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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

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Abstract

The need to transform the United States military is a top priority of the Department of Defense. President Bush emphasized this in his National Security Strategy when he noted: “The major institutions of American National Security were designed in a different era to meet different requirements. All of them must be transformed.” Transformation is a challenging imperative, especially in a service as rich in tradition as the United States Navy. Two generations ago, President Franklin Delano Roosevelt, frustrated with how slowly the United States Navy was changing, famously said “To change anything in the Navy is like punching a feather bed. You punch it with your right and you punch it with your left until you are finally exhausted, and then you find the damn bed just as it was before you started punching.” Unlike the Navy of President Roosevelt’s day, today’s naval leadership is committed to transforming the Navy and ensuring that the Navy of tomorrow is a critical component of the Joint warfighting force and is a Navy that, in the CNO’s words, “Gives the President options.” Navy leaders have known intuitively that a smaller, better-trained, more stabilized crew could mean a more capable, more professional warfighting team. The ongoing DDG-51 Class Reduced Manning Initiative undertaken by the Naval Sea Systems Command PEO Ships addresses the policy, processes, culture, tradition, and technology aspects of achieving this reduced manning posture on United States Navy ships. This paper will address the full breadth of this Manning Initiative but will focus primarily on the use of technology to better engineer combatant ships in a way that enhances warfighter performance by identifying Sailor tasks and skills, allocating them to hardware, software, and people, and reducing workload. This paper will show that the discipline of Human Systems Integration (HSI) is a key enabler for achieving effective and appropriate technology insertion in U.S. Navy ships.

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

Introduction

As military forces transform, warfighters are increasingly turning to technologists to solve vexing operational challenges through the effective application of emerging technologies. Much of this transformation and a broad array of technologies are focused on naval combatant ships. The discipline of human systems integration presents a number of viable options to better engineer combatant ships in a way that enables warfighters to operate more effectively with fewer people.

The events of September 11, 2001, and the ensuing conflicts in Afghanistan and Iraq reemphasized this need to transform military forces and provided a glimpse of future warfighting as small, minimally manned units achieved exceptional results against enemy forces. The aftermath of the war in Iraq has shown with equal clarity how small units can wreak havoc with larger forces. Concurrently, even as the United States defense budget rises beyond $400B, the U.S. Department of Defense has looked to squeeze substantial savings from every possible account in order to fund the day-to-day costs of the ongoing conflicts in Afghanistan and Iraq while recapitalizing today's force and building the military of tomorrow – the transformed force.

For the United States Department of Defense in general and for the U.S. Navy in particular, there are significant institutional incentives to transform by using technology to replace manpower wherever feasible. As the Navy's fleet size slips below 300 ships for the first time since before World War II, and as the Navy finds itself with an ever-expanding mission set, there is a strong drive to field technologically advanced ships with smaller, more capable crews. For the U.S. Navy, this initiative promises to accelerate naval transformation in two ways. First, more capable crews operating newer-technology systems can make more effective decisions in a more-timely manner. Second, smaller crews can free up resources to recapitalize the fleet.

In an effort to move forward smartly with initiatives to reduce manning on U.S. Navy combatants, the Naval Sea Systems Command 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* and *Phase II The Plan for Assured Manning.*[1] This paper presents the significant results of this study.

This study was coordinated with both past and ongoing manning reduction initiatives, particularly current reduced manning experiments being conducted by Commander, Naval Surface Forces. It came to important conclusions and recommendations regarding ways to reduce manning on DDG-51 Class ships and focused especially on changes to policy, processes, culture, and tradition. The *DDG-51 Reduced Manning Study* manning reduction initiatives covered three primary areas: 1.) Achieving economics of scale by moving many functions currently performed by ship's crew off the ship, 2.) Accepting increased levels of risk by eliminating or consolidating some watch stations and reducing some support and hotel services, and, 3.) Investing in emerging technologies that would reduce the numbers of sailors needed onboard Navy ships.

While all three of these initiative areas are worthy of further discussion and study, this paper will focus primarily on the third area, investing in emerging technologies that would reduce the numbers of sailors needed onboard Navy ships. This paper will show that the use of technology to reduce manning on Navy ships is not a one-for-one substitution but an iterative process that is conducted under the auspices of Human Systems Integration (HSI), a multi-disciplinary methodology encompassing the domains of manpower, personnel, training, human factors engineering, safety, health hazards, survivability, and habitability.[2]

This paper concludes the HSI is a keel-up process that is crucial to inserting technology in weapons systems at right place at right time. The Commander of the Naval Sea Systems Command emphasized this in January 2003 when he noted that:

> "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 with NAVSEA's arena of influence, we're going to use this as a gauge to say; is that program properly addressing the human system integration requirement? And so this organization will examine how we have captured the features for human systems integration in whatever we're doing."[3]

Properly used, HSI will have some impact in back-fitting technology into current DDG-51s, more impact in forward-fitting technology into future DDG-51s and maximum impact in extrapolating this keel-up process into the DD(X) family of ships – as well as ships to be built even further in the future.

The process for applying HSI to existing ship systems like DDG-51 is constrained by the existing architecture of the ship. Through analysis of Sailor tasks, skills and workload levels can be identified and allocated to reduce the workload on the Sailor, reduce associated training, and enhance system performance. The resulting reduction in manning is limited to what can be

accomplished through that process. In contrast, when applying HSI to "clean sheet of paper" systems designs (like DD(X)), top-down functional analysis is used, which identifies tasks and skills and allocates them to hardware, software, and people starting at a baseline of zero.[4] This method provides the "optimal" crew size to support total system performance.

By effectively leveraging HSI to the maximum extent possible, the Naval Sea Systems Command engineering community can deliver warships with the most effective warfighting systems and lowest total lifecycle operating costs. This will have a profound impact on how well and how rapidly the United States Navy transforms, and the lessons learned from this transformation effort can be used to accelerate the transformation of coalition navies.

Transforming the United States Military

Transformation of the United States military was a strong imperative for President George W. Bush since well before his administration began its term in January 2001. Candidate Bush signaled the course for military transformation in a speech at the Citadel in September 1999 where he stated: "I know that transforming our military is a massive undertaking…The real goal is to move beyond marginal improvements – to replace existing programs with new technologies and strategies, to use this window of opportunity to skip a generation of weapons systems."[5]

This theme of transformation of the United States military has remained consistent – and has been reinforced - in the years that the George W. Bush Administration has been in office. This has been articulated in several *Transformation Studies* commissioned by the Secretary of Defense;[6] in the *Quadrennial Defense Review Report*;[7] in the *Secretary of Defense 2002 Annual Report to the President and the Congress*;[8] and in the *Transformation Planning Guidance*;[9] as well as in the *National Security Strategy*.[10] The *Secretary of Defense 2002 Annual Report to the President and the Congress* put a punctuation mark on the importance of military transformation by noting that: "We owe it to our posterity to begin a sustained process of investment and military transformation to meet and dissuade future challenges. Transformation lies at the heart of our efforts to reduce risk posed by future challenges."[11]

Transforming the United States Navy

The Department of the Navy has invested substantial intellectual capital in coming to grips with how to transform the Navy and the Marine Corps in order to make them more effective contributors to a transformed United States military. Innovative concepts dealing with Navy and Marine Corps transformation have been generated in venues such as the Chief of Naval Operations Strategic Studies Group, the Navy Warfare Development Command, the Marine Corps Warfighting Laboratory, the Chief of Naval Operations Executive Panel and the Naval Operations Group (Deep Blue).

The Department of the Navy's plans for transformation were formally articulated in *The Naval Transformation Roadmap*, released in July 2002.[12] Co-signed by the Secretary of the Navy, the Chief of Naval Operations, and the Commandant of the Marine Corps, this document set a clear course for transforming the United States Navy and the Marine Corps. The vision presented in this roadmap was first publicly announced by the CNO at the June 2002 Current Strategy Forum at the Naval War College in what he called *Sea Power 21: Operational Concepts for a New*

Era.[13] This new Sea Power 21 operational concept was later refined in a series of articles in the *U.S. Naval Institute Proceedings*, beginning in October 2002 and continuing for several additional issues.[14] This series of articles represented a clear call for profound transformation of the Navy.

Smaller, More Capable Crews as an Agent for Transformation

Key tenets of *Sea Power 21* are designed to focus the efforts of designing systems that enable warfighters to make better and timelier decisions with fewer personnel. Strong anecdotal evidence suggests that the Navy is committed to efforts to reduce the number of sailors on ships. For example, in the case of the Navy's CVN-21 program, the Navy did not originally plan to build a carrier capable of being manned by 800 fewer people until the second ship of the new class. The initial plan called for CVNX-1, starting in 2007 for commissioning in 2014, to reduce the crew by about 400 sailors and for the later CVNX-2 to reduce it by 400 more sailors. However, those requirements changed dramatically in the fall of 2002, requiring the first ship of the new CVN-21 class to have 800 fewer sailors than the current Nimitz Class carriers.[15]

There are compelling reasons to reduce manning on *all* Navy ships. An examination of Navy budget documents indicates that since 1985 the Navy's Total Operating Budget has declined by approximately 40% and the Navy's ship count by 45%; however, the Operations and Support (O&S) costs (consisting of personnel, maintenance, consumables, and sustaining support) have remained constant during this time. This is because personnel costs comprise over 50% of O&S costs and these personnel costs have been growing more rapidly than other costs.[16] Put another way, according the Vice Admiral Timothy LaFleur, Commander of Naval Surface Forces for the United States Navy, personnel costs now account for 64% of the United States Navy budget.[17]

While the imperative to reduce manning on Navy ships would seem self evident and even compelling, many observers have opined that the Navy has not shown a sufficient commitment to reducing crew size on Navy ships. In a June 2003 report, the General Accounting Office criticized the United States Navy for not demonstrating consistent crew size reduction goals on four new classes of Navy ships, noting that only the DD(X) destroyer program emphasized human systems integration early in the acquisition process and established an aggressive goal to reduce crew size, concluding that:

> "Unless the Navy more consistently applies human systems integration early in the acquisition process and establishes meaningful goals for crew size reduction, the Navy may miss opportunities to lower total ownership costs for new ships, which are determined by decisions made early in the acquisition process. For example, the Navy has not clearly defined the human systems integration certification standards for new ships."[18]

The GAO report also validated the fact that the cost of a ship's crew is the single largest cost incurred over the ship's life cycle and quoted the Assistant Secretary of the Navy for Manpower and Reserve Affairs who noted that; "Failure to incorporate human systems integration approaches can only lead to increasing manpower costs in the future that will threaten the ability of the Department to sustain the transformation, readiness and investment priorities we have established."[19]

Finally, the GAO report attempted to ascertain the factors that inhibit the Navy's ability to consistently implement human systems integration-enabled manpower savings across the shipbuilding programs. Four factors were identified; 1.) Neither the Department of Defense nor the Navy acquisition policies establish specific requirements for using human systems integration, such as its timing and whether the approach should be addressed in key acquisition documents; 2.) Funding challenges often result in decisions to defer human systems integration activities and use legacy subsystems when acquiring new ships to save near-term costs over the long term; 3.) The Department of Defense and Department of the Navy oversight of human systems integration activities is limited, and the Naval Sea Systems Command's role in certifying that ships delivered to the fleet have optimum crew sizes is unclear; and 4.) The Navy lacks an effective process to change its long-standing culture and the extensive network of policies and procedures that have institutionalized current manning practices.[20]

The criticism of the Navy for its lack of an organizational imperative to reduce manning on its ships is not limited to the General Accounting Office or to other entities inside the United States government. In an exhaustive study, the Center for Naval Analysis (CNA) concluded that, within the United States Navy, there are insufficient organizational imperatives to mate technology and manpower decisions. CNA researchers found that in setting requirements, Navy manpower authorities take technology as a given and use decades-old assumptions about average hours of work and the pay grade mix of the crew to determine proper manning of Navy vessels. CNA identified the Navy's business practices and institutional stovepipes that separate technology and manpower decisions, as well as incomplete metrics of how manpower affects safety and readiness, as chief contributors to the Navy's failure to effectively assess manpower requirements and make sufficient headway in substantially reducing manning on U.S. Navy ships.[21]

In spite of these criticisms – or perhaps because of them – the Navy's Sea Power 21 Strategy appears to offer the potential to give needed impetus to the goal of reducing manpower on United States Navy ships through the selective insertion of technology. The intersection of manpower and technology is evident in the supporting processes that facilitate the *Sea Power 21* warfighting imperatives embodied in *Sea Strike, Sea Shield* and *Sea Basing*. *Sea Trial*: *The Process of Innovation* supports rapid concept and technology development that can deliver enhanced technology capabilities to our sailors as quickly as possible. *Sea Warrior*: *Investing in Sailors* moves to develop new combat capabilities and platforms that feature dramatic advancements in technology and optimization of crew size. *Sea Enterprise: Resourcing Tomorrow's Fleet* supports initiatives that will replace Cold War-era systems with significantly more capable sensors, networks, weapons, and platforms. Significantly, *Sea Enterprise* will substitute technology for manpower to achieve warfighting effectiveness in the most cost-effective manner.[22]

The lessons learned from Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) have resulted in dramatic changes to Navy deployment and readiness policies that further emphasize the need to reduce manning on United States Navy combatant ships. The Chief of Naval Operations has determined that the ability of the Navy to surge up to six Carrier Strike Groups for OEF and OIF is a capability that must be institutionalized throughout the Navy if the service is to remain relevant in future warfighting scenarios. The Fleet Response Plan (FRP), implemented in December 2003, places Carrier Strike Groups (CSGs) and Expeditionary Strike Groups (ESGs) in an enhanced readiness posture that will enable them to surge to respond to crises before they have completed the traditional inter-deployment training cycle (IDTC). The

FRP mandates that ships and other units of CSGs and ESGs maintain manning at deployment-ready levels throughout the majority of the IDTC. This new, significantly increased manning requirement will likely put near-impossible strains on the Navy manning system unless or until steps are taken to reduce manning on Navy ships.[23]

Achieving the vision of *Sea Trial, Sea Warrior* and *Sea Enterprise* and effectively implementing the Navy's new Fleet Response Plan presupposes that candidate technologies are now under development that will enable technology to enhance operator performance or substitute for manpower. The complex missions undertaken by naval forces rarely enable manual processes to be replaced by automated ones with a "simple" substitution of technology for operators. Instead the process becomes "mixed," with human supervision of automated processes and human selection of automation levels. With the advent of "smarter" systems that work cooperatively with human supervision, the role of many warfighters shifts from manual control and data input towards strategic thinking and planning. This shift in design focus may allow one operator to supervise processes and systems that were previously controlled by two, three, or more operators.

Thus, automation must be planned carefully and designers must not necessarily take the human out of the information loop just because the control loop is removed in a mission process. In fact, higher quality information may be needed for user understanding of what the automation is doing and what is required during mixed control events. Cost comparisons of human vs. machine must account for mission processes that contain mixed-initiative systems – where the task initiative is sometimes human and other times automation - and the mission conditions that may cause those automation conditions to change. This involves an assessment of risk and reliability of the mission process, and the potential for human intervention based on political, social, reliability and safety factors. The *DDG-51 Reduced Manning Study* represents one important step in understanding the relationship of complex system design and crew reduction and optimization and emphasizes the importance of integrating HSI early in the design process.

DDG-51 Reduced Manning Study – Creating Best Practices for Reduced Manning

The *DDG-51 Reduced Manning Study* was the first comprehensive United States Navy effort to examine a spectrum of choices to reduce the manning on an entire class of surface combatants. The organizational imperative for this study was straightforward. While the manpower authorization for the DDG-51 Class combatant has changed very little since the introduction of the lead ship (USS Arleigh Burke), in the decade since DDG-51 was commissioned, there have been major improvements that suggest that a reduction in manpower for DDG-51 Class ships is achievable. Given the increasing manpower costs noted earlier in this paper, just the *possibility* that manpower on Navy ships might be reduced was sufficient reason to undertake this study.

This study was conducted in two phases by an integrated panel of principals from the Department of the Navy and industry. This panel was charged with examining technologies, both current and prospective – as well as policies and procedures – that have a potential of reducing the manning of the DDG-51 Class combatants. The final report delivered to Naval Sea Systems Command PEO Ships consisted of two distinct parts, the *Phase I Concept Study* that identified a range of possibilities for manpower reductions and *Phase II: The Plan for Assured Manning* which provided a number of options for instantiating recommended initiatives. This paper focused primarily on the results of the *Phase I Concept Study*.

Importantly, the *DDG-51 Reduced Manning Study* began by acknowledging the significant challenges involved in any attempt to reduce manning on United States Navy ships – many of which were also identified in the aforementioned GAO Report and CNA Study. Among the "naysayers" concerns that militate against reducing manning on United States Navy combatant ships identified by the *DDG-51 Reduced Manning Study*:[24]

- There is no incentive for the Fleet to reduce the size of ship's crews. Ships will be asked to maintain the same level of mission readiness, ship integrity, self-protection, and cleanliness with fewer people. The ship takes all the risk while the savings are used to pay other bills and not necessarily improve shipboard conditions or support the minimally manned crew.

- Today's budget environment is particularly challenging. Money is tight and most reduced manning concepts include a restructuring of the shore support infrastructure and/or training base that will require some up front investment. Savings or return may not be apparent until multiple units are integrated into this ambitious plan.

- Despite the best intention of today's leadership, there is no guarantee that the necessary support funds derived from manpower savings will be protected in future budget drills, thereby threatening the shore support infrastructure required to support the minimally manned ships.

- There is no real reason, no driving imperative for the current players to take on the risk associated with significant manning reductions. Savings that will accrue in the out years may not be timely enough to convince the current team to buy in. Clearly, this opportunity has been looked at before and previous studies are consistent with what is being offered today, yet few if any of the initiatives in previous studies were pursued. Skeptics ask what is different today.

- Asking leadership to accept the perceived risk associated with reduced manning without sufficient incentive requires that leadership to take a profound cultural leap. Many of today's Navy leaders point to the USS Cole and opine that the ship could not have survived with a smaller crew. They feel that in the event of a catastrophic incident or accident, we are placing the entire crew at risk by undermanning the ship.

- Today's leaders in the Wardroom and Chief's Mess have grown up with the luxury of a large crew and the flexibility that larger numbers offer. Even with BA (Basic Allowance) being less than the stated requirements of manning documents, there have been sufficient numbers to meet all demands on the ship.

- The normal shipboard pyramidal manpower base that exists in today's ships would be replaced by a more seasoned crew with fewer, more qualified people. This raises the question of how to grow the required technical and managerial experience when there are very few junior-training billets left on the ship.

- All previous studies and analysis have reached the same conclusion and support Sailors' contention that they are "not home when they are home." Force Protection requirements after 9/11 exacerbate this situation. The current crew size, based for the most part on the

manning required to meet underway workload and fill Condition III watch stations, is insufficient to meet the import work load; therefore, there is no way to do it with an even more reduced crew.

- Any significant reduction in crew size would probably be at the expense of the junior, non-rated Sailor leaving behind a more experienced, more mature, more seasoned crew for whom mundane housekeeping chores may not be all that palatable.

- In today's Navy, it is almost impossible to complete all of the required maintenance. INSURV reports maintenance is not being accomplished or not being accomplished properly. Reducing the crew size will only exacerbate the problem and will lead to reduced mission readiness.

- Finally, the most important concern that captures much of what the naysayers believe is the most direct one; what's in it for the warfighter? Given legacy design, any efforts to substantially reduce the size of the crew in United States Navy ships in general, and DDG-51 class ships in particular, means the Fleet will be asked to assume greater risk in its ability to meet mission requirements. Without the benefit of the most efficient match of man and ma chine, the ship will have less flexibility, learn to live with less self-sufficiency, set a new, lower standard for hygiene and lose a normally expected level of hotel services.

The fact that the *DDG-51 Reduced Manning Study* captured the concerns of naysayers up front makes this study all the more powerful. Significantly, it points out that of the three primary areas of manning reduction initiatives (achieving economics of scale by moving many functions currently performed by ship's crew off the ship; accepting increased levels of risk by eliminating or consolidating some watch stations and reducing some support and hotel services; and investing in emerging technologies that would reduce the numbers of sailors needed onboard Navy ships), Fleet concerns are most pronounced regarding the first two areas – situations where the warfighter is asked to assume the preponderance of the risk. This leaves the third area – selective technology insertion enabled by HSI - as the area that has the potential to garner the maximum degree of Fleet support for reducing manning on United States Navy ships.

The *DDG-51 Reduced Manning Study* validated the long-term requirement to reduce manning on United States Navy ships – a requirement that *must* be enabled by technology insertion - by capturing the concerns of Navy leadership regarding the extent to which burgeoning manpower costs imperil the Navy's efforts not just to transform – but to remain relevant in future warfighting scenarios. This study noted that senior Navy leaders strongly believe that the reduction of O&S costs is crucial to recapitalize and modernize the Navy since additional budget authority is not anticipated. These concerns were validated by the President's Fiscal Year 2004 Budget where, in a year where the total number of United States Navy ships dipped below 300 and despite a strong drive to recapitalize the fleet, the Navy's procurement budget increased by only two percent over Fiscal Year 2003.[25]

As the Navy's leadership has sharpened the focus on understanding and managing the total ownership costs (TOC) throughout the life cycle of all weapons systems, the TOC of Sailors has been highlighted as the factor that has been growing most rapidly and as that part of TOC that consumes an enormous part of the budget. In noting that from a TOC perspective personnel

costs comprise over 50% of total O&S costs, the *DDG-51 Reduced Manning Study* highlighted the fact that there are compelling reasons to reduce manning on future Navy ships.[26]

This imperative to reduce manning has gained traction within the Naval Sea Systems Command and was one reason behind the establishment of SEA 03, NAVSEA's Human Systems Integration Directorate. Speaking at a media forum in 2003, the Naval Sea Systems Commander, Vice Admiral Phillip Balisle, explained the reasons for standing up SEA 03: "We created some new organizations in NAVSEA, things that literally did not exist before. One of them was SEA 03. We didn't have anything like it so we stood it up from scratch. It's an organization that is focused on human systems integration and training. We created an organization whose role is to one, be very focused on the commercial sector. What exists in the world of human systems integration? The truth is, it's changing quickly. The technology's rapidly changing. We want to be in tune with that. We want to stay at the state of the art."[27]

SEA 03 will have a vital role in shaping the manning profile of future United States Navy ships. The Navy has mandated that future ship Classes (and in the case of the DDG-51, future flights of current classes) will be manned by significantly smaller crews. The *DDG-51 Reduced Manning Study* noted that to reach the projected DD(X) manning levels of 95-175 people would require a ship design process that begins with a zero-based manning concept and uses HSI as an integral part of the design process. By using this methodology, it is projected that the final ship design will achieve performance, risk and TOC objectives with an optimally manned crew. The *DDG-51 Reduced Manning Study* correctly pointed out one of the unique challenges that must be overcome in designing ships with an optimal crew size is the stovepiped manner in which Procurement and O&S costs are provided. This sometimes makes it difficult to extrapolate the up-front investment in HSI and its impact in decreasing TOC over the lifecycle of the ship class. This study highlighted the importance of using total savings to the Navy as the *only* discriminator in balancing technology insertion costs against the savings in personnel enabled by this technology insertion.

While the *DDG-51 Reduced Manning Study* correctly points out that three areas of manning reduction – economics of scale, accepting increased levels of risk and investing in emerging technologies – all have the potential to reduce manning on United States Navy ships, this study provides the strong anecdotal data that suggests that emerging technology insertion is the manning reduction methodology that promises to provide the greatest long-term impact to reduce manning – especially on new classes of ships – while also engendering the minimum degree of "push back" from the Fleet. This happy scenario is critically dependent on effectively using HSI to ensure that the right manpower-technology tradeoffs are made in the right way, at the right times.

Getting the Manpower-Technology Piece Right – The Importance of HSI

The United States Navy has set ambitious manning goals for new surface ships, including the goal of fewer than 100 people for the DD(X). Future ships must possess the operational flexibility to meet the multi-mission forward presence and warfighting requirements of the littoral or open-ocean environments, while employing a nearly "puncture proof" self-defense capability against all varieties of threats envisioned in the 2010 through 2040 timeframe.

To reach these goals, systems engineering teams must apply human systems integration and advanced technology within their total ship systems engineering process to produce a ship-system design that approaches optimal crewing within approved cost and performance constraints. This approach must maximize ship-system effectiveness, readiness, reliability, total performance, and safety and promote an integrated and interoperable design approach that includes the human as a key component of the total systems design from the outset of the design process.[28]

The importance of human systems integration was highlighted in the remarks by the Commander of the Naval Sea Systems Command at the 2003 Human Systems Integration Symposium when he noted that: "In the final analysis, the performance of our nation's Sailors makes the difference between victory and defeat…HSI must be established as a budget line item in all programs, not buried in the murky word 'logistics.' Sailors are not logistics elements."[29] Significantly, Vice Admiral Balisle has reinforced the importance of HSI on an ongoing basis.

Human systems integration is a recognized analysis and design methodology used to optimize ship manning at the lowest total ownership cost while simultaneously achieving the highest quality of service. HSI requires human centered man-machine interface consideration during the entire design and acquisition process, making it truly a keel-up process. Using effective HSI, ship-manning billets are determined by a zero-based review of workload, captured through a functional human-machine decomposition and allocation of relevant tasks and functions to humans. HSI task-function analysis enables an accurate accounting of total ship workload that is assigned to machines, crew and shore support. This ship is truly designed around the crew and the result is a human centered, optimized billet structure at the lowest total operating cost.

HSI is important in all phases of the design process and becomes crucial as crew size is driven lower. Crew-size optimization calls for much higher precision in task assignments and workload optimization, with minimum waste in workload capacity as tasks are assigned to smaller crews. This necessitates the use of HSI to achieve this workload reduction and must include human-computer task activities such as computer interface control and cognitive workload analysis for work planning.[30]

HSI systems engineers operate from the premise that effective human systems integration can do more than just reduce manning on United States Navy ships. Workload imposed by poor design may create both increased personnel burden and reduced mission effectiveness by increasing the risk of mission failure, or by inducing error and delays during peak mission task loads. Design factors with negative impact on human performance or training must be reduced or eliminated to enable effective naval force transformation.

HSI systems engineers at SEA 03 and elsewhere have shown that effective design does not by nature have to be complex or expensive. Sometimes simple solutions can produce significant performance gains. For example, in 1991 Office of Naval Research initiatives led to a new method for selecting objects on a display, by changing the way the screen cursor related to the objects and shifting more of the selection work from the human visual and motor systems to the computer. The result improved performance for all types of input devices.[31] Ongoing Office of Naval Research initiatives conducted under the auspices of Future Naval Capabilities Studies in

the areas of Knowledge Superiority and Assurance and Capable Manpower continue to validate the performance gains enabled by effective HSI.[32]

Results of the *DDG-51 Reduced Manning Study*, as well as ongoing research within SEA 03, has shown that quite often, the roles of warfighters will need to shift toward supervisory control of multiple mission processes rather than manual control of a single mission process. Software systems must be designed to produce high-quality mission products enabling warfighters to do more with fewer personnel. In many cases, costs for duplicate functionality can be shared across systems thereby reducing the cost of automation or decision support. The costs of better automation and high quality software mission products must be compared to the "true" cost of personnel.

Thus, the complexity of measuring the impact of Human Systems Integration on reducing manning on United States Navy ships cuts across technology, system integration and mission processes and protocols. HSI systems engineers have shown that technology insertion and automation is not a dichotomy existing in either an "off" or "on" state, but instead a continuum across multiple levels of human supervisory control. They have shown that models cannot simply trade off automation for human processing one-to-one. Given the interaction between design and process factors, each factor must be included in models that estimate design impact on crew workload and crew size. HSI techniques must be central to the process from beginning to end.

In the final analysis, effective HSI will become a crucial factor in leveraging technology to enable warfighters to make more effective decisions in a timelier manner with fewer personnel. The Commander, Naval Sea Systems Command, highlighted the importance of HSI-enabled technology insertion in building the United States Navy of the future:

> "In the case of the Navy surface combatants, we evolved the Aegis fleet which today is a proven, extremely capable force. We have a Nimitz carrier fleet that is a proven, capable, lineage of ships that can do what we need. We have a submarine force with wide proven characteristics. By luck, design, or whatever, we have created a moment in time when leveraging those proven capabilities the Navy can, I believe, take some risks we might not otherwise be willing to take. We can move forward, jump ahead a little further in technology than we might be willing to do if we didn't have those solid foundations. And in ships like DD(X), CVN-21, Virginia-class submarines, LCS, it is our goal to move that technology as far ahead as we think we can."[33]

Conclusions

The *DDG-51 Reduced Manning Study* represented a bold step for the United States Navy in its efforts to define the parameters for manning DDG 51 Class surface combatants with the right-sized crew while extrapolating these lessons learned to future ship classes. The ultimate goal of these efforts is not only to reduce manpower on U.S. Navy ships but also to enable these ship's crews to make better decisions in a more timely fashion. The implications for Navy leadership will have a profound impact on the Navy's ability to transform and require an enhanced understanding of, and dependence on, the discipline of human systems integration.

This study noted that new technology alone can not reduce manning significantly in current flights of DDG-51 class ships – this new technology must be complemented by removing some functions from the ship and by accepting an increased level of risk. However, it also showed that the introduction of new technology can improve warfighting effectiveness on these fights of ships as well as future DDG-51 flights and newer classes of ships – while also reducing manning significantly on ships planned for the future.

One of the important conclusions of this study was that new technologies that have the potential to reduce manning of Navy ships need to be prototyped *now* to ensure preparedness for the introduction of a new generation of warfighting ships that will be manned at unprecedented levels. This initiative will be facilitated by the Navy's new concept of Spiral Development where technology prototyping will be required as proof of concept prior to broad implementation. PEO Ships indicates that if these new technologies are prototyped in a new DDG-51 ship design by 2004, they will have excellent potential to reduce manning on the next flight of DDG-51 class ships.[34]

Another key conclusion of the *DDG-51 Reduced Manning Study* is that technology itself is an enabler. Whether it involves automation, better and more reliable sensors, electrons vice paper, better, faster computers or other inserted technologies, it is these technologies, combined with process change and cultural acceptance, which will enable the Navy to go beyond initial modifications to crew makeup and make even deeper cuts to ship's manning profiles. This study also concluded that risk could be mitigated if technology and reduced manning initiatives are piloted on a single platform or series of similar platforms that demonstrate equal or better capability than traditionally manned ships. Implicit in these conclusions is the requirement for the Navy to accelerate the acceptance of HSI techniques as an integral part of the ship design process from the keel up.

The *DDG-51 Reduced Manning Study* provided compelling metrics for the importance of manpower saving emerging technology insertion into Navy ships. In its final evaluation of the three primary manning reduction initiatives; achieving economics of scale by moving many functions currently performed by ship's crew off the ship, accepting increased levels of risk by eliminating or consolidating some watch stations and reducing some support and hotel services, and investing in emerging technologies that would reduce the numbers of sailors needed onboard Navy ships – this study reached the following conclusions:[35]

- Excellent economics of scale in the shore support area can be achieved by applying manpower reductions across the entire DDG-51 Class. The crew reduction of 34 (69 bodies removed from each ship – 35 reinvested in the shore infrastructure) people across 40 ships at an advertised rate of $44K per sailor per year equates to about $60M in MPN (manpower account) savings per year.

- By demonstrating a willingness to accept an increased level of risk, 22 additional billets could be eliminated by, for example, eliminating all lookouts, consolidating more watch stations, reducing hospital corpsmen and reducing hotel services (barber shop, laundry services, ship's store and other services). This savings equated to about $98M in MPN savings per year.

- Technologies, such as the multi-modal work stations, could be introduced into a future DDG-51 prototype that offer even more opportunity for future manpower reductions if sufficient up front investment is made. A conservative estimate of 17 additional billets being removed from each ship equates to about $128M in MPN savings.

Thus, although the study co-leads conducting the *DDG-51 Reduced Manning Study* did not begin the study assuming that technology would have a significant part in reducing manning on DDG-51 Class ships, technology insertion proved to offer the greatest potential to save total lifecycle operating costs on future flights of DDG-51 Class. The fact that these technology-insertion initiatives are likely to experience less Fleet "pushback" than the consolidation or increased risk initiatives offers a compelling reason to accelerate HSI-enabled manpower reductions throughout today's – and particularly tomorrow's Fleet.

There are encouraging signs that the importance of HSI in designing Navy platforms, systems, or "systems of systems," in gaining traction throughout the United States Navy. In a comprehensive report prepared for the Navy's FORCEnet Office - *Summary Report: FORCEnet Human Systems Integration (HSI) Outreach and Coordination Initiative: Exploration of Cost-Effective Human Performance Improvements in a Total Ship Systems Construct* - the report's authors strongly recommended the establishment of a FORCEnet HSI Stakeholder Working Group to provide a coordinated approach to HSI in the broader FORCEnet system as a crucial step in implementing FORCEnet Fleet-wide. This report, currently in its implementation stages, concluded that, for a system-of-systems as far-reaching and all encompassing as FORCEnet, HSI is critical to yielding improved human performance and improved systems performance.[36]

While HSI is gaining traction within the United States Navy, the service continues to confront many challenges on this front, ranging from the lack of qualified HSI practitioners within government and among defense contractors, to a lack of understanding of the benefits that early application of HSI efforts can have on the life cycle costs of naval combatants, to a general dearth of metrics available to track the benefits of using HSI methodologies.[37] One encouraging sign is a relatively recent United States Navy initiative in the form of a "Virtual SYSCOM Memorandum of Agreement" among the four U.S. Navy Systems Commands – the organizations charged with designing and procuring weapons systems for the U.S. Navy. This directive charges these four Systems Commands to work together to support and implement HSI throughout the United States Navy, and while it remains to be seem how effective this transformational will be, at a minimum, this MOA provides strong direction on the part of the Systems Command Commanders to make HSI an important part of all Navy weapons systems design work.[38]

Finally, the active and involved participation of Navy leadership in the 2003 Human Systems Integration Symposium is another important indication that, at the highest levels of the United States Navy, the increasing importance of HSI is recognized. As noted by the Chief of Naval Operations:

> "The stakes are high…We must never lose sight of the challenge of a future enemy…an enemy who uses asymmetric means. But the Navy has two asymmetric advantages – incredible technology and incredible people…industry must help the Navy improve HSI to win the battle for finance and be competitive economically in acquisition."[39]

The *DDG-51 Reduced Manning Study* has helped the United States Navy take an important step in enhancing the importance of HSI in enabling the U.S. Navy to design ships from the keel up that support ship's crews in making better decisions in a timelier manner with fewer people. Now, as the U.S. Navy capitalizes on this important step and makes HSI an important lever in optimally manning all platforms, the implications for transforming coalition naval operations may be profound.

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