Future Warfare 20XX Wargame Series: Lessons Learned Report

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I. THE FUTURE WARFARE 20XX WARGAME SERIES

BACKGROUND

The 20XX wargame series is premised upon a future security environment in which the key technological and strategic trends associated with an ongoing Revolution in Military Affairs (RMA) have been fully played out. The 20XX wargame scenario posits multidimensional, asymmetric, advanced RMA conflicts between the United States and its allies and a large peer competitor (LPC) and its allies. The LPC (modeled on a rising China) is an autocracy with a robust economy, sophisticated technology base, and expansionist foreign policy. The conflict scenarios are set in the unspecified year of "20XX" to avoid needless debate over the precise time frame during which the postulated forces and capabilities might become available. However, the date can be assumed to be approximately 2025-2030. The principal objective of the 20XX series has been to:

- Analyze a future RMA regime and associated force capabilities;
- Evaluate candidate RMA operational and organizational concepts; and
- Surface operational and organizational issues meriting further investigation.

The 20XX series revolves around key operational challenges thought to be associated with an advanced phase of the ongoing RMA:

- Defending homelands against multidimensional attack;
- Projecting power from extended range in anti-access, deep-inland environments and conducting urban eviction and control in such environments;
- Conducting space and information operations and assuring space and information system survivability;
- Conducting large-scale unmanned warfare; and
- Conducting complex, distributed operations and network-on-network warfare.

These challenges, albeit in more virulent form, are essentially identical to those described in the 2001 Quadrennial Defense Review.[1]

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[1] Secretary of Defense Donald H. Rumsfeld, *Quadrennial Defense Review Report* (Washington, DC: Department of Defense (DoD), September 30, 2001), pp. 30-31.

The 20XX series began with a future warfare concept paper produced in 1993 by the Office of Net Assessment (ONA) in the Office of the Secretary of Defense (OSD).[2] Full, seminar-style wargaming was initiated in November 1995 and continued through December 2000 under ONA sponsorship. To date, the series has comprised nine major wargames, three preparatory workshops (i.e., aerospace issues, maritime issues, and dimensional control issues), two functional workshops (i.e., organization and command and control, and robotics and biotechnology), and one force-redesign workshop. These events have variously emphasized individual engagements, operations, theater campaigns, multi-theater war, and global war. The series has employed three basic scenarios: an LPC attack on an independent Siberian Republic (the former Russian Far East); an LPC incursion into Kazakhstan; and an LPC intervention in an Indonesian civil war.

This chapter provides an overview of the scenarios, methodology, and key assumptions about military capabilities that underpin the 20XX wargame series. Selected insights derived from the wargames dealing with future strategy, force postures, and the operational environment are addressed in Chapter II, while those associated with future operational and organizational concepts are described in Chapter III. Potential implications of lessons learned from the 20XX wargame series for transformation of the U.S. military are described in Chapter IV. The report concludes with a brief summary of possible topics that might be explored in future RMA wargames and study efforts.

SCENARIOS

The LPC in 20XX is on a quest for Asian dominance resulting in intensified, asymmetric, global competition with the United States. Prior to 20XX, the LPC successfully "absorbed" Taiwan and employed a range of economic inducements, along with threats of trade embargoes and commercial traffic interdiction, to create an LPC-controlled Asian common market. The chief constraint to continued LPC economic growth is its rapidly increasing energy requirements, which far exceed its domestic sources of supply. The LPC is also plagued by chronic shortages of water. Military conflicts between the United States and the LPC erupt for a variety of reasons, including:

- An LPC invasion aimed at seizing control of the Siberian Republic's (the present Russian Far East) sizable oil and gas reserves under the guise of protecting oppressed LPC nationals living in Vladivostok, Khabarovsk, and other cities in the Amur River valley;

- An LPC invasion of Kazakhstan to rout out Uighur terrorists conducting cross-border operations into Xinjiang, to secure a recently built oil and gas pipeline, and to tap additional water supplies; and

[2] Michael G. Vickers, *A Concept for Theater War in 2020*, (Washington, DC: OSD, November 1993). The paper was expanded into a table-top wargame in 1994 with contractor support provided by Booz Allen Hamilton, and then into a full seminar-style wargame in late 1995 in conjunction with the Strategic Assessment Center at Science Applications International Corporation (SAIC). In late 1996, the Center for Strategic and Budgetary Assessments (CSBA) became a sub-contractor to SAIC for the 20XX wargame series. CSBA and SAIC jointly conducted the 20XX series through December 2000.

- An LPC intervention in an Indonesian civil war to install an LPC-friendly regime and to secure access to natural gas from Indonesia's large Natuna gas field and other reserves (e.g., oil fields on the island of Sumatra).

These scenarios were selected principally for the RMA operational challenges they represent rather than their inherent political plausibility. For example, the first scenario, in which the LPC could invade Siberian territory quickly from jump-off positions adjacent to the border and subsequently support its invasion forces with assets based in the LPC homeland, presented several important challenges to the Blue (U.S.) team:

- Rapidly halting an air-ground-sea attack on a regional ally by using survivable "presence" forces already in the area bolstered by rapid-response, extended-range strike assets;

- Countering multidimensional, anti-access challenges presented by the LPC;

- Conducting combat operations against an in-place adversary that can leverage potent, multidimensional, reconnaissance-strike capabilities, most of which are secured within a nearby homeland sanctuary; and

- Conducting close-combat operations in densely populated urban areas (e.g. Khabarovsk and Vladivostok) as well as distributed-strike operations in open terrain.

The Kazakhstan scenario provided the context for exploring deep-inland, denied-area operations in both open and restricted terrain. The combination of the Siberian and Indonesian scenarios provided the context for a two-theater maritime campaign along an extended littoral that reached from the Bering Sea to the South Pacific and encompassed both relatively confined waters (e.g., Sea of Okhotsk, Sea of Japan, and numerous straits around Indonesia) as well as open ocean. Operations in space also formed a core aspect of the 20XX scenario set, as did global strategic-strike operations (including limited homeland attacks). Japan and a Unified Korea were kept neutral, complicating the U.S. power-projection problem. The scenarios have generally given the LPC the benefit of interior lines and the opportunity to strike first. (See Figure 1 for a map of the Siberian theater of operations.)

Figure 1: 20XX Siberian Theater of Operations

METHODOLOGY

Unlike other RMA wargames, the 20XX series is concept-driven and assumes a discontinuous future. Instead of requiring the players to craft innovative operational and organizational concepts from whole cloth, they are given a conceptual starting point that they can build upon, or depart from, in whatever manner they choose so long as it is consistent with the basic tenets of the regime. The players are provided with a comprehensive description of the 20XX regime, detailed descriptions of the forces and capabilities at their disposal, candidate operational concepts and force postures, doctrine for fighting in 20XX, and strategic guidance for dealing with the particular challenges presented in a given wargame. Players are offered competing capabilities (e.g., multiple means of conducting long-range precision strikes, dimensional-control operations, or close combat) to gain analytical insight into future system-choice questions.

The 20XX wargames are discontinuous in that the players are lifted up in time from today and set down in 2025-2030 into a future warfare regime that has been transformed by the RMA. Although legacy forces remain for other contingencies, nearly all of the weapons systems and capabilities for fighting high-end theater warfare are either completely new or significantly transformed relative to contemporary systems. In addition, promising concepts for future weapons systems that surfaced during a particular wargame were, in several cases, integrated into subsequent 20XX activities. Placing the players in an unfamiliar warfare environment seemed to stimulate their creativity, perhaps because they could no longer resort to rote doctrine and concepts. They were forced to use their imagination to formulate new warfighting concepts since concepts associated with the current regime were generally no longer practicable.[3]

20XX game play typically involves three-to-four, interactive moves over a three-to-four day period. One or more Blue teams are arrayed against one or more Red (LPC) teams. Eight to twelve players are usually assigned to a team, with players consisting principally of field-grade officers occupying future warfare billets across the Services, on the Joint Staff or in the forces of allied nations. Australia, Canada, Germany, and Sweden have sent representatives to 20XX games.

KEY DRIVERS OF THE 20XX REGIME

As in any wargame that focuses on the future, important assumptions about the character of the security environment in 2025-2030 must be made. The three key drivers of the 20XX regime are that nuclear weapons will continue to truncate conventional war at the strategic level; offensive striking capabilities tend to dominate defensive ones; and that stealth, broadly defined, not only remains practicable, but is central to surviving in an increasingly transparent battlespace. These three assumptions establish the basic contours of the future warfare regime that underpins the 20XX wargames.

While these assumptions about the future may ultimately prove incorrect, they appear probable in light of current trends. Since changing any one of these three drivers would create a substantially different warfare regime, they have been held constant in the interest of keeping a consistent baseline for analysis across the wargame series. Subsequent activities, however, could explore alternative futures in which one or more of these drivers are modified.

Nuclear Weapons and Limited War

The possession of robust nuclear deterrent forces by belligerents limits not only the strategic scope of conventional homeland attacks, but also the employment of new forms of strategic warfare such as advanced information warfare (IW) and novel means of biological warfare (BW). As a result of this "nuclear overhang," it is assumed that respective homelands will generally be accorded some measure of sanctuary status in general wars between large, peer competitors in 20XX. Owing to the risk of escalation to nuclear war, adversaries are understood to be reluctant to attempt to change the regime of the opposing side.

Offensive Dominance

One of the central features of the 20XX regime is the existence of very capable intelligence, surveillance, and reconnaissance (ISR) systems networked with myriad precision-strike capabilities. Although physical armor has improved significantly, so too has the lethality of precision-guided munitions (PGMs). In effect, this creates a regime in which, "if you can be

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[3] In contrast, most other RMA wargames provide players with modernized legacy systems and a handful of new weapons systems and then ask them to devise revolutionary operational and organization concepts. Unfortunately, more often than not, players just plug these new capabilities into traditional units and warfighting concepts.

seen, you can be killed." Accordingly, the key to force protection and survival is to evade detection in the first place through a combination of stealth, speed, and information operations (e.g., offensive IW, radio-frequency (RF) warfare, and deception operations).

It is assumed that large numbers of high-precision, low-observable missiles on both sides limit the practical effectiveness of missile defense systems. Belligerents in 20XX can amass missile arsenals large enough to exhaust interceptor stocks that are immediately available within a given portion of a theater of operations at any given point in time. The application of stealth technologies and hypersonic propulsion systems to low-flying cruise missiles makes them difficult to detect, track, and engage. Sophisticated penetration aids (e.g., multispectral decoys and active jammers) for ballistic-missile warheads further complicate the target discrimination challenge relative to today. Moreover, the high-power radars currently used in active missile defense systems are vulnerable to anti-radiation missiles and RF weapons.

Missile defenses, however, have also improved substantially by 20XX. Directed-energy (DE) systems can engage missiles at the speed-of-light and, in some cases, destroy them in a matter of seconds. Long-endurance unmanned combat air vehicle (UCAVs), hypersonic missiles and next-generation, loitering PGMs offer a means for destroying enemy missile transporter-erector-launcher (TEL) vehicles, and under some circumstances, for intercepting ballistic missiles in their boost phase. Despite these improvements, it is assumed that defenses can be countered through a variety of means. For example, the effectiveness of directed-energy defenses can be degraded by applying ablative or reflective coatings to the outer skin of missiles, or in the case of ballistic missiles, rotating the missile around its longitudinal axis during its boost phase. In short, while potentially very useful, active missile defenses remain incapable of fundamentally altering the strategic or operational battlespace in 20XX.

The Centrality of Stealth

Owing to advances in sensor and data processing technologies, the ability to find opposing forces (and the corresponding ability to destroy or neutralize what one can find) is assumed to have improved dramatically by 20XX. New sensors include, for example, foliage penetration (FOPEN) radar systems that can reliably find combat vehicles hiding under trees or other vegetation; multistatic acoustic arrays than can detect and track ships and submarines operating over a wide area more effectively than is currently possible; and hyper-spectral sensor systems that can not only detect the presence of specific materials on the battlefield, but also reduce the effectiveness of traditional camouflage, concealment, and deception (CCD) measures. These sensors are assumed to have been incorporated into myriad platforms, including long-endurance unmanned aerial vehicles (UAVs), micro air vehicles (MAVs), unmanned undersea vehicles (UUVs), unmanned ground vehicles (UGVs), and constellations of small satellites.

If future "finding" capabilities completely dominated hiding capabilities, however, operational movement would be stymied and combat would likely be limited mainly to extended-range, precision-strike duels. It is assumed in the 20XX wargames that parallel advances in stealth, deception, jamming, offensive IW, and other forms of information protection have also occurred. Military forces have improved their ability to hide in a sensor-rich battlespace by taking some combination of the following steps:

- Applying signature reduction techniques and design principles to military platforms of all types, including strategic mobility aircraft, surface ships, and ground combat vehicles;

- Increasing reliance upon submerged platforms that can hide in the world's oceans;

- Using multispectral decoys to confuse sensor systems;

- Developing advanced materials for camouflage netting that reduce radar, infrared, and other signatures;

- Jamming and dazzling imagery satellites and other sensor platforms to mask force movements and other activity;

- Exploiting miniaturized platforms such as micro-robots and MAVs that are inherently difficult to locate, track, and engage;

- Emphasizing force mobility and dispersion, including logistics, command and control, and combat service support functions; and

- Relying more upon fiber-optic networks and passive sensor systems to reduce electronic transmissions.

In sum, in the 20XX games, it is assumed that the combination of passive and active signature management, miniaturization, and information operations has kept pace with the development of detection, identification, and tracking technologies. Stealth in many forms remains feasible, and no dimension of the battlespace is completely transparent. While finders may have the upperhand in some respects, hiders are still in the game.

WARFARE IN 20XX: CAPABILITIES AND KEY CHALLENGES

The conduct of war has been transformed on land, at sea, and in the air in the 20XX warfare regime. New forms of warfare have also emerged in near-earth space, the information domain, and the biological realm. More specifically, it is presumed that significant capability advances have occurred in eight major areas:

1. **Long-Range Precision Strike (LRPS).** LRPS capabilities have progressed from destroying and denying fixed facilities to attacking distributed, mobile, land targets and non-stealthy surface naval targets. LRPS attacks can be conducted by air-, land-, sea-, and space-based assets, both manned and unmanned.

2. **Land-, Undersea-, and Space-Based Sea Denial.** The emergence of advanced ISR capabilities (e.g., over-the-horizon radars, synthetic aperture radar (SAR) satellites, naval UAVs, and underwater sensor systems) linked with LRPS systems has made it practical to conduct land-based defense of the sea out to 1,000 kilometers or more from a defended coast.

3. **Space Warfare.** Space has emerged as an independent warfare dimension involving anti-satellite (ASAT) operations, active defense against enemy missile attacks, and even space-to-ground strikes involving kinetic energy penetrators and directed-energy weapons. Space warfare has been fully integrated with warfare in other dimensions.

4. **Information Warfare.** IW has developed into an independent warfare dimension with specialized offensive and defensive information operations forces fighting for control of cyberspace. IW operations constitute an integral component of nearly all other military operations.

5. **Advanced Biological Operations.** Advances in molecular biology and biochemistry have led to novel BW agents. For example, agents can be designed to target particular groups based upon their genetic makeup and pathogenic genetic material can be hidden inside otherwise innocuous microorganisms. Developments in biotechnology substantially enhance operations in other dimensions as well (e.g., biosensors, biomaterials, and performance-enhancing drugs).

6. **Stealthy and Unmanned Air Operations.** Low-observable designs and materials, as well as active signature management technologies, have been applied to a wide range of aircraft, including intercontinental transports and refuelers. Highly autonomous UAVs and UCAVs linked into global information networks have assumed many of the roles previously conducted by manned aircraft, including reconnaissance, IW and close- and deep-strike operations.

7. **Undersea-Based Power Projection.** In response to the increasing vulnerability of surface vessels to LRPS systems, an increased proportion of naval power-projection assets (both strike and amphibious warfare) operate beneath the surface of the ocean to lower their signature, and thereby, improve their survivability.

8. **Information-Intensive, Roboticized Ground Operations.** With the advent of stealthy, robotic, information-intensive ground combat systems, it is now possible to conduct highly distributed, non-linear ground operations.

Although all eight of these elements shape the 20XX warfare regime, the overarching regime is sufficiently robust that one or more could be changed without upsetting the overall character of the regime. For example, the regime would not be disrupted appreciably if space warfare and advanced biological operations do not mature as expected. These eight features do, however, provide a plausible, coherent vision of an advanced RMA warfare regime, which is, of course, an indispensable starting point for RMA wargaming.

The United States and the LPC are presumed to have pursued these RMA elements asymmetrically—with respect to the RMA warfare elements each pursued, the forms by which they implemented a given RMA capability and the intensity with which they pursued it (see Table 1). The LPC is assumed to have invested primarily in the first five areas as part of a strategic concept that emphasizes LRPS-based, regional power projection; multidimensional, area denial or anti-access; and global reach made possible by space and IW capabilities. While the LPC also has a robust attack submarine fleet and a wide range of UAVs and UCAVs, these capabilities are oriented more toward regional anti-access than extra-regional, power projection. LPC submarines and UCAVs, however, could be used to conduct offensive operations against the U.S. homeland, as well as the territory of regional U.S. allies. The United States is assumed to have pursued all RMA areas aggressively with the exception of land-based defense of the sea and offensive BW.

Table 1: US and LPC RMA Investment

20XX RMA	U.S. Investments	LPC Investments
Long-Range Precision Strike	✓	✓
Land-, Undersea- and Space-Based Sea Denial		✓
Space Warfare	✓	✓
Information Warfare	✓	✓
Advanced Biological Operations		✓
Stealthy and Unmanned Air Operations	✓	
Submerged Power Projection	✓	
Information-Intensive, Roboticized Ground Operations	✓	

War in the Air

One of the dominant features of air warfare in the 20XX regime is the substitution of manned aircraft for missiles, UAVs, and UCAVs. Ground-based, mobile ballistic and cruise missile launchers account for most of the offensive striking power of the LPC's "air force." However, it can also conduct land-attack missions using wide-body aircraft armed with extended-range, air-launched cruise missiles (ALCMs); medium and long-range, low-observable UCAVs; and manned multirole aircraft (Joint Strike Fighter-equivalent) based in the LPC homeland.

The LPC also has an array of capabilities for attacking enemy aircraft attempting to fly within the airspace, or to operate from airbases, proximate to its homeland. For example, it can strike airbases with waves of long-range, highly precise ballistic and cruise missiles armed with conventional high-explosive warheads, advanced RF weapons (e.g., conventional electromagnetic pulse (EMP) and high-power microwave (HPM) devices), or weapons of mass destruction (WMD).[4] To detect airborne threats, it has a robust surveillance and targeting network incorporating high-altitude, long-endurance (HALE) UAVs, battle management aircraft similar to the U.S. Airborne Warning and Control System (AWACS), and an integrated network of ground-based sensors. The land-based portion of the network includes, for example, mobile multistatic radars, mobile passive coherent location (PCL) systems,[5] infrared search and track

[4] As it is used here, WMD includes chemical, biological, and nuclear weapons.

[5] In areas where the level of ambient commercial radio and television signals is sufficiently high, it may be possible to detect—but probably not to track—stealthy aircraft with multistatic surveillance systems based on PCL

systems, and advanced electro-optical surveillance systems. Air-to-air UCAVs, surface-to-air missiles (SAMs), airborne laser aircraft, and manned fighters based in the LPC homeland can be cued to interdict detected enemy aircraft.

Owing to these anti-access challenges, U.S. air power in 20XX is dominated by long-range, stealthy, and automated platforms. Stealthy UAVs perform ISR missions at all levels of warfare. At the strategic and operational levels, extremely long-endurance UAVs provide a valuable complement to space-based remote sensing.[6] At the tactical level, cheap, rugged, bird-sized MAVs have revolutionized forward scouting and surveillance.[7]

Stealthy intercontinental bombers and long-range UCAVs dominate the airborne, penetrating component of U.S. deep-strike forces. Owing to their extended endurance, UCAVs are particularly valuable for finding and attacking mobile, time-critical targets (e.g., missile TELs and mobile SAM batteries). Aside from being able to drop large numbers of smart, relatively low-cost PGMs on both fixed and mobile targets, stealthy bombers can also deliver the large gravity bombs and heavy earth-penetrator weapons needed to destroy hardened and deeply buried targets.

Stealthy, loitering UCAVs are also relied upon for much of the close-strike mission. Engaged ground troops in 20XX can call upon UCAVs orbiting overhead and ships positioned offshore for rapid-response fire support. As a consequence of the dramatically increased effectiveness of LRPS weapons (e.g., shorter time-of-flight made possible by hypersonic propulsion, in-flight retargeting capabilities, and brilliant submunitions that can identify and attack specific targets) and the unique loitering capability of UCAVs, short-range artillery has largely disappeared from the 20XX battlefield.

To compensate for the unavailability of in-theater airbases, the United States has fielded an array of new combat systems as of 20XX with which to mount air-to-air and strike operations from extended range. One example is the UAV tender, which is an intercontinental-range, high-endurance, stealthy aircraft capable of launching, controlling, recovering, rearming, and refueling a squadron of relatively short-range strike and air-control UCAVs. UAV tenders not only enable air power to be surged forward early on in a crisis, but can also be used to help gain and maintain some measure of air control within contested airspace.

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technologies. PCL systems do not use a transmitter. Instead, they passively detect the energy reflected by an aircraft as it passes through RF energy emitted from known sources (e.g., radio and television transmitters).

[6] Building upon extended endurance UAV concepts developed under the Advanced Airborne Reconnaissance System (AARS) in the 1980s, a "Tier III" UAV design was proposed to the Services in 1992. This UAV reportedly could have loitered in the sky for several days at a time. See Thomas P. Ehrhard, *A Comparative Study of Weapon System Innovation: Unmanned Aerial Vehicles in the United States Armed Services* (John Hopkins University PhD Dissertation, 2000), pp. 136-158. The Special Projects Department of Sandia National Laboratories has recently proposed the development of an extremely long endurance vehicle (ELEV) that could stay on station for six months to a year. See Sandia National Laboratory, Briefing on "Extremely Long Endurance Covert UAV," February 2001, p. 2.

[7] As an indicator of what might be possible a decade or two hence, the U.S. Marine Corps is already experimenting with Dragon Eye UAVs for local-area ISR missions that can be disassembled and carried in a backpack. The five-pound UAV has a wingspan of 45 inches, cruises at 35 knots, and can stay aloft for up to 60 minutes. See John G. Roos, "WarBots," *Armed Forces Journal International*, November 2001, p. 60.

Signature reduction technologies have also been applied to both inter- and intra-theater air transports to facilitate the insertion and sustainment of ground forces. Low-observable refuelers can be used to extend the endurance of stealthy aircraft operating in the heart of an adversary's anti-access defenses. They increase the on-station time of stealthy aircraft—both manned and unmanned—by obviating the need to return all the way back to a remote peripheral base or to uncontested airspace to refuel.

The increased prevalence of long-range cruise and ballistic missiles, as well as stealthy UAVs and UCAVs able to loiter at high altitudes makes it very difficult to gain control of the air dimension in 20XX. This challenge is complicated by the possibility that in a regional conflict in Asia, LPC aircraft could operate from bases secured within their relatively nearby homeland "sanctuary," whereas U.S. forces could be forced to operate from more geographically distant bases. Depending on the U.S. rules of engagement, it may be necessary for U.S. aircraft to wage offensive counter-air operations from extended range *directly* against LPC aircraft rather than against their fixed basing and support infrastructure within the LPC homeland.

War on Land

Owing to the threat posed by the proliferation of sensors linked to progressively more capable precision-strike weapons, high-signature insertion platforms are vulnerable to detection and attack in the 20XX warfare regime. Consequently, especially early on in a conflict, U.S. ground forces need to be inserted into a theater of operations via stealthy airlifters, stealthy surface insertion vessels, and submerged troop-carrier platforms. This requirement constrains the type and number of ground forces that can be successfully inserted and sustained. In order to enhance the combat power of those U.S. ground forces that can be inserted and sustained, ground forces in 20XX are all equipped with advanced command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) capabilities and various kinds of robotic support. They are also tightly networked with units operating in the other dimensions of the battlespace. A large portion of their firepower, for example, resides in stealthy surface ships and submerged strike platforms waiting offshore or aboard UCAVs orbiting overhead.

Three different types of U.S. ground combat units—which vary primarily in terms of how "light" and stealthy they are—are represented in the 20XX wargames. The heaviest unit, called a "Combined Arms Regiment" (CAR), is organized as two ground maneuver battalions, a mechanized infantry battalion, and a fire support battalion. The ground maneuver battalions consist of 10-ton, electric-drive, stealthy advanced combat vehicles (ACVs) armed with a powerful electromagnetic (EM) gun.[8] Only one in four of these ACVs, however, are actually

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[8]This ACV could be viewed as an outgrowth of the Future Combat Systems (FCS) development program that was recently launched by the Defense Advanced Research Projects Agency (DARPA) and the Army. The FCS program envisions a relatively stealthy, hybrid-electric, 20-ton vehicle that would be produced in direct-fire, indirect-fire, infantry carrier, air defense, and sensor variants. All FCS vehicles would be networked with various unmanned ground systems, UAVs and other robotic platforms. Although a number of significant technological shortfalls still need to be overcome, the Army has moved up the original objective date for fielding the FCS from 2020 to 2008. The current plan calls for a technology freeze in 2003, design selection in 2005, engineering and manufacturing development in 2006, low-rate initial production (LRIP) in 2008, and full scale production starting in 2010. As a result, it is widely considered to be a very high-risk program. In all likelihood, the program will either slip well

manned. The mechanized infantry battalion consists of advanced infantry troops carried aboard stealthy, electric-drive, infantry fighting vehicles (IFVs). The fire support battalion is outfitted with stealthy, 10-ton, electric-drive, missile launchers.

The second type of ground combat unit, called a "Deep Strike Brigade," comprises extended-range, stealthy attack helicopters (i.e., a follow-on to the Comanche); stealthy, 20-ton, electric drive missile launchers; and organic IW and local security units. The third type of unit, and by far the lightest, are "Exoskeleton Regiments" and advanced light infantry regiments. Both are modeled loosely on today's Ranger regiments.

Each Exoskeleton Regiment comprises nearly 800 soldiers equipped with self-powered, robotic suits that provide individual soldiers with dramatically increased operational and tactical mobility, lethality, personal protection, situational awareness, and physical endurance. Exoskeleton suits, for example, allow soldiers to move for extended distances without getting tired, carry a relatively heavy load of miniaturized weapons (e.g., anti-armor, anti-personnel), and generate false images of themselves to confuse enemy defenders. The exoskeleton suits also incorporate multispectral sensors and advanced communication systems, as well as a user-friendly interface for controlling support robots of various kinds.

Light infantry regiments in 20XX are composed of upwards of 800 information-intensive troops optimized for combat in urban areas. They are equipped with extensive robotic support including robotic porters that carry food, water and ammunition; MAVs and UGV scouts that perform short-range reconnaissance and surveillance; sapper robots designed to carry out small-scale demolition; countermine robots equipped to tag, map or clear minefields; and counter-sniper robots. These units can also be equipped with a variety of non-lethal weapons and mobility enhancements for operations in urban terrain.

The bulk of the LPC ground forces, by comparison, are much "heavier" across the board. Most of the LPC's troop strength is based upon 9000-troop, fully digitized, air-assault and ground-maneuver divisions that were modeled in part upon U.S. Army Force XXI concepts. The former incorporates Comanche-equivalent attack helicopters, ultralight 155-mm howitzers, UAVs, and electric-drive armored gun systems. Ground-maneuver divisions each contain several hundred heavily armored vehicles that could be described as comparable to next-generation Abrams main battle tanks, Bradley infantry fighting vehicles, and Crusader self-propelled howitzers. The most lethal component of the LPC's ground force, however, is precision-strike brigades containing mobile, long-range, EM guns digitally linked to sensor-laden UAVs.

One of the central ground combat challenges in the 20XX regime is signature management. During all phases of combat, ground units must keep their signature as low as possible in order to avoid being detected by the opponent's sensor systems and subsequently attacked. When elevated signatures are unavoidable, ground forces must be careful to return to low-signature operations *before* the adversary can bring superior long-range firepower to bear. For example, a

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beyond 2010, or the Army will settle on a sub-optimal design. The ACV included in the Combined Arms Regiment reflects the full maturation of the technologies underpinning the original FCS concept.

ground unit attacking an enemy force in its immediate vicinity needs to concerned not only about its spatial flanks being turned, but also about its "time flank."[9] In other words, while it might be possible to pummel an enemy unit in close combat, the attacking unit must devise a way of doing so without elevating its signature so long that the enemy can engage it with long-range counter-attacks launched from a remote location. Seizing territory is also much easier to accomplish in 20XX than physically holding it. Stationary troops holding ground, just like any other fixed target, are vulnerable to detection and attack.

War at Sea

As mentioned above, in the 20XX regime, U.S. adversaries can contest control of the sea for extended distances from their borders by networking various types of ISR and strike assets into an anti-navy "system of systems." In the case of the LPC military, this anti-navy architecture comprises the following:

- Maritime-reconnaissance satellites with inverse SAR, electro-optical, infrared, and signals intelligence (SIGINT) sensor payloads;
- Acoustic (active and passive) and non-acoustic sensor arrays that can be rapidly deployed by attack submarines or aircraft;
- Over-the-horizon radar;
- Land-based, extended-range UAVs equipped with SAR and electronic intelligence (ELINT) sensors, as well as UCAVs armed with anti-surface and anti-submarine munitions;
- Mobile, land-based, EM guns that can propel precision-guided, ship-killing projectiles to a distance of several hundred kilometers;
- Air-, sea-, and ground-launched cruise missiles that are stealthy and have an effective range of up to 4,000 kilometers;
- A large mixed fleet of very quiet nuclear-powered and air-independent-propulsion (AIP) diesel attack submarines; and
- A massive stockpile of sea mines and a robust minelaying capability.

This architecture makes it possible for the LPC to locate, track, and sink most non-stealthy surface ships operating within a few thousand kilometers of its coast. Aside from potentially denying foreign navies the ability to operate non-stealthy surface combatants within this anti-

[9] A time flank can be defined as the period of time starting when forces undertake some activity in the battlespace (*e.g.* insertion, firing, moving, resupplying, extraction, etc.) that results in their tripping an adversary's sensors, and ending when the opponent is no longer able to track and target them. Between these two boundaries in time, the enemy has a window of opportunity in which to strike.

navy envelope, this architecture also enables the LPC to exert a strong influence over regional maritime trade flows during peacetime. Essentially, no commercial shipping can transit waters within the East Asian littoral without the tacit consent of the LPC.

In order to project power from the sea in this type of threat environment, the United States has invested heavily in submerged vessels and distributed networks of relatively small, stealthy surface ships.[10] The capital ship of the U.S. fleet in 20XX is the nuclear-powered, guided-missile submarine (SSGN) armed with several hundred ballistic and cruise missiles. In conducting long-range precision strikes from the sea, SSGNs are complemented by a mix of novel and legacy platforms, including:

- Submerged, nuclear-powered vessels equipped with electromagnetic rail guns capable of sustaining a high volume of fire at a range of several hundred kilometers;[11]
- Undersea strike modules, which are submerged, unmanned vessels that house several hundred missiles of various types and can remain on-station for up to a year after being towed to an area of interest by a nuclear-powered attack submarine (SSN);
- Air-droppable, remotely activated “missile pods” that contain six stealthy, extended-range cruise missiles;
- Carrier-based, long-range stealthy UCAVs; and
- Legacy aircraft carriers, SSNs, and major surface combatants (e.g., DD-X).

Capabilities for surface and undersea control operations include legacy aircraft carriers and surface combatants, a substantially enlarged fleet of SSNs equipped with long-range UUVs, a small fleet of special-purpose littoral warfare submarines, stealthy frigates, and land-based, intercontinental-range UCAVs. Establishing sea control in 20XX against an adversary such as the LPC, however, requires winning not only the undersea and surface battles, but also the space, air, and land battles as well.

The U.S. fleet in 20XX also comprises submerged mine countermeasure ships (employing UUVs for mine detection and mapping), undersea amphibious assault vessels, submerged fleet replenishment and logistics prepositioning ships. Fast combat support ships, surface submarine tenders, and surface amphibious assault ships equipped with rotary-wing transports and air-

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[10] It is assumed that the ability of submerged vessels to operate quietly and manage nonacoustic signatures will stay ahead of developments in anti-submarine warfare (ASW) technology. Despite new sensors (advanced deployable sensors (ADS)-like arrays) and sensor platforms (e.g., UUVs and anti-navy UAVs), detecting and localizing sub-marine vessels operating in a vast ocean continues to be a labor intensive *and* time consuming enterprise in the 20XX regime.

[11] Since these ships have to expose their gun tubes to fire, which elevates their signature, they are operated in multi-ship squadrons and employ "pop-up" tactics in which one ship fires while another submerges and moves to another location.

cushioned landing craft (LCACs) are also available for operations in relatively benign threat environments.

War in Space

The space order of battle postulated in the 20XX wargames is almost symmetric. While the U.S. military has some qualitative advantages in terms of system performance, both sides operate a robust constellation of remote-sensing satellites, high-bandwidth communication satellites, and global positioning system (GPS) satellites. In terms of space-control operations, U.S. and LPC forces both possess space-based laser (SBL) constellations; small, maneuvering satellites capable of conducting lethal and non-lethal "proximity operations" against specific enemy satellites;[12] and ground-based, directed-energy ASAT systems. Both sides could attack terrestrial targets from space using either orbiting satellites capable of de-orbiting, inert, precision-guided projectiles or manned trans-atmospheric vehicles (i.e., space planes).

One of the central challenges of space warfare in the 20XX regime is the difficulty of defending relatively fragile, space-based systems. It is impractical to armor satellites to withstand the impact of kinetic-kill ASATs and difficult to intercept them in flight. Attacks using directed-energy weapons allow almost no time for defensive measures to be taken. Hedging against enemy preemption at the outset of strategic and theater warfare campaigns, therefore, is a critical concern in 20XX. Another challenge is rapidly replacing damaged or destroyed space-based systems following an attack given that the opposing side can potentially intercept space-launch vehicles (SLVs) used to loft satellites into orbit.

War in Cyberspace and The Biological Realm

Information warfare has emerged as a new warfare dimension in 20XX affecting all levels and dimensions of warfare. The information aspects of war—information acquisition and denial, information strikes, information-based protection and movement—permeate all military operations. Maneuvers on information "terrain" such as computer network attacks (CNA) are tightly linked with maneuver on physical terrain in the 20XX regime. To a significant degree, information-based protection has supplanted traditional notions of physical protection. The emergence of war in the information spectrum, moreover, has added a qualitatively new means for destroying enemy targets and disrupting enemy operations.

The IW capabilities of the U.S. and LPC forces are symmetrical in the 20XX series. Both sides have dedicated information warfare specialists capable of launching a wide array of computer network attacks. Physical information infrastructures relied upon by U.S. and LPC forces are also subject to attack with conventional EMP and HPM weapons. To defend against and minimize the damage caused by IW attacks, both sides have access to intelligent, self-healing

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[12] Proximity operations might include jamming a satellite's uplinks and downlinks, fogging the optics of imaging satellites, applying an opaque coating to a satellite's solar panels or shrouding them, severing the power cables leading from a satellite's solar panels, or simply nudging it into an unstable orbit. At the more destructive end of the spectrum, proximity operations could also include damaging a targeted satellite's electronics with a high-power RF weapon or rendering it inoperable with a small, well-placed, high-explosive charge.

communication networks; redundant, global communication links that are based not only upon radio waves, but also fiber optic, laser and other waveforms; and sophisticated firewall software, automated intrusion detection software, powerful encryption algorithms and anti-jamming techniques. If a significant advantage in this offense-defense competition could be attained, it would likely have cascading effects on all the other warfare dimensions at the strategic, operational, and tactical levels.

As suggested earlier, it is assumed that the exploitation of biotechnology by the United States and the LPC has not been symmetrical. Both have harnessed biotechnology for fielding sensors, novel materials, advanced vaccines, drugs that enhance human performance, and other non-lethal purposes. Only the LPC, however, has taken advantage of the biotechnology revolution to develop extremely potent BW agents, including both genetically tailored agents capable of targeting specific ethnic groups and "stealth pathogens" that are very difficult to detect and counter.

In sum, players in the 20XX wargames representing U.S. military planners are offered a wide menu of capabilities, including both modernized versions of current-day systems as well as novel systems, for conducting operations within all dimensions of the future battlespace. Since it is postulated that the LPC has also invested in the RMA, however, the 20XX regime also forces them to contend with a plethora of new challenges at the strategic, operational, and tactical levels of war. In experimenting with these capabilities and grappling with these challenges at the conceptual level, the players have developed many interesting observations and insights over the course of the nine wargames conducted thus far. Those focused on strategy, future force postures, and future operational environment are discussed in the next chapter. Selected operational and organizational concepts for fighting in a 20XX-like regime are briefly described in Chapter III.

II. Strategic Concepts, Future Force Postures and the Operational Environment

The 20XX series has produced dozens of insights about the potential character of post-RMA warfare. This chapter focuses on those concepts associated with future strategy, force postures, and the operational environment. Five insights with particular relevance to the transformation of the U.S. military are summarized below. These findings, however, must be understood in the context of the regime assumptions, force capability assumptions, and the various scenarios postulated in the 20XX wargame series. As with all wargames, caution should be exercised not to overreach with respect to the analytical conclusions that can be drawn from them.

Invisible Presence

In a very transparent, highly networked LRPS-dominant military regime, the most credible and persuasive deterrent forces in the future may be those which constitute a presence that is both responsive and survivable. Barring dramatic advances in active defense technologies, the proliferation of wide-area ISR networks linked to progressively more capable LRPS weapons may make high-signature naval vessels increasingly vulnerable to detection and attack.[13] This trend could erode the future deterrent value of such vessels in the eyes of potential adversaries for at least two reasons. First, adversaries may conclude in time that high-signature naval vessels no longer pose a significant military threat because they could be quickly dispatched by precision-strike weapons before being able to inflict substantial damage. Second, the threat to use high-signature vessels to inflict damage may be increasingly perceived as incredible due to the probable associated cost in terms of exposed men and material.

Accordingly, an "invisible presence" based on low-signature, precision-strike platforms enabled by a robust C4ISR architecture could be a far more valuable instrument of deterrence in the future. Forward presence assets that are difficult to locate and destroy would complicate substantially an adversary's decision whether or not to initiate a theater war. Such a presence might be achieved, in terms of naval power projection, through the forward deployment of SSGNs, SSNs, undersea strike modules armed with long-range missiles, submerged amphibious operations vessels, and perhaps, stealthy surface ships.[14]

This sea-based component could be complemented by strike platforms from other warfare dimensions that could be pre-deployed in theater and covertly remain on-station for extended

[13] This judgment applies even more to land-based, high-signature assets (e.g., aircraft forward based in theater and most forward-deployed ground forces). While pre-hostilities dispersal from their garrison location could make such forces somewhat less vulnerable, the increasing potential for sudden, surprise attacks may make such plans highly problematic.

[14] SSGNs, undersea strike modules, submerged amphibious operations vessels, and stealthy surface ships are discussed in Chapter IV of this report. Stealthy surface ships could become increasingly vulnerable to visual detection by long-endurance UAVs and sea-control imaging satellites with rapid revisit rates.

periods of time, or alternatively, those that could respond very rapidly to aggression. Systems meeting the first criterion, for example, might include land-based remote missile pods and long-endurance, stealthy UCAVs. The rapid response requirement could be met with hypersonic space planes; two-stage, suborbital strike systems;[15] and instantaneously employable IW capabilities. This resulting multidimensional strike complex could provide not only an enormous amount of responsive firepower, but would also be relatively survivable and difficult to defend against. ISR assets, of course, also contribute substantially to presence. ISR assets consistent with the invisible presence concept include SSNs equipped with extended-range UUVs; stealthy, HALE UAVs; and reconnaissance satellites (particularly those capable of tracking mobile ground and air targets).

Since deterrence hinges on an adversary's perceptions, it would be important to ensure the high readiness of these invisible presence forces by routinely demonstrating their capabilities during peacetime. An analogy might be drawn to the role of nuclear-powered ballistic missile submarines (SSBNs) during the Cold War. Although these low-observable platforms took great pains to avoid detection, few questioned the deterrent value of their nuclear-tipped, submarine-launched ballistic missiles (SLBMs). The key to deterrence in the future could be the ability to demonstrate firepower, rather than physically displaying—and thus exposing—actual strike platforms. Overt presence may still be desirable, however, for political reasons such as reassuring friends and allies by sharing risk.

Forward-deployed SSNs and long-endurance UUVs could also significantly affect initial balances in future sea control campaigns.[16] In addition to providing a survivable means of countering regional aggression, they could also contribute to a covert ISR architecture within the conflict area and provide the option of clandestine, preemptive mining.[17]

REVERSIBLE FORCE STRATEGIES

The advent of novel forms of force could lead to new strategies, one of which might be strategically notable because of its inherent reversibility. Such a "reversible force" strategy might employ strategic IW and/or advanced BW for coercive purposes. For example, an IW attack could be used to disable critical economic and governmental infrastructure (as well as enemy forces), but might also be easily reversed with the requisite software or computer codes. Similarly, advanced BW agents might not only be precisely targetable against a particular ethnic group or individual, but also treatable with an easily supplied antidote or vaccine. Depending

[15] An example of suborbital strike capability would be the Smart Hypersonic Vehicle (SHV) concept. See pp. 67-68 of this report.

[16] As in the Cold War's maritime strategy, for example, forward-deployed SSNs might track an adversary's high-value, undersea assets in peacetime in order to sink them quickly in the event of war.

[17] See SAIC, *Future Warfare 20XX—Volume III: Insights & Observations from Wargame III (Maritime Operations)*, Report submitted to OSD / Net Assessment, February 1997, pp. 10-11. See also CSBA and SAIC, *Future Warfare 20XX—Volume VI: Insights & Observations from Wargame VI (Dimensional Control)*, Report submitted to OSD / Net Assessment, July 1999, pp. 9-10. Operating in enemy littoral waters, of course, carries with it significant inherent risks. For instance, these assets could quickly find themselves severely outnumbered if an adversary unexpectedly flushed its undersea warfare assets from port and commenced aggressive ASW exercises within their bastion waters.

upon an opponent's response to an ultimatum, these remedies could be either supplied or withheld. The pain induced by these attacks could be gradually ratcheted up or down in order to maximize their coercive effect and to ensure compliance.

Reversible force capabilities of the form just described may be difficult to detect, posing a significant challenge for indications and warning systems. The strategic utility of these forms of force may, on the other hand, be perishable once revealed. In addition, there is always the risk that competitors will develop defensive measures independently that render a particular weapon ineffective. As a result, a state benefiting from what is perceived as an ephemeral advantage may be tempted to exploit it while a window of opportunity still exists. The tension between the potential strategic utility of reversible force capabilities and their limited shelf life could spawn a new strategic competition in which adversaries strive to develop and exploit new capabilities before their adversaries can find counters.[18]

STRATEGIES OF PREEMPTION AND DENIAL

Strategies for preemption and denial could both increase substantially in efficacy given the capabilities postulated in 20XX. Stealth- and missile-based power projection, directed-energy weapons, space warfare, information warfare, and advanced biological operations (e.g., stealthy pathogens) could all increase the potential efficacy of preemptive strategies. These strategies could take many forms. For instance, in the case of an RMA-capable aggressor state, a preemptive strategy might involve massive missile barrages on the armed forces and critical national infrastructure of a neighboring state as a precursor to invasion. These attacks might be supported by a series of offensive IW strikes initiated in peacetime.[19] By striking first, the aggressor would not only have a chance of at least partially knocking out an adversary's retaliatory capabilities, but could also significantly degrade its defensive capabilities as well. Simultaneous attacks against airfields, ports, military garrisons, command and control nodes, the electrical power grid, information infrastructure and other supporting infrastructures could rapidly and seriously undermine the targeted state's ability to mount either offensive or defensive military operations.

These strikes might also coincide with a preemptive attack against the space assets of allies of the targeted state in an effort to forestall their ability to mount an extended-range defense. While the targeted state was still reeling from these initial "bolt-from-the-blue" strikes, the aggressor could potentially follow-up with rapid air, sea, and ground assaults oriented on key nodes or other valuable terrain. The goal would be to achieve a fait accompli before the allies of the targeted state could effectively intervene.

Other preemptive strategies surfaced in 20XX games include the use of tailored, non-lethal, biological attacks against a neighboring state in peacetime to provide the justification for

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[18] See CSBA and SAIC, *Future Warfare 20XX—Volume IV: Insights & Observations from Wargame IV (Theater Strategy in Multidimensional Warfare)*, Report submitted to OSD / Net Assessment, June 1998, p. 12.

[19] Malicious code could be inserted secretly into the targeted state's C4ISR systems during peacetime and triggered once hostilities began.

humanitarian intervention and reliance upon various forms of peacetime tagging to increase the effectiveness of bolt-from-the-blue LRPS attacks. Strategies for preemption might also involve "cascading preemption," whereby preemption in one warfare dimension is leveraged to preempt in other warfare dimensions. An example of this might be covert, pre-hostilities information operations that facilitate preemption in the space dimension by electronically disrupting an opponent's space surveillance and satellite protection systems. With these systems compromised, an adversary would be less able to see an attack coming in space or to mount an effective defense.

After seizing key nodes, an aggressor state could adopt a denial strategy aimed at preventing allied forces from coming to the aid of the beleaguered state. For instance, by taking advantage of a multidimensional, reconnaissance-strike architecture, they could attempt to deny allied forces from gaining access to in-theater port or airfields and prevent high-signature surface ships from operating safely in littoral waters.

Meanwhile, from the moment hostilities began, allies of the targeted state could attempt to derail the aggressor's power projection efforts by attacking its invading forces with extended-range, precision strikes and myriad survivable, rapid-response, power projection capabilities. The effectiveness of such conquest-denial operations could be enhanced significantly by providing threatened allies with survivable, anti-access capabilities of their own during peacetime. Examples might include long-endurance UAVs equipped with modular sensor payloads, unattended ground sensors (UGS), long-range SAMs, man-portable air defense systems (MANPADS), anti-ship cruise missiles (ASCMs), AIP submarines, brilliant mines, and a variety of precision-strike weapons. Bristling with such weapons, even a relatively weak state would likely appear much less appetizing to an aggressor state. While this "porcupine strategy" might not deter a determined aggressor state from attacking, it would increase the price of conquest significantly and slow down the invasion timetable. Moreover, with more time available, allies of the targeted state would likely be able to mount a more successful defense.

In short, future power projection operations could be conducted in the face of opposing denial strategies, with both sides trying to keep the other from achieving its theater objectives. In a contest between two major powers with LRPS capabilities secured within their homeland, it seems likely that either side could deny the other from achieving its war aims by holding at risk key economic and political infrastructure in the targeted state. The aggressor could be denied the fruits of victory (e.g., exporting resources such as oil and gas) with a very low level of force. For example, allies could prevent the aggressor from benefiting from the oil and gas reserves of a targeted state by periodically striking wellheads, pumping stations, and other supporting infrastructure with PGMs. At the same time, however, the aggressor could prevent the targeted state and allied forces from restoring critical utilities and reasserting local government control by launching periodic missile strikes against public services infrastructure (e.g., power stations, telephone switching nodes, and water pumping stations) and government buildings.

Thus, increased opportunities for preemption notwithstanding, denial strategies may actually prove more robust strategically, which could make war termination very difficult. Frustration stemming from an inability to attain war aims could carry with it the risk of vertical or horizontal escalation. Adversaries who believe that conflict could be protracted may also employ coercion strategies, rather than on overt force, which could, paradoxically, be more difficult to counter.

STRATEGIC LEARNING OPERATIONS

Future strategic decision-makers and operational-level commanders will likely require new kinds of pattern recognition skills to cope with future multidimensional warfare. First, instead of having a relatively well-bounded area of responsibility like a regional Commander in Chief (CINC) today, they will likely confront the daunting task of managing a theater that could conceivably extend thousands of miles in all directions, and encompass near-earth space and the boundless information realm. Second, this task will likely be complicated by the emergence of network-based operations involving relatively large numbers of widely dispersed, individual elements that could interact with each other in unpredictable ways. To evade detection, these elements would likely take advantage of stealth, miniaturization, jamming, IW, and decoys. This emphasis on battlefield concealment and deception would make accurate pattern recognition all the more challenging.

Moreover, in a regime characterized by network-on-network warfare, it would also be difficult to measure the mobilization potential and combat power of prospective adversaries. A system-of-systems network would necessarily be extremely complex, comprising a multitude of inter-connected sub-networks of different configurations and sizes. The internal coupling within local networks, or the sharing of data between individual elements, would likely be relatively loose in some cases (e.g., between submarines), but very tight in others (e.g., between UAVs or microrobots). Individual sub-networks could often consist of widely distributed, heterogeneous force elements, temporarily working together for a specific task. The connectivity between sub-networks would almost certainly vary widely throughout the broader network. In addition, the overall configuration of the network would likely evolve over the course of a campaign in response to changing military requirements. Even if all of these datalinks and dynamic sub-network configurations were visible, it would still be difficult to map an adversary's network due to its sheer complexity. But, to aggravate matters, the pipes linking the multitude of individual nodes comprising a network would, in fact, not be readily observable. Assessing the likely effectiveness of a myriad of military units of varying composition that are not even physically co-located, but rather geographically distributed and virtually connected through largely invisible information links would be an extremely daunting task.

The outcome of RMA operations could also hinge upon hidden capabilities. Information operations and advanced BW, for instance, could play a central role in future campaigns. However, the sophistication and size of such programs could be easily masked. In both cases, the physical infrastructure required to develop and field operational capabilities would be minimal. IW tools could be developed by a handful of programmers working out of a small office building. Absent reliable human intelligence (HUMINT), it could be practically impossible to gain insight about a competitor's actual IW capabilities. The development of advanced BW agents could exploit proprietary R&D conducted by commercial pharmaceutical companies and civilian biotechnology research laboratories. The agents themselves could be grown and harvested in any number of government facilities, perhaps disguised as work related to the production of vaccines or other BW defenses. With few observable indicators and absent persuasive HUMINT, it would be very difficult to gauge a competitor's actual IW and BW capabilities until they were used.

It is almost self-evident that war with these characteristics would involve substantially different patterns of operations than present-day campaigns. To decipher enemy patterns of operations and identify exploitable weak points, what might be termed "strategic learning operations" could become an integral part of future operations. Probes (both virtual and real) of an adversary's defenses could be a valuable tool for gaining insight into future patterns of operations. They could be used, for example, to help flush out the configuration of an adversary's networks, as well as to gain a better understanding of the performance attributes of key systems and routine operating procedures. These probes would be similar to electronic preparation of the battlespace (e.g., collecting data on enemy radar sites) that U.S. forces routinely conduct today, but would be carried out on an operational, theater-level scale.

Based on the data gleaned from these probes, future decision-makers and commanders could use computer simulations and models to help assess the pros and cons of various U.S. campaign plans. Military competitors might also employ what might be termed "reflexive control" techniques, in which they adjust their own operations to impair an opponent's ability to learn. Because vulnerabilities might only last for a few seconds in some cases (e.g., in the information sphere), continuous probing and/or immediate exploitation may be required.[20]

Operations in Restricted, Transparent Urban Environments

Future adversaries will almost certainly continue to be drawn toward urban areas because they contain valuable material resources, useful military-related infrastructure (e.g., ports, airfields, radio and television broadcast stations), and the physical apparatus of government. They may also gravitate toward urban areas to make command and control of U.S. forces more difficult and to degrade the performance of U.S. ISR and precision-strike systems.

However, the combination of theater- and local-level precision-strike capabilities and heightened situational awareness could potentially transform the urban battlespace from a sanctuary, in which enemy forces can easily hide, into a "glass prison," in which they can be cut off from external support and then precisely targeted and destroyed in detail. For example, see-through-wall radars, MAVs, and microrobots could substantially increase local-area transparency within future urban environments. This increase in transparency could shift the advantage at the tactical level—and potentially at the operational level if tactical successes cumulate operationally—to the offense. These improvements in situational awareness, coupled with the advent of new urban, tactical-offensive capabilities (e.g., performance-enhancing exoskeletons, precision-insertion means that provide for multi-axis avenues of approach, robotic support vehicles, microrobots, long-endurance UCAVs, and tailorable non-lethal weapons), could transform the take down of

[20] Diagnostic operations, albeit less provocative ones, would likely become a regular feature of peacetime competition as well.

urban strong points into a tactical situation more akin to a counter-terrorist force's take down of a barricaded building.[21]

This is not to suggest, however, that evicting enemy units from the sprawling urban megacities of tomorrow will be either undemanding or swift. Theater and local-level anti-access capabilities will severely restrict the size and type of friendly forces that can be safely inserted into and sustained within an urban area.[22] Local and theater-level anti-access assets could also impede surface or uncovered mobility within a city. Extensive use of networked micro-sensors could also potentially advantage the tactical defense. The relative protection from long-range strikes that the urban environment provides concealed defenders, coupled with the increased vulnerability that even many stealthy capabilities face when approaching too close to in-place defensive systems (e.g., stealthy helicopters would be vulnerable to man-portable SAMs), would likely add an additional dimension to area denial.

Given the limited number of forces that could be inserted into urban areas in an anti-access environment and subsequently sustained, it will be problematic for either side in a conflict to gain and maintain control over a city housing potentially tens of millions of inhabitants. The combination of dense sensor coverage, advanced C3 systems and increased mobility could allow RMA forces to police urban areas much more efficiently than in the past. Nevertheless, conducting urban control operations in an anti-access environment will likely remain exceedingly difficult. Winning over the population will likely be essential for gaining an upper hand in urban eviction and control campaigns. This requirement will likely place a premium on psychological and information operations. In addition, an important advantage could be gained by developing irregular forces and employing robotic forces as force multipliers.

Realizing that strong point defenses could be glass prisons, future competitors might opt to exert indirect land control using unattended sensors mated to a myriad of precision-strike "overwatch" assets. This would likely produce a much different operational pattern, potentially favoring the protracted operational defense of a seized node. The offense-defense balance in future urban warfare could, of course, shift enormously depending on the diffusion of capabilities. If only one side—the attacker, or counterattacker, as the case may be—possessed RMA forces, it would likely enjoy a significant tactical overmatch.

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[21] See CSBA and SAIC, *Future Warfare 20XX—Volume V: Insights & Observations from Wargame V (The Battle of Vladivostok)*, Report submitted to OSD / Net Assessment, December 1998, pp. 11-13.

[22] Precision air drops from stealthy transports, perhaps from stand-off range, and personal air mobility vehicles may offer the stealthiest means of force insertion in urban areas.

III. Operational and Organizational Concepts

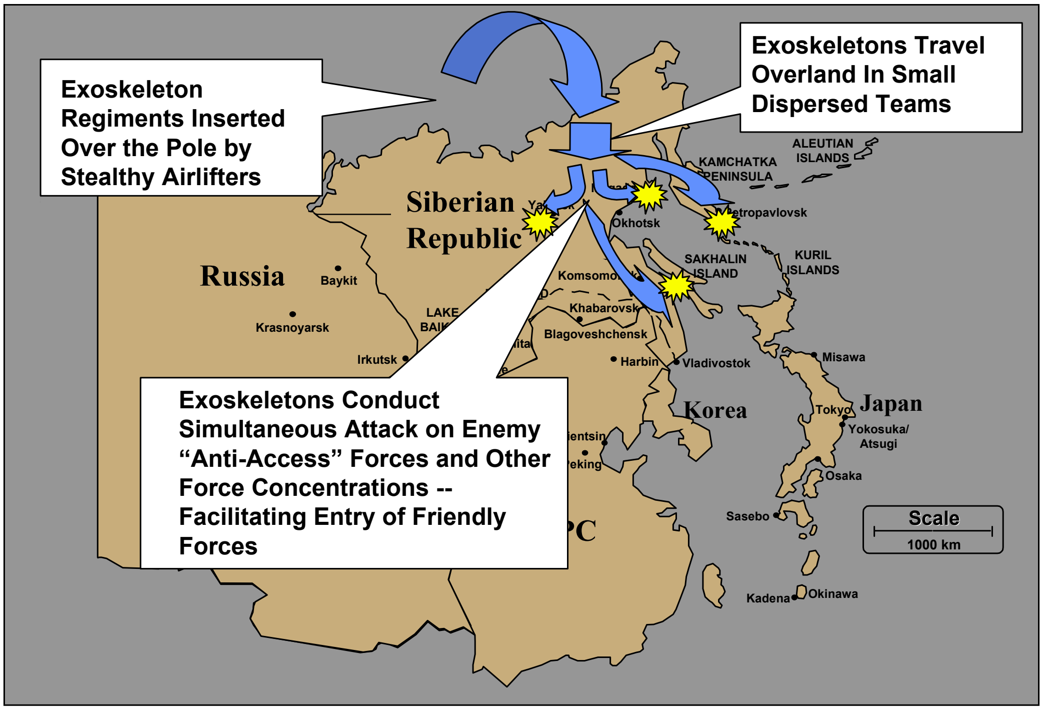
Numerous warfighting concepts consistent with the 20XX regime have been developed and analyzed over the last several years. While players were provided an umbrella 20XX concept for multidimensional warfare, they developed several sub-concepts governing specific aspects of 20XX operations. We have briefly described eight of these concepts below. These concepts were selected in part because they cover a broad array of topics including future combat organization; unmanned warfare; extended-range air operations; undersea warfare and submerged power projection; maneuver and close combat operations in an information-intensive environment; urban warfare in an anti-access environment; space warfare; and information operations.

Exoskeleton-Based Ground Operations

The potential operational utility of individual soldiers equipped with performance-enhancing exoskeletons is one of the key surprises of the 20XX series. Players in game after game organized their ground combat operations around relatively small, highly trained, exoskeleton-equipped light infantry units and special operations units. The use of performance-enhancing exoskeletons was originally conceived as a specialized capability that might be organic to future high-end infantry and special operations units (e.g., Army Rangers) for urban warfare missions. In the first game in the 20XX series, however, players stripped exoskeleton-equipped forces from larger units and employed them separately to take better advantage of their operational and tactical mobility, inherent stealth, and lethality. In conjunction with supporting LRPS and ISR assets, they were used as a distributed, mobile, ground-combat strike force tasked with finding and attacking an adversary's key anti-access systems (e.g., mobile EM-gun batteries, ASCM launchers, and missile TEL vehicles) to clear the way for follow-on forces. This asymmetric approach sought to exploit the ability of a relatively small number of stealthy ground forces to engage an adversary's anti-access forces under conditions in which they would be ill-equipped to defended themselves: a close-in ground attack. (See Figure 2 for a schematic of exoskeleton-equipped forces used in distributed strike operations.) This use of exoskeleton-equipped forces to roll back an adversary's anti-access capabilities was repeated in several subsequent games.

Facing an adversary with robust anti-access capabilities that constrain the number and type of ground forces that could be successfully inserted into the theater of operations and sustained, players have sought to increase the combat power of those relatively few friendly troops that can be deployed by taking advantage of robotic capabilities of various kinds. As part of this overall strategy, exoskeleton-equipped light infantry have generally been the force of first resort, for both urban combat (and more generally, in most forms of close combat) and non-linear, distributed strike operations. Air drop via stealthy, long-range, air mobility aircraft has been the preferred method of strategic entry for 20XX ground forces, followed by covert undersea delivery.[23] Operational and tactical mobility was generally provided by the inherent capabilities of exoskeleton-equipped forces (e.g., long-endurance mobility under a load, coupled with tactical burst speed), by personal mobility aircraft, and stealthy intra-theater mobility aircraft.

Figure 2: Exoskeleton Distributed Strike Operations



Specialized sustainment techniques were developed to resupply exoskeleton-equipped forces. In several wargames, for example, the participants formulated detailed plans for conducting distributed, high-precision, air drops of resupply packages with GPS-guided parafoils or semi-rigid wing systems. Basically, the expectation was that with advances in information technology it should be possible to monitor the activity of exoskeleton units, anticipate their resupply requirements, and prepare tailored logistics packages that could be precisely air-dropped from stealthy airlifters or resupply UAVs. By taking advantage of their independent mobility, exoskeleton-equipped units could join up with these supply caches, whose precise location would be depicted on digital maps of the area of operations, as part their overall scheme of maneuver.

In urban warfare, exoskeleton-equipped forces were repeatedly used as the principal close combat force, often as part of a robotic combined arms team with various types of UAVs, UCAVs, microrobots, and UGVs. High-flying UAVs were used for wide-area ISR over sprawling urban areas, while MAVs and microrobots were used to enhance local situational

[23] Air landing operations, using touch and go offloading at dispersed, transitory landing sites (e.g., rural, infrequently used roads), is the third 20XX method of insertion. See SAIC, *Future Warfare 20XX – Volume I: Insights & Observations from Wargame I,* pp. 11-18.

awareness at the street and building level. UCAVs were used for rapid-response fire support. UGVs were typically used as a heavy gun carrier for fire support, wall breaching, and perimeter security; as a microsensor dispenser and see-through-wall radar carrier; and as a non-lethal weapons carrier.[24] The enhanced lethality and tactical mobility of exoskeleton-equipped forces was combined with false image generation capabilities (organic to the exoskeleton and supporting UGVs or UAVs) to create a tactical overmatch. Exoskeleton-equipped forces were also used as a key force multiplier in urban, leveraged-force operations, in which indigenous forces were combined with specialized, inserted, high-end forces.[25]

ANTI-ACCESS CONSTRAINED URBAN EVICTION

Over the course of the 20XX wargames, three broad approaches were developed to deal with the problem of urban eviction in an anti-access environment. These concepts would, of course, not be mutually exclusive. The first concept, dubbed "LRPS siege," basically involved employing multidimensional LRPS and local-area situational awareness assets to restrict inter- and intra-city movement of the occupying force and its sustainment assets. ISR UAVs, UGS networks, micro-robots, and other systems would be used to create a "sensor cordon" around the city. This cordon would be enforced by air-to-air UCAV patrols and long-range fires launched from SSGNs, UCAVs, remote missile pods, and other on-station, precision-strike platforms.[26] Once the city was isolated, the specific location of occupying force concentrations within the city would be ferreted out with MAVs, microrobots, robotic scouts, and other local-area ISR assets. Based on this information, localized enemy units would be attrited over time by precision strikes from loitering UCAVs and offshore naval platforms.

Discrimination of enemy forces from non-combatant populations would be difficult, especially in an urban setting. The combination of advanced automated target recognition (ATR) capabilities and new sensor systems (e.g., multi- and hyperspectral imaging) might help somewhat in this regard. Another option might be to use microrobots, MAVs, or partisans to tag clandestinely enemy forces with a passive marker or active beacon of some type.

The LRPS siege would not require the introduction of a large number of forces into the theater, but could involve a protracted conflict because of the occupying force's ability to demass, hide, and live off the land by resupplying itself with resources available in the city. Even if complete isolation of a city could be attained with a precision-strike-enforced sensor cordon, it would likely have an unacceptable impact on the civilian population, including mass food shortages.

"Leveraged force" operations were conceived of as using small numbers of high-end ground forces to add close combat and ground maneuver capabilities to the LRPS siege. These high-end

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[24] On-call, remote missile pods also formed part of robotics/unmanned, combined arms team, particularly in distributed-strike operations.

[25] See CSBA and SAIC, *Future Warfare 20XX – Volume V: Insights & Observations from Wargame V (The Battle of Vladivostok)*, pp. 9-10; SAIC, *Future Warfare 20XX – Volume III: Insights & Observations from Wargame III (Maritime Operations)*, p. 25.

[26] A critical question, of course, would be how to enforce a partial cordon in which selected civilian and noncombatant traffic would be permitted to come and go from an LRPS-sieged city.

units could compel enemy forces out of information-based or physical concealment, thereby exposing them to precision strikes. U.S. forces leveraged in this way would, of course, have to be stealthy, highly mobile, and easy to sustain, given the likelihood that they might have to operate for extended periods in a very high-threat environment.

In addition, robotic-enhanced close combat forces (e.g., exoskeleton-equipped soldiers, Marines, special operators) and unconventional warfare specialists would be used to more aggressively organize broken military units, as well as to mobilize and develop irregular forces from the civilian population. While the combat power of these indigenous forces would be directly augmented in some measure by the presence of these RMA forces, the more significant multiplier would be derived by virtue of being plugged into the U.S. C4ISR network and by the ability to request precision strikes from U.S. assets. Friendly close combat forces and urban warfare specialists would, in effect, provide a secure, reliable conduit through which reformed allied units, urban guerrillas, and partisans could gain access to much needed information and fire support. Conversely, these low-tech forces could supplement the relatively small number of U.S. forces on the ground with their greater numbers to accomplish labor-intensive tasks (e.g., conducting house-to-house fighting).[27]

High-end force operations were envisioned as employing more manpower- and capital-intensive ground forces (e.g., advanced light infantry, advanced combat vehicle-equipped formations, and stealthy attack helicopters) in conjunction with the forces described under the two preceding concepts to locate and destroy enemy units occupying a given city. Entry into the city would be accomplished through multiple avenues of approach and would include stealthy air drops, covert insertion from submarines (if the city were within operational range of the sea), and ground infiltration from multiple points surrounding the city. Insertion operations would likely be conducted in parallel with offensive IW attacks and deception operations at the operational level (e.g., large-scale seeding of multispectral decoys and feints), and would take advantage of integrated tactical-level deception capabilities (decoys, 3-D holographs, etc.).

While high-end force operations could be potentially more decisive than the other two courses of action, they would also require the ability to reliably insert and sustain large numbers of ground forces for an extended period. Even if this could be accomplished, whenever they elevated their signature, these forces would be exposed to the opposing force's LRPS assets. High-end force operations probably could not be conducted early on in a 20XX campaign, but might be achievable in later phases, once the enemy's anti-access architecture had been degraded. Based on 20XX wargames, leveraged-force operations seem to be the preferred concept for urban eviction in severe anti-access environments.[28]

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[27] Like the LRPS siege, leveraged force operations have the potential to be protracted because of the training time required to make indigenous forces combat effective and the potential lack of truly decisive force.

[28] See CSBA and SAIC, *Future Warfare 20XX—Volume V: Insights & Observations from Wargame V (The Battle of Vladivostok)*, pp. 8-10. Given that the local population could tip the balance in anti-access constrained urban operations, its disposition could determine the concept employed. A take down of a LRPS-overwatched city with a large, hostile population base (i.e., an enemy city) might have to be reduced by LRPS siege as long as an area-denial threat remains. Conversely, leveraged-force operations could prove more decisive in an occupied city.

BUILDING CLEARING AIDED BY MAVs

In Game IX of the 20XX series, players contemplated how RMA-equipped forces might take down a heavily defended urban structure. In their view, microrobots, MAVs, and UGS should be deployed into the area surrounding the objective building well in advance of an assault. The intent would be for crawling microrobots to enter the building through ventilation shafts, drainage pipes, and other unprotected openings. Meanwhile, MAVs could perch silently on window ledges to observe activity within the building. The primary mission of these micro-sized robots would be to determine the approximate location of enemy troops and noncombatants, as well as to map the interior of the building as accurately as possible. As alluded to earlier, the players also suggested that, if possible, it would be very useful for the robots to tag enemy troops at this stage.

As a prelude to the assault phase, sapper robots and rotary-wing UAVs would assist in creating breaches at multiple locations throughout the building. During the actual assault, the first units to exploit these breaches might be intelligent fast-flying MAVs that could generate real-time situational awareness for human troops. They could fly around corners, down hallways and into uncleared rooms and pass pertinent information (e.g., presence of enemy sensors, booby traps or troops) to human troops following seconds, or minutes behind. Weaponized MAVs could also attack concentrations of enemy forces and contribute to intra-building security. By clearing predetermined floors or areas within the building, they could appreciably reduce the amount of physical space that human troops (perhaps substantially limited in number) would need to clear. The basic goal of the take down within the building would be to maximize shock and speed.[29] The combination of superiority in information operations tools (e.g., decoys and holographs), microrobots and MAVs, and other potentially high-leverage future urban capabilities, such as exoskeleton-equipped forces, could provide the basis for tactical dominance in future building take downs.[30]

MICRO JOINT TASK FORCE OPERATIONS

An organizational surprise of the 20XX series is the extent to which multidimensional RMA capabilities in general, and advanced C4ISR networks in particular, might allow joint force integration to be pushed to very low levels of power-projection force organization. In Game I, players were given flattened organizational hierarchies to take advantage of system of systems joint integration and the substantially greater capabilities possessed by smaller units. They were also given a joint task force structure for power projection that essentially pushed full joint force integration (i.e., what is done today at the highest operational echelons, such an Army corps) down to the regimental or major-platform level.

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[29] There are potential counters to this course of action. An intelligent adversary, for instance, might use high power jammers in and around the building to disrupt the highly complex C3 linkages that would be required for such an operation to succeed. Meanwhile, enemy forces could take advantage of internal, high-bandwidth, fiber-optic lines for establishing a local area C4ISR network.

[30] Exoskeleton-equipped infantry could overmatch enemy defenders in several important ways. In addition to benefiting from much better organic C4ISR, tactical mobility, and ballistic protection, exoskeletons troops could also use their false image generation capability to gain a decisive advantage in close quarter encounters.

Players assessed that the exigencies of operating within the 20XX battlespace required that joint force integration be pushed far lower for ground combat operations. Their primary concern was that the anti-access environment postulated in the scenario severely restricted the size of ground force units that could be safely inserted and sustained in a theater. Fortunately, new ground force capabilities postulated in the wargame (e.g., exoskeleton-equipped infantry and various means of robotic support) dramatically enhanced the power of very small units, making even individual soldier operations appear feasible. In addition, non-organic capabilities could provide many of the capabilities that previously had to be organic to ground force organizations. For instance, loitering UCAVs and precision, high-volume fires from long-endurance assets (e.g., SSGNs, undersea strike modules, and land-based missile pods) could supplant traditional tube artillery. In light of these considerations, the players assessed that in the future much greater operational responsibility could and would be devolved to much lower organizational levels than today.[31]

For example, faced with the challenge of finding and destroying hard-to-locate, distributed LPC forces, Blue team players opted to create hundreds to thousands of "micro joint task forces," centered on exoskeleton-equipped soldiers. The composition of these micro task forces would vary widely and they would be rapidly formed and disbanded as missions required. A single micro joint task force might comprise a sensor pass from a space-based asset, a strike from a loitering UCAV or offshore SSGN, and close combat or target designation by an individual exoskeleton-equipped warrior. The net effect could be thousands of distributed, tactically autonomous actions linked for joint operational purposes.

Type organizations (e.g., units organized around a single combat system) might, in some cases, play a role more akin to the Title X role of training and equipping units than to operational command. (An exoskeleton regiment as analogous to a submarine squadron.)[32]

ASSURED SPACE RECONSTITUTION

Given its asymmetrical reliance on space-based assets for power projection, the U.S. military has a requirement to be able to reconstitute its space capabilities in the event it has to absorb a first strike in space. This reconstitution capability could be more dependent upon an assured, counter-space control capability than it is on large stocks of rapid-launch, replacement satellites. As in the realm of assured nuclear destruction where deterrence rests on an assured second strike capability, space reconstitution could rest on an assured counter-space capability.

It is at least theoretically possible that a future adversary could denude the United States of critical space-based assets in a bolt from the blue. A preemptive strike could, for example,

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[31] This would, of course, have enormous implications for professional military education (e.g., joint force integration training at the beginning of an officer's career, along with the required specialty training).

[32] SAIC, *Future Warfare 20XX—Volume I: Insights & Observations from Wargame I,* pp. 19-23. The key condition to make this analogy hold is if exoskeleton-equipped soldiers were employed only—as are submarines—as individual combat platforms. Exoskeleton-equipped forces, however, might be employed in concentrated units (e.g., perhaps up to company—assuming, as a first approximation, that there might be 64 exoskeleton-equipped operators per company) for some missions (e.g., larger force or building take down) and as individual combat platforms in others (e.g., micro joint task force operations).

involve the coordinated use of CNA capabilities; ground-based ASATs of various types; pre-positioned, co-orbital microsatellites capable of conducting lethal proximity operations; and perhaps, space-based, ASAT platforms that employ a DE beam to destroy or disable U.S. satellites. To gain a sustained advantage, however, the aggressor would also have to neutralize U.S. space control and reconstitution capabilities. Otherwise, after absorbing the first blow, the U.S. military could counter-attack in space and eventually repopulate its network of space-based assets. If, however, the aggressor could knock out or defend against U.S. counter-space weapons, as well as intercept U.S. space launch vehicles soon after lifting off the launch pad, it could impose a "space blockade" and profit from asymmetrical access to space.

The first step to regaining access to space-based capabilities in the event of a "space Pearl Harbor" would be to conduct offensive space control operations. In terms of enabling U.S. space reconstitution, the principal focus of such operations would be the enemy's space surveillance assets, which could be used to track newly orbited, replacement satellites; space-based strike systems, which could be used to attack U.S. space launch facilities or the SLVs attempting to loft replacement satellites into orbit; and, of course, space- and ground-based ASAT systems. In addition to fielding a survivable, effective surveillance and tracking network, three future capability options, in particular, might feasibly provide an assured second strike in space:

1. A DE-based ASAT weapon carried aboard a designed-for-purpose, nuclear-powered submarine, which would benefit from stealth, global mobility, and long endurance.

2. Micro-sized satellites designed for conducting proximity operations that could covertly shadow opposing space control/anti-space launch capabilities prior to the outbreak of hostilities and remain in striking range until needed.

3. IW tools that could be used to neutralize opposing space control/anti-space launch capabilities. (For example, it might be possible to disable an enemy's SBL system long enough to prevent it from defending itself against direct-ascent ASAT salvo attacks.)

After an adversary's offensive space-control capabilities had been neutralized, space reconstitution would depend upon having a survivable satellite launch capability (an SSGN, or a built-for-purpose submarine might provide the needed immunity from global precision strike) and a stockpile of ready-to-launch, multifunction satellites.[33] In addition to taking steps to assure space reconstitution, participants in several games emphasized the importance of implementing protective measures as soon as possible to prevent an adversary's first shot in space from being a disarming, "knock out" blow. It was also suggested that the U.S. military should hedge against a preemptive attack in space by investing in terrestrially based capabilities that can stand in for damaged or destroyed satellites until they can be reconstituted. For example, extremely long-endurance, stealthy UAVs could be equipped with sensor and communications payloads to fill in gaps in satellite coverage following an attack in space.

[33] The concept of submerged platforms for launching replacement light satellites and/or direct-ascent ASATs was developed during Game II and was incorporated into subsequent wargames. SAIC, *Future Warfare 20XX—Volume II: Insights & Observations from Wargame II (Aerospace)*, Report Submitted to OSD / Net Assessment, 1996, pp. 18-20.

Extended Air Sustainment and Airborne Basing

Maintaining an on-station network of air superiority, C4ISR, and airborne precision-strike assets from extended range in an anti-access environment could require, in addition to a very large tanker fleet, new concepts for aerial refueling and, perhaps, rearming.[34] A premium would be placed upon air platforms that are fuel-efficient and can be easily sustained at extended ranges. In addition, a much greater emphasis might be placed upon unmanned aircraft because, unlike manned aircraft that are constrained by the physiological limits of human endurance, they could conceivably loiter in the skies for days or weeks at a time. Stealth and other forms of information protection would also be a prerequisite for air operations in an anti-access environment.[35]

Players in Game II of the 20XX series proposed a concept for extended air refueling in an anti-access environment that made use of two classes of refuelers: traditional, high-volume refuelers that would sustain the bulk of the air bridge; and a new class of smaller, low-observable refuelers that would operate close to and over the theater. The principal task of low-observable refuelers would be to extend the endurance of stealthy unmanned and manned aircraft capable of operating in the heart of the adversary's anti-access defenses. By obviating the need to return all the way back to a remote peripheral base or to uncontested airspace to refuel, a low-observable refueling capability would allow a higher proportion of these stealthy assets to remain on-station at any given point in time than would otherwise be the case.

The basic concept was that the high volume, traditional refuelers, operating out of dispersed, peripheral bases, would contribute to the air bridge by refueling inbound and outbound aircraft (e.g., stealthy bombers and transports) to optimize their range and endurance. They could also provide additional fuel at a "refueler transition area" to extend the endurance of the low-observable refuelers. Even though the traditional refuelers would operate in lower-threat areas, air superiority aircraft (manned or unmanned) would still need to protect the air bridge against the extended-range air threat of the other side (e.g., stealthy long-range UCAVs or refueled fighters). (See Figure 3 for a graphical depiction of the extended range air sustainment concept.)

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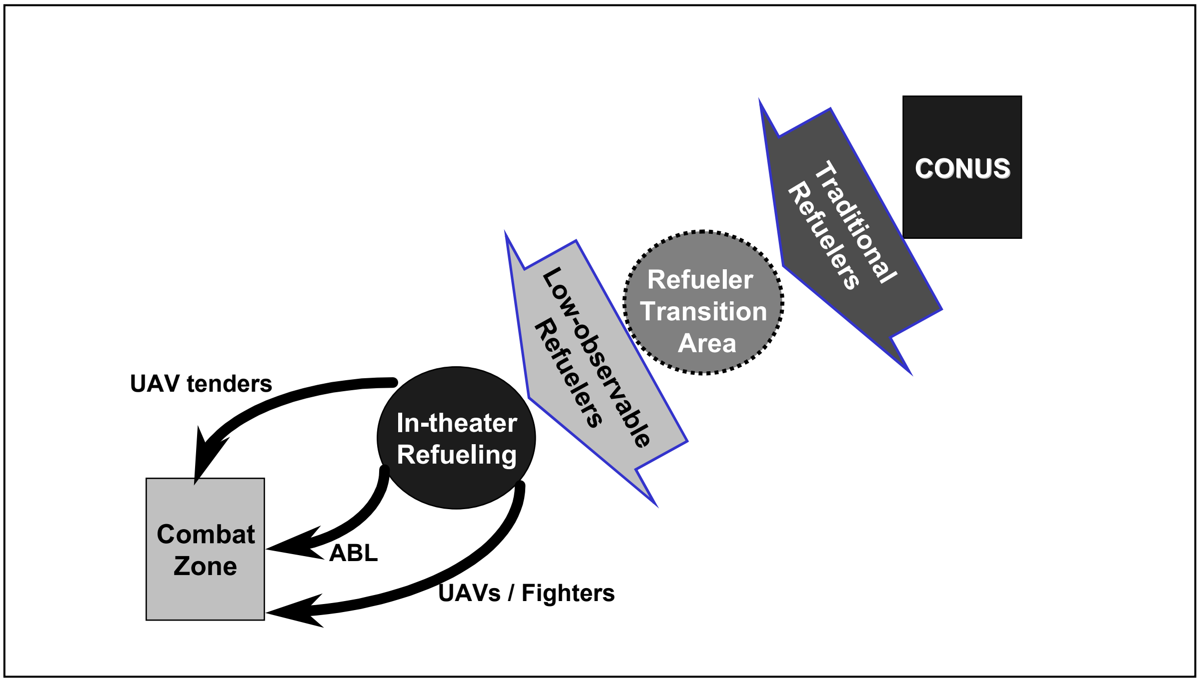
[34] Extended range in this context means about 3,000 miles, allowing the use of peripheral or "rim" bases, but not fixed, easily targetable ones in theater. Even in extended-range operations, aircraft should be based as close as possible to the theater of operations to maximize their sortie rate. In the 20XX scenario described above, aircraft were based out of Alaska for operations over the present-day Russian Far East. In other 20XX wargames, aircraft were based in Australia for operations over Indonesia and Southeast Asia. Guam is another rim base that might be used to project extended range air power into the Asian continent.

[35] See SAIC, *Future Warfare 20XX—Volume II: Insights & Observations from Wargame II (Aerospace)*, pp. 21-22. See also SAIC and CSBA, *Future Warfare 20XX—Volume VI: Insights & Observations from Wargame VI (Dimensional Control)*, pp. 17-18. The two most challenging air missions to sustain from extended range were close strike (which requires rapid-response, precision-strike platforms) and counter air (e.g., establishing and maintaining an air cordon over the theater). Persistent airborne, wide-area surveillance, to the extent that the mission cannot migrate largely to space, presents a third major challenge. Together, these missions form the bulk of the extended-range air occupation and sustained, multidimensional LRPS problem.

Figure 3: Extended-Range Air Sustainment



A concept for airborne basing was also developed in Game II. As alluded to earlier, this concept revolved around the idea of a UAV tender, an extended-range air platform that could transport multiple UAVs to distant theaters and sustain them once in theater. As envisioned by the players, UAV tenders would be capable of launching, controlling and recovering about a dozen or more small UCAVs that could be armed with a mix of miniaturized air-to-air and air-to-ground munitions.[36] Owing to their small size, on-board UCAVs would have limited range, endurance, and payload but could be recovered, refueled, and rearmed multiple times by the UAV tender. To enhance its operational utility, the UAV tender would incorporate low-observable materials and active signature management. Its organic UCAVs would provide additional force protection.[37]

This same idea was extended to maritime sustainment in Game III. The participants advocated submerged replenishment operations to provide a low-signature means of resupplying submerged power projection vessels. The submerged resupply vessels could themselves be resupplied by linking up with the larger surface replenishment ships located outside the primary sea-denial envelope of the enemy. The participants noted that submerged replenishment would be both technically challenging and time consuming. The precision, in-close maneuvering required to properly align and dock large vessels underwater; establishing a reasonably-sized, pressurized lock between the vessels; and then conveying weapons and other supplies through this shared lock at depth would all present significant technical hurdles. The general view, however, was that all these envisioned obstacles could be overcome, albeit at a price.

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[36] In light of the merit of the UAV tender concept, it was added to the 20XX order of battle following Game II.

[37] Since recovery and refitting, though feasible, are the most challenging aspects of the UAV tender concept, an alternative air basing concept is to use loitering, expendable munitions in lieu of UCAVs.

INFORMATION BAITING OPERATIONS

The use, denial, and manipulation of information could become far more integral to strategy, operations, and tactics in the decades ahead. At the operational and tactical levels, what might be termed "information baiting" operations could be used to support both LRPS operations, as well as maneuver and close combat. The goal of such operations would be to induce enemy forces to move, power up active sensors, employ their weapons or otherwise engage in activity that reveals their location or places them in a more vulnerable position.[38] Three variants of information baiting operations have surfaced over the course of the 20XX wargame series: "hunter-killer" operations, "missile sponge" tactics, and virtual feints. While the basic concept was similar in each case, these operations varied in terms of their primary objective. As will be elaborated upon below, hunter-killer operations were focused mainly upon evoking enemy targets, while missile sponge tactics were directed more toward compelling an adversary to waste precision-strike assets, and virtual feints were intended to trick an adversary into focusing its ISR assets in the wrong direction.

Hunter-killer operations were envisioned as platform pairings in which a relatively non-stealthy, low-cost, emitting platform would be used to evoke targets that would then be destroyed with a stealthy killer platform lurking nearby or at a remote location. In the air dimension, for example, a hunter UAV could broadcast the signature of a lucrative airborne platform, or release decoys that did so.[39] In the event that an enemy UCAV, fighter, or SAM unit took the bait by raising their signature in some way (e.g., powering up active targeting sensors or firing a weapon), a stealthy killer UCAV would be in position and ready to fire.

Similarly, as part of the undersea competition, a hunter UUV could sprint a significant distance away from its host submarine toward a possible enemy contact. Upon reaching the general vicinity of the contact, it could transmit the signature of a friendly submerged vessel or even just acoustic transients (e.g., the sound of a dropped wrench or slammed watertight hatch). If an enemy submarine took the bait, a hunter UUV lurking nearby could attack the enemy submarine with a short-range, high-speed torpedo. Alternatively, the hunter UUV could release a buoy to the surface signaling the approximate range, bearing, and depth of the enemy vessel to orbiting killer ASW UAVs that would in turn hunt the enemy submarine down.

Missile sponge tactics involved the widespread use of multispectral decoys and information spoofing techniques to bait an adversary into firing missiles at false targets. This tactic would not only impel the adversary to waste its finite inventory of precision-strike weapons, but would also expose its missile batteries to counter-strikes. In addition, large numbers of spurious targets would also be expected to slow down the adversary's detection, targeting, and attack cycle since additional computer processing time would be required to discriminate actual targets within a

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[38] See SAIC, *Future Warfare 20XX – Volume I: Insights & Observations from Wargame I*, p. 32; SAIC, *Future Warfare 20XX – Volume II: Insights & Observations from Wargame II (Aerospace),* p. 24; SAIC and CSBA, *Future Warfare 20XX – Volume VI: Insights & Observations from Wargame VI (Dimensional Control)*, pp. 12-13.

[39] Similar capabilities such as the Miniature Air-Launched Decoy (MALD) are already used today for force protection.

vast quantity of misleading, unreliable data. This lag in response time caused by this information overload could permit greater freedom of operation for friendly platforms.

Virtual feints entailed the use of false-image generators, multispectral decoys, and other deception techniques in order to mislead an adversary about the capabilities, strength, movement, or location of friendly forces. For example, players in several 20XX wargames have used task forces comprising a mix of real and virtual assets in order to lure the enemy's attention away from sensitive areas. While virtual feints have been used throughout all phases of 20XX campaigns, they are often viewed as a particularly essential element of operational and tactical force insertion operations.

Aside from information baiting, other signature magnification tactics frequently employed over the course of the 20XX wargames included tagging and channeling. Tagging referred to the practice of affixing some type of indicator or beacon to enemy platforms. For a variety of reasons, tagging would most likely be conducted in peacetime while platforms were in port, on the ground, or in garrison. Alternatively, it might be possible to tag assets while moving through spatially constricted areas. For example, naval vessels could be tagged while passing through straits, and ground vehicles might be tagged while moving through urban areas, over narrow roads and bridges, and so forth. Channeling operations consisted of arranging mines, or in the case of the undersea, active sonar beacons, in such a fashion so as to shepherd enemy platforms into kill zones where friendly forces had asymmetric advantages in terms of sensor or shooter density.

CASCADING UNDERSEA CONTROL OPERATIONS IN INNER, DEFENDED SEAS

In Games VIII and IX of the 20XX series, players were asked to penetrate and collapse enemy maritime bastions protected by geography and by multidimensional anti-access forces for follow-on exploitation by other friendly forces.[40] In both cases, the adversary's bastion was defended with active and passive sensor networks (similar to the U.S. Advanced Deployed System and Sound Surveillance System), large numbers of smart mines concentrated at maritime choke points, attack submarines, land- and sea-based ASCMs, long-range coastal artillery (based on EM-guns), ASW frigates, maritime attack aircraft (both manned and unmanned), and air superiority fighters and long-range UCAVs.

The first phase of the anti-bastion concept involved the use of long-range UUVs, released from attack submarines positioned well outside of the bastion, to precisely map the sea floor (using high-frequency sonar) and search for undersea cables, sensor arrays and mines through the narrow entrances into the defended, inner seas. If mines were detected, small, onboard minehunter UUVs would use fiber-optic guided torpedoes to tag or destroy them in place. To avoid telegraphing the location of friendly forces, it was considered preferable to tag mines with low-power acoustic beacons and avoid them, rather than to destroy them and possibly generate

[40] In Game VIII, players were given a scenario requiring them to penetrate and collapse a bastion in the Sea of Okhotsk, and in Game IX, they were given a similar task in the Sea of Japan.

detectable signatures. As enemy sensor arrays were discovered, they would either be severed so as to minimize the enemy's ability to locate friendly forces, or moved so that data generated by them would be misinterpreted.

As soon as a mine-free path had been mapped out and enemy sensors disabled, long-range UUVs would be sent through the breach to deploy a friendly Advanced Deployable Underwater Surveillance System (ADUSS) array just inside the bastion.[41] By generating enhanced situational awareness over this local area, the ADUSS array would effectively create a limited sanctuary in which friendly submerged assets could operate at a reasonable level of risk. Once the array became operational, high-value assets waiting outside the barrier could enter, following a route mapped out previously by UUVs. Friendly smart mines would also be air-dropped into the sea lines of communication (SLOCs) leading into the bastion to isolate the battlespace.

UUVs would then be sent forward to establish another ADUSS array, at which point, friendly submerged assets would move forward into the next undersea sanctuary. This process would have to be iterated several times en route to the objective, creating a large requirement for rapidly deployable arrays and UUVs. These series of actions were described as a "cascading ASW sanctuary."

After several ADUSS arrays had been laid, friendly situational awareness might be expanded by employing the "distant thunder" concept. UAVs would drop high-explosive charges, which had been set to detonate at a predetermined time, into the sea a considerable distance away from the arrays. As the acoustic spike caused by the explosions propagated through the water, enemy submarines in its path would necessarily reflect some of the energy. By taking advantage of the large ear provided by the multiple ADUSS arrays established as part of the cascading ASW sanctuary described above, it might be possible to detect these returns and plot the approximate location of enemy contacts over a very large area. While these wide-area sonograms would not provide exact three-dimensional fixes, they could be sufficient to cue ASW UAVs and SSNs to suspected enemy submarine operating areas. Deception UUVs would also be used in support of wide-area ASW operations.[42]

The players recognized that order-of-magnitude improvements in undersea command, control, and communications (C3) would probably be required to implement this concept of operations successfully. One proposed solution for improving undersea C3 was to have long-range UUVs and ASDS vessels trail out fiber optic cable and fix it to sea floor. They might even be able to perform this function while conducting other operations such as searching for cable, mines, and other features on the sea floor. Periodically, these vessels could install a junction box along the cable that would not only connect fiber cables running in different directions, but would also be

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[41] The Blue team was equipped with an ADUSS as a follow-on to current ADS technology. The system was described as a rapidly deployable array containing a mixture of elements including neutrally buoyant (at depth) strings of passive hydrophones up to 2,000 feet in length, sonubuoys (passive and active sonar, magnetic anomaly sensors, etc.), and UUVs. It was assumed that with the exception of the lengthy hydrophone arrays which have to be deployed by submarines or surface ships, all other ADUSS elements could also be deployed via aircraft.

[42] See CSBA and SAIC, *Future Warfare 20XX—Volume VIII: Insights & Observations from Wargame VIII (East Asian Littoral)*, Report submitted to OSD / Net Assessment, June 2000.

capable of releasing a tethered communications buoy up to the ocean's surface to provide an interface to airborne RF communications. These junction boxes could also serve as "phone booths" for friendly submerged platforms in that they could provide a convenient, secure access point into the undersea C3 grid. Connectivity might be established either by using a short-range acoustic modem, a blue-green laser link, or a fiber cable physically carried from the vessel and plugged into the phone booth by a UUV. Even if individual underwater grids within a given theater of operations were not connected, communication would still be possible between them by using surface buoys as crosslinks.

Building upon this same basic idea, it might also be possible to tap into pre-existing commercial, fiber optic lines in the area of operations rather than stringing out new fiber. In order to piggyback on existing fiber trunks during a conflict, however, it would be very helpful to know their exact location in advance. Precisely mapping fiber optic lines throughout the world's littoral waters, and perhaps installing dormant taps and access nodes, could be an important covert mission during peacetime.

IV. Implications for Transformation

Across all of the 20XX wargames and workshops, several postulated capabilities were often judged by participants to be particularly useful for fighting within the proposed future warfare regime, while others were considered to be much less useful, or in some cases, completely anachronistic. This chapter provides an overview of capabilities that were generally more highly valued than others and why.

In addition, we thought it would be useful to draw links between systems-choice assessments that were repeatedly made over the course of the 20XX wargame series and force investment decisions presently facing DoD's senior leadership.[43] After all, many of the challenges presented in the 20XX wargames are likely to emerge well before 2025-2030 (e.g., anti-access, space control, and new forms of homeland attack), at least in embryonic form. Accordingly, we have attempted to walk backward in time to identify current or emerging capabilities that could be built upon or accelerated to hedge against mid-term threats that could emerge over the decade or so.[44] We have also identified ongoing R&D initiatives and new program starts that could be critical to realizing a future military capable of fighting effectively in a mature post-RMA regime such as the one proposed in the 20XX wargame series.

Air Forces

Given the postulated threat environment in 20XX wargames, it is not surprising that stealthy, long-range aircraft were considered especially valuable. Denied access to in-theater airbases, extended-range aircraft could operate from U.S. territory or bases located on the outer periphery of a given theater of operations. Stealth was critical for enabling aircraft to penetrate the LPC's anti-access architecture. The combination of long range *and* stealth were essential for extended operational endurance in high-threat areas.

In a future warfare regime in which enemy targets may often be highly dispersed, stealthy, hidden, and mobile, it will take time to find, track, and engage them. Operational endurance in denied areas, therefore, may become a key performance metric for future ISR and strike platforms. Unmanned systems were considered to be particularly useful in this respect because their endurance was not bounded by the limits imposed by human physiology. Unlike pilots who get tired and whose alertness begins to fade after a few hours on patrol, UAVs and UCAVs could technically remain aloft, ever vigilant, for days on end.

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[43] Systems choice problems arise in the evaluation of competing capabilities within a complex systems environment. These decisions are particularly difficult during periods of transformational change. For example, in the course of the ongoing transformation of war, systems choice problems could arise from competing approaches to C4ISR, long-range precision strike, strategic mobility, maneuver and close combat and dimensional control.

[44] For our purposes, the expression "mid-term" covers the period between 2007-2013, and "long term" encompasses the period between 2013-2025. These temporal dividing lines track closely with those used in the 2001 Quadrennial Defense Review. See "2001 QDR Terms of Reference," *Inside the Pentagon*, June 28, 2001, pp. 13-14.

While stealthy, relatively short-range fighters might have been used in conjunction with extensive aerial refueling, players did not typically pursue this option for two reasons:

- Repeated aerial refueling of stealthy fighters was considered to be a highly inefficient use of limited aerial refueling assets that were already over-stretched supporting longer-range assets operating from peripheral bases; and

- Stealthy fighters had only limited endurance or "time over target" in denied airspace, which significantly reduced their effectiveness as mobile-target killers and as air control platforms.

The possession of stealthy refuelers and transports by the Blue team was considered a major advantage. In several wargames, the Red team indicated that they wished that they had them and the Blue teams wished they had more of them. Conversely, both teams viewed the other side's non-stealthy mobility assets as a vulnerability. On several occasions, for example, the Red team planned to attack U.S. non-stealthy refuelers and transports operating well outside the immediate theater (e.g., in Europe) in order to disrupt the flow of fuel, equipment, and troops into the theater of operations.

The logical implications of these 20XX systems-choice assessments on U.S. military transformation through the mid-term, could be summarized as follows:

- Invest in additional stealthy, long-range B-2 bombers;

- Accelerate and expand the Air Force and Navy UCAV programs;

- Expand the Global Hawk HALE UAV program and develop stealthy, HALE UAVs; and

- Develop stealthy transports and aerial refueler prototypes.

The rationale for each of these recommendations is provided below.

B-2 Stealth Bombers

The B-2 bomber has four important attributes that not only offer a hedge against the emergence of anti-access threats within the mid-term, but that also make it well suited for the challenges likely to be associated with warfare in a post-RMA regime:

- The stealth required to penetrate into denied areas and loiter in hostile airspace for extended periods;

- The range to reach targets wherever they may be;

- The endurance required to hunt down mobile targets; and

- The ability to carry a large complement of a wide-array of ground-attack PGMs

The B-2 benefits from a high degree of broad-spectrum, all-aspect stealth. Its flying-wing design provides one of the lowest signatures possible for any aircraft. The radar-cross-section (RCS) of the B-2, for instance, is about equivalent to that of an aluminum marble.[45] As a result, it is extremely difficult for even the most modern air defense networks to detect and target, and will likely remain so through at least the mid-term. Stealth also enables the B-2 to strike without warning, thereby increasing the prospect of catching prospective adversaries off guard. In the future, the signature of the B-2 could be further reduced by the application of next-generation, low-observable materials (e.g., Advanced High Frequency Material and magnetic radar absorbent material). Its survivability could be further improved by the incorporation of advanced electronic warfare systems.

The high aspect ratio and modest wing sweep of the B-2 makes it a very efficient aerodynamic vehicle. As a consequence, it can deliver heavy payloads 5,000 to 7,000 miles without being refueled. In addition, at a mission radius of 1,000 nautical miles, the B-2 can loiter for well over six hours without being refueled.

Each B-2 bomber can carry a payload of 40,000 pounds. At present, it can deliver all of the following: 16 2000-lb Joint Direct Attack Munitions (JDAMs), 80 500-lb JDAMs, 16 Joint Standoff Weapon (JSOW) glide bombs, 16 stealthy Joint Air-to-Surface Standoff Munitions (JASSMs), or 16 Wind Corrected Munitions Dispensers (WCMDs). When the 250-pound Small Diameter Bomb (SDB) becomes available around 2004-2007, a single B-2 could potentially strike several hundred discrete aimpoints in one sortie.[46]

In sum, the B-2's stealth, range, endurance, and payload would enable it to address a number of mid-term challenges and strategic opportunities. An expanded fleet of B-2s could, for instance, offer the following:[47]

- Increased combat power early on in a conflict and enhanced strategic responsiveness;

- The ability to conduct sustained, deep-strike operations in robust, anti-access environments;

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[45] See David A. Fulghum and Robert Wall, "Stealth Remains High Priority for Research," *Aviation Week & Space Technology*, November 20, 2000, p. 49; David Fulghum, "Stealth Retains Its Value, But Its Monopoly Wanes," *Aviation Week & Space Technology*, February 5, 2001, p. 54.

[46] The B-2 can carry up to 128 winged-SDBs using the same smart-ejection bomb rack as the Joint Strike Fighter (F-35). According to some sources, including retired Air Force General James McCarthy, who chaired the recent DoD review panel on defense transformation, the B-2 could potentially carry up to 324 non-winged SDB munitions. To carry this number, however, the B-2 would need to be outfitted with a new bomb rack. According to Northrop Grumman, a better estimate for the number of non-winged SDBs that could be carried by the B-2 is 254. General James P. McCarthy, *Special DoD News Briefing on Defense Transformation*, June 12, 2001. See also: Elaine Grossman, "Quickly Fielded Small Diameter Bomb among Top USAF Weapon Priorities," *Inside the Pentagon*, March 29, 2001, p. 1; Gail Kaufman, "Smaller Bombs Could Quadruple Strike Capacity," *Defense News*, July 2-8, 2001, p. 5; Adam Hebert, "Air Force Awaits Go-Ahead to Begin Push for Small Diameter Bomb," *Inside the Air Force*, April 13, 2001, p. 1.

[47] For additional discussion of the operational and strategic benefits offered by an enlarged B-2 fleet, see Michael Vickers and Robert Martinage, *Transforming the U.S. Military* (Washington, DC: CSBA, 2002).

- Increased freedom of action made possible by operational independence from in-theater airbases; and

- Superior mobile target killing potential.

Additional B-2s should be fielded as a mid-term hedge against the growing possibility that the Air Force may need to conduct power-projection operations without access to in-theater bases. To prepare for longer term challenges, DoD might also commence R&D on a follow-on to the B-2 that could be fielded in the 2020-2025 time frame.

Unmanned Combat Air Vehicles (UCAVs)

UCAVs have figured prominently in all of the 20XX wargames. In addition to conducting deep strikes in denied areas, these highly autonomous platforms were also used for counter-air missions, close air support of ground troops, hunting down time critical targets such as missile TEL vehicles, and even ASW and anti-surface warfare (ASuW) operations.

Under the direction of DARPA and the Air Force, Boeing is currently developing a stealthy, 26-foot long, boomerang-shaped UCAV. It is expected to have a mission radius of up to 1,000 miles, be able to fly 550 miles per hour and as high as 40,000 feet, and carry up to a dozen 250-pound bombs.[48] The UCAV program has focused mainly upon performing the suppression of enemy air defenses (SEAD) mission because it was "the hardest mission envisioned for a UCAV outside of air-to-air fighter combat" and would implicitly demonstrate the UCAV's capability to conduct many other ground-attack missions.[49] The UCAV could eventually take on a myriad of other missions including hunting for mobile, time-critical targets; jamming an adversary's communication links, conducting electronic strikes with RF weapons, and dropping all manner of PGMs on stationary and mobile targets. According to Colonel Michael Leahy, who is the UCAV program manager, the aircraft is expected to be nearly autonomous:

> We're developing a weapon that has a high amount of intelligence on board. It should be able to detect targets, cooperate with other elements of a strike package, perform automatic rerouting during ingress and egress, perform SAR imaging, decide which UCAV in a multiship flight should prosecute the attack, choose weapons and make decisions about bomb damage assessment. . . all without operator intervention.[50]

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[48] The operational version of the UCAV is expected to have a mission radius of 500-1000 nautical miles, a 1,000-3,000 pound weapons payload, and a wide array of sensor systems, including SAR. See Colonel Michael Leahy (Program Manager), Briefing—*DARPA/USAF Unmanned Combat Air Vehicle Advanced Technology Demonstration: UCAV Program Overview*, October 1, 2001, slide 8. See also: Elaine Grossman, "Air Force Mulls Mission Control Issues for Unmanned Combat Aircraft," *Inside the Pentagon*, April 26, 2001, p. 3; Stanley Kandebo, "SEAD, Other Ground Attack Capabilities Planned for UCAV," *Aviation Week & Space Technology*, October 2, 2000, p. 69; Dave Moniz, "Pilotless Bombers to be Tested Next Year," *USA Today*, August 21, 2000, p. 8; and John A. Tirpak, "UCAVs Move Toward Feasibility," *Air Force Magazine*, March 1999, pp. 32-37.

[49] Statement by UCAV program manager, Colonel Michael Leahy. See Kandebo, "SEAD, Other Ground Attack Capabilities Planned for UCAVs," p. 69.

[50] Ibid., p. 69.

While the first UCAV prototype is expected to fly in early 2002, under current plans, a limited operational capability will not be achieved until 2008, at the earliest.[51] If possible, this timeline should be accelerated.[52] This first-generation UCAV should also be equipped with an aerial refueling capability as soon as practical in order to give it an enhanced denied-area, deep-strike capability.[53] As a step toward fielding a 20XX-like UCAV fleet, the Air Force should also explore the possibility of equipping the Boeing UCAV with a rudimentary air-to-air capability and increasing its maximum payload. Refuelable, air-to-air UCAVs could make an important contribution to extended-range air superiority operations, especially in denied areas.

It would also be beneficial to accelerate development of a maritime-version of the UCAV, or UCAV-N, that could operate off large- and small-deck carriers.[54] The Navy's goal is for the UCAV-N to carry 1,800 kilograms of weapons on a 1,110 kilometer-radius strike mission.[55] Northrop Grumman's stealthy, kite-shaped, naval UCAV demonstrator, called Pegasus, is slated for flight testing this year.[56] A competing design is also being developed by Boeing. Within the mid-term, it may be possible to develop a longer range, refuelable variant of the UCAV-N, which could enable aircraft carriers to stand-off farther away from an adversary coastline, beyond the range of emerging anti-navy threats (e.g., long-range ASCMs) and still project power against inland targets.

High-Altitude, Long-Endurance Stealthy UAVs

Although UAVs have experienced their share of false starts and development setbacks over the last two decades, they finally seem to be coming of age. "Precursor wars" in Iraq, Bosnia, Serbia, and Afghanistan have provided a valuable indication of the potential future utility of unmanned aircraft. Moving forward in time two to three decades, stealthy, long-endurance UAVs were in high demand across all of the 20XX wargames. Participants found them to be a valuable complement to space-based remote sensing because unlike satellites that quickly pass over an area of interest, sensors carried aboard a UAVs can stare down at an area of interest for an

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[51] EMD is planned to begin in 2008. OSD, *Unmanned Aerial Vehicles Roadmap 2000-2025* (Washington, DC: DoD, April 2001), p. 9.

[52] According to George Muellner, vice president and general manager of Boeing Phantom Works, "The pacing item is the command and control so you have confidence in putting [UCAV] out there, operating autonomously, with a human in the loop to get weapon consent, and a human operating three or four of these vehicles." Frank Wolfe, "Boeing Proposes UCAV Acceleration to the Air Force," *Defense Daily*, April 24, 2001, p. 2.

[53] As discussed later in this chapter, the UCAV's ability to strike deep-inland targets in an anti-access environment would be further enhanced by the development and fielding of a stealthy aerial refueler.

[54] See Andrew Koch, "U.S. Navy Starts Work on UCAVs," *Jane's Defence Weekly*, April 19, 2000, p. 1; Robert Wall and David Fulghum, "Navy UCAV, Other Designs Defense Future Research," *Aviation Week & Space Technology*, November 20, 2000, p. 52; and David Fulghum, "U.S. Navy Eyes Full Range of Unmanned Aircraft," *Aviation Week & Space Technology*, November 6, 2000, p. 59.

[55] See Bill Sweetman, "UCAVs Spread Their Wings," *Jane's International Defense Review*, May 2001, p. 57.

[56] The operational version of the Pegasus is expected to have a wingspan of more than 60 feet, an operating altitude of 35,000 feet, a range of about 1,500 kilometers, and a payload capacity in excess of 2,000 pounds. Robert Wall and David Fulghum, "New Demonstrator Spurs Navy UCAV Development," *Aviation Week & Space Technology*, February 19, 2001, pp. 52-54; Frank Wolfe, "Boeing Unveils Bat-Winged Naval UCAV Offering," *Defense Daily*, April 27, 2001, p. 3; Linda de France, "Northrop Grumman Prepares to Fly Naval UCAV Demonstrator," *Aerospace Daily*, February 27, 2001.

extended period of time. In terms of getting the Air Force on the path leading toward a robust fleet of stealthy, long-endurance UAVs by 2025-2030, it would make sense to expand the Global Hawk program and, more importantly, initiate development of a stealthy HALE UAV as soon as possible.

The Global Hawk is currently configured to carry a sensor payload that includes an electro-optical and infrared sensor package, as well as a SAR system with ground-moving-target-indicator (GMTI) capability.[57] It has a range of 14,000 miles, a cruising speed of 350 knots, an altitude ceiling of over 65,000 feet, and an endurance of over 36 hours. Given these performance attributes, the Global Hawk can fly autonomously to locations up to 5,000 kilometers away from its base and transmit ISR data back to field commanders over satellite links for up to 24 hours at a time.

The Air Force plans to procure a total of up to 78 Global Hawk UAVs and 16 ground control stations.[58] According to current plans, which are tentative, Global Hawk UAVs will be procured at a rate of four per year starting in 2005. In addition to upgrading the Global Hawk with an improved SAR/GMTI radar or an active electronically scanned array (AESA) radar, DoD should also accelerate development of future payload alternatives such as an airborne communications relay, a lightweight SIGINT package, broadband jammers similar to those employed on the EA-6B Prowler, and a FOPEN radar. Aside from addressing today's pressing ISR requirements, the Global Hawk provides a valuable near-term opportunity for the Air Force to gain experience conducting unmanned, extended-range air operations.

While the Global Hawk is a capable aircraft, its ability to penetrate and loiter within contested airspace will likely erode as increasingly sophisticated air defenses (e.g., high-altitude, long-range SAMs such as the Russian-built S-300PMU2 and S-400 systems) proliferate over the next 25 years. What is needed is a *stealthy* version of the Global Hawk. Fortunately, most of the R&D required to field this type of system was conducted in the 1980s under the Advanced Airborne Reconnaissance System (AARS) program.[59] Originally intended to find and track mobile launchers for Soviet intermediate- and intercontinental-range ballistic missiles, the AARS platform, code-named "Quartz," was envisioned as an extremely stealthy UAV equipped with an array of high-resolution sensors and high-capacity satellite communications capabilities.[60] With a wingspan of some 250 feet, it would have been able to fly at an altitude of about 80,000 feet for

[57] For additional performance details for the Global Hawk, see: OSD, *Unmanned Aerial Vehicles Roadmap 2000-2025*, p. 4.

[58] See Office of the Director of Operational Test & Evaluation, *Annual Report FY 2000* (Washington, DC: DoD, 2001), p. V-159. Other sources indicate that the current plan is to procure 50-66 aircraft. See Bill Sweetman, "HALE Storms to New Heights," *Jane's International Defense Review*, March 2001, p. 51 and Bruce Rolfsen, "First U.S. Air Force Global Hawks to Fly by 2003," *Defense News*, March 12, 2001, p. 14.

[59] For an excellent overview of this program, see Ehrhard, "A Comparative Study of Weapon System Innovation: Unmanned Aerial Vehicles in the United States Armed Services," pp. 136-158.

[60] See John Boatman, "USA Planned Stealthy UAV to Replace SR-71," *Jane's Defence Weekly*, December 17, 1994, p. 1.

several days at a time. In outward appearance, it was more or less a substantially scaled-up version of the Darkstar UAV that was cancelled in 1999.[61]

A stealthy HALE UAV program based upon the AARS and Tier-III designs should be restarted soon.[62] Able to operate unescorted in contested airspace for an extended period of time, stealthy HALE UAVs could use passive sensor systems (e.g., electro-optical, infrared, PCL, and SIGINT) or a low-probability of intercept (LPI) AESA radar to provide continual ISR coverage over a wide swath of ground.[63] The AESA radar would be particularly advantageous in that it could be used to search for targets actively or passively, as well as to jam enemy radar systems. An AESA radar could incorporate a number of techniques for reducing the probability of intercept while emitting, including minimizing side lobes and reducing beam width. The signature could be further reduced by using two or more UAVs simultaneously, with each aircraft taking a turn emitting a radar pulse that would then be received and processed collectively.[64]

With a time-on-station measured in days, a stealthy HALE UAV could be particularly valuable for finding and tracking mobile, time-critical targets such as missile TELs and SAM launchers. This type of persistent surveillance could be critical to rolling back the anti-access capabilities of prospective adversaries. Stealthy HALE UAVs could also provide a meaningful hedge against the potential loss of imaging and communication satellites in a space Pearl Harbor.

Stealthy Transports and Aerial Refuelers

As mentioned earlier, stealthy transports were critical to ground-force insertion in the 20XX wargames. Similarly, without access to in-theater bases, players depended upon stealthy aerial refuelers to sustain low-observable assets operating in the teeth of the LPC's anti-access envelope.

At present, the U.S. military is not developing any type of capability for inserting special operations forces or conventional ground forces deep into the interior of a large country equipped with robust anti-access capabilities. Current airborne insertion methods (e.g., high-altitude, low-opening (HALO) drops from non-stealthy aircraft) will likely become increasingly untenable as the anti-access capabilities of potential adversaries mature over the next two decades.

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[61] See David A. Fulghum, "Stealthy UAV Is a Flying Wing," *Aviation Week & Space Technology*, July 11, 1994, p. 21; Michael Dornheim, "Mission of Tier 3 Reflected in Design," *Aviation Week & Space Technology*, June 19, 1995, p. 54.

[62] Lockheed's Skunk Works is apparently already developing some design concepts for a stealthy U-X based in part on technology developed under the Darkstar (Tier-III minus) program. See Amy Butler, "Lockheed Wants to Reach Deep into Hostile Turf with U-X Concept Plane," *Insidedefense.com*, June 20, 2001.

[63] The AESA radar for a stealthy UAV could be based upon the system that is currently being developed for the Global Hawk, JSF, F-22, and Joint Surveillance and Target Attack Radar System (JSTARS) platforms.

[64] See David Fulghum, "Stealthy UAVs Snag Rumsfeld's Attention," *Aviation Week & Space Technology*, June 4, 2001, p. 30.

As a complement to current covert, undersea delivery options, a stealthy means for the deep-inland insertion (i.e., up to 7,000 kilometers from the point of embarkation) of several SOF teams could be a very beneficial capability to have in future contingencies (e.g., a China-Taiwan conflict). Lockheed Martin has completed preliminary work on several stealthy "advanced theater transport" design concepts that could meet this requirement. Against a future adversary equipped with robust air defenses and other anti-access capabilities, a stealthy SOF insertion aircraft could be the only means available for inserting ground forces, albeit limited numbers of them, into deep-inland operating areas, especially early on in a conflict. Although only a relatively small number of SOF could be inserted and supported in this manner, they could contribute to U.S. power-projection operations by performing myriad special reconnaissance and direct-action missions. The latter might include, for example:

- Supporting distributed, multidimensional, strike operations by designating hidden or mobile targets for precision, stand-off attack;

- Conducting covert IW operations (e.g., gaining physical access into an adversary's C4ISR network); and

- Conducting small- to large-scale raids against critical nodes that cannot be attacked by other means for either technical or political reasons (e.g., high risk of collateral damage).

An intensive R&D program should be initiated now to develop and deploy a first-generation stealthy, long-range transport within the next 10-15 years. There could be a significant amount of technical risk associated with this development effort. However, absent an immediate program start, the U.S. military could be left without any practical options for the deep-inland insertion of SOF forces in an anti-access environment should the need arise between 2010-2020.

DoD should also develop and deploy low-observable refuelers into order to support extended-range air operations in denied-area threat environments. By enabling stealthy combat aircraft (e.g., the B-2, F-22, UCAV, and UCAV-N) to refuel in contested airspace, stealthy refuelers could tremendously enhance their overall combat effectiveness. For example, since the loiter time of manned combat aircraft would then be limited only by crew fatigue, they would be better able to locate and attack mobile, time-critical targets. A stealthy aerial refueling capability would allow the F-22 and UCAV to strike targets deeper inland in anti-access environments than would otherwise be possible. It would also enable F-22s to conduct denied-area, air-superiority operations much more effectively.

U.S. aerospace companies have already developed several alternative low-observable tanker designs. In comparison to transport aircraft, the technical challenges associated with applying signature-reduction technologies and design techniques to aerial refuelers would likely be considerably lower. The flying-wing and large bomb bay of the B-2, for example, could accommodate additional fuel stowage rather easily. Moreover, a stealthy refueler could almost certainly be based on the same airframe as the stealthy transport discussed above.

GROUND FORCES

As discussed earlier, owing to the 20XX threat environment, players tended to rely upon stealthy, light forces arranged into much smaller individual force packages than is the case today. Considerable importance was placed on supportability and signature management. As a result, "heavy" units like CARs that were organized around stealthy, 10-ton, electric-drive ACVs—light by today's standards—were not seen as particularly useful in this regime. When CAR units were allocated to them for mission planning, Blue teams often opted not to deploy them for three reasons:

1. The CAR was not seen as providing significant additional or unique combat capabilities;

2. The relatively large footprint of the CAR was considered to present an unacceptably high risk of detection by enemy sensors; and

3. The ACVs were too difficult to support logistically, especially in terms of force insertion and extraction.

The players generally concluded that the warfighting capabilities offered by the CAR could also be accomplished in other ways that were stealthier and less burdensome logistically. For example, the direct-fire capability of the ACV could be supplied by loitering UCAVs, while the indirect fire of the CAR's electric-drive missile launchers could be achieved with land- or sea-based missile pods, as well as offshore SSGNs, undersea strike modules, and submerged fire support ships armed with EM guns. Based on this same logic, one might question the future utility of the 80-ton Crusader self-propelled howitzer system.[65]

Deep Strike Brigades were also used sparingly for similar reasons. The players generally did not feel that the combat capabilities offered by stealthy attack helicopters outweighed the logistical challenge of supplying them with adequate fuel. Moreover, the helicopter's reconnaissance function could be performed by UAVs, which benefited from considerably longer loiter time, and close-strike missions could be conducted by UCAVs orbiting overhead. This reasoning would suggest that DoD might consider scaling back the procurement of the Comanche armed-reconnaissance helicopter. The Army currently plans to buy over 1,200 Comanche helicopters over the next 25 years at a cost of about $48 billion.[66]

The mostly highly sought ground combat capabilities in the 20XX wargames were exoskeleton-equipped infantry, UGVs, MAVs and microrobots, remote missile pods, and deception tools.

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[65] The Army officially plans to acquire 480 Crusader self-propelled artillery systems beginning in 2008 at a cost of about $11 billion. See Mark Thompson, "Blasting the Crusader," *Time*, January 15, 2001, p. 34. The Army has suggested that a beta battery equipped with six Crusader prototypes might be set up at Fort Sill, Oklahoma, to evaluate the system under field conditions as early as 2004.

[66] The Comanche entered into EMD in FY 2000. Production is projected to reach 62 helicopters per year by fiscal 2010 and would extend out until about 2026. See Marc Strass, "Army Considering Increase in Comanche Production Rate to 96 Aircraft Per Year," *Defense Daily*, April 19, 2001, p. 3; Ron Laurenzo, "Army Wants Leaner, Faster Helicopter Force," *Defense Week*, April 10, 2000, pp. 1, 15; Rowan Scarborough, "Copter Cutbacks Get Army Support," *Washington Times*, February 28, 2000, p. 1.

Performance-Enhancing Exoskeletons

As discussed in Chapter III, exoskeleton-equipped troops were used extensively throughout the 20XX wargame series. They were relied upon not only for close combat, including urban operations, but also for non-linear, distributed-strike operations in open terrain. When the 20XX wargames began over six years ago, the exoskeleton system was considered to be a very distant prospect from a technological point of view. While the exoskeleton idea was frequently touted as a truly revolutionary capability in that it could dramatically increase the lethality of the individual soldier, the participants questioned if it could ever be fielded.[67] Without any development programs underway, the feasibility of deploying a first-generation exoskeleton by 2020-2025 seemed remote.

Within the last two years, however, that technology forecast has changed considerably. DARPA is now in the early stages of designing and building a self-powered, wearable exoskeleton suit that could augment the speed, strength, and endurance of human soldiers. According to the acting director of DARPA, the Exoskeletons for Human Performance Augmentation program is focused on developing technologies that:

> [E]nhance a soldier's physical performance to enable him, for example, to handle more firepower, wear more ballistic protection, carry larger caliber weapons and more ammunition, and carry supplies greater distances. This will provide increased lethality and survivability to ground forces in combat environments, especially for soldiers fighting in urban terrain. . . [W]e plan to explore systems with varying degrees of sophistication and complexity, ranging from an unpowered mechanical apparatus to full-powered mechanical suits.[68]

Core technological enablers for the exoskeleton include energy efficient actuators, high-density energy storage, active control approaches that sense and enhance human motion, biomechanics and human-machine interfaces. With the possible exception of very high-density energy storage, the key enabling technologies for the exoskeleton are now reasonably close at hand. Moreover, important strides in energy storage have been made within the last year or so. The current goal is to conduct a proof of concept demonstration for an upper and lower-body exoskeleton system in the 2005 timeframe. A more robust operational system with considerably increased strength and endurance might be fielded by 2010-2015. If the lessons learned from the 20XX wargames are any indicator, DoD should fully fund and support this promising technology development initiative.

As a complement to the exoskeleton program, DoD should also consider expanding and accelerating the Objective Force Warrior program, which is a follow-on to the ongoing Land Warrior program. The Objective Force Warrior program is slated to receive about $240 million

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[67] It was often noted, for example, that the lethality of the individual soldier has not increased dramatically since the advent of the breach-loading rifle. The exoskeleton could not only increase the individual soldier's firepower but also his mobility, protection, and situational awareness.

[68] Dr. Jane Alexander, Acting Director of DARPA, *Testimony before Subcommittee on Emerging Threats and Capabilities of the Senate Armed Services Committee*, June 5, 2001, pp. 29-30. See also Frank Fernandez, Director of DARPA, *Testimony before Subcommittee on Emerging Threats and Capabilities of the Senate Armed Services Committee*, March 21, 2000, p. 29.

in funding over the next five years. At present, the scope of the program is relatively undefined.[69] The goal is to equip individual light infantry soldiers with the following:

- Jam-resistant, lightweight, high-bandwidth, secure communications gear;
- A heads-up visor that displays critical situational awareness information;
- Very lightweight personal armor and integral chemical and biological warfare (CBW) protection;
- A "active camouflage" uniform that changes color to blend into the local surroundings
- A micro-climate heating and cooling system; and
- An improved version of the Objective Individual Combat Weapon (OICW) complete with thermal and video weapon sights and a laser range finder;[70]

These types of capabilities could significantly enhance the lethality and overall warfighting effectiveness of future light infantry.

Unmanned Ground Vehicles

One of the recurring themes across the 20XX wargames was the need to maximize the combat power of the relatively small number of troops that could be deployed into the postulated sensor- and LRPS-rich threat environment. In addition to adopting network forms of organization made possible by advances in C3 technologies and taking advantage of the enhanced situational awareness conferred by new ISR systems, the players sought to increase the combat power of ground troops with stealthy, easily sustained UGVs.

A myriad of different combat support roles for UGVs are currently being explored.[71] For example, robotic platforms figure prominently in the Army's Future Combat Systems concept.

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[69] John Roos, "Objective Force Warrior," *Armed Forces Journal International*, October 2001, pp. 24-27.

[70] Many of these capabilities are being developed under the Lightweight Warrior Advanced Technology Demonstration program and the Future Warrior 2025 program. The OICW, which will replace the M-16 rifle and M-4 carbine starting in 2007, will be able to fire both 5.56 millimeter kinetic energy rounds and 20 millimeter high-energy, air-bursting munitions that can be programmed to burst at a specified location (e.g., at the corner of a building or above a foxhole or trench). See Sandra Erwin, "Land-Warrior Follow-On Planned for '04*," National Defense*, September 2000, pp. 15-20; George Seffers, "U.S. Army Envisions New Kind of Soldier," *Defense News*, February 14, 2000, pp. 1, 18; Kim Burger, "Independent Study Says Soldier Systems Not Being Transformed," *Inside the Army*, February 12, 2001, p. 1; Glenn Goodman, "Revolutionary Soldier," *Armed Forces Journal International*, October 1999, pp. 56-64; Scott Gourley, "Arming the Modern Infantryman," *Jane's Defence Weekly*, October 7, 1998, pp. 39-42.

[71] For a more detailed discussion of robotic ground system concepts see: John G. Roos, "WarBots: Eyes and Ears for MOUT Operations," *Armed Forces Journal International*, November 2001, pp. 58-61; Board of Army Science & Technology, *STAR 21: Strategic Technologies for the Army of the 21st Century: Special Technologies and Systems* (Washington, DC: National Academy Press, 1993); Robert Palmquist, Jill Fahrenholtz and Richard Wheeler, "Robotic Concepts for Small Rapidly Deployable Forces," May 30, 1996, paper submitted to DSB 1996 Study of Tactics and Technology for 21st Century Military Superiority; Scott Gourley, "U.S. Rethinks Unmanned Ground

Under the FCS program, two classes of UGVs are being developed, those capable of carrying a payload of less than 150 kilograms (e.g., sensors), and those capable of carrying over 1,500 kilograms (e.g., supplies or weapons).[72]

Future UGVs could serve as platforms for launching precision fires of all types; as porters, moving equipment and supplies; as scouts, performing dangerous forward reconnaissance and observation missions; as sentries, providing local area security in the field; or even as medics, providing doctor-assisted medical treatment and even performing battlefield surgery.[73] Specialized UGVs could also be built for clearing and mapping minefields; breaching walls, doors and other obstructions; detecting and returning fire against snipers; dispensing obscurants; and evacuating wounded personnel.

MAVs and Microrobots

Bird-sized MAVs could dramatically improve the local situational awareness of dismounted forces, especially in urban settings. Cheap and rugged enough to be issued to platoons, or even to individual soldiers, these tiny aircraft could be invaluable for forward scouting. For example, a soldier could take one out of his rucksack and instruct it to fly over an adjacent hill or down to the next city block to determine if enemy units are in the vicinity. As discussed in Chapter III, MAVs could also potentially be used as a vanguard force when taking down occupied urban building.

In 1996, DARPA launched a program to develop MAVs, which were defined as being no larger than 15 centimeters in any dimension. Considerable progress has already been made toward building MAVs that meet or exceed a range of ten kilometers, an endurance of 60 minutes, and a speed of 30 knots. A variety of propulsion alternatives are being explored, including fixed-wing, rotary-wing and flapping-wing designs.[74] While over a dozen different prototypes have been designed and tested, at present, they are all comparatively fragile and impractical for use in the field.[75] In order to field militarily useful MAVs, technological advances will be required in the following areas: aerodynamic control and platform stabilization in a low Reynolds-number regime;[76] high-density energy storage (e.g., next-generation batteries and fuel cells); ultra-light,

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Vehicles," *Jane's International Defense Review*, July 1999, p. 11; Hunter Keeter, "Marines Pursue Miniaturized UGV Technologies," *Defense Daily*, August 11, 1999, p. 4.

[72] Specific DARPA projects in this area include, for example: Mobile Autonomous Robot Software, Software for Distributed Robotics, and Tactical Mobile Robots.

[73] Malcolm Ritter, "Army Studies Robot Surgery," *Washington Times*, March 29, 1998, p. D8.

[74] See Mark Hewish, "A Bird in the Hand," *Jane's International Defense Review*, November 1999, pp. 22-28.

[75] Lee Gomes, "Creation of Small Avian Robots Helps Development of Spy Plane," *The Wall Street Journal*, April 6, 1999, pp. 1-3; David Mulholland, "Micro Vehicles Could Play Big Military Role," *Defense News*, November 1, 1999, p. 12; Michael Dornheim, "Several Micro Air Vehicles in Flight Test Programs," *Aviation Week & Space Technology*, July 12, 1999, p. 47; Niels Sorrells, "Six-Inch Miniature Aircraft Could be Eyes, Spies of Tomorrow's Soldiers," *Inside the Pentagon*, November 5, 1998, p. 17; Michael Dornheim, "Tiny Drones May Be Soldier's New Tool," *Aviation Week & Space Technology*, June 8, 1998, pp. 42-47; Bruce Nordwall, "Micro Air Vehicles Hold Great Promise, Challenges," *Aviation Week & Space Technology*, April 14, 1997, pp. 67-70; Warren Leary, "Tiny Spies Take Off for War and Rescue," *The New York Times*, November 18, 1997, p. C1.

[76] A Reynolds number is a measure of an airfoil's size multiplied by its forward speed. For a MAV with a wing smaller than 15 centimeters and a relatively slow forward velocity, the Reynolds number is very low compared to

low-power sensors and communication systems; and artificial intelligence required for autonomous operations.

Fortunately, considerable progress has been made in all four of these areas over the last several years.[77] Based on the status of ongoing MAV development programs, it should be possible to procure various types of robust, nearly autonomous MAVs within the mid-term that could perform local-area ISR missions, jam enemy sensors, drop microsensors, relay communications, and even identify, track and tag high-value enemy assets based upon ATR algorithms. Moreover, given current trends in microelectomechanical (MEMs) technology, there is good reason to believe that MAVs could indeed be cheap enough to issue to individual soldiers. Although current MAV prototypes typically cost about $20,000-50,000 each, this figure is expected to drop as low as $1,000-$5,000 per unit once they enter large-scale production.[78]

Over the next decade or so, it may also become practical to field microrobots that can move several kilometers over complex terrain with little or no human supervision. Disguised as commonplace articles (e.g., litter, construction materials or insects), these tiny robots could provide a valuable means of infiltrating into closed facilities, urban buildings and other denied areas. Their duties might range from clandestine ISR missions, to sentry duty, to perhaps even conducting lethal attacks against enemy personnel and critical C3 systems.[79] In order to field these types of microrobots within the mid-term, DoD should consider accelerating and expanding DARPA's Distributed Robotics program.

Remote Missile Pods

Remote missile pod, which were included in the first 20XX wargame held in 1995, were envisioned as expendable, air-droppable missile canisters that could be cued to fire up to six, 500-kilometer range missiles equipped with brilliant submunitions. The Defense Science Board (DSB) subsequently endorsed this idea in 1998 as the "missiles-in-a-box" concept.[80]

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traditional aircraft. In fact, the flight aerodynamics of a MAV are much closer to that of a bird or a large insect than to a traditional aircraft. Designing reliable flight control systems for MAVs, therefore, will require new research.

[77] See [www.darpa.mil/tto/mav]. See also: OSD*, Unmanned Aerial Vehicles Roadmap: 2000-2025,* pp. 9-10, A-33-A-35; Hewish, "A Bird in the Hand," pp. 22-28.

[78] Hewish, "A Bird in the Hand," p. 23. This year most of DARPA's MAV-related research was refocused toward development of an Organic Air Vehicle (OAV) as part of the Army's Future Combat System development program. According to DARPA, the OAV will be "small, lightweight, and inexpensive enough to be carried, launched, and operated by lower-echelon ground units." The goal is for the OAV to be less than one foot in any dimension, weigh less than two kilograms, and cost approximately $1,000 each in quantities of 100,000 or more. It is being designed to carry a variety of sensors, including LIDAR, infrared, and electro-optical systems. See Alexander, *Testimony before Subcommittee on Emerging Threats and Capabilities of the Senate Armed Services Committee*, p. 15.

[79] Bruce Bigelow, "Robotic Cockroaches the Next Army Special Forces?", *San Diego Union Tribune*, November 20, 1996, p. E2; Pat Cooper, "U.S. Army Develops Army of Tiny Robots," *Defense News*, November 11-17, 1996, p. 4; Mark Hewish, "Mini-Robots Sniff Out Chemical Agents," *Jane's International Defense Review*, June 1998, p. 87; and Pat Cooper, "Microrobots Will Help U.S. Combat Bio-Chem Weapons," *Defense News*, November 11-17, 1996, p. 22.

[80] This emerging weapon system was referred to by the 1998 DSB Summer Study as "Missiles/Smart Rounds in a Box." Defense Science Board 1998 Summer Study Task Force, *Joint Operations Superiority in the 21st Century*,

The "missiles-in-a-box" system was described as a lightweight cargo container loaded with a variety of precision-guided weapons that could engage targets hundreds of kilometers away. The container would also house a GPS-receiver for self-localization (i.e., determining its geo-spatial position), a tamper- and jam-resistant C3 module that could interface with all of the Services, and an automated fire control system. The containers and missiles could potentially be made light enough to insert with GPS-guided parafoils or semi-rigid wing deployment systems released from intercontinental transports, which could be an important insertion option in an anti-access threat environment.[81] Missile containers could be distributed throughout a theater of operations early on in a conflict, or even in peacetime. In place and ready-to-fire, they could provide highly responsive, precision fire support.

This type of system could be fielded within the mid-term by building upon the NetFires program currently funded by the Army and managed by DARPA. The objective of the NetFires program is to develop a containerized launch unit that is four by four by six feet in size, weighs about 1,000 kilograms, and houses 15 vertically launched missiles.[82] As part of this effort, Raytheon and Lockheed Martin are developing a 40 kilometer-range missile for attacking heavily armored targets, as well as a Loitering Attack Missile (LAM) that will be capable of flying at least 40 kilometers and loitering for at least 30 minutes. Alternatively, the LAM could fly directly to targets up to 200 kilometers away.[83] With the current NetFires design, a single C-130 could transport ten missile containers housing a total of 150 missiles.[84]

Many of these same technologies, of course, could be readily incorporated into 20XX-like remote missile pod prototype. The only major program adjustment would be building longer-range missiles, which should not present a major technical obstacle.

Deception Tools

During the 20XX wargames, players repeatedly used various types of deception tools to spoof enemy troops and their sensor systems. Deception tools were used to bait enemy units into revealing their location, to draw fire away from friendly forces, and to multiply the apparent size of U.S. ground unit formations. In short, deception tools were a critical enabler of ground operations, especially for close combat.

DoD should seriously consider developing and fielding multispectral decoys for ground vehicles. In concept, this would be much like the Miniature Air-Launched Decoy (MALD) system in use

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(October 1995), Volume II, Chapter 1, pp. 34-36. See also Ernest Blazar, "Tomorrow's Instant War," *Washington Times*, January 1, 1999, p. 8.

[81] Unpowered parafoils today can already support a payload of up to 40,000 lbs. See DSB, *Tactics and Technology for 21st Century Military Superiority* (Washington, DC: Office of the Secretary of Defense, October 1996), p. V-40. See also: John G. Roos, "High-Tech 'Sky Barge'," *Armed Forces Journal International*, July 1998, p. 52.

[82] Andrew Koch, "DARPA Works on Missiles for Possible Use on FCS," *Jane's Defence Weekly*, September 20, 2000, p. 12.

[83] Ibid.

[84] Alexander, *Testimony before Subcommittee on Emerging Threats and Capabilities of the Senate Armed Services Committee*, p. 16.

by the Air Force. The MALD system emits VHF, UHF, and microwave signals that resemble in power, amplitude and frequency distribution the radar signal that would be reflected by various types of U.S. combat aircraft.[85]

In addition, an intense R&D program should also be initiated to develop false-image generation technologies (e.g., three-dimensional holograph projections) that could be used to deceive optical sensors and human vision. If fielded, false-image generators could be used to make it appear that friendly forces are somewhere they are not, or to make a given U.S. ground force seem much larger than it actually is. Dynamic holographs could also be used in psychological operations.[86]

While the enabling technologies are comparatively immature in this area, some important strides have been made recently. The Army Research Laboratory has generated realistic three-dimensional images with lasers.[87] Under a program called "Mirage," several years ago DARPA explored the technological feasibility of developing a portable, three-dimensional, image projection capability that would be practical to set up and operate in the field. The holograph could be projected in free air containing a dispersed aerosol or gas.[88]

NAVAL FORCES

The 20XX wargame series presumes that increasingly effective anti-access capabilities will diffuse over the next two to three decades, including long-range ASCMs, submarines, mines, and sophisticated sensor systems. While it is unlikely that prospective adversaries will be able to field mature, anti-navy architectures similar to the one operated by the LPC in the 20XX games much before 2020, significant threats could emerge within the mid-term that present a serious challenge to traditional U.S. power projection from the sea.

Russia, for example, has reportedly sold the Kh-35 Uran and Moskit ASCMs to China.[89] The former is essentially a Russian version of the U.S. Harpoon system and has a range of about 130-140 kilometers, while the latter has a range of 250 kilometers and attacks its target at faster than Mach 2, while making rapid (10-g) turns to evade ship defenses.[90] Russia has also recently completed development of a supersonic ASCM that will probably be available for export within

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[85] While the MALD was designed to emulate the F-16 fighter, it could be adapted to mimic a wide range of aircraft, including bombers, stealthy platforms, UAVs, and UCAVs. See David Fulghum, "New Decoys May Simulate Stealth Aircraft Targets," *Aviation Week & Space Technology*, October 27, 1997, p. 71.

[86] While it would require a long-term R&D effort, it might eventually be possible to project a realistic false image of a political leader, a cultural icon, or a religious figure and then have the computer-generated image deliver a speech that serves U.S. interests.

[87] Andrew Gilligan, "Army Goes to War with Platoons of Holograms," *The Sunday Telegraph* (London), May 11, 1997, p. 5; George Seffers, "U.S. Army Studies Holograph Imagery," *Defense News*, May 5-11, 1997, p. 18.

[88] David Whelan, Briefing on DARPA Tactical Technology Office Projects (unclassified), March 1998.

[89] Dmitriy Safonov, "Moskit Has Been Completely Declassified. The Chinese Navy Will Get Unique Russian Missile," *Moscow Kommersant-Daily* (as translated by FBIS), April 14, 1998, p. 2.

[90] Ibid., p. 2. See also: Yihong Zhang, "China to Acquire Anti-Ship Missiles," *Jane's Defence Weekly*, February 21, 2001.

the next couple years.[91] This missile has a stand-off range of 300 kilometers and flies as close as five meters above the water during the terminal phase.[92] Next-generation ASCMs that are not only longer in range, but also stealthier, faster, and more difficult to intercept than currently fielded systems are expected to become available on world markets within the decade.[93] Meanwhile, according to the General Accounting Office (GAO), major classes of U.S. surface ships will have, at best, a low to moderate capability to defend themselves against 2012-class cruise missile threats.[94]

Over the last decade, Russia has fueled the proliferation of conventional submarines by exporting Kilo-class diesel submarines and related-technology to several countries including China, India, and Iran.[95] Prospective U.S. adversaries may also soon be able to purchase conventional submarines that take advantage of AIP systems and improved energy storage systems to extend their submerged endurance significantly. France, Germany, Italy, Pakistan, Russia, and Sweden, for example, all produce or plan to produce AIP submarines that could be exported.[96] Diesel submarines now becoming available on the world market also benefit from lower levels of radiated noise; increased submerged speed; greater diving depth; anechoic coatings and hull designs that make them less detectable by active sonar; and improved sensors, weapons, and battle management systems relative to older Soviet-era submarines such as the Kilo.[97] They are also being armed with more lethal weapons (e.g., wake-homing and advanced acoustic-homing torpedoes). In their home littoral waters and regional maritime chokepoints (e.g., straits), modern diesel submarines could pose a significant threat to commercial shipping and U.S. surface combatants.

Many countries are amassing large stocks of cheap, low-technology mines, which, if used properly, could be very disruptive to U.S. power-projection operations in littoral waters.[98]

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[91] Richard Scott, "Russia's 'Shipwreck' Missile Enigma Solved," *Jane's Defence Weekly*, September 5, 2001, p. 28.

[92] The supersonic SS-NX-26 or Yakhont ASCM uses an active/passive radar seeker for end-game target acquisition. Richard Scott, "Russia's Anti-Ship Missile Developments," *Jane's Defence Weekly*, August 30, 2000, p. 26. Russian firms hope to tap into what they estimate to be a $10-12 billion market for ASCMs through 2005. Nikolai Novichkov, "Russian Anti-Ship Missile Targets Multi-$B Market," *Jane's Defence Weekly*, June 9, 1999, p. 13.

[93] Richard Scott, "Global Developments in the ASCM Threat," *Jane's Intelligence Review*, June 2000, pp. 52-55. See also Robert Holzer, "Faster, Craftier Cruise Missiles Bode Ill for U.S. Ships," *Defense News*, May 28-June 3, 2001, p. 36; Robert Holzer, "Deadlier Missiles Threaten Naval Defenses," *Defense News*, July 7, 1999, p. 6; and Naval Studies Board, *Naval Forces' Capability for Theater Missile Defense* (Washington, DC: National Academy Press, 2001).

[94] GAO, *Defense Acquisitions: Comprehensive Strategy Needed to Improve Ship Cruise Missile Defense*, p. 13. See also: Owen Coté, "Assuring Access and Power Projection," *Conference Report*, MIT Security Studies Conference Series, Summer 2001, pp. 31-32.

[95] Other countries include Algeria, Poland, and Romania. See Project 877 Kilo class, Project 636 Kilo class, Diesel-Electric Torpedo Submarine at [http://www.fas.org/man/dod-101/sys/ship/row/rus/877.htm].

[96] Richard Scott, "Boosting the Staying Power of the Non-Nuclear Submarine," *Jane's International Defense Review*, November 1999, pp. 41-50; Richard Scott, "Power Surge," *Jane's Defence Weekly*, July 1, 1998, pp. 24-27; and Anthony J. Watts, *Underwater Warfare Systems 2000-2001*, (United Kingdom: Jane's Defence Group, January 2000).

[97] David Foxwell, "Sub Proliferation Sends Navies Diving for Cover," *Jane's International Defense Review*, August 1997, p. 30. See also: Coté, "Assuring Access and Power Projection," pp. 23-25.

[98] Mark Hewish, "Sea Mines, Simple But Effective," *Jane's International Defense Review*, November 2000, p. 45.

Dozens of countries are investing in modern mines that are triggered by a wide-range of influences (e.g., magnetic, acoustic, seismic, underwater electric potential, or pressure) and incorporate other advanced technologies to improve their lethality, reliability and versatility.[99] By taking advantage of inexpensive microprocessors, modern mines can target specific classes of ships. The National Academy of Sciences has estimated that, over the next twenty years, the Navy is likely to confront "smart mine fields" in which diverse kinds of mines—bottom, floating, moored, or propelled and guided—might be controlled by a system of networked sensors that can trigger specific mines in a sequence that would inflict maximum damage on a approaching fleet or shipping train.[100] Producers are also making mines more difficult to detect by crafting irregularly shaped designs, by applying anechoic coatings, by equipping them with self-burying capabilities, and by constructing them of non-magnetic, composite materials.

Given these technology diffusion trends, non-stealthy surface ships operating in an adversary's littoral waters may become vulnerable to attack long before the 2025-2030 timeframe of the 20XX game series. In order to hedge against the emergence of serious anti-navy threats within the mid-term, as well as to place the U.S. Navy on the transformation path leading toward a 20XX-like portfolio of maritime capabilities, DoD should consider converting up to eight SSBNs to SSGNs. In addition, it should initiate rapid operational prototype development programs for undersea strike modules, stealthy "Streetfighter" ships, extended-range UUVs, and submerged troop insertion vessels.

Nuclear-Powered, Guided-Missile Submarines (SSGNs)

As the number of SSBNs required for strategic deterrence declines over the next decade, owing both to arms control agreements and the rapid erosion of Russia's nuclear forces, DoD should consider converting up to eight of them to SSGNs. The 1994 Nuclear Posture Review (NPR) concluded that 14 SSBNs—four fewer than previously planned—would be sufficient to meet the nation's strategic nuclear deterrence requirements.[101] Until this year, these four surplus SSBNs were slated for de-activation, two in 2003 and two in 2004, at a cost of over $100 million per boat. The DoD budget for fiscal year 2003, however, is expected to include the funding necessary to refuel their reactors and begin the conversion process. Once refueled, they will be able to operate for another 20 years, based upon a 42-year expected service life.[102]

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[99] Ibid.

[100] National Academy of Sciences, *Technology for the United States Navy and Marine Corps, 2000-2035* (Washington, DC, National Academy Press, 1997), Vol. 1, Chapter VII, p. 22 (electronic version). See also: Robert Holzer, "U.S. Navy Seeks Ways to Counter Threat of Mines," *Defense Ne*ws, November 10-16, 1997, p. 12.

[101] If the START II agreement with Russia eventually enters into force, the United States would meet the treaty's limit of 1,750 SLBM warheads with 14 SSBNs, each carrying 24 D-5 missiles armed with five W-88 warheads (1,680 SLBM warheads in total). William J. Perry, *Annual Report to the President and the Congress* (Washington, DC: GPO, 1995), p. 87.

[102] See DoD, *Trident SSGN Study—Analysis of Converting Trident-Class Ballistic Missile Submarines (SSBNs) to Nuclear-Powered Guided-Missile Submarines (SSGNs)* (Washington, DC: DoD, 1999). Hereafter referred to as the *Trident SSGN Study*. See also: William H. McMichael, "Should Four Trident Subs be Scrapped or Rebuilt?" *Navy Times*, December 25, 2000, p. 10; Robert Holzer, "U.S. Navy Eyes Submarine Conversion," *Defense News*, May 3, 1999, pp. 1, 19; Walter Pincus, "Panel Urges Converting 4 Tridents to Conventional, Covert Weapon," *Washington Post*, January 29, 1999, p. 7; John Donnelly, "Navy Focuses on Tridents as Arsenal Subs," *Defense Week*, April 21,

Over the next decade, four additional SSBNs could become available for conversion. Regardless of whether or not the recent joint pledge by Presidents Bush and Putin to reduce the number of U.S. and Russian operational nuclear warheads to between 1,700 to 2,000 is implemented, most analysts believe it is unlikely that Russia will be able to field over 1,500 warheads by 2010. According to several reports, unless there is a large increase in defense spending, by 2008 the number of Russian operational strategic warheads is likely to fall to between 800-1,500.[103] Some analysts put the estimate as low as 500 warheads by the end of 2012.[104] Therefore, absent a major turnaround in the Russian economy or a rapid Chinese buildup of its nuclear forces, the United States could unilaterally draw down its nuclear forces to 1,500-3,000 deployed warheads over the next decade without a significant increase in strategic risk.[105] Even assuming that most of these warheads would be carried by SSBNs to reduce their vulnerability to a preemptive, counterforce attack, ten SSBNs would still be more than adequate for maintaining a credible nuclear deterrent. If each Trident D-5 was uploaded to eight warheads, for instance, a ten-boat fleet could carry nearly 2,000 warheads. If for some reason the strategic nuclear balance shifted unexpectedly, the U.S. military could quickly respond by deploying nuclear-armed, sea-launched cruise missiles (SLCMs) aboard SSGNs and SSNs, or by adding additional warheads to the bomber and ICBM legs of the strategic triad.

Each Ohio-class SSBN released from the nuclear deterrence mission contains 24 SLBM launch tubes that could be converted to other purposes. The two forward-most missile tubes could be converted into lockin/lockout trunks, which would allow Special Operations Forces (SOF) to come and go from the submarine while submerged. Interior modifications could also be made to the submarine to provide working, berthing and C2 space for 66 or more SOF personnel. Fittings could be added to the hull for attaching up to two Advanced Seal Delivery System (ASDS) mini-submarines or Dry Deck Shelters (DDSs).[106] The remaining 22 missile tubes could be modified to hold seven-pack canisters of Tomahawk cruise missiles or, when developed, other types of standoff missiles such as the Tactical Tomahawk, a naval variant of the Army Tactical Missile System (ATACMS), and a sea-launched variant of the JASSM. Since these canisters could be easily loaded and unloaded at port, the weapons inventory of an SSGN could be tailored to meet specific mission requirements.

1997, pp. 1, 14; Jim Courter and Loren Thompson, “Arsenal under the Sea,” *Sea Power*, June 1997, pp. 41-44; Jim Courter, “The Boomer Reborn,” *Proceedings*, November 1997, pp. 51-53.

[103] Arkin, Norris and Handler, *Taking Stock: Worldwide Nuclear Deployments* (Washington, DC: Natural Resources Defense Council (NRDC), March 1998), p. 12; David Hoffman, “Downsizing a Mighty Arsenal,” *The Washington Post*, March 16, 1998, p. 1.

[104] See Bruce Blair, *Testimony before the Subcommittee on Strategic Forces, US Senate Armed Services Committee*, March 31, 1998. According to Russia’s former First Deputy Prime Minister Yuri Maslyukov, the decay of Russia’s nuclear stockpile is even more acute. He concluded that in ten years, “the most we can hope for is several hundred nuclear charges.” Joseph F. Pilat and Terence T. Taylor, “Amid Russia’s Turmoil, Finishing START Remains a Priority,” *Wall Street Journal* (Europe Edition), October 15, 1998.

[105] For an in-depth discussion on the future of U.S. strategic strike forces, see Andrew Krepinevich and Robert Martinage, *The Transformation of Strategic Strike Operations* (Washington, DC: CSBA, March 2001).

[106] The ASDS is a 65-foot mini-submarine capable of transporting a SEAL team over 120 nautical miles. A DDS enables a submarine to launch and recover special operations personnel, vehicles and equipment (e.g., Combat Rubber Raiding Crafts) while remaining submerged. If two ASDS vessels were attached to the submarine, the missile load would be reduced to 140 missiles, and if two DDS units were attached, the missile load would fall to 126 missiles. DoD, *Trident SSGN Study*, ES-5, ES-6.

The conversion of up to eight SSBNs to an SSGN configuration over the next decade or so would provide a dramatic increase in the Navy's conventional, long-range, precision-strike power. With up to 154 missiles onboard, an SSGN would carry more than twice as many missiles as any other ship currently in the U.S. fleet. For example, the Arleigh-Burke-class destroyer (DDG-51) has 90 vertical launch system (VLS) cells, but only about 30 typically house land-attack missiles.[107] In fact, the load of Tomahawk missiles aboard a single SSGN would be about 70 percent of that available within an entire aircraft carrier battlegroup today. With a crew of only 144 and no escort or logistics support ships in train, the SSGN would also deliver Tomahawks far more economically than other platforms.

Moreover, the SSGN's ability to ripple fire all 154 missiles in six minutes would provide the Navy with a mass, unwarned, precision-strike capability.[108] This type of capability could prove valuable, for instance, in halting an advancing, multi-division armored force; shutting down an airfield for an extended period; or rapidly degrading an adversary's C4ISR capabilities. Owing to its stealth, adversaries would have no idea whether or not one or more SSGNs happened to be stationed off their coast. This uncertainty would bolster deterrence by complicating the cost-benefit calculus associated with launching a military attack against a friend or ally of the United States. Assuming they were operating like their SSBN counterparts with two crews per ship, eight SSGNs would be sufficient to have at least four boats forward deployed at all times (e.g., two in Persian Gulf area and two in the East Asian littoral).

Aside from giving a dramatic boost to the Navy's LRPS capability within the mid-term, SSGNs would also offer at least four other important benefits. First, SSGNs could provide a potent hedge against the earlier-than-expected development of robust anti-navy capabilities by prospective adversaries. Taking advantage of their inherent stealth, SSGNs could penetrate into an enemy's littoral waters with near impunity and, assuming that the requisite targeting information was available, launch precision strikes against critical anti-access nodes such as missile-TEL garrisons, C3 bunkers, air-defense radars and SAM launchers, and ASCM sites. By degrading the adversary's anti-access capabilities early on, SSGNs could enable other less stealthy assets to flow into theater at a lower level of risk.

Second, SSGNs would reduce multi-mission pull on other more specialized assets. For example, the regional CINCs currently require a certain number of Tomahawks to be in theater at any given time.[109] To meet this requirement, it is often necessary to pull attack submarines away from important ISR and ASW missions in other theaters. Similarly, destroyers and cruisers may be pulled away from air and theater missile defense assignments. With an SSGN in theater,

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[107] The DD-21 Land Attack destroyer, which has yet to be built, will carry about 100 land attack missiles. See DoD, *Trident SSGN Study*, p. 2-3. See also Owen Coté, *Mobile Targets from under the Sea* (Cambridge, MA: MIT, 1999), pp. 57-58.

[108] DoD, *Trident SSGN Study*, p. ES-3.

[109] The SSGN would help particularly in the Persian Gulf, where there is a requirement to maintain 300 Tomahawks on station in case Iraq should act up. The requirement sometimes forces ships to be there just to fill out the numbers.

fewer SSNs and surface combatants would be needed to meet a given CINC's requirement for available land-attack missiles.[110]

Third, SSGNs could help reduce the currently elevated operation tempo (OPTEMPO) of the SSN fleet. They could be equipped with the same sonar equipment that is currently being back-fitted aboard SSNs and SSBNs as part of the Acoustic Rapid COTS Insertions (ARCI) program. During the conversion process, SSGNs could also be outfitted with advanced towed acoustic arrays and upgraded ISR sensor suites. When so configured, they would have sonar and ISR capabilities on par with late-model SSNs. Accordingly, they could conduct most standard SSN missions such as ASW, ASuW, covert ISR operations, mine reconnaissance, and offensive mining.

Finally, the introduction of SSGNs into the Navy would provide a unique opportunity to experiment with futuristic submerged power-projection concepts. In addition to assessing the efficacy of various mixes of precision-strike weapons, SSGNs could be used to experiment with new types of submarine payloads such as recoverable UUVs and UAVs.[111] Current restrictions on the size and shape of UUVs and UAVs, which stem from the need to pass through a 21-inch torpedo tube, would be eliminated. In addition, given the tremendous storage space available aboard an SSGN, it could carry many more UUVs, UAVs and deployable sensors than is possible with SSNs. Outfitted with ASDS and DDS interfaces, converted SSBNs could also serve as a testbed for next-generation submerged troop-insertion concepts and systems.

Undersea Strike Modules

The Defense Science Board formulated the "stored undersea strike module" concept in 1998.[112] It was subsequently introduced into 20XX wargames. Players in 20XX games took full advantage of stored undersea strike modules for providing fire support to engaged ground forces as well as for conducting LRPS attacks against fixed and mobile targets.

The module is envisioned as a stealthy, submerged platform containing a large quantity of missiles that could be towed to an area of interest by a SSN. Once on station, the module would be released from the submarine and either bottom, self-anchor, or both. It would then power down to a sleep mode to preserve energy and keep its radiated signature as low as possible. In this mode, it could sit passively on the bottom for up to 12 months, and be awakened at any time by an encoded extremely low frequency (ELF) message or acoustic signal. Once on-board command and control systems were up and running, the module could receive targeting coordinates, or alternatively, coded references to preset target packages that had already been downloaded into its digital library. After launching the strike, it would wait for additional instructions, and after a pre-defined period of time had elapsed, return to its sleep mode. The

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[110] Stored Undersea Strike Modules could also help reduce multi-mission pull in this area.

[111] DSB 1996 Summer Study Task Force, *Submarine of the Future,* pp. 22-23, 27-28.

[112] DSB 1998 Summer Study, *Joint Operations Superiority in the 21st Century* Vol. II (Washington, DC: Office of the Undersecretary of Defense for Science & Technology, 1998), pp. 5-14. The description of the stored undersea strike module that follows is derived from the DSB report.

module could be towed back to ports around the world and rapidly refueled and rearmed. While the DSB did not specify how many missiles would be stored aboard the module, a magazine of a few hundred certainly seems plausible.[113]

Like SSGNs, stored undersea strike modules would offer theater CINCs a major increase in available precision firepower and would provide a useful hedge against emerging anti-access challenges. Modules could be inserted covertly into high-threat waters and would be extremely difficult to detect while on-station. With an endurance of up to 12 months, they could bolster conventional deterrence in key regions in a very cost-effective manner. DoD should consider implementing an R&D program focused on fielding a handful of operational undersea-strike-module prototypes within the mid-term. Based on lessons learned from operational testing and evaluation, a follow-on generation could be fielded in quantity beyond 2010.

Stealthy "Streetfighter" Ships

For the first six wargames in the 20XX series, there were no stealthy surface ships included in the U.S. order of battle. During Game VI, which focused on dimensional control, the players championed the idea of networked, stealthy surface ships with a relatively small individual displacement. They were primarily concerned with conducting surface, sea-control operations, such as embargo enforcement, in an anti-access environment. While submarines can be used to sink commercial shipping, they are obviously not suitable for boarding and inspecting vessels believed to be carrying contraband. They also argued that stealthy surface ships could also provide a hedge against the possibility, however remote, that a breakthrough in ASW could make submerged LRPS platforms more vulnerable to attack. Accordingly, a system called the "stealthy sea control frigate" was added to the U.S. order of battle in Game VII. The players found it to be a particularly useful sea-control asset, especially in Game VIII, which focused on littoral operations in East Asia.

Both as a hedge against the emergence of anti-navy threats within the mid-term and as a means of maintaining sea control in mature anti-navy threat environments, DoD should pursue the development of several "Streetfighter" ship prototypes over the next decade or so. The Streetfighter concept is the brainchild of Vice Admiral Arthur Cebrowski, the former president of the U.S. Naval War College and now Director of Force Transformation within OSD. While there is currently no detailed design plan for Streetfighter vessels, they are envisioned as fast, heavily armed, stealthy ships with a displacement of around 2,000 tons.[114] As a point of comparison, this would be about four times larger than the Sea Shadow stealth ship prototype developed in the 1980s.[115] An even smaller design in contention is the Sea Lance vessel concept

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[113] Instead of storing missiles, the undersea module could also house supplies, sensor systems, mine warfare systems, and various types of UUVs.

[114] According to some designs, the Streetfighter would have a catamaran hull form and would be constructed mainly with kevlar and carbon fiber. Greg Jaffe, "Debate Surrounding Small Ship Poses Fundamental Questions for U.S. Navy," *Wall Street Journal*, July 11, 2001, p. 1; Robert Holzer, "U.S. Navy Touts Stealth Warship," *Defense News*, March 8, 1999, pp. 1, 34.

[115] The stealthy Sea Shadow vessel, which was developed by Lockheed Martin in the early 1980s, is reported to have the following characteristics: 160 feet length, beam of 70 feet, draft of 14 feet, speed of 13 knots, and displacement of 560 tons. David Abel, "Navy Stealthy about Details of 'Sea Shadow' Ship," *Defense Week*, August

recently developed by students and staff at the Naval Postgraduate School. The Sea Lance is envisioned as a stealthy, 146-foot long catamaran with a displacement of about 500 tons that would tow a barge-like vessel containing a combination of sea-based sensors and munitions.[116] In the event of hostilities, Sea Lance vessels would rapidly disseminate these sensors and munitions over a wide area, which in turn would be quickly configured into a distributed network that could be accessed by friendly systems operating in the area.

The technology for building a stealthy, 2,000-ton displacement surface ship is already well in hand. The Streetfighter could not only build upon the technology used in the Sea Shadow demonstrator, but might also take advantage of design features and technologies incorporated into the Sea Wraith stealth frigate built by the United Kingdom's Vosper Thornycroft, the La Fayette-class frigate built in France, and the Visby-class corvette built in Sweden.[117] Given the requisite resources, it is certainly conceivable that several operational prototypes could be built within the next decade or so. Admiral Cebrowski has suggested that an experimental prototype could be built in a few years and a new Streetfighter-class could be fleet tested and fielded within ten years.[118] Operational prototypes of either Streetfighter or Sea Lance ships, or both, would not only provide a limited hedge against the emergence of adversaries equipped with robust anti-navy capabilities, they would also provide an invaluable testbed for evaluating concepts for conducting stealthy, network-based, surface operations in future high-threat littoral environments.

Long-Range, Multi-Purpose UUVs

In several of the 20XX wargames, participants leveraged UUVs for a wide-variety of missions. One of the principle reasons for doing so was to minimize the signature generated by manned SSNs. Rather than have an SSN itself hunt down an enemy submarine or hunt for mines, they thought it made much more sense to have onboard UUVs perform such functions. They relied on UUVs to find, tag, and map the location of enemy mines; to precisely survey and map the seafloor, including locating and manipulating sensor arrays and fiber optic cables; and to conduct "expeditionary ASW" far away from the host SSN.

As the first step in expeditionary ASW operations, UUVs and aircraft would deploy long sensor arrays, similar to today's ADS, in suspected enemy submarine operating areas. When a contact

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2, 1999, p. 7; and Abe Dane, "America's 'Invisible' Warship," available on-line at [http://www.popularmechanics.com/popmech/sci/9307STMIAM.html], July 1993.

[116] See Robert Holzer, "U.S. Navy Boosts War College's Sea Lance Concept," *Defense News*, February 19, 2001, p. 10 Dale Eisman, "Unconventional Ship May Be What Bush Has in Mind," *Norfolk Virginian-Pilot*, February 12, 2001, pp. 1-3.

[117] The Visby-class corvette, for example, incorporates numerous signature reduction techniques to reduce its RCS, above-water noise, hydro-acoustic noise, underwater electric potential, infrared signature, magnetic signature, and visual profile. See David Foxwell and Joris Janssen Lok, "Approaching the Vanishing Point: The Emergence of Stealth Ships," *Jane's International Defense Review*, September 1998, pp. 44-45. See also Joris Janssen Lok, "Visby Heralds Big Changes for Sweden's Hit and Run Navy," *Jane's International Defense Review*, August 2000, pp. 27-33.

[118] Geoff S. Fein, "Street Fighter Concept Evolves to Include Unmanned Version," *Inside the Navy*, September 18, 2000, pp. 1-2.

was detected, UUVs and ASW UAVs would be dispatched to investigate, and if possible, hunt down and destroy the enemy submarine. As discussed in Chapter III, participants also exploited UUVs to bait enemy assets into giving away their location.

Consistent with the findings from the 20XX series, a recent DSB task force on future submarine concepts identified UUVs as a high-priority research area and concluded that UUVs could perform many valuable missions in the future, especially in shallower waters, such as "surveillance, reconnaissance, mine-removal, people delivery, and others. . ."[119] At present, however, the utility of UUV systems is limited by the fact that most of them still need to be supervised closely by human operators, have a range of less than 100 kilometers, and have an endurance of, at best, about 24-48 hours.[120] Most UUV development programs currently underway are focused narrowly on mine reconnaissance and mapping.[121]

Advances in data-processing power, robotics (e.g., artificial intelligence and machine perception), high-density energy storage (e.g., fuel cells), and underwater communications (e.g., acoustic modems and laser links) could make it possible to field UUVs over the next decade that are much more capable than today.[122] The Navy plans to demonstrate a maritime reconnaissance UUV between 2002-2004 that can transit nearly 200 kilometers to its operating area and then spend at least 100 hours on station during a single sortie.[123] Between 2003-2005, it plans to demonstrate cooperative undersea search and survey operations with multiple UUVs, each able to map a swath of the sea floor nearly 400 meters wide and up to 100 kilometers long.[124] By building upon these programs, it should be possible to field autonomous UUV prototypes within the mid-term that have an operational range of several hundred kilometers and an endurance measured in days, or even weeks.

Submerged Troop Insertion Vessels

As part of the future warfare regime underpinning the 20XX wargames, it was postulated that the proliferation of wide-area sensors (e.g., space-based reconnaissance, HALE UAVs, submerged sensor nets, etc.) linked to very capable LRPS systems had made traditional, high-signature

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[119] DSB, *Report of the Task Force on Submarine of the Future,* p. 7, 23. See also: Christian Bohmfalk, "Admiral Calls For More Off-Board Unmanned Undersea Vehicles," *Inside the Navy*, September 11, 2000.

[120] Mark Hewish, "Robots from the Deep," *Jane's International Defense Review*, May 2001, pp. 46-53.

[121] The most prominent example of the latter is the Long-Term Mine Reconnaissance System (LMRS). Ibid., pp. 46-48. See also: Richard Scott and Mark Hewish, "Remote Hunting Key to Littoral Waters," *Jane's International Defense Review*, December 1999, pp. 48-54; David Abel, "Boeing Vehicles Could Help Clear Sea Mines," *Defense Week*, November 8, 1999, p. 2; David Abel, "Competition Heats Up for Underwater Vehicles," *Defense Week*, August 9, 1999, p. 2.

[122] State-of-the-art underwater acoustic modems used aboard current UUVs, for example, already support a data transfer rate of about 5,000 bits per second at a distance of five kilometers. This is sufficient to allow multiple UUVs operating in a particular area to share data and coordinate their activities. Rapidly deployable fiber optic networks and blue-green laser technologies could also help solve underwater connectivity problems. See Keven R. Schexnayder et al, "New Generation AUVs Enter Navy Operations Area," *Sea Technology*, December 2000, pp. 35-41.

[123] Hewish, "Robots from the Deep," p. 50.

[124] Ibid., pp. 50-51.

insertion platforms vulnerable to detection and attack. For example, large sealift vessels moored at known, fixed ports or amphibious assault ships operating close to shore would generate a readily detectable signature, especially if in the process of off-loading troops, equipment, and supplies. Once detected, they could be attacked with a wide array of precision strike weapons launched from platforms on land, in the air, or at sea.

Even if they braved this hazard, amphibious assault units would encounter a number of additional obstacles in moving troops and material from offshore ships to inland objectives. Amphibious assault vehicles, such as the Advanced Amphibious Assault Vehicle (AAAV) currently slated to enter into service with the U.S. Marine Corps, would not only be subject to a torrent of missile strikes, but they would also need to navigate through concentrated fields of lethal mines. Given the prevalence of SAMs with extended-range intercept capability and easily hidden MANPADS, high-signature, rotary-wing transports such as the V-22 would likely fare no better in a 20XX-like threat regime.

Given these challenges, future amphibious operations could become far smaller in scope and rely on more covert insertion methods than is the case today. For example, in the 20XX games, the U.S. fleet included submerged insertion, transport, and supply ships that were designed specifically for conducting amphibious operations from under the sea. As a first step in developing this type of capability, DoD should investigate the possibility of converting two or more of the "surplus" SSBNs mentioned earlier into submerged troop carriers.

With the additional exercise and living space made possible by converting the missile section of the boat, up to 300 troops could potentially remain at sea for long stretches of time without a major diminution in their physical readiness. In addition to ASDS mini-submarines, these troop-carrier submarines might also be equipped with larger submerged amphibious infiltration vehicles for ferrying troops and equipment from ship to shore. The submarines could, in effect, provide a long-endurance, stealthy, mobile operating base for conducting prolonged special-operations campaigns.

This capability could provide a valuable hedge against the emergence of anti-access threats that preclude U.S. grounds forces from being inserted by surface ships or non-stealthy airlifters. Each troop-carrier submarine could potentially insert and support more than 20 times the number of SOF personnel that can be inserted by an SSN. Moreover, given the amount of available space aboard an SSGN, these forces could also be better equipped and supported logistically.

Prior to the outbreak of hostilities, SOF units could conduct special reconnaissance missions to locate high-value targets that cannot be reliably identified by other means. During a conflict, they could designate targets for precision, standoff attack; conduct covert IW operations; and carry out raids against critical nodes and targets that cannot be attacked by other means. Operations by these units, however, would necessarily be limited to coastal areas. Until stealthy airlifters are fielded, the combination of troop-carrier submarines, SSGNs, and SSNs could be the *only* means available for inserting U.S. ground forces into severe, anti-access threat environments, especially early on in a conflict.[125]

Space Forces

In the 20XX wargames, both the U.S. and LPC militaries relied heavily upon satellites for terrestrial ISR, communications, and precision navigation and targeting. They were also equipped with broad menu of capabilities for fighting in, through, and from space. Systems included in their respective space order of battle, however, varied considerably in terms of their perceived utility. Moreover, in a few cases, the perceived utility of a system changed over the course of the 20XX wargame series.

In several of the early 20XX wargames, for example, SBLs were judged by players as very valuable owing to their apparent ability to intercept an adversary's ballistic missiles during their boost phase and to conduct offensive space control missions. During subsequent wargames, however, the SBL lost favor. In terms of the missile defense mission, players noted that adversaries could take a number of steps to counter the effectiveness of an SBL system. Moreover, given its size and cost, individual SBL platforms would be lucrative targets for ASAT weapons and space control microsatellites.

While there were many space systems that the players considered useful in the 20XX wargames, this section focuses on the following standout capabilities that are especially relevant to defense transformation within the mid-term:

- A space-based radar (SBR) constellation with GMTI capability;
- Space survivability enhancements;
- Space control systems, including microsatellites for proximity operations; and
- Global terrestrial-strike systems.

Space-Based Radar Constellation

Over the course of the 20XX game series players repeatedly stressed the value of having a SBR constellation capable of tracking multiple, non-stealthy, moving targets on land, at sea, and in the air. The U.S. military's space-based remote sensing network in the 20XX game, of course, also

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[125] Another option might be to use non-stealthy, high-speed troop insertion craft to insert forces in an anti-access environment. This would appear to be a poor alternative for at least two reasons. First, the basic assumption of this idea is that the insertion craft could transit sensor-laden waters and offload troops and equipment *before* the adversary could localize friendly forces and bring precision firepower to bear. Given trends in data processing power, connectivity and hypersonics, however, this assumption seems questionable. Second, the existence of large numbers of increasingly sophisticated mines could make it rather difficult to transit littoral waters at high speed, thereby negating this vessel's primary means of survival. In contrast, stealthy undersea ASDS vessels could move more slowly and deliberately through enemy minefields, possibly following a course mapped out by an advance force of counter-mine UUVs.

included electro-optical, infrared, and signals and communications intelligence satellites. The SBR constellation, however, was considered the crown jewel of the network.

Currently, however, the U.S. military has no means of tracking and targeting time-critical, mobile targets from space.[126] A constellation of about two dozen (or more) SBR satellites could provide near-continuous GMTI coverage of critical areas of the globe, day or night, and in all weather conditions.[127] Moreover, unlike manned reconnaissance aircraft such as the JSTARS, a SBR constellation would not be limited by overflight restrictions, basing availability, and crew fatigue. The performance of a SBR constellation would also be much less affected by terrain masking (e.g., mountains, urban structures and other tall obstructions). As a robust, distributed constellation it would also be more survivable than a large, non-stealthy airframe such as the Boeing 707 that houses JSTARS.

Appreciating the potential military benefits of such a distributed space-based radar constellation, the Air Force, DARPA and National Reconnaissance Office (NRO) launched an advanced R&D program in 1998 called, "Discoverer II." The goal of this research effort was to assess the technical feasibility and affordability of a space-based surveillance system offering GMTI, various types of SAR imaging and high resolution, digital, three-dimensional terrain mapping.[128] Unfortunately, in fiscal year 2000 over half of the funding for the Discoverer II project was cut ($68.5 million of the $108.5 million request). In making appropriations for fiscal year 2001, Congress effectively terminated the program. Of the $130 million requested, Congress appropriated only $30 million to the NRO to "undertake steps to further develop and mature low cost electronically scanned array radar technologies for space applications."[129]

Full funding for the Discoverer II R&D effort should be restored. If the program gets back on track soon, it may still be possible to conduct on-orbit tests of two operational-prototype satellites in the 2007-2008 timeframe. Assuming these tests are successful, a complete constellation should be built, tested and lofted into orbit as expeditiously as possible. According to the Air Force, an initial operational capability, comprising eight to 12 satellites, could be achieved by 2010 with a full operational capability following in 2013.[130]

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[126] While JSTARS can track and target multiple moving ground vehicles, the Boeing 707 airframe housing the system will likely become increasingly vulnerable to enemy air defense systems over time.

[127] In terms of meeting the goal of near-continuous coverage of critical areas of the globe, the technical tradeoffs between the size of the constellation, satellite altitude and inclination, and radar power and aperture are still being worked out. If this system is eventually fielded, the size of the constellation, for example, might be significantly smaller or larger than 24 satellites.

[128] This program was based on DARPA research on inexpensive, lightweight satellites under the Starlight program initiated in 1997. For a good overview of the Starlight-Discoverer II program, see:

[http://www.fas.org/spp/military/program.imint/starlight.htm].

[129] House of Representatives, *Appropriations Conference Report—FY 2001*, p. 264.

[130] Michael Sirak, "USAF Eyes Space-Based Radar by End of Decade," *Jane's Defence Weekly*, August 22, 2001, p. 8; Jeremy Singer, "Stenbit Proposes Faster Development of Radar Satellites," *Space News*, October 29, 2001, p. 6.

Space Survivability Enhancements

As the U.S. military relies more heavily on space for both force enhancement and force application, competitors will undoubtedly attempt to develop and field space-denial capabilities. As the former commander of U.S. Space Command, General Charles Horner cautioned, "Our military forces are so dependent on space that it's created a vulnerability for us. . . We may be faced with a Pearl Harbor in space."[131] The recent Commission to Assess United States National Security Space Management and Organization, chaired by Donald Rumsfeld prior to him becoming Secretary of Defense, reached a similar conclusion:

> The relative dependence of the U.S. on space makes its space systems potentially attractive targets . . . Those hostile to the U.S. possess, or can acquire on the global market, the means to deny, disrupt, or destroy U.S. space systems by attacking satellites in space, communications links to and from the ground or ground stations that command the satellites and process their data . . . An attack on elements of U.S. space systems during a crisis or conflict should not be considered an improbable act.[132]

These concerns were borne out in several of the 20XX wargames. Red teams often identified "over-reliance" on space as the Achilles' heel of the U.S. military. They repeatedly attempted to attack U.S. satellites in order to render the U.S. military "deaf, dumb, and blind." In light of this experience and the ongoing diffusion of space-denial capabilities to prospective U.S. adversaries, it would be prudent for DoD to take whatever steps are necessary to improve the survivability of U.S. space-based assets. Examples that were mentioned in both Games II (aerospace) and VII (deep-inland operations) include the following:

- Fielding a more capable ground- and space-based space surveillance system for characterizing and tracking objects in space;

- Taking advantage of advances in MEMS technology and signature reduction techniques (e.g., special coatings, radar absorbing material, and innovative designs) to fabricate small, stealthy satellites that are more difficult to find and track;

- Taking advantage of new manufacturing processes to produce cheaper satellites in order to add much needed redundancy to on-orbit constellations and ground-based replenishment stocks;

- Masking or camouflaging military satellites as innocuous, commercial satellites or "piggy-backing" military assets within commercial satellites to discourage attack;

- Incorporating co-orbital decoys into future satellites that could be released during periods of high tension, or in the event of hostilities in space; and

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[131] Comments at a Heritage Foundation Forum. See Andrea Stone, "Dependence on U.S. Satellites Makes U.S. Vulnerable," *USA Today*, January 11, 2001, p. 5.

[132] See Rumsfeld (chair), *Report of the Commission to Assess United States National Security Space Management and Organization* (Washington, DC: January 2001), p. viii.

- Designing satellites with the additional maneuvering capacity needed to "jink" periodically into slightly different orbits to complicate enemy tracking efforts.

Space Control Systems

Since prospective adversaries will be able to exploit space for ISR, communications, and precision navigation, and perhaps terrestrial strike, the U.S. military will need to be equipped with effective space control capabilities. Near- to mid-term investment options include:

- High-power jammers designed to interfere with satellite uplinks and downlinks;

- GPS jammers and spoofers; relatively low-power lasers that can temporarily blind or "dazzle" electro-optical and infrared sensors;

- Lasers with sufficient power to induce thermal overload in targeted satellites; and

- IW capabilities that can directed not only against the satellites themselves (e.g., sending false commands), but also against terrestrial nodes (e.g., satellite command and control facilities, data processing installations, etc.).

DoD should also consider accelerating the development of microsatellites capable of performing both lethal and nonlethal proximity operations. The latter might include jamming a satellite's uplinks and downlinks; bumping it out of its intended orbit; fogging the optics of imaging satellites; applying an opaque coating to a satellite's solar panels or shrouding them; or severing the power cables leading from a satellite's solar panels. At the more destructive end of the spectrum, proximity operations could include damaging a targeted satellite's electronics with a high-power, RF weapon or rendering it inoperable with a small, well-placed, high-explosive charges.[133]

During peacetime, most of these small- or micro-sized satellites could be stored near U.S. space launch facilities. If a crisis were to erupt, however, dozens of them could be placed into orbit at once with a single SLV. At which point, they could maneuver clandestinely toward targeted satellites and shadow them.[134] If hostilities commenced, these stalker satellites could begin immediate space control operations.

The Air Force is already planning to conduct a series of experiments, referred to as the "XSS program," to demonstrate the maturity of microsatellite technology.[135] The first experiment in the

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[133] In the recent "Schriever 2001" space wargame set in 2017, for example, the U.S. team was equipped with microsatellites that could block the view of enemy satellites, jam their transmissions or damage their electronics with radiation. Thomas Ricks, "Space Is Playing Field for Newest War Game," *Washington Post*, January 29, 2001, pp. A1, A12.

[134] In designing proximity-operation satellites, a tension would likely exist between making them small enough to evade detection versus increasing their size to enhance maneuverability and extend on-orbit longevity.

[135] For an overview of the XSS and related micro-satellite programs, see: OSD, *Space Technology Guide FY 2000-01* (Washington, DC: DoD, 2001), pp. 12.5-12.10.

series, dubbed XSS-10, is scheduled for 2002 and is expected to demonstrate semi-autonomous operations of a microsatellite in space, including close proximity inspection of a space object.[136] XSS-11, which is slated for 2004, is designed to demonstrate autonomous microsatellite operations and gain experience with command and control of proximity operations.[137] During the experiment, the 100-kilogram XSS-11 satellite will fly several hundred kilometers away from its expended booster and then return to within 10 meters to inspect it autonomously with an onboard sensor payload weighing up to 15 kilograms.[138] This program should be accelerated and broadened to include a menu of non-lethal and lethal proximity operations capabilities.

Global Terrestrial Strike

While the basic concept of conducting rapid, global strikes from space was appealing, players were less than enthusiastic about space-to-ground attack satellites capable of de-orbiting inert, precision-guided projectiles. They favored trans-atmospheric vehicles (TAVs) or space planes, which could achieve a similar result without the attendant financial, political, legal, and technical burdens associated with permanently stationing terrestrial-strike weapons in orbit. Moreover, since they could be launched into innumerable trajectories, TAVs were also considered to be more survivable than satellites flying in very predictable orbits.

Through the mid-term, the only practical option for developing a rapid, global terrestrial strike capability appears to be the Smart Hypersonic Vehicle (SHV). The SHV is envisioned as an unmanned, rocket-powered, fully reusable, sub-orbital vehicle that would take-off and recover vertically.[139] The SHV would be based upon the same technology developed and tested under the DC-X program in the 1990s.[140] Atop the SHV could be placed either a Space Maneuver Vehicle (SMV) upper-stage for space-control operations, or as many as ten expendable Common Aero Vehicles (CAVs) for conducting precision strikes against terrestrial targets.

The SMV could refuel friendly satellites, repair damaged satellites, jam enemy satellites, launch co-orbital ASATs, or conduct other offensive and defensive space control missions. The CAV is currently under development and is slated to be flight tested in 2003-2004. It is basically a 12- to 16-foot long, cone-shaped, maneuvering reentry vehicle that could carry and dispense up to six

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[136] Dr. Donald Daniel, Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering, *Statement before the Senate Armed Services Subcommittee on Emerging Threats and Capabilities*, Hearing on "Fiscal Year 2002 Air Force Science and Technology," June 2001, p. 16.

[137] Ibid.

[138] Mark Hewish, "U.S. Air Force to Test Lockheed Microsatellite," *Jane's International Defense Review*, September 2001, p. 8.

[139] This system should not be confused with the SOV that was envisioned as a military spin-off of the recently canceled X-33/X-34 technology demonstrator effort and the X-43 development effort run by NASA. For more information on the SOV concept, see: Keith Hall, *Statement of the Senate Armed Service Subcommittee on Strategic Forces*, March 8, 2000, p. 8; William B. Scott, "Is USAF Sandbagging Spaceplane Project?" *Aviation Week & Space Technology*, November 20, 2000, p. 60; Bill Sweetman, "Securing Space for the Military: Hypersonic Military Spaceplanes Go Quietly about Their Business," *Jane's International Defense Review*, March 1999, pp. 49-55.

[140] The DC-X experimental rocket, or Delta Clipper, was successfully flight tested several times before it was destroyed in a NASA test. See Michael Dornheim, "DC-X Holds Promise: Big Questions Remain," *Aviation Week & Space Technology*, August 28, 1995, pp. 56-59.

powered, Low-Cost Autonomous Attack System (LOCAAS) munitions, three SDBs or other PGMs.[141] Instead of acting as a PGM bus, the CAV itself could be hardened to serve as a unitary, kinetic-kill projectile for attacking some classes of hardened and deeply buried targets.

If successfully developed, SHVs armed with CAVs could strike fixed and possibly mobile targets as distant as halfway around the earth in tens of minutes after launch.[142] A single sortie employing six CAV-armed SHVs, for example, would be sufficient to engage up to 360 discrete targets nearly anywhere in the world. Moreover, they could recover, refuel, rearm, and strike again within a matter of hours. Given the retraction in U.S. forward basing overseas over the last decade, the strategic need to project power to distant corners of the globe, often on short notice, and the ever-present possibility of strategic surprise, this type of capability could be invaluable.

The key enabling technologies for the SHV have already been developed and evaluated under the DC-X program. In fact, two different versions of the DC-X were flight tested between 1993-1996. By leveraging this investment, DoD and industry sources estimate that a prototype SHV-CAV system could be fielded within the decade with the requisite funding.[143]

BW AND IW FORCES

Although defensive BW and a full-range of IW capabilities were included in the 20XX order of battle, capability tradeoffs in these areas have not yet been explored in any depth. In terms of BW, one lesson that can be derived from the 20XX wargames is that new technologies that reduce the threat posed by advanced BW agents could be critical to the survival of U.S. troops in the future. Candidate areas for investment include the following:

- Lightweight, breathable protective suits fabricated from novel biomaterials;
- Extremely sensitive biosensors and lidar-based sensors able to detect BW agent clouds at standoff range;
- Broad spectrum anti-viral and antibiotic drugs; and
- New immunization techniques such as DNA vaccines and therapies.

The competition between offensive and defensive IW is likely to be central to warfare in a mature RMA regime. Through the mid-term, DoD should invest in both offensive and defensive capabilities. In terms of defenses, candidate investments include the following:

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141 The CAV would be boosted into the desired trajectory with a low-cost, expendable upper-stage or modular insertion stage (MIS). After separation, the CAV would have a cross-range of over 2,400 nautical miles. William B. Scott, "Wargames Zero in on Knotty Milspace Issues*,"* *Aviation Week & Space Technology*, January 29, 2001, p. 52; and USAF Scientific Advisory Board, *Why and Whither Hypersonics Research in the U.S. Air Force* (Washington, DC: USAF, SAB-TR-00-03, December 2000), pp. 35-36.

142 The requisite targeting information could be provided by loitering UAVs or SBR satellites.

143 Conversation with and briefing from U.S. Air Force Lieutenant Colonel Bill Bruner, March 16, 2001.

- Hardening of critical electronic systems to RF weapons;

- Cyber intelligence tools such as "virtual agents" that could provide early warning of hostile actions;

- Global access control solutions such as public key infrastructure systems comprising millions of access "tokens" distributed around the world and biometric user authentication systems;[144]

- More reliable intrusion detection and monitoring systems (i.e., fewer false alarms), including those based upon automated, anomalous behavior detection and the correlation of data from multiple defensive systems;

- Malicious code detection and mitigation;

- Fault tolerant, "self healing" networks;

- Attack attribution capabilities such as message signature processing and active code beacons; and

- Network integrity restoration, recovery, and reconstitution capabilities.

Owing to classification issues, it is not possible to describe investment opportunities for improving the offensive IW capability of the U.S. military. To the fullest extent possible, DoD should extend the U.S. military's apparent lead in offensive IW by investing in the development and fielding of more powerful CNA tools. In addition, DoD should support the development and fielding of RF weapons (e.g., conventional EMP and HPM devices) designed to damage the sensitive electronic equipment upon which modern militaries increasingly depend.

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[144] Tokens are keys of different types that are required to gain access to a network or run certain applications. They can range from small devices that physically plug into computers, to credit card-sized devices that display new passwords every minute or so in synchronization with a server, to so called "smart cards" that contain an embedded computer chip. Biometric user authentication systems use fingerprints, retina scans, voiceprints or other biological markers to confirm an individual's identity prior to granting them access to a network. See David Freeman, "Information Warfare," *Technology Review*, November 2001, p. 64; and Frank Tiboni, "Pentagon Emphasis Shifts to Network Protection," *Defense News*, October 15-21, 2001.

V. AREAS FOR FUTURE RESEARCH

Future RMA wargaming efforts could profitably focus upon:

- Examining in more detail promising operational and organizational concepts that have been developed thus far, perhaps by integrating simulation tools into the wargaming process;
- Investigating selected operational issues in more depth such as unmanned operations, undersea operations, and the role of SOF in a 20XX-like regime;
- Analyzing tactical interactions and competitions to a greater degree;
- Exploring the strategic uses of coercion;
- Relaxing scenario constraints on strategic strikes against the homelands of nuclear powers;
- Expanding the scenario set to include conflicts between China and Japan;
- Revisiting the conduct of multi-theater and global campaigns in a 20XX-like warfare regime; and
- Addressing larger questions of grand strategy, emerging strategic challenges (e.g., threats to global financial markets), and the dynamics of long-term competition with rising powers.

Games and workshops could also be designed to consider mid-term transformation challenges and explore paths to 20XX-like forces and concepts more directly. Two scenarios that come to mind in this regard are defeating a Chinese asymmetrical attack on Taiwan and rapid power projection in the face of a failed nuclear state (e.g., Pakistan). In both cases, critical transformation challenges could be explored in the following areas:

- Power projection in an anti-access, deep-inland environment;
- Assuring the survivability of U.S. space assets and controlling an adversary's access to space;
- Offensive and defensive information operations; and
- Large-scale, ground-force operations needed to rapidly defeat a robust adversary and gain control of multiple critical nodes, including those in densely populated urban areas.

The games could employ an alternative-forces methodology in which the anticipated military effectiveness of baseline forces and selectively transformed forces could be evaluated in the context of one or both of above-mentioned scenarios.