) DESIGN FEATURES

The CG(X) analysis of alternatives completed in summer of 2007 considered a wide range of design features to optimize the capabilities of the future cruiser. The Navy appears to favor a conventionally-powered vessel that re-uses the

Naval war-fighters aboard the CG(X) must be able to respond quickly and precisely to a range of overhead threats.

hull, mechanical and electric systems developed for the DDG-1000 class of destroyers. That approach would save time and money in designing the cruiser and allow economies during the service life of the two warship classes. One of the reasons originally advanced for developing the DDG-1000 was to refine technologies that could be used across the future fleet, and CG(X) is a logical place to apply those new technologies. However, there are at least three key areas in which CG(X) will have to be significantly different from DDG-1000 to successfully accomplish its air and missile defense missions.

Radar. The tracking of ballistic missiles and stealthy aircraft requires a radar that is much more powerful and sensitive than that carried on Aegis warships or the DDG-1000 destroyer. According to Ronald O'Rourke of the Congressional Research Service, the CG(X) combat system, including the new radar, may require about 30 megawatts of power, compared with the five megawatts required for today's Aegis combat system. The size of the apertures for the radar's phased array also will have to be considerably bigger to achieve the resolutions necessary for detecting and tracking low radar-cross-section aircraft that generate minimal radar returns compared with conventional aircraft. This will place a premium on low-weight radar designs since the radar must be placed fairly high in the ship's structure where it could create stability problems if it is too heavy. In addition, it will be necessary to build scalability into the radar antennas, processors and cooling systems since overhead threats at mid-century may be far more demanding than those that exist today. If CG(X) fails to incorporate a flexible, scalable radar design, then the Navy will either have to invest up front in excess capacity not needed to cope with near-term threats or come back later and redesign the radar at considerable cost.

Weapons. CG(X) is not expected to carry the long-range guns that enable the DDG-1000 to sustain high rates of precision fire against land targets. Instead, it will host a large number of vertical launch systems suitable for employing an array of missiles against airborne, ballistic and surface targets. The *Ticonderoga* class of Aegis cruisers carries 128 vertical launch cells, and Navy planners will probably want to equip CG(X) with an equivalent or greater number. The DDG-1000 only has 80 launch cells, because much of its firepower is provided by guns. Since the Navy has little visibility into the operational demands likely to be imposed on CG(X) three or four decades into the future, it will probably decide to develop a modular launch system for the cruiser that allows employment of many different types of missiles and facilitates rapid reconfiguration of on-board armaments in response to changing conditions. One option that has been proposed is a "cold-launch" system in which missiles are ejected from tubes by pressurized gas before they ignite, reducing wear and tear on the launcher and enabling the use of higher-energy missiles in the future. Another option widely discussed is to equip the cruiser with unconventional weapons such as electromagnetic rail guns or directed-energy devices. These systems are still in their infancy, but they will undoubtedly mature during the early stages of the cruiser's operational life and offer war-fighting options not available from traditional munitions.

Power. The CG(X) will probably incorporate an evolved version of the integrated electrical power system developed for the DDG-1000 destroyer. However, the cruiser version will need to be considerably more capable than the baseline design because of the high power demands of the CG(X) radar and any non-traditional munitions included in the design. Furthermore, past experience suggests that electrical power requirements will grow over time, so the integrated power system must offer the same scalability exhibited in other key on-board systems. If the cruiser's power-generation system lacked significant growth margin, it would have to be redesigned along with the radar to address more capable threats in the future. Recent breakthroughs in "power-dense" machinery, electrical storage devices, and other technologies will probably enable designers to fit a much more robust electrical-generation capacity within the seaframe constraints of the DDG-1000, but the Navy will need to invest in relevant technologies to bring the system to a suitable level of maturity.

Beyond these major design changes, CG(X) will include a range of other modifications making it significantly different from the DDG-1000 and Aegis warships. For example, the number and configuration of communications apertures in its deckhouse will be different to accommodate the demands of network-centric operations, and the combat information center from which sensors are monitored and engagements managed will be substantially upgraded. In addition, many on-board functions will be automated to reduce the size of the crew. It is possible that after further analysis the Navy will decide to use a more conventional hull form rather than the reduced-visibility shape adopted for the DDG-1000. There has even been some discussion of using nuclear power to drive the ship's propulsion system. As a practical matter, though, most of the design innovations on the future cruiser will have to focus on optimizing performance for the primary air and missile-defense missions, because if the Navy strays far from its core mission requirements, the CG(X) could become unaffordable.

VITAL SUPPORTING SYSTEMS

The CG(X) will be designed for networked and distributed operations, meaning that it will function in an environment of continuous connectivity and cooperation with other elements of the joint force. Reliance on other, off-board systems will be especially important for CG(X) because the airborne and ballistic-missile threats against which it must defend will often originate at points beyond the range of the cruiser's radar. Even when the radar can accurately capture and characterize threats, it will sometimes be desirable to engage them using off-board systems that are better positioned for timely interception. For example, carrier-based aircraft may be better situated for engaging cruise missiles or their host aircraft far from the fleet, rather than waiting until they are within range of weapons aboard the CG(X). The off-board systems most critical to the success of CG(X) in future air and missile-defense missions are missile-warning satellites, airborne surveillance aircraft, and orbital communications nodes.

Missile-warning satellites. The United States is currently developing a successor to its cold war missile-warning satellites called the Space Based Infrared System, or SBIRS. Each geosynchronous satellite in the planned constellation will have scanning and staring sensors capable of detecting a wide range of thermal phenomena, including ballistic-missile launches, aircraft afterburners and artillery muzzle flashes. Additional sensors hosted on classified satellites in polar orbits will search for submarine-launched ballistic missiles in polar regions. As the primary missile-warning system at the time CG(X) becomes operational, SBIRS will play a central role in detecting initial launch of theater ballistic missiles and alerting CG(X) to impending danger. Armed with that information, the cruiser can orient its sensors and cue its weapons to maximize the likelihood of successful interception. A second constellation of satellites called the Space Tracking and Surveillance System (STSS) will provide precise reporting on the path of ballistic warheads during the midcourse portion of their trajectory, when warheads are coasting through space and harder to detect. The two next-generation satellite systems, in combination with agile ground networks for quickly interpreting spacecraft reconnaissance, will be essential components in the global missile-defense architecture of which CG(X) is a part. Without such overhead surveillance, it would be difficult for the CG(X) to recognize and respond to longer-range ballistic threats until relatively late in their trajectories.

Airborne surveillance systems. The SBIRS satellite cannot detect heat signatures through clouds. Satellites operating in other portions of the electromagnetic spectrum such as the proposed Space Radar could track missiles through clouds, but it is not clear those spacecraft will ever be built. The resulting gap in air and missile reconnaissance between orbital platforms and surface sensors therefore must be filled by airborne surveillance systems such as the carrier-based E-2D Advanced Hawkeye radar plane. The next-generation Advanced Hawkeye will be a highly networked airborne sensor capable of tracking stealthy aircraft and ground-hugging cruise missiles from a much higher vantage point than the CG(X) radar could provide. With appropriate infrared detection capability, it could also capture the launch of theater ballistic missiles before they were within sight of distant surface sensors. The E-2D will be an essential surveillance and battle management node in networked operations, greatly enhancing the capacity of CG(X) to track and destroy elusive missiles before they can threaten the fleet. In combination with other joint assets such as the Air Force's Airborne Warning and Control System (AWACS) aircraft, it will generate the detailed picture of nearby air space necessary to assure effective fleet defense.

Orbital communications nodes. The emerging CG(X) concept of operations requires a comprehensively networked force posture.The only practical way to assure such connectivity to Navy forces scattered around the globe is with communications satellites configured to deliver secure, high-capacity links for diverse types of communication. The Department of Defense is developing a series of next-generation satellite constellations to satisfy this need, all of which will in some measure support the kind of "internet-protocol" transmissions that maximize capacity utilization and flexibility. The most important such system is the Transformational Satellite Communications (TSAT) architecture, which will deliver unprecedented bandwidth, access, and reliability even to disadvantaged war-fighters in remote locations. In combination with other initiatives such as the Joint Tactical Radio System and the Navy's own Mobile User Objective System satellite program, TSAT will provide the "glue" for networked and distributed operations in which the performance of CG(X) can be optimized. Without these linkages, CG(X) could not achieve the desired level of performance required against emerging threats.

Next-generation surveillance and communications satellites will play a key role in the CG(X) defensive mission.

With the exact performance features and operating concepts of CG(X) still in flux, it is not feasible at this point to define precisely how CG(X) will mesh with other elements of the fleet, the joint force, and allied militaries. However, it is clear that both budgetary constraints and net-centric operating values drive designers towards a future cruiser that depends on off-board systems for many functions. Whatever the virtues of CG(X) may be as a future class of warships, it cannot be understood separate from the highly integrated force posture of which it will be but one part.

THE WAY FORWARD

CG(X) is a necessary investment in the future survivability and effectiveness of the joint force. However, its development will unfold against a backdrop of controversy concerning efforts to modernize the Navy's fleet. In recent years the service has managed to acquire only a handful of new warships, and some of them have cost far more than originally planned. The Navy will not be able to sustain an adequate fleet over the long run if it remains on its current course in shipbuilding. Therefore, CG(X) should be viewed not just as a necessary investment in future war-fighting capabilities, but as an opportunity to change the way complex surface combatants are designed and built. A successful approach to buying the Navy's next cruiser must begin with four basic goals:

- CG(X) must be able to maintain dominance in its primary mission of theater air and missile defense for decades to come.

- CG(X) must be sufficiently versatile to conduct other naval missions such as force projection and sea control during the same multi-decade period.

- CG(X) must be able to function in an environment of distributed and networked operations where cooperation is the norm rather than the exception.

- CG(X) must be affordable to a service with many other priorities, not just in its initial construction but in subsequent efforts to upgrade its baseline capabilities.

These goals all drive the Navy's acquisition strategy for CG(X) in the same direction — toward a modified repeat of the existing DDG-1000 seaframe hosting systems that can be scaled up to deal with more demanding challenges as they arise. In other words, CG(X) must employ modular design concepts and open information architectures that facilitate continuous improvement as missions evolve. Scalability in this context means much more than simply having enough "growth margin" to accommodate future increases in weight or volume. It means thinking through the technology of sensors, weapons, power-generation and other onboard systems to assure that they will not be rendered obsolete in a few years by the actions of adversaries. CG(X) must retain its relevance during a period of rapid technological progress and political uncertainty, and that dictates a more open-minded, innovative approach to its design and construction.

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