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Technology Insertion OODA Loop Strategy for Future Flexible Surface Warship Acquisition and Sustainment

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Abstract

The post-Cold War era is over. Demand for advanced future U.S. Naval capabilities continues to grow in the face of resurgent/rising military and technological competitors. The nation needs a more powerful Navy that incorporates new technologies and new operational concepts that combine manned and unmanned systems. The surface warship acquisition and sustainment process must evolve to address this challenge. It requires careful consideration of solutions—old and new—to efficiently insert the technology that achieves dominant warfighting effectiveness for these future warships over their entire service lives.

The ability to rapidly transition advanced mature technology and confidently integrate evolving HM&E and Combat Systems into our ships to outpace the threat and assure naval superiority is an imperative. History is replete with examples of leading companies—and militaries—that failed to dominate due to miscalculations in the management of new technology and poor execution of operational processes. In the same way that Colonel John Boyd, USAF, developed and applied the concept of an OODA Loop (a decision cycle of observe, orient, decide, and act) to combat operations, a construct for a Navy Warship Acquisition OODA Loop can provide a model of individual and organizational learning and adaptation.

Introduction

Sun Tzu, the great Chinese general from the fourth century BCE, is credited as the author of *The Art of War* and founder of maneuver warfare. Maneuver warfare is defined by characteristics like swiftness of action, cycles of dispersion and concentration, deception, surprise, fluidity, shock and flexibility. The other defining feature of maneuver warfare was that it tried to avoid actual combat. When fighting was necessary, Sun Tzu emphasized maneuver warfare characterized by quickness, variety, surprise, and harmony (Giles, 1910).

U.S. Air Force Colonel John Boyd was a military strategist of the late 20th century whom some considered the modern Sun Tzu (Coram, 2002). Boyd's statement "He who can handle the quickest rate of change survives" was in reference to aerial dogfighting but applies equally to the Navy warship acquisition and sustainment challenge. His idea of "fast transients" suggests that in order to win or gain superiority, we should operate at a faster tempo than our adversaries, or inside our adversary's time scale.

The lesson for us still today, whether in operational warfighting or in the defense acquisition sphere supporting the warfighter, is that speed and agility can overcome raw power. Future battles are to be won through the disruption of the enemy's decision cycle and ability to react, through maneuver—in acquisition as well as at sea—and not only through the physical destruction of forces. In his whitepaper *The Future Navy*, previous CNO Richardson affirmed this and amplified the warning that the uni-polar post–Cold War world has changed, stating that time is of the essence (Richardson, 2017).

The former CNO is not alone in his views, nor is the problem solely a Navy one. In testimony before the Senate Armed Services Committee (SASC), Under Secretary of Defense for Acquisition, Technology and Logistics Ellen M. Lord stated:

> Arguably, the weapon systems that the Department delivers to the warfighter today are the finest in the world. Inarguably, however, the current pace at which we develop advanced capability is being eclipsed by those nations that pose the greatest threat to our security, seriously eroding our measure of overmatch. Additionally, the increasing cost of our major weapon systems has placed at risk our ability to acquire and sustain these systems at the level required by our fighting forces. (Lord, 2017)

Acting Secretary of the Navy Thomas Modly (Department of the Navy, 2018) and Assistant Secretary of the Navy for Research, Development and Acquisition (ASN[RD&A]) James F. Geurts (Abbott, 2018a, b, c; Geurts, 2018; Weisgerber, 2018; Werner, 2018) are focused on the same issues and are inspiring the Navy acquisition team to improve. But some are quite blunt in their assessment of our significant organizational challenge. According to Arnold Punaro, a retired Marine Corps general and former staff director of the SASC, our post–Cold War acquisition process can be summed up in seven words: “spend more, take longer and get less” (Lubold, 2013). We must fight bureaucratic inertia and adopt fast-cycle behaviors, or we will be unable to keep up with the increasing pace of technological change, and our Navy will suffer.

There are too many examples to count of leading companies—and militaries—that failed to dominate in the long term due to miscalculations in the management of new technology and poor execution of operational processes that implement it. Navy acquisition must accept the concept of disruptive innovation described by Harvard Business School’s Joseph Bower and Clayton Christensen (1995) and guard against the self-deception that can come with past success to avoid this fate. In short, our potential adversaries can implement and benefit from emerging technologies the same as us and are already doing so without many of our bureaucratic constraints. Our nation’s dominant position in military technology over the past several decades is no longer assured.

The ever-increasing pace of change we face presents a daunting challenge to traditional surface ship acquisition as well as ship sustainment practices and processes. As clearly stated by former Secretary of the Navy Dr. Richard Danzig (2011), we must question our methods, starting with those that suppose we can develop clear, unchanging operational requirements today for a complex surface warship over the next 40+ years. When it takes more than 10 years to conceive of, design, and construct a warship, and then it may operate at sea for more than 30 years, it is simply unrealistic to expect that the current requirements process will produce a warship that will be combat effective for that long. This once might have worked, when cycle-times for defense technology were measured in decades, but those timelines have compressed drastically and can now be measured in years for hardware, and in months for software. But today it can yield a lead ship for a new class that is no longer effective in the prevailing environment. Since (especially today and going forward) there is no way of knowing if the future, or set of futures, being planned for is the right one, we must design and build our surface warships, manage technology development and insertion, and integrate these systems, differently. Warships must be able to respond more easily to a future of uncertainty.

Our challenge today is formidable. The system that won the Cold War, but since the McNamara era has added ever more prescriptive acquisition management policies, may be structurally unable to keep up with the increasing pace of technological advancement. We need a much more responsive approach. But this change should come from within, not simply be a response to a Congressionally driven acquisition reform initiative, or (heaven forbid) the result of a spectacular U.S. Naval defeat. In fact, the Navy acquisition community has selectively shown this can be done with the tools, people, and processes that already exist. We need to combine the right "parts" and execute widely.

Key Challenges for Warship Acquisition

The Navy ship acquisition community faces a call to action from many quarters. Driving issues to be addressed include the following:

- Demand for Increased Force Structure
- Pace of Technology
- Better Ship Design for Lifecycle Sustainment

Demand for Increased Force Structure

A 350-ship Navy became a plank in the 2016 Trump campaign platform in response to changes in the post-Cold War world, and the "near peer" competition threats to the United States. In December 2016, the Navy released a new Force Structure Assessment calling for 355 ships (U. S. Navy, 2016). This recommendation is an increase of 47 in the minimum number of ships from the previous requirement of 308. Within a year, Congress prescribed that "it shall be the policy of the United States to have available, as soon as practicable, not fewer than 355 battle force ships, comprised of the optimal mix of platforms" (*Current State of Defense Acquisition*, 2017).

Actualizing the funding and fielding the human and industrial resources to meet this demand is a challenge given the many fiscal priorities of our nation. The Navy currently has 296 deployable Battle Force Ships (NAVSHIPSO, 2020). Given the U.S. shipbuilding average of delivering 5.4 large naval ships and submarines per year since the post–Cold War drawdown of the mid-1990's (The Heritage Foundation, 2019), along with the anticipated ship decommissionings, it will take time to realize the new goal. In addition, the industrial base, including shipyards, combat systems developers and their respective supply chains, have adjusted their capacities for the prevailing orders over the past 25 years. The human and industrial capacity investments to execute this work will also take time. Meeting the demand for more new warships will be an "across the board" effort that evokes past mobilization eras and the attendant challenges, well described by Doerry and Koenig (2018) and Koenig and Doerry (2019).

While acquiring more ships must clearly be a part of the solution, the size of our fleet is determined by many factors, not the least of which is whether the ships we do build stay in service as long as we expect. Implications for future naval force structure planning and the relationship with ship service life has been well described by members of the Future Ship and Force Architecture Concepts Division in the Naval Sea Systems Command (Koenig, Nalchajian, & Hootman, 2009). The Navy has also taken steps to extend the service life of current DDG-51 class ships (Eckstein, 2018) and has examined options for other ship types (Eckstein, 2018). But this cannot be done by fiat. Extending service life requires a significant investment in maintenance and modernization to be effective.

Pace of Technology

A major disruptive force in our society is the acceleration in the scope, scale, and economic impact of technology. The accelerating growth in technological change is an increasing dynamic in our society and in our military, as shown in Figure 1 (Westerheide, 2015).

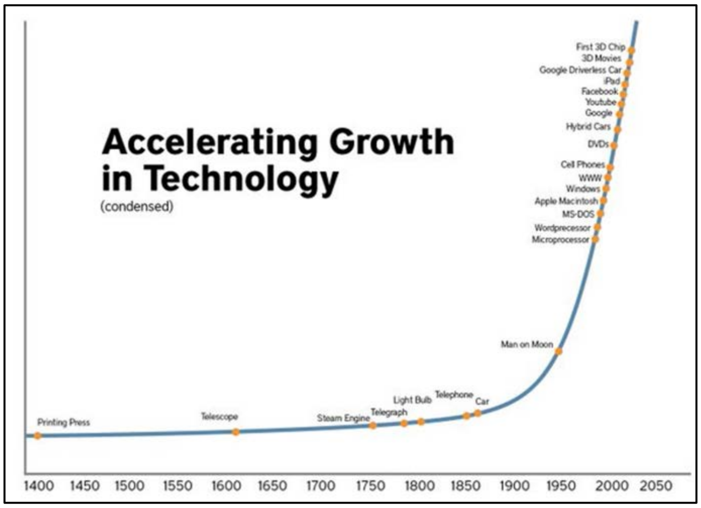

Figure 1. Accelerating Growth in Technology

As important as the growth of technology overall is the rate at which it proliferates and the time it takes to be adopted. These have also been steadily trending to become faster, as documented by well-known venture capitalist Mary Meeker (2018), and experts believe that technological innovation is poised to continue to evolve and grow, likely at a speed beyond our ability to anticipate based on our past experience, due to rising and cheaper computing power and storage capacity, and rising and cheaper connectivity and data sharing. But these improvements may not be the whole story. Their impact is amplified by the associated data revolution that places unprecedented amounts of information in the hands of users and businesses (and militaries). These combined disruptive technological forces will bring significant impacts to nearly every sector, with many dual-use technologies having important military acquisition and operational impact.

CNO Richardson clearly described the broad scope of this increasing rate of technological creation and adoption in *A Design for Maintaining Maritime Superiority* (Richardson, 2016). He called for increased interaction with industry, academia, and non-traditional partners in research and acquisition. In *The Future Navy* (2017), he further directed: “The Navy must get to work now to both build more ships, and to think forward—innovate—as we go. To remain competitive, we must start today and we must improve faster.”

The Department of the Navy’s Naval Research Enterprise (NRE) has recognized that to win, the Navy must be first to field decisive capabilities. The NRE promulgated its strategy (U. S. Navy, 2017) to address the gaps, affirming the need to accelerate processes, stating: “Maritime superiority requires outpacing adversaries. The RDT&E status quo is inadequate to keep pace with technology innovation.” The surface warship acquisition community that leverages the products of the NRE must look at its processes to align with Navy Research and Development (R&D) as well as academic research and industry Independent Research and Development (IRAD) sources to insert mature technology into our fleet at a rate that assures military preeminence.

Better Ship Design for Lifecycle Sustainment

Traditional surface warship design has typically focused almost solely on the initial configuration of the combat system suite and its supporting systems developed using a "single step" acquisition model. After a development process of over 12 to 15 years, the lead ship enters service and operates for several years until its capability atrophies and a "mid-life" upgrade is required. This timeline, depicted in Figure 2, represents an average of development times for major weapons systems and surface combatants over the past several decades (Simmons, 1975).

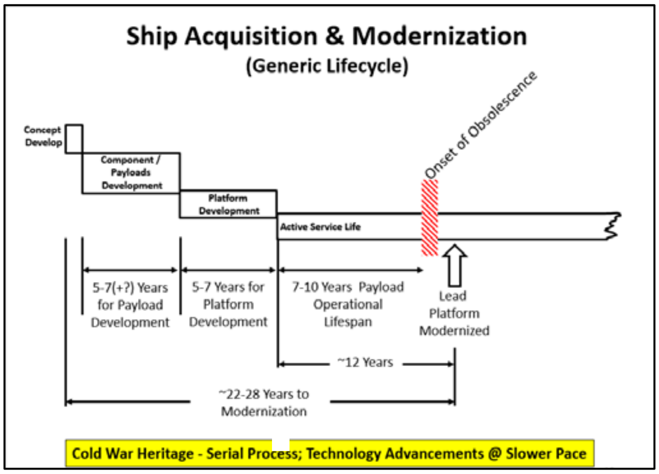

Figure 2. Traditional Surface Combatant Lifecycle Model

The traditional ship acquisition model requires payloads and platforms be developed in series. To minimize ship construction program risk, a combat system element or other supporting ship system "payload" is required to be fully mature. This approach permits highly accurate and well-defined parameters to be incorporated into the platform requirements documents. Though there is a benefit from tight programmatic control, there is an inherent cost to the Navy warfighter, however. As time passes, the military worth of a combat system payload declines, primarily due to the change in the adversary threat, but also due to technology obsolescence. As a result, the traditional series development of payload and platform severely limits the useful life of a combat system that is designed for an adversary whose capabilities are robust and continually evolving. Follow-on ships of a "flight" or "baseline" will have an even shorter effective life before modernization is required, and a large, Multi-Year Procurement may well result in the delivery of later ships with limited effectiveness against near peer competitors. These ships have traditionally had a "closed" physical architecture, which has limited the change to the more dynamic elements of naval warships, as depicted by the blue shapes in Figure 3.[1] This is a heritage from an era when technology was advancing more slowly than it does now and was sustained during the post-Cold War era when the threat from a near peer competitor was not a driving issue.

[1] With acknowledgement to the inspiration for this depiction of "Surface Combatant stable vs dynamic design elements" owed to Dr. Norbert Doerry who created a similar list for one of the draft slides supporting the ASNE Day 2013 panel "Modularity: Benefits of Modular Adaptable Ships" moderated by (then) PEO Ships, RDML David H. Lewis, USN.

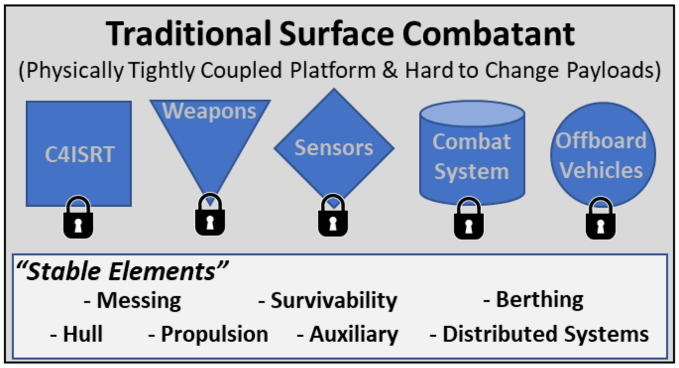

Figure 3. Traditional "closed" ship architecture

In addition, these ships have often reached the point with a need for upgrades that the cost vs. performance trade-offs led to a decision to decommission the ship before it reached its estimated service life, rather than spend large sums of funding to conduct extensive complex overhauls on these warships over long durations. As discussed by Koenig et al. (2009), a key element influencing realized service life of U.S. Navy warships has been technical obsolescence and the difficulty to modernize them cost effectively. In Table 1 of their paper, the authors provide a comprehensive look at the realized service lives of all the surface combatant classes that have been fully retired since WWII, as well as some that remain in service. In an update to this table, Dr. Koenig briefed the Navy's Flexible Ships Integrated Product Team (IPT) (Koenig, 2018) on results through mid-April 2018. This data showed that for Large Surface Combatants (Cruisers and Destroyers) with an estimated service life of 35 years, and Small Surface Combatants (Frigates) with an estimated service life of 30 years, none had achieved these goals to date.[2] The average service life of all 256 of these surface combatants calculated from this data is less than 24 years—far below the expectation that the Navy had for the investments in these warships.

Previous CNOs ADM Jonathan W. Greenert and ADM Richardson promulgated direction that challenges the acquisition community to change the way those previous warships were designed, shipbuilding programs were executed and ships were sustained. Improved ship design is required to keep the ships relevant in service and deliver longer effective life.

In his article "Payloads over Platforms: Charting a New Course," CNO Greenert made the case for a different kind of ship, a "dependable truck" (Greenert, 2012), stating:

> To ensure our Navy stays relevant, these platforms have to adapt to the changing fiscal, security, and technological conditions they will encounter over their long service lives. It is unaffordable, however, to adapt a platform by replacing either it or its integral systems each time a new mission or need arises. We will instead need to change the modular weapon, sensor, and unmanned vehicle "payloads" a platform carries or employs.

In a major step to enable this vision, CNO Greenert signed out two memoranda on mandatory SWaP-C[3] margin requirements, invoking key cost, schedule, and performance parameters. As stated in the August 11, 2014 directive (Greenert, 2014):

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[2] Some individual ships came very close to the service life goal, but class averages did not. It remains to be seen how the remaining Ticonderoga-class cruisers and the in-service Arleigh Burke–Class destroyers will meet current service life extension goals.

[3] SWaP-C: Space, Weight, Power and Cooling.

> Establishment of SWaP-C requirements will help ensure new platforms begin with sufficient–and clearly defined–design margin. This will ensure platforms will accommodate new payloads or other systems needed to remain relevant as new threats and opportunities emerge over the platform's life.

CNO Richardson amplified this approach in *The Future Navy* (2017). These excerpts from that document provide specific ideas:

> The pace of change also demands that we design ships with modernization in mind. The "core" of those future ships—the hull, and the propulsion and power plants—will likely be built to last for decades. To leave room for future modernization, we should buy as much power capacity as we can afford. On top of that hull and power plant, we must plan from the outset to modernize the "punch"—the combat systems, sensors, and payloads—at the speed that technological advances allow. Future ships should be made for rapid improvement with modular weapons canisters and rapidly swappable electronic sensors and systems. Related, future designs must aggressively go after ways to drive down the costs to operate and maintain the future fleet, no matter its composition.
>
> … If we build with faster improvement cycles, the inherent cost of our systems and platforms can come down.
>
> Designing in the ability to modernize—plug and play hardware matched with software-programmability—will make upgrades quicker and more affordable even as we stay more capable.

We must resolve the inherent tensions between conventional acquisition processes that drive us toward very dense ship designs with closed physical architectures that are incredibly difficult and expensive to modernize, and the need to implement innovative advanced technologies in order to sustain the current fleet with affordable combat relevance over the full ship life cycle as well as increase the overall size of the fleet by enabling ships to reach their estimated service lives.

Key Enablers for Change

Seven enablers must be applied to address these imperatives by building upon demonstrated capabilities within NAVSEA and its six affiliated PEOs as well as industry partners having shipbuilding, combat system and ship systems acquisition responsibilities. They are

- More Agile Ship Acquisition Strategies
- Responsive Coordination of Requirements, Resourcing, and Technology Selection
- Flexible-Adaptable-Modular Open Systems Warship Design
- Digital Engineering
- Direct Fleet Operator Engagement
- Experimentation
- Innovative Contracting

More Agile Ship Acquisition Strategies

The U.S. Navy surface ship acquisition community could learn much from a careful examination of the Japanese auto maker Toyota's fast-cycle strategies to compete and win against the U.S. auto industry, especially in the 1980s and 1990s. Insightful analysis is provided by Cusumano of MIT's Sloan School of Management (1988), Bower & Hout in "Fast-Cycle

Capability for Competitive Power" (1988), and the book *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer* by Liker (2004) among others. In Bower and Hout's *Harvard Business Review* article, they illuminate the agility and the focus on process time at Toyota, as shown below in Figures 4 and 5 from their text. Note the cycle-time comparison between Toyota and Detroit in the second figure. This is the kind of advantage the U.S. Navy surface acquisition community must seek in order to maintain naval superiority over near peer competitors.

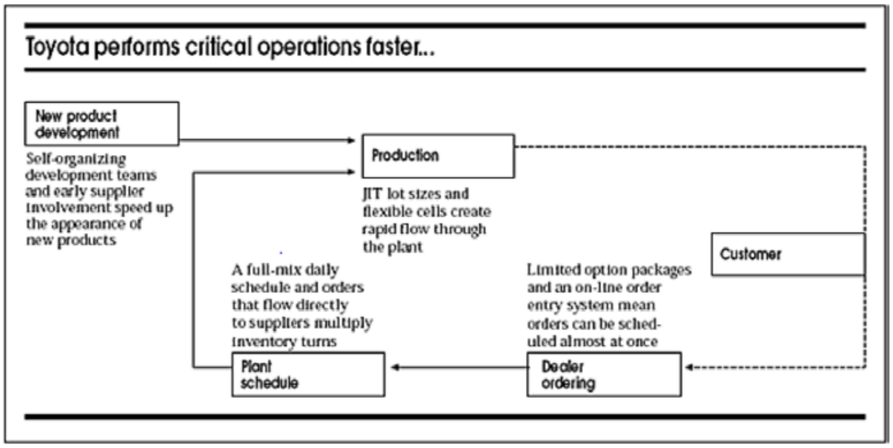

Figure 4. Toyota performs critical operations faster...

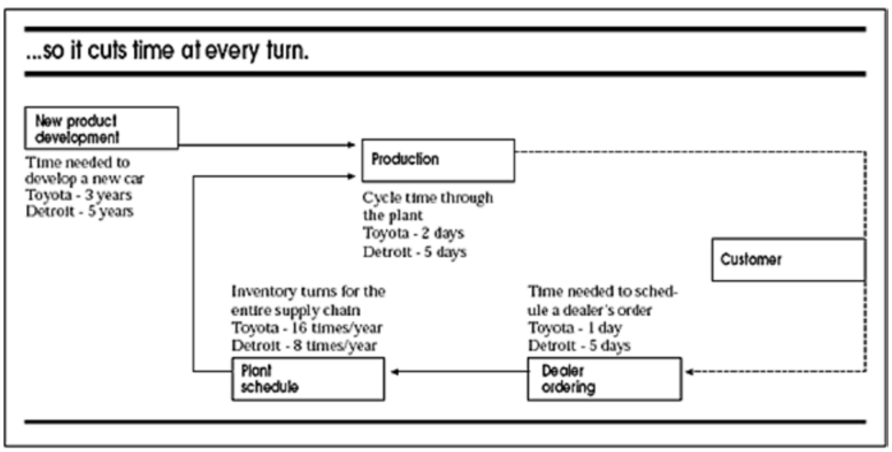

Figure 5. ...so it cuts time at every turn.

In the manufacturing industry, Toyota is well known for their Lean Six Sigma (L6σ) implementation, known as the Toyota Production System. Toyota designed automobiles faster, with more reliability—yet at competitive cost—even when paying the relatively high wages of Japanese workers. As impressive was that every time Toyota showed an apparent weakness and seemed vulnerable to the competition, they fixed the problem and came back even stronger. A careful reading of the challenges that Toyota very effectively addressed to become the world's best auto manufacturer will sound quite familiar to those that our U.S. Navy ship acquisition community faces. The Navy acquisition community must reenergize its commitment to L6σ and more proactively pursue fast-cycle strategies in its standard processes. Appropriately employing solutions like Toyota did in auto manufacturing (guiding principles, strategies, and processes) to the ship design, construction, and sustainment domain can provide a model for development and production excellence.

In order to "tilt the table" in our favor to achieve greater agility, we propose employing Evolutionary Acquisition (EA) and the new acquisition authorities provided by Congress to decouple the development of the payload from the development of the platform along the lines of CNO Greenert's *Payloads over Platforms* thinking and adopt a Flexible - Adaptable – Modular Open Systems Warship Design as described in the next section of this paper. This decoupling will yield major benefits, as well as several ancillary ones. The key benefits include the following:

- By designing the combatant subsystems (payload) in parallel with the ship platform, rather than in series with it, a new ship can put to sea with payloads that are five to seven years newer than would be the case under the current approach.
- By permitting the relatively rapid swap-out of equipment and integration of new capabilities into a new weapon (or any other) system—at the speed of relevance—it is possible to modernize ships with less time and cost penalties than the current approach. This helps ensure combat relevance over the full ship life cycle.

EA is a DoD procurement approach where capability is developed and delivered in increments as shown in Figure 6, where the acquisition program recognizes up front the need for future capability improvements. The objective is to balance needs and available capability with resources, to achieve more rapid acquisition of mature technology that supports earlier fielding of usable warfighting capability, coupled with technological upgrades in successive blocks to achieve full capability over time ("Evolutionary Acquisition," 2018). EA essentially divides large systems into smaller chunks, increasing delivery flexibility and decreasing scheduling risk. Each block upgrade is managed as a separate increment for a fully operational system. Each increment will have its own set of requirements, funding, review cycles, certification and accreditation, milestones and Acquisition Strategy, in sequence, as shown in Figure 6.

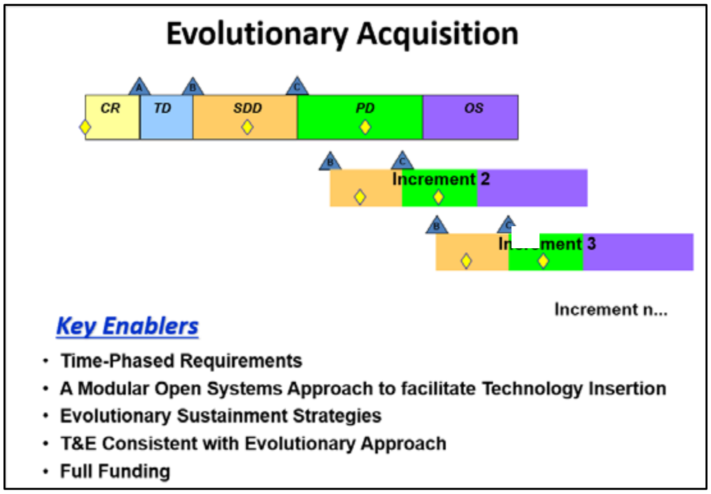

Figure 6. Evolutionary Acquisition Strategy

While this makes for a more complex program to manage, and imposes other potential risks (Dillard, 2010; Dillard & Ford, 2007), incremental development provides great benefit by allowing future capabilities to be added to a system as upgrades through either improved technology or other advantageous operational capabilities to meet a desired state. This is a necessary strategy to give the Navy a responsive framework to address the competition of near peer competitors.

The fielding of these upgrades can be more rapidly done using recent acquisition authorities. The 2016 National Defense Authorization Act (NDAA) Section 804 provided guidance on a Middle Tier of Acquisition (MTA) for Rapid Prototyping and Rapid Fielding. Notably, these MTA approaches are not subject to the Joint Capabilities Integration and

Development System (JCIDS) Manual and Department of Defense Directive 5000.01, “The Defense Acquisition System.” Formal guidance for the processes governing MTA was released in *Operation of the Middle Tier of Acquisition* (DoD Instruction 5000.80) from the Defense Department on December 30, 2019 (Office of the Under Secretary of Defense for Aquisition and Sustainment, 2019). It identifies MTA as a pathway

> intended to fill a gap in the DAS[4] for those capabilities that have a level of maturity to allow them to be rapidly prototyped within an acquisition program or fielded, within 5 years of middle-tier acquisition program start. The MTA pathway may be used to accelerate capability maturation before transitioning to another acquisition pathway or may be used to minimally develop a capability before rapidly fielding.

As depicted in the Figure 7 graphic below (LaCamera, Jr., 2019), which is simplified compared to the DODI 5000.80 Figure 1, this expands the opportunities to be more agile with the insertion of innovative and proven technologies. The MTA avenue can be used synergistically with the incremental development approach in EA for shipbuilding programs, as well as to field improvements in the current fleet.

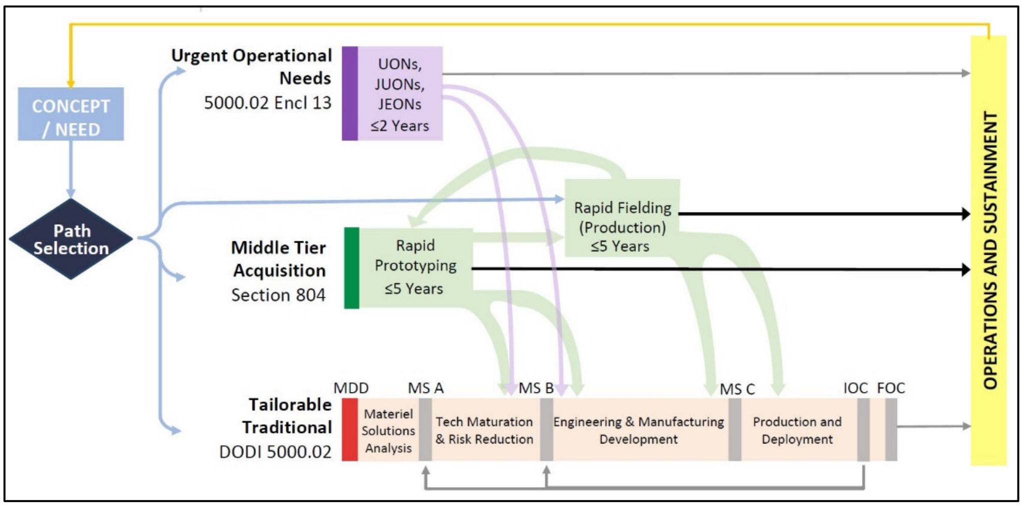

Figure 7. Potential Rapid Pathways

Building upon the previous year’s Congressional acquisition reforms, the FY 2017 NDAA Acquisition Agility Act clearly communicated the aim to get better technology into the hands of the warfighter faster. Significant aspects championed by the House Armed Services Committee Chairman, Congressman “Mac” Thornberry (Gould, 2016), were implemented into law. This legislation (House Armed Services Committee, 2016) included provisions to:

- Field better technology faster, encouraging only mature technology to go into procurement, while also promoting faster upgrades of key components.
- Require all defense systems to be designed with modular open architectures to facilitate easy upgrades as technology and threats evolve and to allow for more competition for those upgrades.
- Authorize each of the Services to utilize funding that is not tied to a specific Program of Record in order to prototype upgrades of components and to develop technology faster and more efficiently.
- Promote experimentation and prototyping, not only to field capability, but to learn and develop new operational concepts.

[4] DAS: Defense Acquisition System

The Navy ship acquisition team needs to fully embrace these authorities from Congress and direction from Secretary Geurts in his subsequent Middle Tier Acquisition and Acquisition Agility Guidance memos (Geurts, 2018, 2019), and aggressively work toward making it the norm for doing business.

Responsive Coordination of Requirements, Resourcing, and Technology Selection

In order to support an agile acquisition process, the supporting aspects of requirements definition, financial resourcing and decisions on what technology to pursue must be made more responsive. This requires a tighter coupling of the efforts, on an appropriate drumbeat, between the Surface Warfare Directorate (OPNAV 96) staff, the Ship Acquisition Program Manager (SHAPM) and Technology Managers in the NRE as well as within the SYCOMS, PEOs and programs.

In OPNAV N96, the Surface Warfare Tactical Requirement Group (SWTRG) offers a model to consider. It was formally established in July 2012 (Deputy Chief of Naval Operations for Warfare Systems (OPNAV N9), 2012) to provide guidance, governance, and definition for Surface Navy Combat System incremental modernization to be provided through the Advanced Capability Build (ACB) process. It aims to provide coordination and collaboration across resource sponsors, program offices, and the fleet to provide integrated surface warfare capability requirements to the acquisition community. The SWTRG is the decision-making body for aligning existing Programs of Record (PORs), new technologies, and new requirements to a given ACB. The SWTRG is positioned to provide the coordination needed for a future surface warship design and incremental modernization Tactical Requirements Group (TRG), and consideration could be given to expanding its scope.

Technology selection requires a group of ship acquisition professionals and technologists organized as a Technology Insertion Group (TIG) that will provide disciplined and focused governance of the process by which technology is screened, evaluated and selected for insertion. The TIG will need to synchronize with the N96 TRG, the SHAPM, NAVSEA Director for Surface Ship Maintenance and Modernization (SEA 21) Program Manager and DASN RDT&E staff in its execution. The Navy undersea warfare community's Technology Insertion (TI) process for hardware and Advanced Processing Build (APB) process for software offer examples to examine and adapt for the surface warship domain.

Flexible - Adaptable - Modular Open Systems Warship Design

Executing an EA strategy combined with Middle Tier of Acquisition pathways for the design, construction and modernization of Navy warships requires future ships to have inherent flexibility in mission reconfiguration, allowing them to be capable of accommodating new technologies over the entire service life of the ship and keeping pace with the shorter life cycles of commercial-off-the-shelf (COTS) products. The implications of this were discussed in the 2003 SNAME paper by Abbott, Devries, Schoenster and Vasilakos (2003).

Development of modularity solutions and codification of standard payload-to-platform interfaces offer ship designers and systems engineers the opportunity to redefine the distinction between the payload and the platform. Modularity in some forms, such as the Mk 41 Vertical Launching System (VLS), has been successfully implemented in U.S. Navy surface combatants since the design and construction of USS *Bunker Hill* (CG 52), the first Baseline 2 AEGIS cruiser, and a similar approach continued in the Arleigh Burke (DDG 51) destroyers. The Littoral Combat Ship (LCS) and accompanying LCS Mission Modules fielded a very different solution. The DDG-1000 program developed yet another. For the future, it is proposed that any modularity should be targeted toward facilitating regular periodic upgrades, rather than tactical flexibility[5] that was the original vision for LCS.

The Surface Navy's vision of delivering warships with increased flexibility and modularity to achieve more affordable relevance over the life cycle has led to a growing initiative. Beginning in the spring of 2013, OPNAV N96 conducted a 90 Day Flexible Ships Assessment, followed by a rapid Ship Concepts Study. PEO Ships subsequently kicked off a Flexible Ships Roadmap development effort in the fall of 2013, and a Navy Flexible Ships IPT was established to build upon this work. This IPT was formally chartered on September 30, 2017, to provide a governance structure for a multidisciplinary group across stakeholder organizations to address and resolve cross-program policy, technical, and programmatic issues as well provide advocacy for the implementation of flexible solutions in surface ships. That group has determined a set of features and described anticipated benefits of a Flexible Ship design (Sturtevant, 2017):

Features

- Payloads de-coupled from platforms
- Standard interfaces
- Rapid re-configuration
- Planned access routes
- Growth margins for modernization

Benefits

- Separates payload development from platform production
- Affordable alternate business model to lengthy and costly ship production work
- Increased competition and innovation
- Cross-platform commonality
- Rapid prototyping of payloads enables rapid acquisition of new capabilities
- Modular open systems enable Acquisition Agility
- Efficient technology refresh and incremental upgrades
- Outpaces the threat

Akin to the great strides made in surface combat systems with AEGIS Open Architecture (OA) (DeLuca et al., 2013) on software OA, shipbuilding must develop a physical OA like that articulated by the Flexible Ships IPT to enact the open architecture vision described by Secretary Geurts (Abbott, 2018) and permit future technology refresh and incremental capability upgrades at the speed of relevance, as depicted in Figure 8.

[5] The LCS has an unclassified operational requirement to pull into a suitable port and change out a complete warfighting Mission Package in 96 hours. This supports converting the role of this "focused mission" ship between Mine Countermeasure (MCM), Surface Warfare (SUW) and Anti-Submarine Warfare (ASW). The requirement was a design driver for the modularity solution, directly influencing Seaframe and Mission Module design.

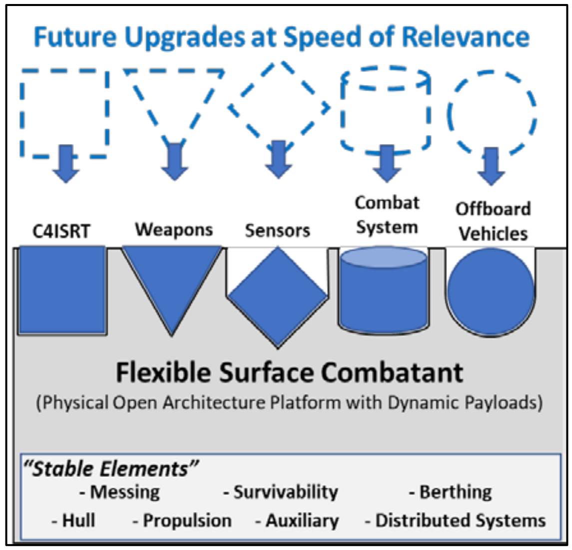

Figure 8. Upgradeable Flexible Surface Combatant

In order to keep pace with the technological changes and outpace adversary threats, and in view of our inability to perfectly predict the future, warships must be Designed for Change (DfC). This is imperative to enable more rapid construction and modernization, delivering more effective warships with increased operational availability (A_o) and address the demand for increased force structure with more dominant warships, changing the age-old calculus and delivering the benefits depicted in Figure 9 (Drewry & Jons, 1975; Simmons, 1975; Systems Consultants, 1974).

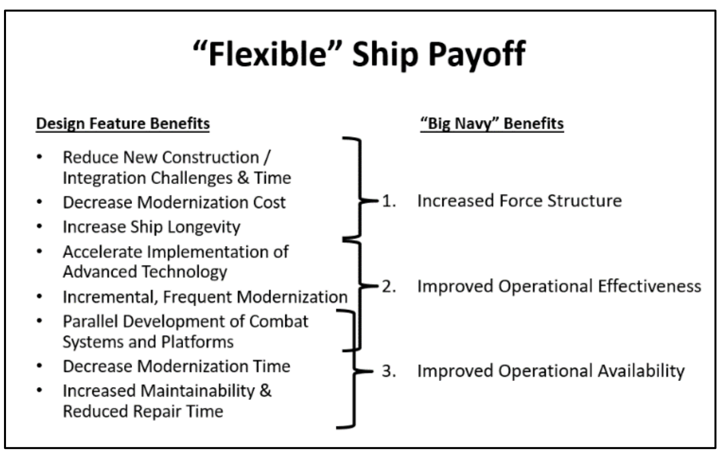

Figure 9. Flexible Ship Payoff

A DfC strategy that addresses attributes such as Adaptability, Agility, Changeability, Flexibility, Modifiability, Robustness and Scalability (Fricke & Schulz, 2005; Ross, Rhodes, & Hastings, 2008) will support continuous evolution and achieve affordable combat relevance over the full ship life cycle.

Looking at the payoff of this strategy at a Navy "enterprise" level, rather than only the ship acquisition community's point of view, a Flexible Ship design employing an EA strategy delivers tangible operational benefit to the warfighter. By enabling more rapid upgrade cycles more often, a Flexible Ship provides the acquisition community a way to deliver more consistent military value to the warfighter over the entire service life of the warship. This is shown in Figure

10, adapted from work (Systems Consultants Inc., 1974) done during the SEAMOD[6] R&D program, an early Navy study to examine a modular ship concept.

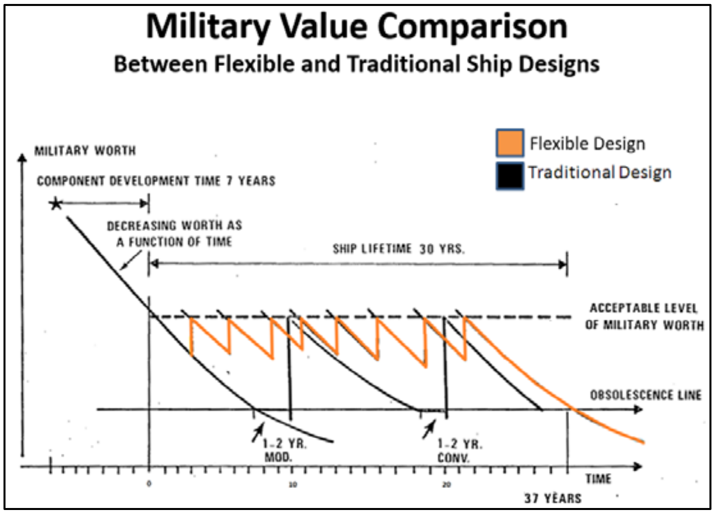

Figure 10. Military Effectiveness Comparison Between Traditional and Flexible Ship Designs

Once only an idea of visionary ship designers (Abbott, 1977; Abbott & Garver, 2014; Doerry, 2012), the Flexible – Adaptable – Modular Open Systems Warship Design approach has increasingly gained wider acceptance (Griffin, 2015; Khalifa, 2017; Shank et al., 2015). This approach is the accepted design architecture for the Large Surface Combatant, part of the broader Future Surface Combatant Force. The previous Director, Surface Warfare (OPNAV N96) RADM Ronald Boxall stated: “Flexibility and adaptability, the ability to upgrade quickly, is going to be a key requirement” (Larter, 2018).

Digital Engineering

Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business (Gartner, Inc., 2018). Digitalization has become a key enabler for making commercial industry more innovative, efficient and positioned for future operations. Major firms in the automotive, health care, and aerospace sectors have made significant investments in developing a digital business model and are transforming the way that their work is done.

In June 2018, the Under Secretary of Defense for Research and Engineering (USD[R&E]) Dr. Michael Griffin released the DoD Digital Engineering Strategy (DoD, 2018). This strategy promotes the use of digital representations of systems and components and the use of digital artifacts to design and sustain defense systems. Among the DoD’s strategic goals is the aim to adopt and support digital engineering across the life cycle.

In the maritime domain, a handful of international shipyards appear to be leading the way with digital implementation and a few shipbuilders in the United States are not far behind. Huntington Ingalls–Newport News Shipbuilding and Electric Boat have made real progress on the “Digital Shipbuilding” path, supported by the National Shipbuilding Research Program over the period from December 2014 to September 2017 (NSRP, 2018). Significant work has been

[6] SEAMOD: SEA Systems MODification and MODernization by MODularity and InterMODality

accomplished in implementing a Digital Twin[7] of the Nuclear Aircraft Carrier and Nuclear Submarine product lines, and by employing a Digital Thread[8] (Debbink, 2017).

Benefits expected from having a Digital Twin for each product unit include

- More effective assessment of a system's current and future capabilities during its life cycle
- Early discovery of system performance deficiencies by simulating results before physical processes and product are developed
- Optimization of operability, manufacturability, inspectability, and sustainability leveraging models and simulations applied during the entire life cycle of each tail number[9]
- Continuous refinement of designs and models through data captured and easily cross referenced to design details (Leiva, 2016).

The commercial marine sector has seen that the use of digital models and in-situ data collection enables more rapid identification and response to issues in service (Borgschulte, 2017). Use of affordable sensors and increased connectivity, along with the availability of increasing data storage and computational power are enablers for new ways of managing a ship's safety and performance in operation. Digital models and analysis tools also enable more efficient future upgrade planning and responsive technology insertion.

The Navy ship acquisition community needs to execute a digitalization implementation strategy and solidify the government's side of the equation along with the operational fleet maintenance staffs to create synergy with industry and deliver the powerful results that are possible. Naval shipbuilding engages many suppliers and stakeholders and depends on efficient communication among them throughout the life cycle of each ship. The Digital Twin and Digital Thread can be effective tools to facilitate this valuable collaboration and evaluate new capabilities. The promising pilot program "virtual twin" of the AEGIS Combat System being developed by PEO IWS is a significant step in this direction and could present a model for the ship design and shipbuilding community (Eckstein, 2017; Freedberg, 2018).

Direct Fleet Operator Engagement & Input

Strong involvement from a cross section of the fleet–and not just officers–can provide the direct user input that allows the acquisition community to address specific capabilities and fleet needs. Since 2011, submarine community participation in the development process has grown with more junior officers and sailors added to the mix through the Tactical Advancements for the Next Generation (TANG) design thinking forums (DON Innovation, 2017; Hall, 2012; Johnston & Featherstone, 2014; Nobles, 2014; Smith, 2013; TANG, 2018). As described by TANG Director Josh Smith, then-VADM John Richardson (while Commander, Submarine Forces) and then-RADM James Caldwell (while Commander of Submarine Force U.S. Pacific Fleet) asked squadron commodores to "nominate two switched-on JO/ST/FT (three-man) teams from each squadron to participate. Ideally, your nominees should be motivated, energetic, creative Sailors with recent deployment or patrol experience." This warfighter-centered innovation approach has revolutionized the submarine advanced technology development community and made a real, positive impact, especially for human-centered design, for the submarine operational and acquisition communities. As shown in Figure 11, their success has

[7] A Digital Twin ship is a digital copy of a real ship, including its systems, that combines the information available about the ship in a digital realm.
[8] The Digital Thread refers to the communication framework that allows a connected data flow and integrated view of the asset's data throughout its lifecycle across traditionally siloed functional perspectives. The Digital Thread concept raises the bar for delivering "the right information to the right place at the right time." (Leiva, 2016)
[9] Or in the context of this paper, each warship.

led to a wider variety of TANG forums being conducted beyond Anti-Submarine Warfare (ASW) (Adams, 2017), and have involved some groups from the Surface Force.

Figure 11. Growth of the TANG forums initiative

Since 2013, a second forum, The Athena Project, has been established (The Athena Project, 2018a, b). This initiative was founded in the Surface Community, beginning aboard USS *Benfold* (DDG 65) in 2013 (Cannon, 2014). It is focused on harnessing deckplate innovations to create a cadre of forward-thinking, creatively confident sailors for the fleet of tomorrow. The Athena Project creates a formal process for sailors to pitch innovative ideas to improve their command or the Navy in an open forum to fellow sailors as well as leaders in industry, academia, and government.

The rise of both TANG and The Athena Project show that the fleet is ready and willing to put the energy into innovation. The time is right for the surface ship acquisition community to engage them.

Experimentation

Military experimentation is a military activity conducted to discover, test, demonstrate, or explore future military concepts, organizations, and equipment and the interplay among them, using a combination of actual, simulated, and surrogate forces and equipment (National Research Council, 2004). Experimentation can examine technology, doctrine, and organizational concepts. As described by Kass, warfighting experiments are vital from the beginnings of the acquisition process through fielding of a capability and can be grouped into one of four general methods: analytic wargame, constructive, human-in-the-loop, and field experiments (Kass, 2008). A significant advantage of the first three methods is an ability to use simulation to examine capabilities that do not yet exist. Once a prototype exists, however, the ability to experiment with it under operational conditions provides critical feedback on its warfighting relevance. Because the operational environment cannot be controlled in field experiments like it can in the other three methods, and at-sea operations have increased cost and complexity, a consistent, systematized approach to experimentation under operational conditions is critical to obtaining valid results and better understanding the military impact. The Navy's undersea acquisition community has worked closely with a Submarine Development Squadron to help provide this structure. Over the past several decades, the Surface Navy has not had a unique organization like this (Boulay, 2019) and has had to coordinate experimentation activities with ships of opportunity. But that changed in 2019 with the creation of Surface Development Squadron ONE (SURFDEVRON ONE).

SURFDEVRON ONE was established on May 22, 2019, to rapidly accelerate experimentation, with its primary functions to

- Execute experimentation to support development of new and emerging surface warfighting capabilities.
- Develop material and technical solutions to tactical challenges.
- Coordinate doctrine, organization, training, material, logistics, personnel and facilities requirements for unmanned surface systems (Commander, Naval Surface Force, U.S. Pacific Fleet Public Affairs, 2019).

SURDEVRON's Commodore Henry Adams has described one of his lines of effort as DevOps,[10] with the intent to inform Surface Warfare requirements by "getting to the left of the acquisition/requirements process" and employing "aggressive experimentation to inform what we want." He has described two focus areas: establishing a capability to "broker" between the development community and fleet; and figuring out how to get installs done faster" (Adams, 2019). This organization provides a critical capability for experimentation with emerging technology and providing a path to insert that technology in a structured, consistent manner.

In addition, linking the recently created Surface Development Squadron experimentation venue as a proofing environment with Surface Warship TANG and Athena Project innovators would be invaluable to effect direct fleet operator engagement in the surface warship acquisition and sustainment process. Leveraging the excellent work and expansion of the TANG and Athena Project forums, the surface ship acquisition community should work with the SURFDEVRON to develop this model and establish a Surface Warship Design TANG to engage creative sailors and boost human-centered design in our surface fleet. In parallel, an Athena Project on Surface Warship Design should be considered to capture deckplate innovations and get them into the technology development pipeline to mature them for future implementation. These combined inputs could be a potent influence on future surface combatant designs.

Innovative Contracting

Like the previously discussed acquisition authorities, the Navy shipbuilding community should expand the use of Other Transaction Authorities (OTAs) to facilitate more responsive technology upgrade insertion and keep our warships combat-relevant in service. OTAs are legally binding contracts that can be used to carry out research projects that meet the stipulations set forth in two sections of 2016 NDAA Section 815. They enable programs to gain access to innovative research and development from non-traditional contractors who are challenged by the standard requirements of a traditional Federal Acquisition Regulation (FAR)-based procurement contract. Secretary Geurts has encouraged the use of OTAs, citing their benefit in rapidly awarding prototyping contracts for technology supporting naval exercises (Abbott, 2018) and has given System Commands OTA authority up to $100 million (Maucione, 2018).

The Navy Surface Technology and Innovation Consortium (NSTIC) OTA presents a unique opportunity "supporting naval surface technology innovation to provide research, development, test and evaluation, analysis, integration and certification of complex naval warfare systems across a broad range of systems-related areas and disciplines" (Naval Surface Technology & Innovation Consortium [NSTIC], 2020). This OTA enables ship acquisition and

[10] DevOps is a set of practices most commonly used in software development and Information Technology operations. A definition is: "the combination of cultural philosophies, practices, and tools that increases an organization's ability to deliver applications and services at high velocity: evolving and improving products at a faster pace than organizations using traditional software development and infrastructure management processes. This speed enables organizations to better serve their customers and compete more effectively in the market" (Amazon Web Services, Inc., 2020).

sustainment organizations to pursue innovative prototype projects in 21 technology areas that involve advanced concept demonstrations, risk reduction prototyping, technology demonstrations, and development of pre-production prototypes. This OTA venue can support experimentation and become a valuable element of the rapid technology insertion strategy.

In summary, the Navy surface ship acquisition community could improve its ability to respond to the demanding challenges it faces by considering the seven strategies outlined. Combining these “fundamentals” with a specific “playbook” for Technology Insertion using an OODA Loop Strategy (and what that is) will be discussed in the remainder of this paper.

John Boyd & The OODA Loop

Col John Boyd is described by some as the greatest military strategist in history no one knows about. And while some deify him—and others loathe him—his example as a person who “bucked the system” to make a lasting difference is compelling (Coram, 2002; Thompson, 2008). Perhaps his most significant contributions to military strategy came from a series of briefings he gave in various forums. In the 1970s and 1980s, Boyd started to see that the insights he’d developed in his Energy-Maneuverability Theory, how surprise, variety, quickness and harmony led to dominance in air-to-air combat, had far reaching implications. One of his key ideas is a powerful concept: the OODA Loop—Observe, Orient, Decide, Act. It has subsequently been applied by conventional militaries and terrorists alike. It has also been adopted by businesses to help them thrive in a volatile and highly competitive economy.

What Is an OODA Loop?

The OODA Loop is a mental model. According to Boyd, decision-making occurs in a recurring cycle of observe-orient-decide-act. An entity (whether an individual or an organization) that can process this cycle quickly, observing and reacting to unfolding events more rapidly than an opponent can thereby “get inside” the opponent’s decision cycle and gain the advantage (“OODA Loop,” 2018). A simple version of the OODA Loop is depicted in Figure 12.

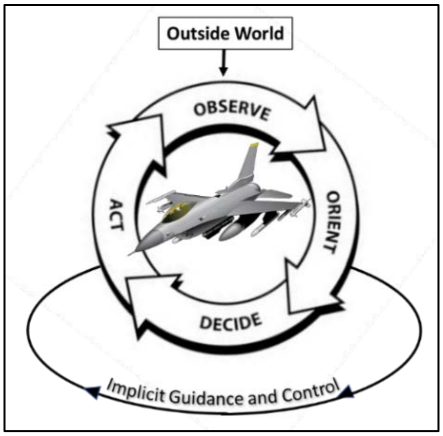

Figure 12. Simplified OODA Loop

First, we observe the outside world and the result of our previous actions. Next, we take time to orient—analyzing and synthesizing everything we learned in the observation phases. Third, the orientation guides our decisions and actions. And finally, the result of those actions becomes more information that begins the next cycle of observation. Those who are familiar with the scientific method: Observation - Hypothesis - Testing will immediately see the similarity. But Boyd added Orientation and strongly emphasized that Orientation was the most important step in the OODA Loop. Furthermore, the key aspect of Orientation is to develop alternative courses of action.

Boyd synthesized this simple idea from his experience as a fighter pilot, and then extended it to a more complex final version, shown in Figure 13, in his presentation “The Essence of Winning and Losing” (Boyd, 1996; Boyd, Richards, Spinney, & Richards, 2010).

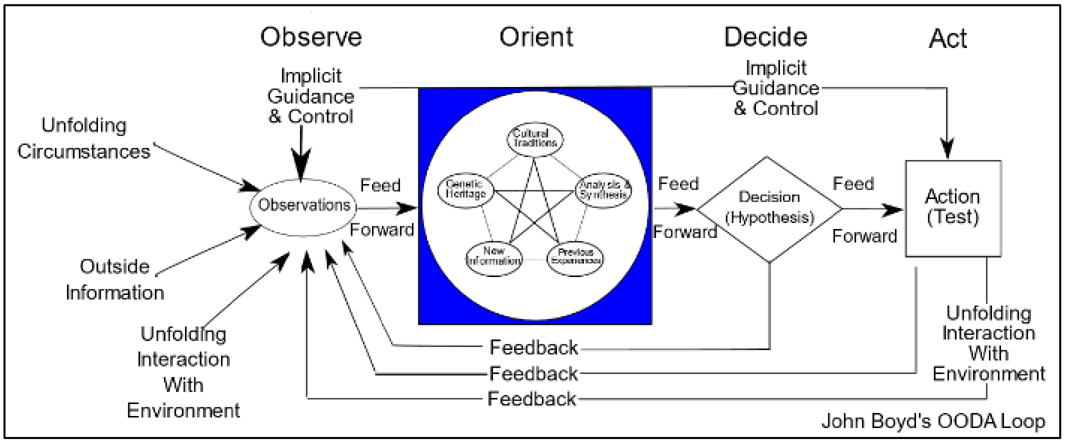

Figure 13. Boyd's OODA Loop—Final Version

In this version, the observation stage involves a broad range of inputs: unfolding circumstances, outside information, one’s unfolding interaction with the environment, and feedback from the other three stages. The orientation phase is the focus of the diagram and is (intentionally) larger than the other three steps combined. It involves analyzing your cultural traditions, genetic heritage, new information, and previous experiences and then synthesizing the elements into a new orientation. The major enhancements in the final version are with the Orient phase, in keeping with Boyd’s view that it was the most important element, the focal point of the loop (Richards, 2004). It is this more complex depiction that will be used to develop the proposed technology insertion OODA Loop for future surface warship acquisition.

With the great potential benefit in using the OODA Loop model, there are also some aspects to watch out for. These include the misinterpretation of speed versus tempo and the decision paralysis that can come with applying it in large organizations or for complex product development.

Caution 1: Speed vs. Tempo Variation

The commonly used phrase “get inside your adversary's OODA loop” is sometimes interpreted as moving feverishly, going through the cycles O > O > D > A > O > O > D > A faster than your adversary. This can create the idea that you always need to be moving at incredible (perhaps unrealistic) speed. What Boyd meant to imply was not frenetic movement. He meant varying your tempo. Boyd called this variation in tempo a “fast transient.” The transient is the change between maneuvers. The ideal fast transient is an abrupt, unexpected, disorienting change. Boyd stated in his slide presentation *New Conception for Air-to-Air Combat* (Boyd, 1976):

- Idea of Fast Transients suggests that—in order to win or gain superiority—we should operate at a faster tempo than our adversaries time scales.
- Why? Such activity will make us appear ambiguous (non-predictable) thereby generate confusion and disorder among our adversaries…

He went on further to state:

Action: Exploit operational and technical features to:

- Generate a rapidly changing environment (Quick/Clear Observations, Fast Tempo, Fast Transients, Quick Kill).

- Inhibit an adversaries [sic] capacity to adapt to such an environment (suppress or distort observations).

> Goal: Unstructure adversaries [sic] system into "Hodge Podge" of confusion and disorder by causing him to over and under react because of activity that appears uncertain, ambiguous or chaotic.[11]

And he summarized with the pithy statement: "He who can handle the quickest rate of change survives."

Caution 2: Large Organization Paralysis

In his paper *"OO-OO-OO!" The Sound of the Broken OODA Loop*, Dr. David Ullman (Ullman, 2007) describes a significant problem with the application of the OODA Loop model to large organizations. Especially in business and product development, where teams are working the OODA Loop, it often gets stuck at the "D":

> Since the OODA loop was designed to describe a single decision maker, the situation is usually much worse than shown as most business and technical decisions have a team of people observing and orienting, each bringing their own cultural traditions, genetics, experience, and other information. It is no wonder that we often get stuck here, and the OODA loop is reduced to the stuttering sound of OO-OO-OO.

Making a single decision, and then repeatedly cycling through deciding what to do next, is essential. In contrast to the traditional warship acquisition framework, which emphasizes control and cost minimization for fixed requirements leading to a "single loop" process, the cyclical OODA Loop approach inherently focuses on learning and refinement in stride. With an emphasis on a faster pace, action must be taken without perfect knowledge and it is recognized that there is an increased chance that the wrong choice might initially be made. Risk aversion inherent to a bureaucracy can stymie the process. But the cyclical nature of the OODA Loop fosters learning and with multiple iterations, analysis and decision making are refined with more observations of results and outside information, including the adversary's responses to actions taken. This leads to fruitful results. Ullman also provides an expanded OODA Loop for consideration, and an extensive list of guidelines for "unsticking the OODA Loop" that should be taken into consideration by all those involved in the complex undertaking of surface warship acquisition in order to avoid large organization paralysis.

Technology Insertion OODA Loop Process

Finally, a tailored process is needed that ties these elements together. The proposal is inspired by the work of Boyd and supports the ability to be agilely executed at the right tempo. In current parlance, this might be called "the speed of relevance." As former Secretary of Defense James Mattis stated in his remarks on the National Defense Strategy (Mattis, 2018):

> To keep pace with our times, the department will transition to a culture of performance and affordability that operates at the speed of relevance. Success does not go to the country that develops a new technology first, but rather, to the one that better integrates it and more swiftly adapts its way of fighting.

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[11] The underlined words, word spellings and word usage in these two text selections may appear odd but are exactly as Boyd originally wrote it on slides 19 and 22 of his *New Conception for Air-To-Air Combat* briefing.

The proposed process is depicted in Figure 14, incorporating tailored inputs and adapting the standard OODA Loop model to include current and proposed constituents of the surface warship acquisition enterprise.

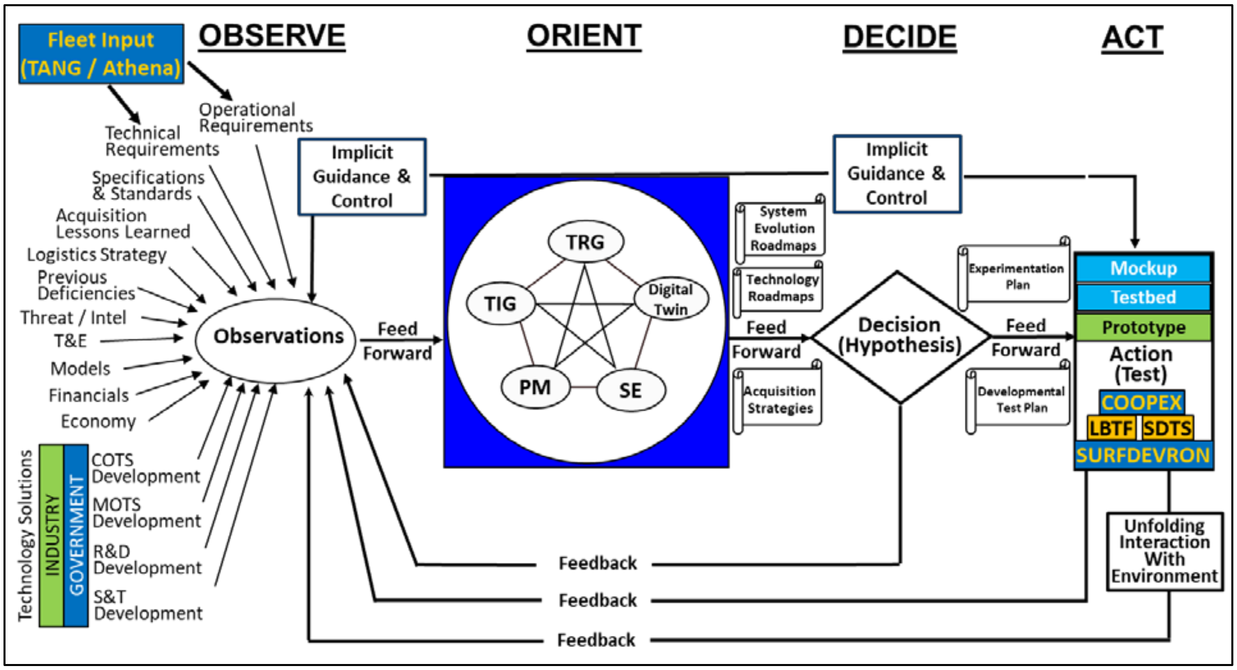

Figure 14. Technology Insertion OODA Loop

Tailored inputs to the Observe stage include:

- Fleet Input (via TANG / Athena)
- Operational Requirements
- Technical Requirements
- Specifications and Standards
- Acquisition Lessons Learned
- Logistics Strategy
- Previous Deficiencies
- Threat/Intelligence
- Test and Evaluation strategies and results
- Operational and Technical Models
- Financials (including budget, execution, color of money aspects, and investment estimates)
- Economy (global and national considerations)
- Technology Solutions from industry, academia and government, including:
    - Commercial Off The Shelf (COTS)
    - Military Off The Shelf (MOTS)
    - Research and Development activities
    - Science and Technology activities

The Orient stage is modified from the elements described by Boyd to those aligned with the Navy ship acquisition domain and discussed earlier:

- Tactical Requirements Group (TRG)
- Technology Insertion Group (TIG)
- Digital Twin
- Program Management (PM)
- Systems Engineering (SE)

The Decide stage is informed by System Evolution Roadmaps, Technology Roadmaps and Acquisition Strategies from the Orientation stage, then feeds forward Experimentation Plans for prototypes or Developmental Test Plans with mature/maturing systems to be executed in the Act stage. The Act stage is where experimentation or various developmental tests, verifications and evaluation of products, product elements, or manufacturing or support processes is conducted (Defense Acquisition University (DAU), 2018). These are done throughout the acquisition process to assist in engineering design and development and to verify that technical performance specifications have been met. Proposed methods include use of:

- Mockups
- Testbeds
- Prototypes
- Concept of Operations Exercises (COOPEX)
- Land Based Test Facilities (LBTF)
- Self Defense Test Ship (SDTS)[12]
- SURFDEVRON

The creation of modular open system payload stations and installation of other Flexible-Adaptable-Modular ship features would be especially valuable on the Navy's SDTS at NSWC Port Hueneme and on SURFDEVRON vessels. This would permit a beneficial stepwise maturation and accompanying examination of capabilities, bridging the gap between the land-based environment and demonstration/experimentation that could be conducted at-sea with sailors from the SURFDEVRON.

Conclusion

In summary, there is much work to be done to put the proposed process in place, but there is also great promise in what it can deliver to improve outcomes. NAVSEA and the affiliated PEOs are positioned to solidify the key enablers and put a strategy in place. The result can neutralize our adversaries, and perhaps avoid costly direct conflict, in harmony with the principles of Sun Tzu. As stated by Boyd in his work *The Strategic Game of "? and ?"* (Hammond, 2018):

> Mentally we can isolate our adversaries by presenting them with ambiguous, deceptive, or novel situations, as well as by operating at a tempo or rhythm they can neither make out nor keep up with. Operating inside their OODA loops will accomplish just this by disorienting or twisting their mental images so that they can neither appreciate nor cope with what's really going on.

In partnership with the fleet and OPNAV staff, the surface warship acquisition community can overcome rigid industrial-age processes by bringing these enablers to bear and adopting an OODA Loop framework for technology insertion in its future flexible surface warship acquisition and sustainment process. This would present a formidable challenge to our adversaries and help achieve our goal of naval superiority.

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[12] And other test ships that the fleet and acquisition community determine are suitable.

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