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"The Penultimate C4ISR Challenge: Reducing Military Manpower and Total Operating Costs"

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"The Penultimate C4ISR Challenge: Reducing Military Manpower and Total Operating Costs"

Abstract

Military officials, respected think-tanks and Congressional researchers are universal in their contention that the cost of military manpower makes up the largest part of the total ownership cost (TOC) of military systems across all the Services. These same officials also note that overall military manpower costs are the fastest growing accounts even as the total number of military men and women decrease.

This challenge has been addressed at various conferences and symposia – including multiple times in the ICCRTS fora – and those who have studied the issue are universal in their opinion that "something must be done" to reduce military manpower to reduce TOC. But thus far, solutions and "best practices" have been elusive.

Network-Centric technologies combined with the emerging disciplines of human factors engineering (HFE) and human systems integration (HSI) offer the potential to realize significant manpower savings. But these network-centric methods and practices have been employed only sporadically to reduce manning and today remain extraordinarily underleveraged.

We will offer a best-practices model and show how using these methods and practices have dramatically reduced manning for the U.S. Navy's DDG-1000 *Zumwalt*-class destroyer and will extrapolate these lessons learned for a community of best practices that is now emerging.

Perspective:

"Tools, or weapons, if only the right ones can be discovered, form 99 percent of victory….Strategy, command, leadership, courage, discipline, supply, organization and all the moral and physical paraphernalia of war are nothing to a high superiority of weapons – at most they go to form the one percent which makes the whole possible."[1]

J.F.C. Fuller (1919)
Quoted in *War Made New*

While few today would ascribe to Major General J.F.C. Fuller's contention regarding the influence of technology on not only warfare, but the course of history, the impact innovation and technology have on military power is profound.[2] As Max Boot points out elsewhere in *War Made New*, "Few would deny that at least the first three (revolutions) were periods when new technology combined with new tactics to reshape the face of battle."[3]

However, the link between the invention of a new technology and its impacting warfare is never assured. What has proven crucial has been how aggressively nations develop, test, improve and field these technologies as weapons of war. In *Global Trends 2025*, the Director of National Intelligence and the National Intelligence Council address the importance of shepherding new technologies to the point where they transition to the end-users, noting; "The pace of technological innovation will be key. Major technologies historically have had an 'adoption lag.'"[4] Max Boot captures how uncertain this transition is, noting, "Inevitably, there was a lag, ranging from a few decades to a few centuries, between the initial development of a technology and the moment when it transformed the battlefield."[5]

Today, most would agree that the pace of technological change has accelerated and the United States has been especially adept at inserting new technology to pace the threat. As Bruce Berkowitz points out in *The New Face of War*, "Recent experience suggests that the right technology, used intelligently, makes sheer numbers irrelevant. The tipping point was the Gulf War in 1991. When the war was over, the United States and its coalition partners has lost just 240 people. Iraq suffered about 10,000 battle deaths, although no one will ever really be sure. The difference was that the Americans could see at night, drive through the featureless desert without getting lost, and put a single smart bomb on target with a 90 percent probability."[6]

The U.S. military understands the profound impact innovation and technology have on the future of warfare, the need for continuous technological experimentation and insertion, and the "unknown unknowns" regarding what future technologies will be needed for America's military decades hence. One of the U.S. military's most forward-looking publications – and the one that under-girds the entire family of Joint publications – the *Joint Operating Environment 2010*, puts the issue of technological uncertainty in stark terms by describing the astounding changes in just the last quarter-century:

> One might also note how much the economic and technological landscapes outside of the military have changed…On the technological side, the internet existed only in the Department of Defense; it's economic and communications possibilities and implications were not apparent. Cellular phones came equipped with briefcases and shoulder straps and only worked in select urban areas. Personal computers were beginning to come into widespread use, but their reliability was terrible. Microsoft was just emerging from Bill Gates' garage, while Google existed only in the wilder writings of science fiction writers. In other words, the revolution in information and communications technologies, taken for granted today, was largely unimaginable in 1983.[7]

While technological change has impacted the U.S. military writ large, the available evidence suggests that technological change has impacted the U.S. Navy and Marine Corps more so than the other Services. The Navy has a rich history of concept generation, concept development, technology innovation and insertion, and embracing both evolutionary and revolutionary changes in technology that have altered the face of naval warfare. That tradition continues today. As noted by a former Chief of Naval Research; "The Navy/Marine Corps of today and tomorrow are and will remain critically enabled by the power of science and technology put to work for our Sailors and Marines."[8]

The U.S. Navy's innovative technology development builds on over 500 years of naval technology that has changed the course of battle – and in many cases – history. From the superior oceangoing sailing ship and heavy cannon technology that helped Elizabeth I defeat the Spanish Armada, to the Civil War-inspired development of ironclad ships in the mid-1800s, to

Japan's ability to better harness the technologies in the transition from sailing ships firing solid cannonballs to turbine-powered dreadnoughts spewing high-explosive shells, to the World War II transition from battleships to aircraft carriers as the principal ship-of-the-line for first class navies; one navy's ability to defeat the other has often depended on who inserted the best technology the fastest and most effectively.[9]

One of the reasons the U.S. Navy is the most powerful Navy ever fielded, and, according to Secretary of Defense Robert Gates, "Larger than the next 13 navies combined,"[10] has been the Navy's support for scientific and engineering-development efforts. Such efforts have ranged from the Navy's support of the optical research of Lieutenant Albert Michelson in the early 1900s, to support for Thomas Edison's experiments, to research into the physical understanding of long-range radar, to the earliest feasibility investigations of nuclear submarine propulsion, to today's support of a wide-ranging portfolio of science and technology, research and development, engineering feasibility, and test and evaluation.[11]

Often, technological innovation and development has reached "closure" as the Fleet or the Fleet Marine Forces bring an operational requirement to the Navy and Marine Corps R&D and Acquisition communities, the requirement is met by inserting new technology, and, except for incremental, evolutionary, improvements to that technology, the enterprise moves on to solve the next technology challenge. However, today, there is one area where technological innovation impacts *all* aspects of Navy acquisition, S&T, and R&D activities. What is that area? Today, the U.S. Navy is making enormous strides in the area of total ownership costs (TOC) by pioneering initiatives designed to substantially reduce manning on Navy ships.

Much of this work is through the discipline of Human Systems Integration (HSI). This paper will address the Navy's challenges and opportunities in using HSI to dramatically reduce manning on one Navy ship (the DDG-1000) as well as cutting-edge HSI efforts at the Navy's C4ISR laboratory, Space and Naval Warfare Systems Center, Pacific (SSC Pacific).[12]

Emerging Requirements:

"Hybrid wars blend the lethality of state conflict with the fanatical and protracted fervor of irregular warfare."[13]

Lieutenant Colonel Frank Hoffman (U.S. Marine Corps, retired)
"Hybrid Warfare and Challenges"
Joint Forces Quarterly, 1st Quarter 2009

With the global economy in crisis to the extent the Director of National Intelligence, Admiral Dennis Blair calling it "The top threat to the United States,"[14] with the wars in Iraq and Afghanistan still ongoing, with a Secretary of Defense directing the U.S. military to focus on today's needs and not just worry about "next-war itis,"[15] and with the enormous sums of money required to "reset" the current force as well as fund weapons systems already planned, any new military technology must do more than just offer the *potential* to reshape how the military fights in the future – it must also have the ability to close current warfighting gaps.

The Navy's view of "How the U.S. Navy of the 21st Century will organize, integrate, and transform," embodied in the Navy's Vision Document, *Sea Power 21: Projecting Decisive Joint*

Capabilities, divides naval capabilities into sea strike, sea shield, sea basing, and FORCEnet.[16] This Vision, which has informed successor documents such as *A Cooperative Strategy for 21st Century Seapower,* calls for a 21st Century Navy that can project persistent, responsive, and precise power (Sea Strike), project global defensive assurance (Sea Shield), achieve operational independence for a new century (Sea Basing) and turn information into power (FORCEnet).

A Cooperative Strategy for 21st Century Seapower focuses the Navy, Marine Corps and Coast Guard on the Sea Services' primary mission with the overarching statement, "United States seapower will be globally postured to secure our homeland and citizens from direct attack and to advance our interests around the world." This strategy, the Navy, Marine Corps, and Coast Guard's first new maritime strategy in a generation, then lists six core capabilities for U.S. maritime forces, four "traditional missions" (Forward Presence, Deterrence, Sea Control, and Power Projection) and two new missions (Maritime Security and Humanitarian Assistance and Disaster Response).[17]

The dramatic changes in the nature of warfare has ushered in a new term "hybrid warfare," that defines the challenges the Joint force and the Navy-after-Next will face over the next decade. Secretary of Defense Robert Gates popularized this term in his article in *Foreign Affairs*, noting, "In reality . . . the categories of warfare are blurring and no longer fit into neat, tidy boxes. One can expect to see more tools and tactics of destruction – from the sophisticated to the simple – being employed simultaneously in hybrid and more complex forms of warfare."[18]

This hybrid warfare environment changes the focus of the U.S. military from having to deal solely with the exigencies of the global war on terrorism or take on the task of somehow preparing for major combat operations against an unnamed peer competitor on some distant horizon, to dealing with both irregular warfare and traditional threats (read, conventional warfare) *today*. The Secretary of Defense, as well as others in positions to determine how the U.S. military will train, equip, and fight in the near- and mid-term, are defining a re-engineering of the military for the warfighting realities of the next decade.[19]

Global Trends 2025: A World Transformed envisions a future where economic growth has the potential to fuel the rise of emerging nations such as "the BRICs" (Brazil, Russia, India, and China). It sees a China with the world's second largest economy and a nation that will be a leading economic power, an India that enjoys rapid economic growth and strives to be part of a multipolar world where it is one of the poles, a Russia that is richer, more powerful and more self-assured, and a Brazil that is exercising greater regional leadership. It also envisions the rise of other powers, most notably Indonesia, Iran, and Turkey, that will seek to assert regional dominance.

Regardless of which of the four scenarios this publication postulates; a "world without the West" where new powers supplant the west, an "October surprise," where global climate change narrows the options of all nations, the "BRICs bust up" where disputes over vital resources emerges as a source of conflict among major powers, or "politics is not always local" where nonstate networks emerge and supplant government in setting the international agenda, the potential for traditional, conventional, state-on-state conflict is enormous and this is a world where the United States could likely be drawn into any number of conflicts.

But *Global Trends 2025: A Transformed World* also envisions a world where the potential for irregular or non-traditional conflict looms large. As some regions, such as Sub-Saharan Africa and parts of Latin America, fall even further behind economically and as the impact population growth in these areas and worldwide climate change exacerbate the scarcity of resources, the potential for failed states to become breeding grounds for radical groups and insurgencies increases, possibly dramatically. [20]

The Joint Operating Environment 2010 follows a different methodology to look at potential scenarios and their impact on the conduct of military operations in the 21st Century. But in doing so it also reaches the conclusion that future conflicts will feature a blending of regular and irregular forms of warfare as well as a convergence between terrorist organizations and transnational crime. It envisions this future world – based on the outcomes of various potential scenarios – as one that increases the complexity of the missions the Joint force may have to undertake.[21]

This world will challenge the ability of the U.S. military – and especially the Navy – to remain relevant across the potential spectrum of conflict. While the Navy-after-Next will need to continue to dominate the littorals, it will need to project power deeper inland for Marine Corps forces and support those forces as they maneuver. It will need to reach even deeper inland to support special operations forces fighting an irregular and unconventional foe, defend against proliferating ballistic and cruise missiles in the hands of a host of littoral nations, defend against swarming small boats in the increasingly crowded littoral, and deal with a range of other threats today's weapons systems are only marginally capable of dealing with.[22]

One of the platforms the Navy is building to deal with this hybrid warfare environment is the DDG-1000. While the attributes of this ship are not the subject of this paper, there is one aspect of this ship that is as revolutionary – perhaps *more* revolutionary – than any other platform the Navy has ever fielded. And that is in the area of manpower reductions to reduce total operating costs. In order to fully examine how the DDG-1000 program accomplished these breakthroughs, a basic understanding of emerging engineering disciplines such as HFE and HSI and the importance of HMI is needed.

Emerging Engineering Disciplines:

"Technologies that reduce overall expenses are worth the up-front investment – things like open architecture, modularity, and minimal manning technologies."

Admiral Gary Roughead
Chief of Naval Operations
Remarks at the 2009 Surface Navy Symposium

Early development of weapons systems required human logic and intuition to compensate for computer processing limitations. Thus, in the absence of enough computing capacity human operators were required to perform the additional processing tasks. As this processing shortfall required operators to fill the processing gap, human operators reached – and often exceeded – their ability to effectively function, often with tragic results. For a time, standardization helped mitigate the impact of these gaps.

Standardization is a common practice found within many industries to minimize costs. For example, Airbus has led the civil aviation/aeronautic industry with numerous innovations such as the commonality of design between Airbus' fly-by-wire aircraft. Such commonality of design has made it much simpler for a pilot and crew on an Airbus to migrate across various airframes but more relevant are the savings associated with training and the increased flexibility for pilots and crews. Over time, standardization began to find its way into design approaches.

For the U.S. Navy, implementation of a standardized design approach can result in a common Human Machine Interface (HMI) that can simplify design challenges exacerbated by the advent of heterogeneous ship systems. While different ships have different design standards, the utilization of common display icons, windows, and terminology has provide some standardization and continuity from ship-to-ship, enabling sailors to deal with often rapidly changing assignments. Such standardized innovations can enable some reductions in manpower requirements and training pipelines. Airbus benefited from the resultant design with the early implementation of HSI into the systems engineering process and integrated human considerations from the start of the design process.

Our capacity to use these disciplines to "design out" routine and often mundane operator actions is well within reach in today's C4ISR systems. But further advances on the horizon can empower the sailor to be even more effective and empower him with enhanced situational awareness. This will provide improved flexibility, reliability, maintainability, and system scalability, and decrease overall life cycle cost; moreover it can provide greater productivity and ultimately reduce manpower requirements. Further, the standardization and early implementation of HFE can help realize the necessitated changes that will one day help realize minimal manning objectives.

However, this process is one fraught with many roadblocks and can only be overcome by relentless pressure from operators, acquisition professionals, and scientists and engineers working in the S&T and R&D communities. As pointed out in a widely-cited DDG-51 class manning reduction study:

> "In an effort to move forward smartly with initiatives to reduce manning in U.S. Navy combatants, the Program Executive Office Ships, commissioned a study to examine and analyze alternatives to reduce manning for Arleigh Burke Class ships with the expectation that lessons learned from this effort would not only benefit current and future flights of DDG 51 Class ships but would also benefit future ship classes, particularly the DD(X) family of ships. The *DDG 51 Reduced Manning Study* … was conducted in two phases by a Navy-Industry Team, *Phase I Concept Study* (Hinkle and Glover 2003 – Concept) and *Phase II The Plan for Assured Manning* (Hinkle and Glover 2003 - Plan)."
>
> "Navy leadership has an enhanced understanding of Total Ownership Cost (TOC) factors that are important if reduced manning initiatives on the DDG 51 Class are to move forward. That said, this Study also revealed that the process to evaluate Return on Investment (ROI) and the TOC impact for manning reduction initiatives is difficult. This Study determined that in evaluating reduced manning initiatives based on TOC, the "color" of money and traditional funding methods can not become an impediment to reducing manning."[23]

Nonetheless, Humans Systems Integration is slowly gaining prominence approximating that of software and hardware considerations within systems engineering (SE). The objective of incorporating HSI into SE is to achieve the proper balance between hardware, software and the human to optimize system performance. However, self-imposed design paradigms currently limit our ability to realize the full potential of C4ISR systems based on a lack of complete understanding regarding the efficacy of HSI. This is not a new phenomenon but one that has been true for many millennia

Since the ancient Trireme, ship design has driven manning requirements. The Trireme is an early example of human systems integration (HSI) that resulted from the innovative approach of adding a third bank of rowers that provided a clear and historically proven tactical advantage. This design consisted of 170 rowers arranged in three banks, with the lowest just 18 inches above the water line, with the remaining compliment of spearmen, archers and other sailors bringing Trireme to around 200 men.

Today's design efforts remain directly coupled to TOC and of all of the domains of HSI, human factors engineering (HFE) is the genesis for consideration of those remaining disciplines. Human Factors Engineering stands upon more than a century of proven research within various fields such as Cognitive Psychology and other applied sciences that provide a firm foundation for system design based on understanding and insights to human capability, capacity and limitations for cognitive process.

HFE improves human performance just as Lean Six Sigma (LSS) improves processes. Through both disciplines people, processes, and systems are streamlined and standardized, improving performance and reducing costs. Nevertheless, the current focus on hardware and software often causes designers to "forget the human" and thus fails to fully capitalize on the gains that can be provided by HFE.

Information processing is the most important challenge we face in this age. While we can provide instantaneous and quantifiable source data; providing that information in a format optimized for the human user is still our greatest challenge. HFE will continue to prove its worth in optimizing the ever-increasing amounts of data and empower sailors with a commonality of optimized human-machine interfaces (HMI).

Armed with this understanding of emerging engineering disciplines and the potential they have to reduce TOC and manpower requirements – as well as some of the systemic impediments to accomplish this, we can turn to the example of DDG-1000 Zumwalt-class destroyer as a best-practices model.

Manpower Reductions

"'Better' is the enemy of 'Good Enough.' This was the favored quote of Cold War Soviet Fleet Admiral S.G. Gorshkov, who while embracing evolutionary improvements to existing naval assets—ensuring they were good enough to perform intended missions—committed billions of rubles to revolutionary naval advancements and game-changing technological firsts."[24]

James Zumwalt
"Zumwalt: 'When Good Enough' is the Foe of 'Better'"
The Washington Times July 27, 2008

While not talked about as widely as other attributes of DDG-1000 Zumwalt-class destroyer's cutting-edge capabilities, the substantial, "step function" reduction in manpower on the DDG-1000 represents what may well be the most profound technological breakthrough this ship contributes as a bridge to the Navy-after-Next.[25] This represents a major breakthrough for the Navy in its ongoing efforts to reduce the number of sailors on ships as a means to lower ship life-cycle costs.

The need to reduce manpower on Navy ships as a vehicle for reducing the ship's Total Ownership Cost (TOC) has been an important imperative for Navy leadership for at least a decade. Successive Chiefs of Naval Operations have made reducing manpower a key part of their annual goals and objectives. The importance of addressing TOC in ship design was perhaps best put by then-CNO Admiral Michael Mullen in an interview in *Government Executive*. In answering a question regarding Navy-wide manpower reductions, Admiral Mullen noted:

> My long term goal is to eliminate the need for jobs and not just keep moving the work around from one part of the workforce to another. In the long run, I am anxious to invest in the technology in order to take the work out. We have a tendency to look at what it takes to get a program out the door. We don't think too much about what the life cycle cost is. It's "Can I build it?" I would like us all to be mindful of what it costs to operate whatever we are building for whatever its life is going to be because I have to pay that bill every single year. That is why I am so excited about the reduced manning potential of the DD(X). That process needs to apply in lots of areas.[26]

Naval professionals at all levels – and especially those in the acquisition community responsible for the design, building, and life-cycle maintenance of Navy ships – are acutely aware of the impact of manpower on the life-cycle costs of ships. A Naval Sea Systems Command report captured the magnitude of the challenge in this way:

> The largest single component of life-cycle cost for a naval ship is acquiring, training, assigning, and supporting manpower for ship operations, maintenance, and support. The primary benefits of optimized crewing are the significant reduction in ownership costs and improved total system performance.[27]

But the task of addressing Human Systems Integration on Navy ships is daunting. The demands placed on Sailors by Navy ship systems are unique in the breadth of their scope and the depth of their complexity. Navy ship systems employed by the fleet today, and those being designed for tomorrow, make severe demands on the readiness, performance effectiveness, and mental and physical capabilities of personnel who man them. These complex systems are extremely demanding on the senses, motor skills, cognitive skills, and decision-making capabilities of the ship's crew. Add the highly varied nature of the threat; the need to conduct multi-warfare scenarios; and the need to integrate, coordinate and interpret information from multiple sources; and it becomes evident we are rapidly approaching the limits of unaided human capacity and capability.

This need to address human performance and concurrently reduce manpower on Navy ships as an essential element of recapitalizing the Navy has been addressed at the highest levels of Navy leadership and widely reported in the defense media.[28] However, prior to the substantial manpower reductions on DDG-1000, major surface combatants (including amphibious ships) have required a heavy crew complement. Not surprisingly, the Navy has been criticized for not moving quickly enough to reduce manpower on warships of all types.[29]

The reasons the Navy has not moved out more smartly in reducing manpower on ships – especially the surface combatant family of ships – are complex and a complete examination of those reasons is well beyond the scope of this paper. A study commissioned by the Navy and conducted by the Center for Naval Analysis probed the breadth and depth of the institutional factors impeding manpower reductions aboard Navy ships, concluding:

> Part of the [manpower reduction] problem rests with business practices of today: an absence of incentives, organizational stovepiping that separates technology and manpower decision, and incomplete metrics of how manpower affects safety, readiness, and other variables…Operating without the intervention of senior guidance, requirements organizations will not work to reduce manning, or even conserve it. As one observer put it, 'manning reductions are an organizational orphan, beyond the reach of even the most diligent, skillful manager.'[30]

This is not just a Navy issue, but one that is being addressed at the highest levels of the Department of Defense.[31] However, the easy calculation of ship size versus crew complement intensifies the focus on Department of the Navy initiatives to reduce manpower on Navy ships and makes efforts to reduce shipboard manpower a matter of urgency.[32] The Chief of Naval Operations has been widely quoted in the defense media as giving reduced manpower an extremely high priority, noting in 2008:

> There's no question that crew sizes have got to come down. We, frankly, are not aggressive enough in employing the technologies that allow us to take people off ships. It's largely a cultural thing we've got to break through…and we can do it, I'm confident. In the past, we've had some initiatives underway but they had a hard time taking through. In my tenure I intend to be a little more on the bold side.[33]

The DDG-1000 Zumwalt-class destroyer is the first major surface combatant to be designed, from the keel up, to make a step-function reduction in crew size. In achieving this breakthrough manpower reduction on DDG-1000 the Navy has drawn on decades of military, industry and academic best practices in Human Dynamics, Human Factors Engineering (HFE) and Human System Integration (HSI).[34] The center of gravity of these efforts resides in the Naval Sea Systems Command (NAVSEA), especially in the Naval Systems Engineering Human Systems Integration Directorate (SEA 05H), and the DDG-1000 is the lead major surface combatant to capitalize on this ground-breaking work.[35] However, as we will present later in this paper, this work is also occurring throughout the entirety of the Navy laboratory community, and we will use, as one example we are quite familiar with, the work going on throughout Team SPAWAR and more specifically, at SSC Pacific.

The importance of having a Human System Integration Directorate – and one with SES-level leadership – within NAVSEA cannot be overstated. A statement by the then-NAVSEA commander explaining the reasons for establishing this Directorate and providing his vision for what this would mean for ship design captures the importance of this initiative:

> You don't build a ship and then put men on it. You build a ship around the human when you start it. The man/machine interface becomes critical. And at the same time, on every program that we are developing within NAVSEA's arena of influence, we're going to use this as a gauge to say, is that program properly addressing the human systems integration requirement? And so this organization will examine how we have captured the features for human systems integration in whatever we're doing.[36]

There are a wide array of specific examples of the way HSI principles were applied in the DDG-1000 Zumwalt-class destroyer program; from establishing HSI requirements in the acquisition documentation and Tier 1 specifications, to early review of the systems designs by Fleet Subject Matter Experts (SME) within the context of operationally relevant scenarios, to evaluating design concepts/solutions throughout the design process under realistic conditions with representative end users, to many others. The then-Program Executive Officer for ships, Rear Admiral Charlie Hamilton, captured the breath and depth of this commitment to HSI in a quote appearing in a 2006 article in *Leading Edge*:

> Our future ships such as DD(X) and LPD-17 will usher in remarkable improvements in the way Sailors live, work, and fight at sea. We are investing in technologies to improve the human factors design of our systems and to improve the ability to sense and monitor our environment both on and off board. New technologies and increased automation will help reduce necessary manpower and maintenance. Human-centric design increases our capability to turn raw data into knowledge, and to provide critical decision support capabilities to our Warfighters.[37]

The DDG-1000 Zumwalt-class destroyer was addressed as a best practices example during the 2009 American Society of Naval Engineers (ASNE)/International Council on Systems Engineering (INCOSE) HSIS Symposium. An article in the *Naval Engineers Journal* provided in the conference materials package highlighted the scope of the Navy's efforts at reduced manpower:

> Application of HSI in the Navy implements a systems engineering approach that addresses requirements for workload reduction and manpower optimization initially for systems and subsystems, and then for the total ship. At the same time, technology is developed or adapted that will reduce cognitive and physical workloads on a ship's crew through function automation, consolidation, simplification, and elimination. Technology is also developed to reduce the incidence of human errors and accidents, and to make ship systems error tolerant.[38]

This article, by a team of recognized government, industry, and academic experts in the field of HSI, went further and focused specifically on the DDG-1000 program as its own best practices model for HSI, noting anticipated cost savings over the life-cycle of the ship:

> Implementation of the Navy's HSI approach in the acquisition program for the DDG-1000 destroyer is a best practice example with HSI effectively enabling improved reliability, maintainability, and safety in design while significantly reducing manpower levels. HSI as the combination of engineering disciplines to

> define the role of the human vice automation was able to identify requirements associated with the human roles. Through application of HSI's emphasis on improving human reliability and reducing human errors, innovative design approaches for equipment, software, procedures, information, environment, communications, and organizations could be shown to satisfy operational requirements.[39]

While there are those who might second guess whether such a large, advanced warship can actually operate with a crew of 148, this crew size reflects extensive due diligence by the Navy and years of deliberate, incremental testing of Fleet sailors manning DDG-1000 combat systems. A *Defense Daily* article captured the essence of this process:

> The crew size of 148 was not pulled out of thin air. This has been from the ground up. Every minute of every sailor in every billet has been accounted for in either workload or in some sort of automation that takes that workload away. It's not magic. Usability testing done with the technologies and engineering design models (EDMs) have validated the crew size of 148. All of that has been modeled, and tested, through each software release with actual sailors and other personnel, in what the Navy calls software usability testing.[40]

Simply put, what made desired manpower reductions on the DDG-1000 Zumwalt-class destroyer "work" was the fact that NAVSEA ensured manpower Key Performance Parameters (KPP) were integrated into ship design decisions at the earliest stages of ship design. DDG-1000 is the first warship – aircraft carrier, amphibious ship, surface combatant or submarine – to have an explicit KPP for manpower. This change made manpower reductions a "forcing agent" for the way the ship was designed.

Crewmember workload was addressed in detail from the outset and the Knowledge, Skills and Abilities (KSA) for crewmembers to perform over 18,000 distinct tasks were addressed and analyzed as to the ability of crewmembers to complete each task. Not surprisingly, watch standing was the largest consumer of crew hours. The NAVSEA and industry design team addressed crew workload and functions in a 60-hour combat scenario as well as in a 60-day operational scenario, validating manpower requirements against typical and most-likely operational environment DDG-1000 would face.

The full details of the methodologies NAVSEA and industry professionals used to achieve these step-function manpower reductions are beyond the scope of this paper. However, perhaps the most important change of philosophy instantiated in the design of the DDG-1000 Zumwalt-class destroyer was the integration of HSI subject matter experts into the ship design process at the outset. This process, dubbed "Human Systems Shipboard Interaction" (HSSI), embedded HSI professionals with engineers and ship designers at all stages of the project ensured HSI initiatives were factored in *prior* to design completion, thereby avoiding additional – and often prohibitive – costs associated with a formal change process.

Another critical factor in determining the optimal manpower profile for DDG-1000 was the extensive involvement of Fleet Sailors in all design, testing and evaluation activities. Other Navy ship programs – most notably the Aegis cruiser and destroyer programs – have included Fleet Sailors in the design process with positive results. However, for DDG-1000 this was done on a heretofore-unprecedented scale, and represented a major investment on the part of the Navy and industry team.

Over 1200 Fleet Sailors were included in every design review and evaluation process over a three-year period, providing the NAVSEA and industry team with strong validation for every manpower design decision made. Including the Fleet early-on helped identify design hazards, so that modifications to optimize design for human performance could be made immediately. Designers leveraged human performance modeling at the outset in order to explore the impact of manpower concepts, automation technologies, and other system design concepts on the crew's ability to perform the mission.

One example of the positive results of this process is the design of the DDG-1000 Zumwalt-class destroyer's bridge. An article in the *Naval Engineers Journal* provided the highlights of this process:

> As an example, DDG-1000 had their bridge design mocked up down there [Naval Surface Warfare Center, Dahlgren Division]. It's a very, very large facility. And even though the bridge is 60 feet across, they were able to mock it up there. They brought in three fleet teams, ran them through three scenarios. And this was very early on. And, as a result of that, we were able to identify a number of design deficiencies before we were even thinking about really building something. And the only things we had to then modify were drawings. Several structural changes that needed to be made were identified…According to industry, for an investment of about $20K, they achieved a cost-avoidance through HSI efforts of approximately $20M.[41]

The results of this long-term, disciplined, iterative process were dramatic. While the Ship's Manning Document (SMD) for the DDG-51 Flight IIA has a crew complement of 314, the preliminary Ship's Manning Document (PSMD) for DDG-1000 has a crew complement of just 148 – 14 officers, 19 Chief Petty Officers, 87 Sailors, and 28 members of the Air Department. This PSMD has been validated during all ship-design phases and HSI has been interlinked in a repetitive process that has spiraled towards DDG-1000's sailor-centric design.

The DDG-1000 is the right ship, at the right time to benefit from a wide-range of manpower-reduction initiatives. As this ship serves as a technology bridge for new systems, sensors and weapons for the Navy-after-Next, the manpower-reduction technologies and procedural changes instantiated in this ship are already serving as a model for future ships, most notably the Navy's next generation aircraft carrier, the CVN-21.[42] This ongoing Navy and industry cooperation to reduce manpower on all future Navy ships, in turn, will accelerate the Navy's recapitalization efforts as future ships have sharply lower manpower profiles than Navy ships today.

Given the DDG-1000 Zumwalt-class destroyer's cutting-edge capabilities, ample room for technical maturation and growth, and especially its unique role as the ideal host platform for the development of effective manpower reduction initiatives, DDG-1000 is the linchpin for the Navy's Future Surface Combatant Program and the ideal technology bridge to the Navy-after-Next. How rapidly these technologies transition from the laboratory and ground test sites to DDG-1000 will offer a unique window on what the Navy-after-Next will bring to the fight.

But it is in the Navy's laboratories where the cutting-edge technologies to reduce TOC on Navy ships through application of HSI methods has taken hold and is evolving. Paper length considerations do not permit a full recounting of all of the HSI work underway at all of the Navy's dozen-plus laboratories – and to be sure – there are many projects underway where these labs collaborate. Instead, this paper will focus on the cutting-edge HSI work in one Navy lab, SSC Pacific.

"Tell it to the Labs" – Manpower Reduction Initiatives at the Lab Level

> "We will win – or lose – the next series of wars in our nation's laboratories."[43]
> Admiral James Stavridis
> SOUTHCOM Commander
> "Deconstructing War"
> *U.S. Naval Institute Proceedings* December 2005

In addition the experience with DDG-1000, several initiatives have demonstrated that technologies based on HSI/HFE principles improve mission performance, usually with fewer people. As one example, network centric technologies offer the potential to realize significant savings in manpower aboard other Navy ships. Fleet experience, embodied in reports such as the Task Force 50 Network Centric Operations Case Study during Operation Enduring Freedom, demonstrates that armed with the proper tools, warfighters are able to make better decisions, faster, with fewer people and fewer mistakes.[44]

There is a direct, but complex, causal link between effective HSI/HFE and personnel costs. Systems that are efficient and easier to operate require fewer personnel resources in all phases of training and operation. Poor design creates increased personnel burden and increased risk of mission failure, by inducing error and delays during peak mission task loads.

The Office of Naval Research (ONR) has sponsored research in HSI/HFE concepts at SSC Pacific for several decades. These concepts, as applied, can reduce manning in the following ways: improved human computer interfaces/decision management systems; reduced operator workload; improved mission process transparency; automation; and/or decreased maintenance requirements. A series of representative projects undertaken at SSC Pacific will demonstrate how manning reductions can be achieved through both improved human computer interfaces/decision management systems, and through automation.

Two projects present manning reductions based on human computer interfaces/decision management systems.

Multi-Modal Watchstation. Initiated in 1996, the Multi-Modal Watchstation (MMWS) is an ONR-sponsored project that demonstrates the application of advanced HCI and how it reduces human workload, task processing time, errors, and training, enabling significant reductions in manning levels.[45] Specifically, it investigated the design concept of "creating and embedding mission tasks and their associated goals within [a] visual user interface, using visual priority cues and task progress summaries."[46] With a design focus on task management issues, this effort provided a definition of estimated task characteristics for future naval systems which provide a baseline for watchstation design concepts.

Littoral Combat Ship Unmanned Surface Vehicle Operations. Another ONR Future Naval Capabilities (Capable Manpower) project is currently investigating advanced HCI for improved control and monitoring of unmanned vehicles. Specifically, the Littoral Combat Ship (LCS) uses unmanned surface vehicles (USV) in both Anti Submarine Warfare (ASW) and Mine Warfare (MIW) missions. The current USV controller is the Multi-Robot Operator Control Unit (MOCU) developed by the SSC Pacific Unmanned Systems Technology Directorate. In conjunction with this group, the User-Centered Design group is developing improved HCI and attention management systems to allow one operator the ability to control more than one USV. This is an example of using HFE to change the HCI to achieve the stated goal of one operator for two vehicles by reducing cognitive and visual workload. Standard Navy manning procedures would have staffed one operator for each USV, so the result of this work is a substantial manpower savings.

Automation and reduction in maintenance requirements can also achieve manning reductions, as the following examples demonstrate:

Mast Clamp Current Probe HF Receive Antenna. The Mast Clamp Current Probe (MCCP) HF receive antenna was developed by the Electromagnetics and Advanced Technology Division at SSC Pacific in the 1990s to reduce maintenance required by existing HF whip antennas. These whips are typically mounted on high-maintenance tilting platforms at the edge of the flight platform or deck so that they can be lowered during flight operations. These failure-prone mechanical tilts take several sailors and a great deal of time to maintain and repair. The MCCP is mounted to a mast or other vertical ship structure, making the previous whip antennas and tilting mechanisms unnecessary. The MCCP has essentially no maintenance; just a regular inspection of the connectors and hardware for corrosion. Several demonstrations on various ship classes in 1999 and 2000 confirmed MCCP performance, and it is being installed on new DDG, LHA, and CVN class ships while efforts are underway to make MCCP a program of record.

Ship's Signals Exploitation Equipment (SSEE). At PEO C4I, PMW 120 has been pursuing efforts to reduce manning on their programs, such as SSEE Increment E and Increment F. SSC Pacific's Signals Intelligence Systems Branch of the Information Operations Division has supported this evolutionary program. The Ship's Signals Exploitation Equipment (SSEE) program is a signals exploitation system that allows the operators to monitor and analyze signals of interest within the Ship's Signals Exploitation Space (SSES) aboard a variety of ship classes. The SSEE system's increasing capability to detect, identify, and locate targets near to and over the horizon contributes significantly to the ship's Command and Control Warfare (C2W) capability and is the center of the ship's Information Warfare (IW) operations.

SSEE INCR E and INCR F are Cryptologic/IO (information operations) systems, and are installed both afloat and ashore. The latest increment will provide for greater signal discrimination, fully remote capability, robust IO capability, and NESI compliance. The main function is to exploit, geo-locate and provide IO Responses to hostile enemy communications. In the evolution of cryptologic/IO programs the manning requirements were reduced from three to five operators and two maintainers for the COBLU program in the late 1990s, to zero to three operators and one maintainer for the SSEE INCR F. The focus on how to reduce the manning associated with these programs was through automation of operations and additional work on the operator interface (i.e. allowing the operator to access all parts of the system through one standard GUI), resulting in operator reduction; the maintenance reduction is the result of a reduction in the number of system parts.

This short review of several optimal manning initiatives at SSC Pacific and Team SPAWAR highlight the role that HFE and automation have in reducing manpower costs. Regardless of the effectiveness of various HFE and HSI technologies, cost weighs heavily on strategic decisions regarding technology purchase. Decisions will be made within the context of hardware, software, and personnel costs if these new systems are installed. These important trade-offs should be made in an objective manner with reliable metrics to guide the Services toward the correct decisions.

The Way Ahead

"For the foreseeable future, this [strategic] environment will be defined by a global struggle against a violent extremist ideology that seeks to overturn the international state system. Beyond this transnational struggle, we face other threats, included a variety of irregular challenges, the quest by rogue states for nuclear weapons, and the rising military power of other states."[47]

The National Defense Strategy
June 2008

As the *National Defense Strategy*, the capstone strategic document for the Department of Defense, makes clear, the strategic environment U.S. military forces will face in the future will comprise a wide-array of threats across the spectrum of violence. Dealing with such a range of threats requires that the United States avoid the "technological surprise" that will enable an enemy to exploit U.S. military weaknesses and deliver an asymmetric blow that will thwart what the United States seeks to achieve at strategic, operational, or tactical levels.

For the U.S. Navy, especially a Navy that will increasingly fight in the littorals, the need to avoid technological surprise is especially acute. This is primarily because the Navy-Marine Corps team operating in the near-shore area will be need to deal with land, air, and naval threats at the conventional, irregular, disruptive and catastrophic levels. A former Vice Chief of Naval Research, Brigadier General Thomas Waldhauser, put this imperative in focus when he noted; "Given the current national security challenges our nation faces and those we expect to face in the future, we must keep our focus forward and push innovative technological solutions to address those future threats."[48]

But "pushing" those technologies out to the Fleet and Fleet Marine Forces is fraught with organic and systemic challenges. Transitioning technologies from the lowest "Technology Readiness Level" (TRL level one – basic principle observed/reported) to the highest (TRL level nine – actual system proven through successful mission operations) is an ongoing challenge for the Department of the Navy.[49]

This challenge of transitioning technologies from a laboratory environment to the operating forces is well-known and a body of work has grown up discussing how to bridge this so-called "Valley of Death" that impedes effectively technology transition.[50] It is an issue of such concern for the Department of Defense that DoD asked the National Research Council (NRC) to investigate the issues surrounding failure of technology to transition to the warfighter and offer recommendations.

While the NRC provided a robust list of recommendations to DoD, the title of their final report *Accelerating Technology Transition: Bridging the Valley of Death for Materials and Processes in Defense Systems* provides a telling indicator of how difficult this technology transition remains today. Significantly, this report notes; "The adoption and acceptance of a new technology likely depends on the real or perceived impact of that technology on high-level military goals."[51]

Concurrently, the unique challenges the Navy-Marine Corps team will face in the future littoral environment are sufficiently compelling that the focus of Navy and Marine Corps research and development, and especially the Naval Research Enterprise, is squarely on dealing with the conventional, irregular, disruptive, and catastrophic challenges the Navy-Marine Corps team will have to deal with in the near-shore area. As noted in an Office of Naval Research Annual Report:

> In addition to serving the S&T needs of Today's Navy and Marine Corps, Tomorrow's Fleet/Force, and the Navy/Marine Corps Team-after-Next, a strong emphasis of ONR research and development since the early 1990s has been the spread of special scientific, technical and operational challenges of littoral warfare. Naval Power 21 identifies the world's littoral as the primary operating area of the Navy-Marine Corps Team. ONR's job is to ensure that the technologies, systems, and platforms are available to make littoral operations – from the sea – a success.[52]

Given the Valley of Death that all-too-often overtakes promising technology programs, and in light of the enormous (and appropriate) focus on littoral warfare for the Joint force in general and the Navy/Marine Corps Team-after-Next in particular, the DDG-1000 Zumwalt-class destroyer can serve as a model for "fast tracking" new technologies – and especially promising manpower-reduction technologies – into the fight. Likewise, due to their prominent position in the Navy Research Enterprise, Navy laboratories working on promising HSI technologies should receive an added level of support to ensure these technologies *leap* over the aforementioned *Valley of Death*.

A Model for the Department of Defense?

"When asked what single event was most helpful in developing the theory of relativity, Albert Einstein is reported to have answered, 'Figuring out how to think about the problem.'"[53]

Men, Women, Messages and Media:
Understanding Human Communication

The DDG-1000 Zumwalt-class destroyer is a uniquely capable platform that will provide transformational capabilities for tomorrow's Navy and revolutionary capabilities for the Navy-after-Next. Naval leaders will need to "think about the problem" if the Navy is to capitalize on DDG-1000's role as a technology incubator and accelerate the development and fielding of game-changing manpower reduction technologies. Absent that focus, the U.S. Navy could begin an "elegant decline" that is may never recover from.[54]

Clearly, the technology insertion – and especially manpower reduction imperatives – for all the Services are as important as those for the United States Navy. What is less clear is how well the Army, Air Force, Marine Corps and Coast Guard have succeeded in developing host platforms that serve as a technology bridge for future systems and *also* reducing manpower in a substantial way. The DDG-1000 Zumwalt-class destroyer offers a compelling case study of best practices on how to succeed in doing just that. Likewise, the extraordinary manpower reduction and HSI initiatives going on in Navy laboratories should be extrapolated to *all* Services.

But unless or until sensors, systems, weapons and platforms are "born Joint" these Service-specific lessons learned are likely to gain traction in only one Service. That conundrum is perhaps the most weighty problem Department of Defense leadership will need to "think about" as they seek to evolve a U.S. military that will remain the most powerful force ever fielded.

ENDNOTES

[1] Max Boot, *War Made New: Technology, Warfare, and the Course of History 1500 to Today* (New York, Gotham Books, 2006).

[2] British military historian and strategist, Army Major General J.F.C. (John Frederick Charles) Fuller was one of the most influential military voices of the early 20th Century and used his experience in the Second Boer War and World War I to develop theories on armored and mechanized warfare that gained and maintained currency up to and through World War II. Far from being a "fuzzy-headed-theorist," Fuller was also an inventor and spoke with particular authority on technical issues. As wildly-off-the-mark as his statement appears today, his influence as a strategist, a historian, and an inventor gave his statements great currency with military forces around the world. While some might consider Fuller's views of technology's prowess extreme, a growing body of evidence suggests that technological breakthroughs can often have profound effects. See, for example, Richard Norton, "Through a Mirror Darkly: The Face of Future War, 1871-2005," *Naval War College Review*, Vol. 62, No. 1, Winter 2009, pp. 123-140. The author, a professor at the Naval War College, notes that a comprehensive review of the works of strategists who attempted to predict what future wars would be like found that those who focused on extrapolating evolutionary and revolutionary technological change got it "right" more often than those who used other methodologies (p. 135).

[3] *War Made New*, p. 8. Boot uses historical examples to show how technological-driven "Revolutions in Military Affairs" such as the Gunpowder Revolution, the Industrial Revolution, the Second Industrial Revolution, and the Information Revolution have transformed warfare and altered the course of history. He goes further to stipulate, and back up with compelling evidence, his contention, "My view is that technology sets the parameters of the possible; it creates the potential for a military revolution." (p. 10)

[4] *Global Trends 2025: A Transformed World* (Washington, D.C., National Intelligence Council, November 2008), p. viii. Accessed at: www.dni.gov.nic/NIC_2025_project.html.

[5] *War Made New*, p. 8.

[6] Bruce Berkowitz, *The New Face of War: How War Will be Fought in the 21st Century* (New York, The Free Press, 2003), pp. 2-3. Berkowitz does not restrict his examples to just one conflict, noting further; "The same thing happened when the United States fought Yugoslavia in 1999 and the Taliban regime in Afghanistan in 2001. Each time experts feared the worst; each time U.S. forces won a lopsided victory." But like Boot, he stresses that it is the possession of better technology alone is not enough, saying; "And simply having better technology does not guarantee success. Victory goes to the side that understands how to use technology more effectively." (p. 3)

[7] *Joint Operating Environment 201: Force* (Suffolk, Virginia, Untied States Joint Forces Command, 2010). Accessed at http://www.jfcom.mil/newslink/storyarchive/2010/JOE_2010_o.pdf. This publication, commonly referred to as "The JOE," serves as the "problem statement" regarding what challenges the U.S. military and its coalition partners will face in the future and informs all subsidiary Joint publications, beginning with the *Capstone Concept for Joint Operations*.

[8] *Science and Technology for the 21st Century Warfighter* (Washington, D.C., Office of Naval Research, 2004).

[9] *War Made New*, pp. 1-473. Boot does not present technology as the only element determining victory or defeat, giving full acknowledgement to a host of other factors, from geography, to demography, to economics, to culture, to leadership. However, he is firm in his contention of technology's huge impact, noting; "Some analysts may discount the importance of technology in determining the outcome of battles, but there is no denying the central importance of advanced weaponry in the rise of the West….The way to gain military advantage, therefore, is not necessarily to be the first to produce a new tool or weapon. Often it is to figure out better than anyone else how to utilize a widely available tool or weapon."

[10] Mark Thompson, "Taming the System," *Time*, February 23, 2009. Secretary Gates has been quoted extensively in the defense and national media extolling the U.S. Navy's technological advantage over the navies of any potential adversary.

[11] *Science and Technology for the 21st Century Warfighter*, pp. 1-35.

[12] While other classes of Navy ships such as the LCS and the CVN have benefited from work to reduce manning, the DDG-1000 remains the most well-documented example as well as, to many, the greatest success.

[13] Frank Hoffman, "Hybrid Warfare and Challenges," *Joint Forces Quarterly*, Issue 52, 1st Quarter 2009, p. 38.

[14] Mark Mazzetti, "Global Economy Top Threat to U.S., Spy Chief Says," *The New York Times*, February 13, 2009.

[15] Secretary of Defense Robert Gates has been vocal regarding the imperative for the U.S. military to focus on the conflicts in Iraq and Afghanistan and not solely on wars in the distant future, and has coined the phrase "next-war-itis," to emphasize his point. See, for example, "How to Pay for a 21st Century Military," *The New York Times*, December 21, 2008, Demetri Sevastopulo, "Gates Wants Action on 'Today's Wars,'" *Financial Times*, December 6, 2008, and Lolita Baldor, "Gates Calls for a Balanced Military," *Washingtonpost.com*, September 29, 2008.

[16] *Sea Power 21: Projecting Decisive Joint Capabilities* (Washington, D.C., Department of the Navy, 2003), pp. 1-35. Prior to the publication of this comprehensive booklet, the Navy unveiled its new vision in the pages of the *U.S. Naval Institute Proceedings* over five months in late-2002 and early-2003, with each issue focusing on some aspect of Sea Power 21. See, Admiral Vern Clark, "Sea Power 21: Projecting Decisive Joint Capabilities," *USNIP*, October 2002, Vice Admiral Mike Bucchi and Vice Admiral Mullen, "Sea Shield: Projecting Global Defensive Assurance," *USNIP*, November 2002, Vice Admiral Cutler Dawson and Vice Admiral John Nathman, "Sea Strike: Projecting Persistent, Responsive, and Precise Power," *USNIP*, December 2002, Vice Admiral Charles Moore and Lieutenant General Edward Hanlon, "Sea Basing: Operational Independence for a New Century, *USNIP* January 2003, and Vice Admiral Richard Mayo and Vice Admiral John Nathman, "FORCEnet: Turning Information into Power," *USNIP*, February 2003.
[17] *A Cooperative Strategy for 21st Century Seapower*, pp. 6-12.
[18] The Honorable Robert Gates, Secretary of Defense, "A Balanced Strategy," *Foreign Affairs*, January/February 2009. Far from being merely a new defense "buzzword," hybrid warfare has a strong pedigree and has evolved over the past year in a number of articles in respected journals. See also, Michelle Flournoy and Shawn Brimley, "The Defense Inheritance: Challenges and Choices for the Next Pentagon Team," *The Washington Quarterly*, Autumn 2008, and Frank Hoffman, "Hybrid Warfare and Challenges," *Joint Forces Quarterly*, Issue 52, 1st Quarter 2009, for influential articles that Secretary Gates' *Foreign Affairs* article built on. Additionally, and more recently, see Frank Hoffman, "Hybrid Threats: Reconceptualizing the Evolving Character of Modern Conflict," Strategic Forum, Number 240 (Washington, D.C., Institute for National Security Studies, National Defense University, April 2009), accessed at: www.ndu.edu/inss. Beyond these articles, read by a small, but select, group, hybrid warfare is gaining increasing currency in the defense media. See, for example, "At Onset of QDR, 'Hybrid Warfare,' Term Gains Momentum," *Inside the Pentagon*, February 12, 2009, Sydney Freeberg, "The Military's New Hybrid Warriors," *National Journal*, March 14, 2009, John Donnelly, "Bold Steps but a Well-Worn Path," *CQ Weekly*, p. 1084, May 11, 2009, and Matthew Jones, "Expert's Vision of Future Warfare is Not Black and White," *Norfolk Virginia Pilot*, May 13, 2009.
[19] As the new Undersecretary of Defense for Policy, Ms. Flournoy is in an especially key position to support Secretary Gates' initiative to field a U.S. military able to simultaneously deal with conventional and irregular tactics. And the focus on hybrid warfare goes beyond OSD policy circles, to the highest levels of the uniformed services, with Chairman of the Joint Chiefs of Staff, Admiral Michael Mullen, noting in the *Capstone Concept for Joint Operations*, "These clean distinctions between conventional and irregular warfare will rarely exist in reality; however, as often in the past, future conflicts will appear as hybrids comprising diverse, dynamic, and simultaneous combinations of organizations, technologies, and techniques that defy categorization;" to the Commander of the Joint Forces Command, General James Mattis, convening a conference at the National Defense University to consider the impact of hybrid warfare on the U.S. military.
[20] *Global Trends 2025: A Transformed World*.
[21] *Joint Operating Environment 2010*.
[22] While most of the focus on so-called rogue nations threatening the United States or its allies has been focused on North Korea for obvious reasons, other nations also present a near-term threat, especially in areas likely to be "contested littorals" for the United States. See, for example, Steven Hildreth, "Iran's Ballistic Missile Programs: An Overview," Congressional Research Service Report RS22758, February 4, 2009. The author notes; "Iran has an active interest in developing, acquiring, and deploying a broad range of ballistic missiles…This was spotlighted several times since 2008. In mid-July 2008, Iran launched a number of ballistic missiles during military exercises, including the medium-range Shahab-3."
[23] James Hinkle and Terry Glover, *Reduced Manning in DDG-51 Class Warships: Challenges, Opportunities and the Way Ahead for Reduced Manning on all United States Navy Ships* (Washington, D.C., Naval Sea Systems Command, 2003).
[24] James Zumwalt, "Zumwalt: 'When Good Enough' is the Foe of "Better,'" *The Washington Times* (July 27, 2008).
[25] While the size of the crew for the DDG-1000 has varied over the life of the program (somewhat in parallel to the various names for the program), the most generally-accepted number for crew size is 148 (See the Navy's Program Guide, *Sea Power for a New Era*). This is a dramatic reduction from the crew numbers of previous major surface combatants such as the CG-47 Ticonderoga-class (crew of 370-387) and Arleigh Burke-class (crew of 380). See Norman Polmar, *The Naval Institute Guide to the Ships and Aircraft of the U.S. Fleet, Eighteenth Edition*.
[26] "Chief Concerns: Interview with CNO Mullen," *Government Executive*, May 2006.
[27] Patricia Hamburger, Robert Bost and Jennifer McKneely, "Optimized Crewing for Surface Ships," accessed at: www.manningaffordability.com. It is important to note that there are additional benefits to pursuing optimized crewing on Navy ships beyond the cost avoidance and cost savings related to reducing the numbers of sailors on Navy ships. Improved operational capability, morale, efficiency, and effectiveness, as well as reduction in errors

and programmatic and schedule risks are all valid measures of meaningful return on investments. The rapidly increasing cost of military manpower is the subject of articles in the defense and mainstream press. See for example, Jim Arkedis, "America's Costliest Weapon," *San Diego Union Tribune*, April 27, 2009. The author cites the "astonishing" cost of military manpower, of $160,000 per person, per year. See also, John Donnelly, "Bold Steps but a Well-Worn Path," *CQ Weekly*, p. 1084, May 11, 2009. The author cites a 2007 report by the Government Accountability Office noting; "…the cost of each soldier in 2006 stood at about $126,000 a year. That figure has risen since then with the increasing cost of health care and the length of foreign deployments." As indicated earlier, much of this work is not "new" as organizations such as ASNE have documented as far back as two decades ago, but rather that this issue is now getting the attention it deserves primarily due to the steep increase in manpower costs.

[28] A Program Executive Office Integrated Warfare Systems/Human Systems Integration HSI Resource CD distributed at the 2009 American Society of Naval Engineers (ASNE)/International Council on Systems Engineering (INCOSE) HSIS Symposium puts it this way: "The trained Sailors that will operate and maintain a new ship or system over the course of its useful life are, far and away, the most expensive component of TOC, which, in turn, has been predetermined by the decisions made very early in acquisition development. If Program Managers (PMs) are now required to demonstrate their respective systems as providing the lowest cost of ownership to the DoN, and if the best time to reduce TOC is early in systems design, then HSI provides both the processes and the tools for PMs to meet TOC program requirements."

[29] The Navy has been criticized in the past for not doing more to reduce manpower on ships. See, for example, United States General Accounting Office, *Military Personnel: Navy Actions Needed to Optimize Ship Crew Size and Reduce Total Ownership Costs*, GAO-03-520, June 2003. While this GAO report was critical of the Navy's overarching efforts to reduce manpower on Navy ships, the then-DD (X) program was singled out as a positive example of manpower reduction efforts. Quoting from the report's executive summary: "The Navy's use of human systems integration principles and crew size reduction goals varied significantly for the four ships GAO reviewed. Only the DD(X) destroyer program emphasized human systems integration early in the acquisition process and established an aggressive goal to reduce crew size...The goal was included in key program documents to which program managers are held accountable."

[30] Carol Moore et al, *Inside the Black Box: Assessing the Navy's Manpower Requirements Process*, CNA Report CRM D0005206.A2, (Alexandria, VA, The CNA Corporation, March 2002). See also, J. Robert Bost, James G. Mellis, and Phillip A. Dent, Is the Navy Serious about Reducing Manning on Its Ships?" Accessed at: www.manningaffordability.com; George Galdorisi and Glenn Osga, "Human Factors Engineering: An Enabler for Military Transformation through Effective Integration of Technology and Personnel," Space and Naval Warfare Systems Center San Diego *Biennial Review*, December 2003; and *Military Personnel: Navy Actions Needed to Optimize Ship Crew Size and Reduce Total Ownership Costs*. This report by the GAO went even further than the CNA report in identifying four factors generally impeding the Navy's consistent application of human systems integration principles and its use of innovations to optimize crew size; (1) DoD acquisition policies and discretionary Navy guidance that allow program managers latitude in optimizing crew size and using human systems integration, (2) funding challenges that encourage the use of legacy systems to save near-term costs and discourage research and investment in labor-saving technology that could reduce long-term costs, (3) unclear Navy organizational authority to require human systems integration's use in acquisition programs, and (4) the Navy's lack of cultural acceptance of new concepts to optimize crew size and its layers of personnel policies that require consensus from numerous stakeholders to revise." See also Alexander Landsburg et al, "The Art of Successfully Applying Human Systems Integration," pp. 77-107, *Naval Engineers Journal*, Vol. 120, No. 1, 2008. In this article the authors note the opportunities and challenges of employing manpower-reduction practices when designing *any* system, opining; "There has long been broad recognition of the importance of applying human behavioral science to improve systems by systems engineers but only recently is the need becoming more generally understood. The extensive data and tools available have been sparingly applied over the years and only in specific areas. While the need for considering human factors is recognized, rationalizing which human factors issues are important and how they need to be addressed during the development or operations of complex systems has not been straightforward. *This is generally true because human factors issues compete for resources while other needs that are more easily understood and defended by hard guidance or specifications*. (Emphasis added).

[31] See, for example, Arnold Punaro et al, Defense Business Board Report, *Decision Making in a Fiscally Constrained Environment* (Draft) (Washington, DC, Defense Business Board, 2009). This report notes that manpower and entitlements represents the first of five primary defense cost drivers, stating; "Fully loaded, people costs over half of baseline budget. Current military manpower cost is over $120,000/person/year and growing. Fully loaded health care costs approaching $60B/year for current health care and future retirees. These costs are increasing as a percentage of available funding, and will increase at a faster rate in a constrained budget." The

importance of Human Systems Integration is addressed in the highest level DoD, Joint Staff, and Navy directives including DoDI 5000.1 and DoDI 5000.2 of 12 May 2003, CJCSI 3170.01D and CJCSM 3170.1A of 12 March 2004, and SECNAVINST 5000.2C of 19 November 2004. All of these directives charge the program manager to fully incorporate HSI into the program's acquisition strategy with a goal of reducing life-cycle and total ownership costs.

[32] The Navy has been "studying" ways to reduce manpower on ships for well over a decade. One of the most significant ways the Navy has learned "best practices" has been through the efforts of the Naval Research Advisory Committee (NRAC), which issued its first report on naval ship manpower in 1995. See for example, Robert Spindel at al, *Naval Research Advisory Committee Report: Optimized Ship Manning, April 2000* (Washington, D.C. Office of the Assistant Secretary of the Navy for Research, Development and Acquisition, 2000) for a comprehensive analysis of manpower and total ownership costs. See also, "Ten Questions: An Interview with Patricia S. Hamburger, Director, Human Systems Integration, Naval Sea Systems Command (NAVSEA)," pp. 15-21 and Alexander Landsburg et al, "The Art of Successfully Applying Human Systems Integration," pp. 77-107, both in *Naval Engineers Journal*, Vol. 120, No. 1, 2008; Glenn Osga et al, "'Task-Managed' Watchstanding: Providing Decision Support for Multi-Task Naval Operations," Space and Naval Warfare Systems Center San Diego *Biennial Review*, *2001*, pp. 176- 185; George Galdorisi and Glenn Osga, "Human Factors Engineering: An Enabler for Military Transformation Through Effective Integration of Technology and Personnel, Space and Naval Warfare Systems Center San Diego *Biennial Review*, *2003*;" Kelly Abruzzo et al, "Human Systems Integration: The Key to Achieving a U.S. Navy of 313 Ships Through the Effective Integration of Technology, Personnel, and Training," in *Proceedings of the 2009 Human Systems Integration Symposium*; Robert Bost and George Galdorisi, "Transforming Coalition Naval Operations by Using Human Systems Integration to Reduce Warship Manning: Lessons Learned from the United States Navy DDG 51 Class Warship Reduced Manning Study," published in *The Proceedings of the Ninth International Command and Control Research and Technology Symposium*, September 2004.

[33] Phillip Ewing, "CNO: Reducing Crew Sizes a Top Priority," *Navy Times*, March 27, 2008. See also Geoff Fein, "DDG-1000: Bigger Ship, Smaller Crew," *Defense Daily*, April 8, 2008. This *Defense Daily* piece captures the importance of DDG-1000's manpower reductions, noting; "While DDG-1000, with its advanced technologies, low radar cross section and modern weapons will provide new direction for the Navy's surface combatant fleet, the ability to operate all of that with a crew of no more than 148 could be the greatest benefit to the Navy," and also observing the dramatic change in prior Navy ship-manpower profiles, noting; "The Navy intends to operate its next surface combatant, DDG-1000, with a crew of 148, a little les than half of what a DDG 51-class destroyer needs to operate today – for a ship that is going to be almost 100-feet longer than a DDG-51." The cultural issues Admiral Roughead refers to are difficult to overstate and have been the subject of professional discourse within the Navy for over a decade-and-a-half. See, for example, J. Robert Bost, James G. Mellis and Philip A. Dent, "Is the Navy Serious About Reducing Manning on Its Ships?" *Proceedings of the Association of Scientists and Engineers (ASE) Symposium, April 13, 1994*, accessed at: www.manningaffordibility.com. The study's authors make a persuasive argument that, "the greatest obstacle to reducing manpower on Navy ships is the resistance to change in U.S. Navy tradition which results in outmoded technology paradigms and organizational culture;" Tom Bush, J. Robert Bost, Trish Hamburger, and Thomas Malone, "Optimizing Manning on DD-21," *Proceedings of the Association of Scientists and Engineers (ASE) 36th Annual Technical Symposium*, April 23, 1999. The authors point out how, for the then-DD 21 Program, the optimized manpower strategy began with an assumed manpower level of zero and how all manpower levels had to be justified by a top-down functional level analysis; and Greg Maxwell and J. Robert Bost, "The Navy Must Put People First," *U.S. Naval Institute Proceedings*, March 2004, pp. 90-92.

[34] See "The Art of Successfully Applying Human Systems Integration," p. 79 for a working definition of human factors as well as recognition of progress the U.S. Navy has made in the field of human systems integration. The article's authors note: "A tremendous amount of progress toward application of human factors has been made in the U.S. maritime field over the last decade or two. The Navy HSI process has made great strides in becoming an accepted process in ship systems acquisition with some accomplishments on record that increases its attraction for programs." They also single out the Navy HSI process for recognition as a "best practices case study," noting; "The Navy HSI process itself could be considered a case study in that it represents a 'best practice.' It is presented here briefly so that it can be compared with other 'best practices' described."

[35] The DDG-1000 is the first major surface combatant to benefit from significant policy and doctrinal initiatives designed to emphasis HSI in program development. Navy-wide, the publication of OPNAVINST 5310.23 represented a crucial policy directive instantiating HSI practices into *all* Navy programs in order to optimize manpower and improve human performance to maximize system capabilities. Importantly, this policy includes language in the Joint Capabilities Integration and Development System (JCIDS) that documents appropriate Human Systems Integration manpower, personnel, training, human factors, habitability, safety, occupational health, and personnel survivability requirements. In addition to the establishment of Sea 03 (with SES-level leadership) as the

Human Systems Integration Directorate, the Navy's five Systems Commands signed a *Virtual Syscom Memorandum of Agreement* (VFS-MOA-25) focused on Human Systems Integration. This omnibus directive, signed by all five Syscom commanders in 2005, contains extensive policies and procedures for institutionalizing best-HSI practices within each command as well as ways to share HSI-related best practices among Syscoms. Volume 1 of the Human Systems Integration Guide provides the accepted definition of HSI: "Human Systems Integration (HSI) is the technical process that integrates the disciplines of human factors engineering, manpower, personnel, training, habitability, personnel survivability, safety and occupational health hazards concerns into the systems engineering of a material system to ensure safe, effective operability and supportability. For the Navy, this translates into a systems engineering process dedicated to providing Navy systems with the best total system performance and the lowest Total Ownership Cost (TOC). In addition to hardware and software considerations, HSI ensures systems are designed, produced, supported, fielded, and modernized through a complete and careful integration of the human component." See also *Military Personnel: Navy Actions Needed to Optimize Ship Crew Size and Reduce Total Ownership Costs*. In the Department of Defense response to this GAO Report, Jeanne Fites, Deputy Undersecretary of Defense for Program Integration acknowledged the GAO's "Well-deserved recognition of the DD(X) program's extensive HSI efforts," and also noted the extent Sea 03 had involved numerous Navy HSI stakeholders in the process of designing the ship.

[36] NAVSEA Media Forum, January 29, 2003, "Balisle's NAVSEA Media Forum with Reporters, *Inside the Navy*, February 3, 2003, pp. 11-14. See also, Greg Maxwell and J. Robert Bost, "The Navy Must Put People First," for a brief description of the responsibilities of this HSI Directorate; "The Directorate serves as NavSea's single point of contact with the Chief of Naval Operations, Fleet Forces Command, Office of Naval Research, other systems commands, Naval Education and Training Command, and other Navy, Defense Department, and joint offices for HSI and human-performance-related activities. The HSI Directorate has been charged with examining the entire Navy acquisition process from the human-performance standpoint."

[37] Daniel Wallace and Jennifer McKneely, "Return on Investment: Lessons Learned in Application of HSI to DD(X) Acquisition Program," *Leading Edge* 2006, pp. 9-11.

[38] "The Art of Successfully Applying Human Systems Integration," p. 93. This article also provides an extensive, eleven-step "best practice" process for applying HSI (pp. 93-96).

[39] "The Art of Successfully Applying Human Systems Integration," p. 96.

[40] "DDG-1000: Bigger Ship, Smaller Crew." This *Defense Daily* article quotes DDG-1000 Program Manager, Captain Jim Syring, to explain the breadth and depth of the testing the Navy has conducted to validate the manpower profile for this ship, noting, "We tested all software in terms of functions. We tested all of the sonar systems with actual fleet sailors. We put the sailor on a console and said, 'O.K., here is a DDG-51 ASW (anti-submarine warfare) problem. Now with DDG-1000's algorithms and software, can you prosecute?' And they are able to do it with one watch-stander doing both passive and active operations. That might take three watch-standers in terms of correlation today. A lot of this has been validated over the last five years. Every tactical scenario that may have been experienced in a DDG-51 is taken and put into DDG-1000. Crews are told they have to take the work load of three watchstanders. What we have is a very fundamental construct in terms of how we are going to operate the ship."

[41] "Ten Questions: An Interview with Patricia S. Hamburger, Director, Human Systems Integration, Naval Sea Systems Command (NAVSEA)," p 20. This is not to say that manning reduction studies were not conducted on earlier classes of aircraft carriers such as the Nimitz class, but merely that NAVSEA in particular is far better organized and more focused on dealing with these issues today than ever before.

[42] While the exact crew size for the first ship in the CVN-21-class, USS *Gerald Ford*, has not yet been precisely determined, most analysts predict the ship will have over 1200 fewer sailors than the predecessor *Nimitz*-class See, for example, Peter Dujardin, "Ford Will Need Fewer Sailors," *Newport News Daily Press*, March 11, 2007 and William Cole, "Navy's Top Admiral Visits Pearl Harbor, *Honolulu Advertiser*, May 8, 2007.

[43] James Stavridis, "Deconstructing War," *U.S. Naval Institute Proceedings*, December 2005.

[44] Garstka, J., Holloman, K., Balisle, C.W., Adkins, M., & Kruse, J. *Network Centric Operations (NCO) Case Study: U.S. Navy's Fifth Fleet Task Force 50 in Operation ENDURING FREEDOM*, Evidence Based Research, Inc., (Vienna, VA. 2006).

[45] Osga, G. (1999). The Task-Centric Watchstation. *Surface Warfare Magazine*, Vol 24, No. 4, pp. 16-19.

[46] Osga G. A., Van Orden, K.F., Kellmeyer, D., & Campbell. N. (2001). "Task-Managed' Watchstanding: Providing Decision Support for Multi-Task Naval Operations. Biennial Review 2001, TD 3117, Space and Naval Warfare Systems Center San Diego, San Diego, CA, pp. 176–185.

[47] *The National Defense Strategy* (Washington, D.C., Department of Defense, June 2008), p. 2.

[48] *Science and Technology for the 21st Century Warfighter*, p. 2.

[49] Detailed information on Technology Readiness Levels (TRLs) is contained in the DoD 5000 Series of publications not typically accessible to the general public. One excellent open-source document explaining TRLs is; "Interview with Dr. Michael F. McGrath, Deputy Assistant Secretary of the Navy Research, Development Test and Evaluation," *CHIPS* Magazine, Jan-Mar 2007.

[50] While this "Valley of Death" can occur between any two TRLs and impede – or stop – technology transition to the warfighter, this most common area where it is addressed in courseware from the DoD's Defense Acquisition University is between TRL 6 (System/subsystem model or prototype demonstration in a relevant environment) and TRL 7 (System prototype demonstration in a flight/space environment). Put another way, this Valley of Death occurs most often in the "handoff" from Advanced Technology Development funding (6.3 "money") to Program Definition and Risk Reduction funding (6.4/6.56 "money").

[51] The National Research Council is a part of the National Academies consortium comprising the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council. This report, *Accelerating Technology Transition: Bridging the Valley of Death for Materials and Processes in Defense Systems* (Washington, DC, National Academies Press, 2004), accessed at: www.nap.edu, notes; "Accelerating the transition of new technologies into defense systems will be crucial to achieving military transformation…Historical precedents for the transition of new technologies into defense systems have been neither fast nor efficient."

[52] *Science and Technology for the 21st Century Warfighter*, p. 18.

[53] Wilber Shramm and William Porter, Men, *Women, Messages and Media: Understanding Human Communication* (New York, Harper and Rowe, 1982)

[54] Robert Kaplan, "America's Elegant Decline," *The Atlantic*, November 2007. Kaplan's argument, that the United States is in a period of "elegant decline" in which it will have a long, slow transition from superpower to something less – not unlike the United Kingdom in the twentieth century – during which time the U.S. might have the opportunity to ship the world by influencing strategic partners, has gained increasing currency among policy and defense planners as well as Navy officials. See, for example, Claude Berube, "The Post-Oceanic Navy, the New Shadow Zones, and the U.S. Navy's Force Structure Challenge," *Small Wars Journal*, 2009, accessed at: www.smallwarsjournal.com.