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CONSORTIUM FOR ROBOTICS AND UNMANNED SYSTEMS EDUCATION AND RESEARCH (CRUSER):

Distributed Maritime Operations (DMO)

Warfare Innovation Continuum (WIC) Workshop September 2017

After Action Report

CRUSER
Consortium for Robotics and Unmanned Systems Education and Research

NPS
PRAESTANTIA PER SCIENTIAM
NAVAL POSTGRADUATE SCHOOL

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EXECUTIVE SUMMARY

This Consortium for Robotics and Unmanned Systems Education and Research (CRUSER) sponsored Warfare Innovation Continuum (WIC) workshop was held 18-21 September 2017 on the campus of the Naval Postgraduate School (NPS) in Monterey, California. The three and a half day educational experience allowed NPS students focused interaction with faculty, staff, fleet officers, and visiting engineers from Navy labs and industry. Featuring a keynote address by the Deputy Assistant Secretary of the Navy for Unmanned Systems Brigadier General Frank Kelly (USMC retired), the workshop culminated in a morning of final concept briefs and fruitful discussion regarding the role of unmanned systems in the future naval force. This workshop also directly supported the Secretary of the Navy's (SECNAV) direction that CRUSER foster the development of actionable operational concepts for robotic and autonomous systems (RAS) within naval warfare areas.

The September 2017 workshop "Distributed Maritime Operations" tasked participants to apply emerging technologies to shape the way we fight. Within a near future conflict in an urban littoral environment, concept generation teams were given a design challenge: *How might advanced autonomy, manned-unmanned teaming, emergent technologies, and unmanned systems reduce risk to the warfighter and increase mission effectiveness?* With embedded facilitators, teams had three days to meet that challenge, and presented their best concepts on the final morning of the workshop.

Figure 1. Divergent design process artifact, September 2017.

This September 2017 WICW included just under 60 active participants and 30 observers and guests – the full participant pool representing over 30 different organizations. Half of the workshop participants were NPS students drawn from curricula across the NPS campus. For this workshop, the final roster also included participants from The Johns Hopkins University Applied Physics Lab (JHU/APL), Defense Advanced Research Projects Agency (DARPA), the Royal Australian Navy (RAN), the Naval War College (NWC), Battelle, Systems Planning and Analysis (SPA) Inc., Draper Labs, General Dynamics Electric Boat, Caterpillar International, and Lockheed Martin. Fleet commands included PMA 262, OPNAV N501, OPNAV N2N6FX, Naval Air Systems Command (NAVAIR), Naval Undersea Warfare Center (NUWC) Keyport, Space and Naval Warfare Systems Command (SPAWAR) Systems Center (SSC) Pacific, Navy

Cyber Warfare Development Group (NCWDG), and Navy Warfare Development Command (NWDC). This workshop included participants from Singapore, Germany, Australia, and Bahrain. The Deputy Assistant Secretary of the Navy for Unmanned Systems was also an active participant throughout the process.

Participants were asked to propose both physical designs and concepts of operation for notional future systems' employment in a plausible real-world scenario with the intent of advancing robotic and autonomous systems concepts. From all the concepts generated during the ideation phase, each team selected concepts to present in their final briefs. CRUSER and Warfare Innovation Continuum leadership reviewed all the proposed concepts and selected ideas with potential operational merit that aligned with available resources. All concepts are described fully in this report, but in summary these concepts include:

1) ***Autonomy in Support of Operations & Logistics:*** this topic area includes autonomy concepts that provide direct support to warfighters in a battlespace. Concepts of interest in this topic area include *Strategic Operational Resource Meteorological and Environmental Renderer (StORMER), Autonomous Track Assess Report Intercept (ATARI), Message Traffic to Operations Center Display, Distributed UxV C2 Architecture*, and some counter-UAS concepts.
2) ***Man-Machine Teaming:*** this topic area includes robotics and autonomy concepts to support warfighters throughout their careers. Selected concepts in this category include *Soldier-size node for HUMINT via Augmented Reality and Body Worn Sensors (SeNTAuR), Watchstander AI Teaming,* the *Modern Day 300* career spanning man-machine teaming, and gravitational sensing.
3) ***Organizational Change & Adoption:*** rather than purely autonomy related concepts, this topic area includes recommendations for change at the organizational level to better leverage the capabilities that autonomy may offer in the future. Parts of the *Modern Day 300* concept fall into organizational change and adoption, and additional concepts warranting further exploration presented in this category include some aspects of gravitational sensing, and a proposed *"FORM-BOT"* designed to autonomously complete standard forms alleviating a common administrative burden.

Selected concepts will begin CRUSER's next Innovation Thread, and members of the CRUSER community of interest will be invited to further develop these concepts in response to the FY18 and FY19 Call for Proposals. Technical members of the CRUSER community of interest will present proposals at a technical continuum gathering such as TechCon 2018 to test these selected concepts of interest in lab or field environments. A final report, the FY18 CRUSER Annual Report, detailing process and outcomes will be released before the end of the 2018 calendar year to a vetted distribution list of leadership and community of interest members. Results of experimentation will be presented to the Office of Naval Research (ONR) in June 2019.

I. BACKGROUND

Sponsored by the Warfare Innovation Continuum (WIC) and the Consortium for Robotics and Unmanned Systems (CRUSER), the September 2017 WIC workshop was held on campus during Naval Postgraduate School (NPS) Thesis & Research Week, 18-21 September 2017. Participants were asked to propose concepts of operations in a near future urban littoral combat scenario in a challenging hybrid warfare environment.

A. ORIGINS

Innovation and concept generation are key drivers for CRUSER, and these workshops are a central element of the overall strategic plan for the CRUSER program. The first NPS Innovation Seminar supported the Chief of Naval Operations (CNO)-sponsored Leveraging the Undersea Environment war game in February 2009. Since that time, workshops have been requested by various sponsors to address self-propelled semi-submersibles, maritime irregular challenges, undersea weapons concepts and unmanned systems concepts generation. Participants in these workshops have included junior officers from NPS and the fleet; early career engineers from industry, U.S. Department of Defense (DoD) laboratories, and other Federal agencies; and officers from allied nations.

One of CRUSER's primary mandates is to develop a community of interest for unmanned systems education and research, and provide venues for communication. These workshops were also designed to maximize relationship building to strengthen the CRUSER community in the future. During Enrichment Week in September of 2012, the Navy Warfare Development Command (NWDC) and CRUSER sponsored a concept generation workshop that was focused on advancing the Design for Undersea Warfare.[1] The March 2013 workshop, Undersea Superiority 2050, took a more focused look at the undersea domain aspects of the September 2012 workshop outcomes. The September 2013 workshop looked at distributed surface and air forces. The September 2014 workshop explored operations in contested littoral environments. The September 2015 workshop was designed to explore the concept of electromagnetic maneuver warfare, and tasked participants with employing unmanned systems in cross domain operations. Following the fleet interests, last year's workshop focused on developing autonomy to strengthen Naval power in response to CNO Richardson's release of the Design for Maintaining Maritime Superiority focusing document in January 2016.

The September 2017 workshop "Distributed Maritime Operations" tasked participants to apply emerging technologies to shape the way we fight. Within a near future conflict in an urban littoral environment concept generation teams were given a design challenge: *How might advanced autonomy, manned-unmanned teaming, emergent technologies, and unmanned systems reduce risk to the warfighter and increase mission effectiveness?* With embedded facilitators, teams had three days to meet that challenge, and presented their best concepts on the final morning of the workshop. Five

[1] *Design for Undersea Warfare Update One*, November 2012: http://www.public.navy.mil/subfor/hq/PDF/Undersea%20Warfare.pdf

concept generation teams with participants from government, industry and academia worked this design challenge for three and a half days. Their work is the subject of this report.

B. PLANNING AND EXECUTION

Planning for this workshop began in earnest several months in advance of the event. CRUSER concept generation workshops are scheduled during the week between the end of classes and graduation in September or March each academic year to maximize the utility of NPS student time. NPS Thesis & Research Week, formerly Enrichment Week – a week without regularly scheduled classes – is intended to allow all NPS students to participate in an activity to further their intellectual growth in specialized areas of study. These concept generation workshops are an ideal fit for this mission.

1. Workshop Participants

Workshop participants were recruited from across the full CRUSER community of interest to include NPS, DoD commands, and from academia and industry. Participants were recruited via targeted invitations to military organizations, government laboratories, academia, and industry DoD contractors. A concerted effort was made to solicit representatives from all naval warfare domains, as well as from the full range of armed services on campus.

Figure 2. September 2017 Warfare Innovation Continuum (WIC) workshop participants

This September 2017 WICW included just under 60 active participants (*see Figure 1*) and 30 observers and guests – the full participant pool representing over 30 different organizations. Half of the workshop participants were NPS students from curricula across the NPS campus. For this workshop, the final roster also included participants from The Johns Hopkins University Applied Physics Lab (JHU/APL), Defense Advanced Research Projects Agency (DARPA), the Royal Australian Navy (RAN), the Naval War College (NWC), Battelle, Systems Planning and Analysis (SPA) Inc., Draper Labs, General Dynamics Electric Boat, Caterpillar International, and Lockheed Martin. Fleet commands included PMA 262, OPNAV N501, OPNAV N2N6FX, Naval Air Systems Command (NAVAIR), Naval Undersea Warfare Center (NUWC) Keyport, Space and Naval Warfare Systems Command (SPAWAR) Systems Center (SSC) Pacific, Navy

Cyber Warfare Development Group (NCWDG), and NWDC. This workshop included participants from Singapore, Germany, Australia, and Bahrain. The Deputy Assistant Secretary of the Navy (DASN) for Unmanned Systems was also an active participant throughout the process. The five concept generation teams were organized to maximize diversity of participant experience. Team workrooms provided individual workspaces while maintaining the ability of team members and facilitators to share many ideas at several stages in concept development. All participants were encouraged to leverage their individual expertise and experience, regardless of their team assignments.

A group networking event was scheduled on the first night to enhance group dynamics, and prepare individuals to work efficiently in an intensive team environment. Senior members of CRUSER, NPS leadership and academic community, as well as visiting subject matter experts were invited to attend any and all of the workshop that fit their interest and schedule. All were encouraged to attend the final concept presentations on Thursday morning.

2. Workshop Design

The September 2017 workshop, "Distributed Maritime Operations," leveraged the innovation lessons learned in previous workshops and was designed specifically to inspire innovative concept generation and development.

Figure 3. Storyboard design process artifact, September 2017.

Scenario

All participants were given an overview of the future scenario titled "Maritime War 2030" focused on a hybrid war conflict in the Baltic Sea. This scenario was derived from current open source media reports, and published thinking by current global military stakeholders. Teams were tasked with developing concepts of operations to counter multiple threats in a hybrid warfare scenario in the urban littoral region of Riga, Latvia on the Baltic Sea. A copy of their scenario is included at the end of this report (*see Appendix B*).

Process

The U.S. Navy (USN), and DoD writ large, have encouraged innovation at all levels and have pointed to Silicon Valley as an innovation exemplar. Product and software development based on user needs led Silicon Valley to become an innovation leader. These user-focused processes have evolved into what is now practiced as “Design Thinking” in industry, academia, and now the military. The WIC workshop employs tools of design for rapid and effective concept generation.

Figure 4. Process map design process artifact, September 2017.

With the help of embedded facilitators, the teams use these tools to address the given design challenge. User input is gleaned from a variety of subject matter experts, and senior military, academic, and industry leaders serving as mentors. Some of this input is given formally in the form of plenary briefs to assembled participants or as part of organized interviews, or informally throughout the workshop. This user input, as well as the assembled team’s experience in the given problem space is the data that begins their concept generation process. The second day of the workshop is focused on divergent creation of choices, and the third day begins by converging on concepts to fully describe for presentation. Summaries of these five team presentations are included at the end of this report (*see Appendix A*), as well as the full workshop schedule (*see Appendix C*).

II. CONCEPT SUMMARY

Knowledge-leveling concept overviews and technology injects related to the design challenge started the exploration into the problem space. Stakeholder perspective statements also focused the concept generation work. Based on the plenary session guidance, read-ahead materials, and subject matter expert input, each team generated numerous concepts and then selected their best ideas to present in their final briefs. Following the final briefs on Thursday 21 September 2017, CRUSER and WIC leadership identified ideas with potential operational merit that aligned with available resources for broader dissemination within the CRUSER community of interest.

A. Concepts and Technologies

Several emerging concepts and technologies were introduced during the plenary sessions on the first three days of the workshop. Teams were encouraged to consider how these concepts and technology injects might benefit combined and allied forces in the scenario presented, but they were not required to include presented technologies in their final selected concepts.

1. Doctrine and Strategy

An overview of the evolving Distributed Maritime Operations concept of operations started the morning, followed by guidance on future fleet design.

Distributed Maritime Operations

CDR David Lewis USN and CDR Jason Canfield USN representing NWDC gave an overview of Distributed Maritime Operations (DMO).

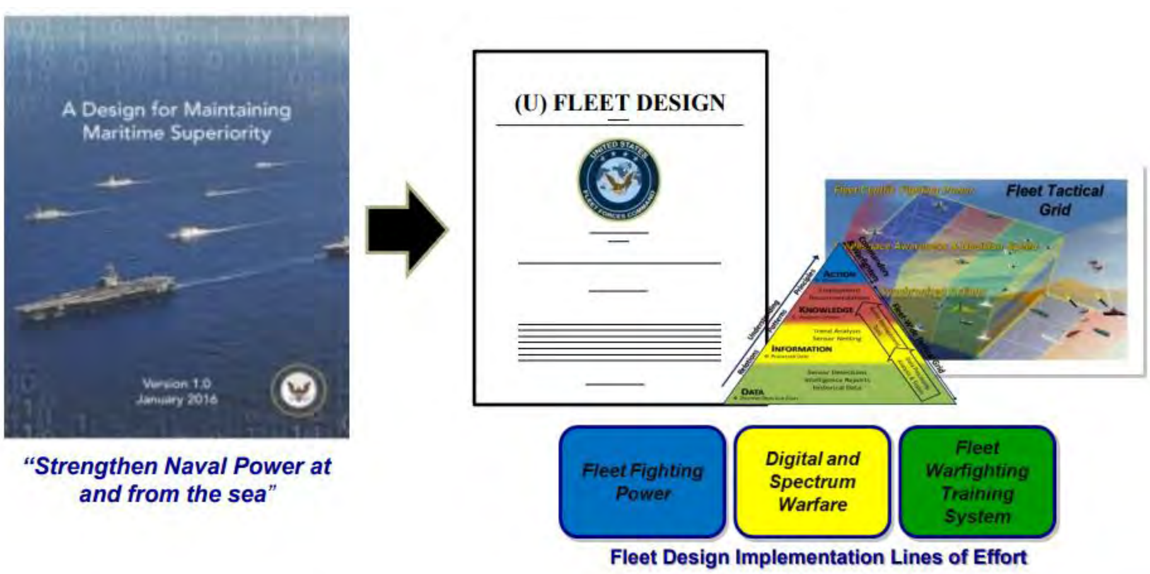

Figure 5. Touchpoints for the distributed maritime operations (DMO) concept.

In January 2016 the Chief of Naval Operations ADM John Richardson USN promulgated *A Design for Maintaining Maritime Superiority*[2] providing implementation guidance for fleet design (*see Figure 5*). Much of our maritime strategy is based on the 30-year-old notion that the U.S. was unrivaled for sea control. That is beginning to change as competition in the maritime global commons is increasing. There are four primary lines of effort in the CNO's design: 1) strengthen naval power at and from sea (BLUE), 2) achieve high velocity learning at every level (GREEN), 3) strengthen our navy team for the future (YELLOW), and 4) expand and strengthen our network of partners (PURPLE). ADM Phil Davidson Commander of U.S. Fleet Forces Command developed a document called Fleet Design (*see Figure 5*) as implementation guidance for his command to implement the CNO's BLUE line of effort.

At the U.S. Fleet Forces level, fleet design has three core elements: integration, distribution, and maneuver – often referred to simply as IDM. How does the Navy fight in a contested and dynamic environment? The nation needs a fighting force that is aligned in terms of IDM. Three enabling components surfaced in initial efforts. The first was the fleet tactical grid which is the technical element. The fleet warfighting training system is the human element. Finally, the overarching DMO concept is the doctrine piece. The resulting fleet design campaign plan developed over the last six months calls out three distinct implementation lines of effort (*see Figure 5*): 1) fleet fighting power, 2) ditigal and spectrum warfare, and 3) fleet warfighting training.

Fleet-centric fighting power, enabled by integration, distribution and maneuver, allows simultaneous employment of synchronized kinetic and non-kinetic mission execution across multiple domains in order to fight, and win in complex contested environments. Rather than platform-centric, a more holistic fleet-centric approach– not just mechanical and physical systems, but including the human element as well – is the desired end state.

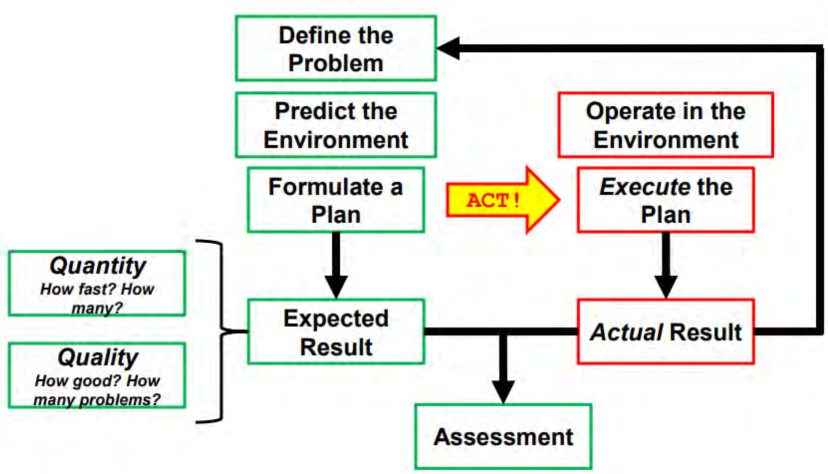

Figure 6. Fleet design implementation process.

Realizing fleet design in operations and warfighting is a process (*see Figure 6*). We have now formulated the plan, and now we must start implementing. As we implement we must pause to assess if we are achieving the expected result. The U.S. Fleet Forces definition of fleet design was stated as: *How the*

[2] Last accessed 14 December 2017 at http://www.navy.mil/cno/docs/cno_stg.pdf

fleet, the Navy's highest warfighting tactical echelon, fights and wins in any environment, as expressed through concepts, doctrine and tactics, techniques and procedures (TTPs). DMO was defined in terms of integration, distribution and maneuver:

- Integration: fleet-centric fighting power
- Distribution: battlespace awareness decision speed
- Maneuver: dynamic synchronized actions

DMO requires employing a total system approach centered on people and culture woven together to greater advantage. Technology alone no longer sustains our decades-old advantage. DMO is scalable based on the region, technology, and assets avaialble, but cannot extend beyond the range of command and control (C2). DMO allows are forces to remain concealed until required – "we are nowhere until we are everywere." Although our current force is distributed across the globe, we are not engaged in DMO – DMO requires distributed forces with one common objective or mission set.

Future Fleet Design

CDR Erik Cyre (USN) from OPNAV N501 Future Fleet Design & Architecture gave the workshop participants a glimpse of a potential future fleet structure envisioned for the year 2045. OPNAV N501 is tasked with looking at future strategies and concepts. Formed as part of the Blue Line of Effort, the Future Fleet Design team was stood up by the CNO to look at a time horizon greater than 8 years out. They work in tandem with the Fleet Forces team looking at efforts in 0-5 years, and an intermediary team focusing on the 3-8 year space. The N501 team is working to answer the question:

> *What is the strategic view of the future operation environment to guide a future fleet design and architecture that sustains U.S. maritime superiority through 2045?*

They chose 2045 because it is beyond the 30-year shipbuilding planning cycle. This time horizon is past the lifecycle of near entirety of in-service fleet assets, beyond the horizon of existing Program of Record (POR), and well into the next-generation threat environment. Their team looks at the problem space through three lenses: 1) what is the future operating environment, 2) what are the things that influence that future operating environment, and 3) what threat analysis, capabilities, and warfighting comparisons are required in the design and architecture phase to achieve certain effects and objectives in a future conflict? Exploring these questions will enable the N501 team to inform today's USN investments and research.

CDR Cyre defined fleet design as how the Navy's highest warfighting echelon fights and wins, and fleet architecture as activities that support fleet design. Their aim is to provide a strategic view that gets out in front of the planning cycle that generates requirements. Lacking this strategic view of budgeting, concept development and prioritization of what is within the realm of the possible exposes the process to the "death spiral of slow iteration." You have trouble innovating to get out in front of the warfare advantage information curve if there is no requirement or any other measure that indicates you need to do so. You can't predict the future, and those that try often suggest that in the future we need everything. We can't have everything, so to try to focus our efforts in terms of how we are going to fight in the future because that will best inform our current efforts.

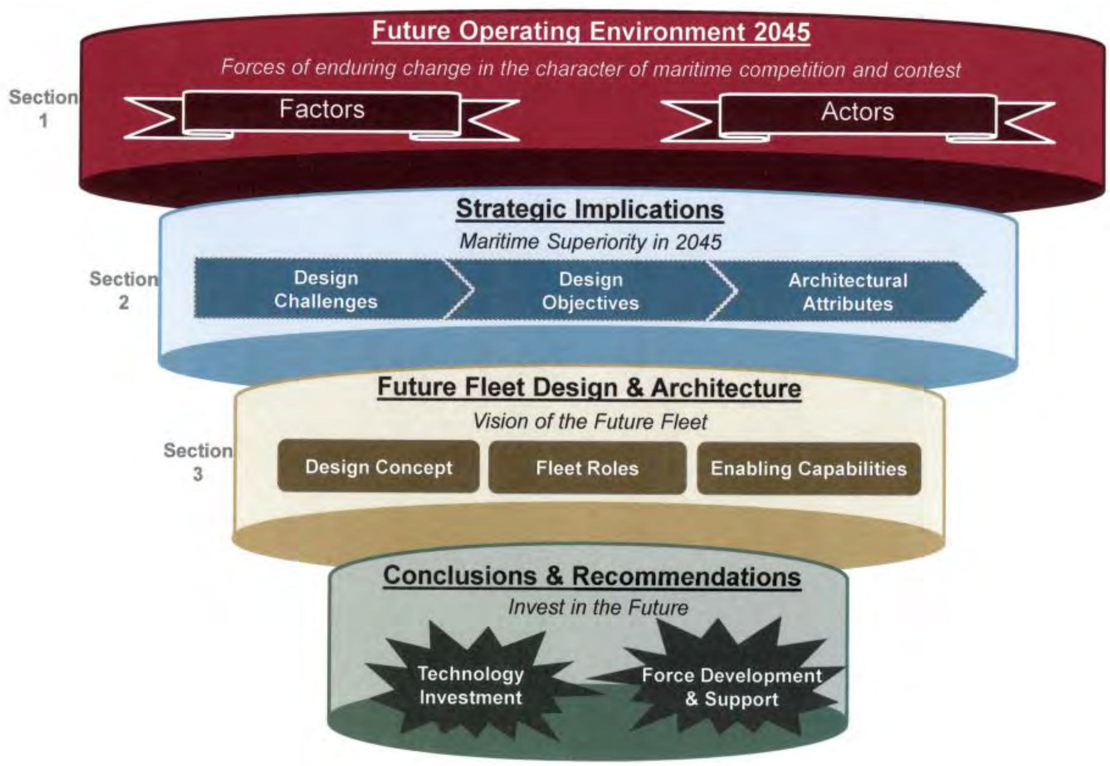

Figure 7. Future Fleet Design & Architecture (FFDA) 2045 approach.

OPNAV N501 does not try to predict the future, but rather analyze trends at three levels (*see Figure 7*) that give us a glimpse of the most likley future operating environment. What is within the realm of the possible, and what might give us an advantage in a world where competition has become the norm in the maritime global commons? OPNAV N501 looked at all the factors and actors that are key to maritime influence, are interested in maritime influence, and have an effect on what determines maritime influence:

> *"In fulfilling our mission, it's important to start with an assessment of the security environment […] in terms of the state and non-state actors on the world stage [and…] the dramatic changes that have taken place on the stage itself."* ***A Design for Maintaining Maritime Superiority, January 2016***

The reulting strategic implications informed their design challenge and objectives, and informed their fleet architecture attributes.

> *"To remain competitive, we must start today and we must improve faster."* ***CNO, The Future Navy, May 2017***

Finally, when they really examined what this future fleet is required to do in terms of roles and capabilities the investment and research paths were clear.

> *"We will not be able to 'buy' our way out of the challenges that we face. The […] environment will force tough choices but must also inspire new thinking."* ***A Design for Maintaining Maritime Superiority, January 2016***

Today we tend to procure on a platform centric basis and then decide what it can to. That leads you down a certain path, but it does not help us get out in front of the cycle where information technolgy and possibility exceed today's understanding. Effects based planning considering strategic implications will result in a future fleet design that do what we need not just look like what we envision.

In the 1970s and 1980s future fleet design was intially threat-based, then capabilities-based. The Navy is now actively engaging in opportunity-based design. Procurement right now follows the folloiwng steps: *I see it, I want it, I ask for it, I get it 10-15 years from now*. As the realm of the possible becomes the realm of the likley and then the realm of the necessary, FFDA 2045 recommends immediate investment in technology to stay on the edge in information and energy, and force development and support for a balanced rapidly tailorable fleet.

2. Technology Injects

Teams were next introduced to some emerging concepts and technologies from diverse stakeholders to seed their concept generation work and introduce the realm of the possible.

Autonomous Data Collection

Dr. Lori Adornato, Program Manager for DARPA's Biological Technologies Office, shared her work in autonomous data collection. In general, DARPA funds high-risk, high-reward projects striving toward great advances in a short period of time. Dr. Adornato completed her graduate work at the University of South Florida where they created their own platform to collect data from the ocean (*see Figure 8*).

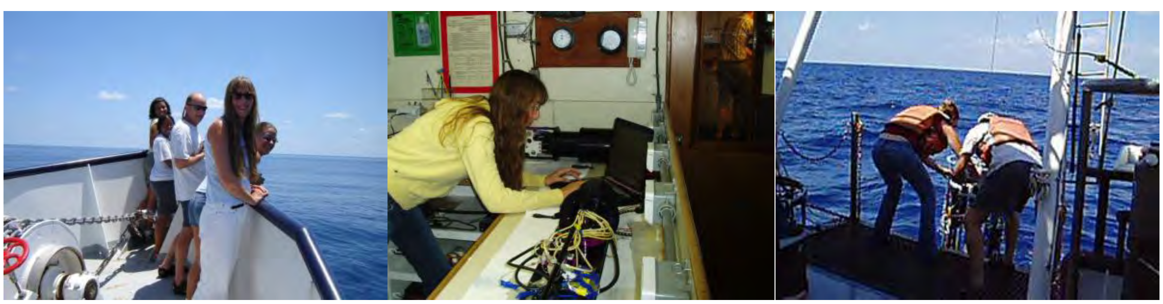

Figure 8. Gulf of Mexico cruises SEAS II.

Starting with a pile of what initially looked like junk, her small graduate research team built a high-resolution, high-sensitivity instrument called SEAS to test water samples. After initial testing, they had a "how might we" design discussion and completely revised the instrument to meet their needs. With connectivity to four peripheral instruments, the team was now able to collect information and create knowledge from that data (*see Figure 9*).

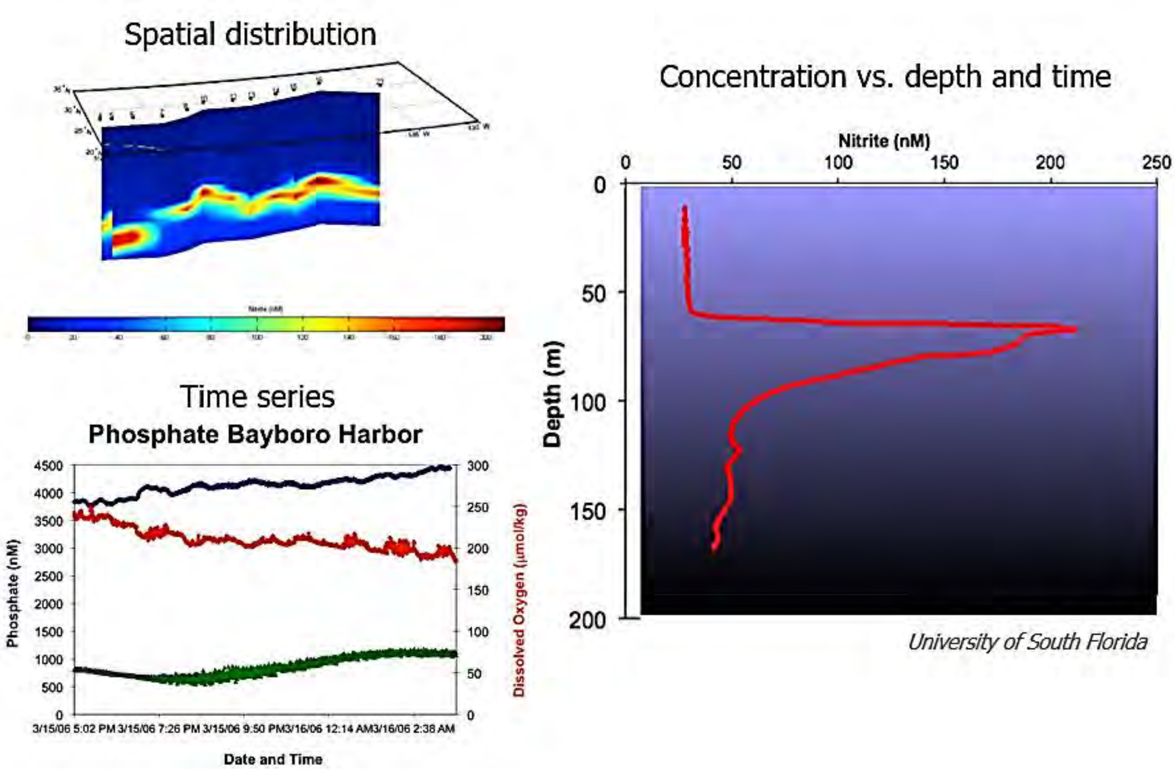

Figure 9. SEAS data.

Following graduation, Dr. Adornato worked at SRI International where her team created a platform to analyze inorganic carbon. Challenged to create a complete portable analysis of carbon-system chemistry to determine carbonate saturation state of sea water, the team developed a new multi-parameter inorganic carbon analyzer (MICA).

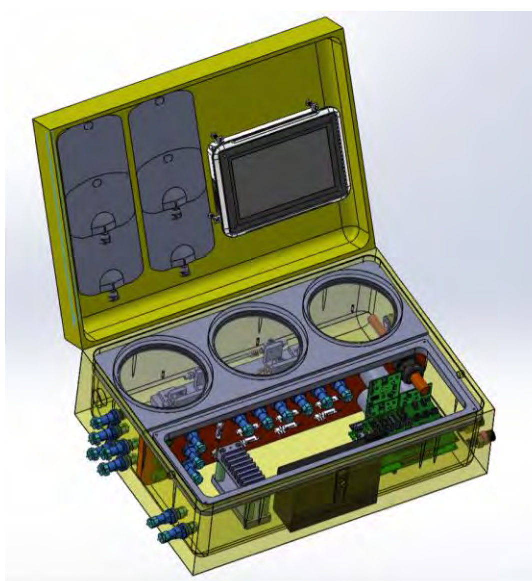

Figure 10. The multi-parameter inorganic carbon analyzer (MICA) developed by SRI International.

Providing required measurements for ocean acidification studies, the MICA measures pH, dissolved inorganic carbon and total alkalinity. Democratizing the ocean acidity measurement process, this device requires little training and produces state of the art measurements.

One of the newest DARPA Program Managers, she presented a "DARPA seedling" project[3] that she has funded as an example of what is possible. The Sequester Carbon with Anaerobic Microbial Populations (SCAMP)[4] project is a small proof-of-concept effort to identify and characterize carbon-fixing microbial consortia collected from the dark marine biosphere that are capable of concentrating and fixing inorganic carbon (*see Figure 11*).

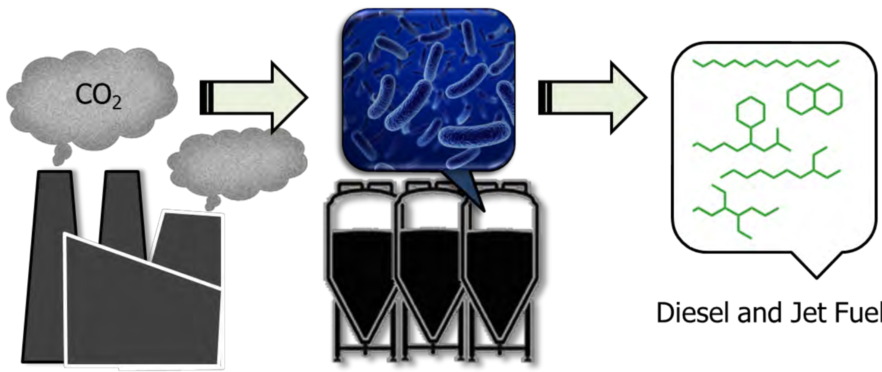

Figure 11. Sequester Carbon with Anaerobic Microbial Populations (SCAMP) DARPA seedling project sequestering atmospheric carbon using dark marine biosphere organisms.

To determine microbial growth and carbon assimilation rates, samples are grown anaerobically at either 4°C or 25°C in the dark and in a defined ONR7A media containing a vitamin solution and a cocktail of electron acceptors. SCAMP testing also included sequestering carbon (C14) as well as the uptake of carbonate.

[3] A DARPA Seedling project is intended to provide proof-of-concept in 3-12 months and generally comes with an award of under $1 million.

[4] SCAMP Principal Investigator: Lisa A. Fitzgerald, Ph.D., Bioenergy and Biofabrication Section, Chemistry Division, U.S. Naval Research Laboratory lisa.fitzgerald@nrl.navy.mil

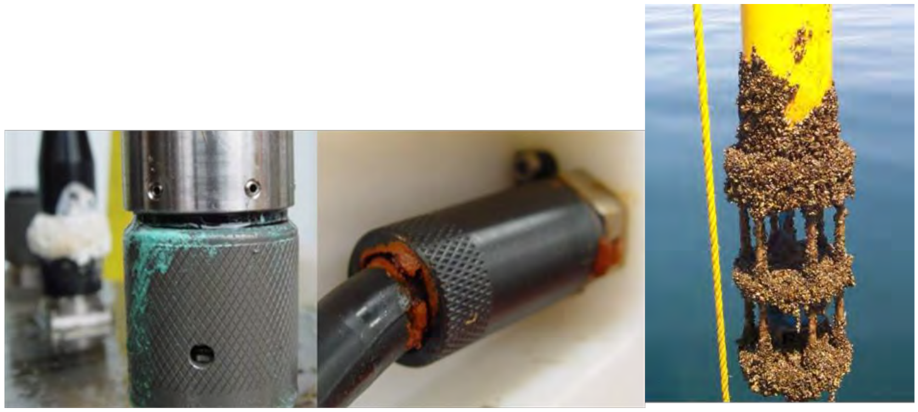

Figure 12. Corrosion[5] (*left*) and biofouling[6] (*right*) are common causes of sensor failure.

Dr. Adornato's next project will go back to her research roots – sensors. There are many common elements that make up a sensor – some sort of sensing element or actuator, a processor or controller, some means of communications, memory, and power supply. Some of these elements are prone to failure. Common causes of sensor failure include corrosion and biofouling (*see Figure 12*). Sensors are expensive to deploy, known signals can easily be blocked or disrupted, battery exchange requires routine maintenance, and the infrastructure and maintenance requirements often limit sensor coverage.

Ocean researchers need a new type of sensor. Organisms are widespread, persistent, and react to changes in their environment. What if devices could detect natural biological activity to provide persistent surveillance while removing some pieces of the sensor? Leveraging known organismal behavior for reliable detection of important targets using living sensors may fill this gap. These "living sensors" might be anything from microbes to whales (*see Figure 13*).

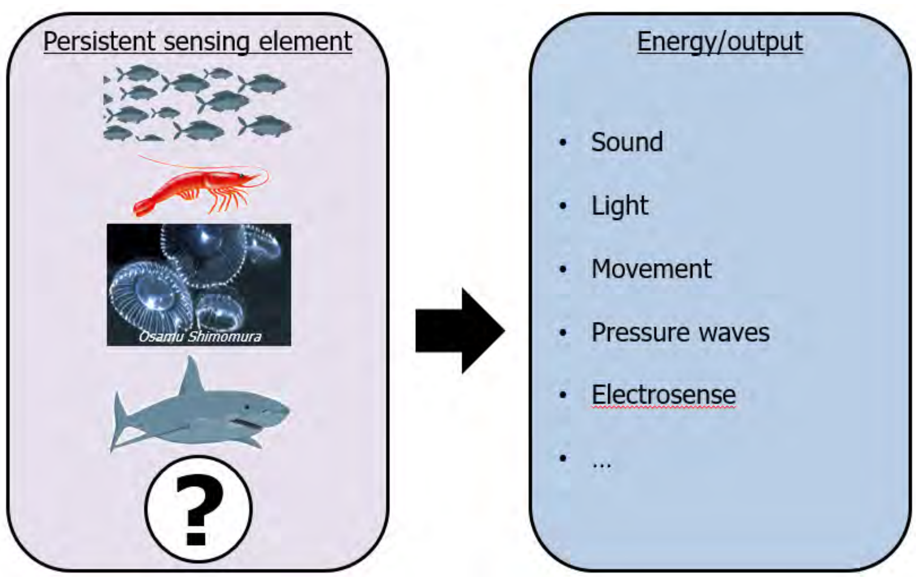

Figure 13. The "Living Sensors" concept to leverage biological organism to provide ISR.

[5] Photo source: Eric McRae, Applied Physics Laboratory, University of Washington
[6] Photo source: Great Lakes Environmental Research Laboratory

There are many things to consider, and this work is just getting underway with a current request for information (RFI) from DARPA to see what others in the ocean research community may be exploring.

MDUSV

NPS Professor David Trask presented his work on the Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV) program as an example of a medium displacement unmanned surface vessel (MDUSV) to inform the work of the concept generation teams as they approached their tasking.

Large unmanned sea vehicles have arrived. How are we going to use them? In the old paradigm (*see Figure 14, top*), unmanned underwater vehicles (UUVs) and unmanned surface vehciles (USVs) were carried by and launched from a manned warship. These assets were limited in size, range, endurance and payload. Under the new paradigm (*see Figure 14, bottom*), UUVs and USVs could be as large as you need and deployable from the pier. These emerging unmanned assets are capable of ocean spanning range, carrying new types of payloads, and will be an integral part of the future mixed manned and unmanned fleet

Figure 14. Current paradigm (*top*) envisions unmanned vehicles as adjunct to a specific host platform such as an LCS or Virginia Class submarine. The new paradigm (*bottom*) envisions self-deploying fully autonomous unmanned vehicles teaming with diverse manned platforms.

Tracking the evolution in USV size and capability (*see Figure 15*) clearly demonstrates the advantages of future self-deploying USVs in the battlespace. With a much greater payload capapcity, range, and endurance these emerging assets can be launched and recovered from the pier. This avoids ship integration and certification in the design process which results in significant time and money savings. Large USVs can provide affordable capacity, independent of manned force structure.

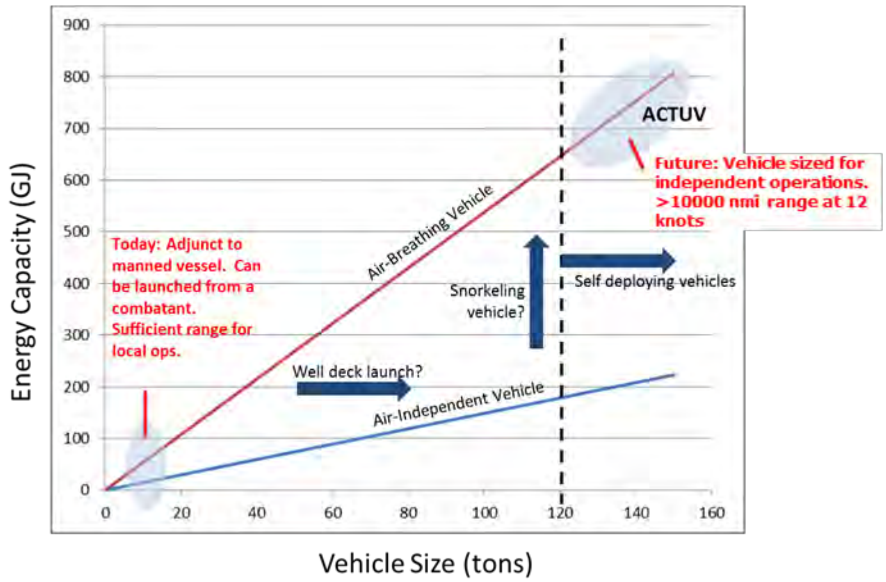

Figure 15. Unmanned vehicle size (*horizontal axis*) in relation to energy capacity (*vertical axis*).

DARPA expressed interest in exploring the potential of a long range, long endurance, large vessel designed to operate with no personnel onboard yet successfully navigate and meet mission requirements. This vessel had to demonstrate operations within the rules of the sea, appropriately responding to international collision avoidance standards and navigation from port to objective to port. In addition the vessel was also required to demonstrate the capability to maintain continuous track and then trail of diesel electric submarines.The resulting ACTUV is an unmanned sea surface vehicle with ocean-spanning range, months of endurance, and substantial payload. Designed with a high level autonomy for independent operations under sparse supervisory control, the ACTUV will likley give future forces a game-changing approach to traditional ASW *track-and-trail* missions. Following two year long test program to confirm its capability to comply with collision regulations (COLREGS), the DARPA ACTUV program has delivered a test vessel – christened SEA HUNTER – to the SPAWAR facility in San Diego. The vessel transferred from DARPA to ONR for the remainder of the test program (*see Figure 16*) to be evaluated for potential roles in ASW, mine warfare (MIW) and mine countermeasures (MCM), anti-surface warfare (ASuW), electronic warfare (EW), and intelligence, surveillance, and reconnaissance (ISR) missions.

Figure 16. Full-scale prototype testing of the ASW Continuous Trail Unmanned Vessel (ACTUV).

With advanced electro-optical and infrared (EO/IR) capability, other key technologies of the ACTUV include advanced autonomy for highly reliable surface collision avoidance while tracking evasive submarine target, a diverse set of ASW sensors for robust track and trail at standoff of up to a few miles, and new payload technologies. Metrics used to evaluate project success include:

- Compliance with International Maritime Organization (IMO) rules for collision avoidance at sea including vessel classification
- Propulsive and maneuvering overmatch v. next generation diesel submarine threat; high assurance target trail over entire operating envelope
- Endurance and reliability to complete 70+ day mission
- Unit production cost approximately $20M
- Minesweeping at Navy objective performance level

The current program with DARPA and ONR funding through FY18, is working to complete builder's trials, acceptance trials, IA certification, and take delivery from Leidos. The project team is also working to complete development and test of baseline capability, and complete development, integration, and test of sensors and payloads. Future work should include development of standards and policy for unmanned operation, a command and control construct, and additional payloads and missions such as ASW, MIW/MCM, ASuW, and ISR. Effective testing of the current prototype will include fleet exercises, integration of ACTUV with manned platforms.

Integrating autonomy into the platform is still the the primary challenge. The ship design must automate actions normally accomplished by the crew. The software must integrate sensors (radar, EO, sonar) for navigation and control systems to conduct maneuvers necessary to transit to a point or patrol area while avoiding other ships, marine mammals, and debris. The project team is also experimenting with ASW sensors, MCM, EW and other experimental systems.

The NPS component of this program was originally intended only to conduct the testing program, but DARPA requested that NPS instead look at the application of ACTUV to operational missions. In 2016

NPS hosted a workshop to develop missions sets to guide further study efforts. The workshop included six breakout sessions:

1) Acquisition strategy
2) C2
3) Cyber security
4) Electronic warfare
5) ISR/Surface Warfare
6) ASW addressed separately by NWDC

Major identified challenges included:

- Translating operational tasks into autonomous behaviors
- Autonomy must work within the construct of current mission TTPs.
- What "behaviors" must ACTUV conduct that are congruent with current Fleet operations
- What specific tasks associated with the Naval Tactical Task List (NTTL) can be refined into mission elements, with those that are appropriate for autonomy in the near future, mid and far future
- As the list of behaviors and capability mature, there will be a natural feedback to NTTL/NTAs and behaviors are constructed.

Opportunities for further work include pursuit of consistent funding and a roadmap for numbers of vessels to be procured. An operational concept, and baseline and mission focused interoperability with Fleet operations must be developed and demonstrated. Specific current missions and tactics in which ACTUV can be implemented in the near term, and a model to determine the improvement in operational capability and comparison of costs will provide needed metrics as the project moves forward. On a larger scale, planning tools to bring autonomous platforms into Fleet operations and means to address specifically cyber and physical security will be essential. What will be the most efficient level of autonomy?

Maritime Dark Networks

NPS Faculty Associate Rob Schroeder and Dr. Wayne Porter presented their work on applying social network analysis to expose dark networks of maritime relationships in the South China Sea. Their Mapping Dark Maritime Networks and Development project analyzed the networks involved in the artificial reef enhancement activity in the South China Sea over the year 2015. Their research set out to answer the questions:

- Can social network analysis enhance maritime domain awareness and interdiction operations?
- What role do maritime dark networks play in supporting artificial reef construction in the South China Sea?
- Can existing analytic tools (e.g. ORA, UCINET for social network analysis; automatic identification system (AIS) and SEAVISION for geo-locating/tracking) be integrated for improved identification,

geo-location, and tracking of maritime dark network platforms (military and commercial), associated owners/operators/State Owned Enterprises, commonly used ports, activities, and cargoes?

- Can technologies currently being pursued by SPAWAR, the U.S. Naval Research Laboratory (NRL), and the Office of Naval Intelligence (ONI) (e.g. ship recognition algorithms and sensors) be integrated as unstructured data into the social network matrices to enhance identification and tracking?
- Can this research be used to enhance maritime domain awareness in other areas of maritime dark network activities such as illicit trafficking, piracy, hybrid warfare, Illegal and Unregulated fishing?

They used social network analysis to track grey maritime networks, often applying “follow the money” heuristics. This analysis used shipping data from various databases including AIS and multi open-source intelligence and created multi-modal networks for ships based on owner, operator, cargo, activity, and ports visited. They identified valued network of ships based on commonalities within grey network of state-sponsors, owners, operators, and activities. This analysis provides enhanced maritime domain awareness for better cueing and collection of maritime platform information and operations for an integrated, inter-agency approach to tracking and influencing reef enhancement activity in the South China Sea.

Figure 17. Standard AIS data output of the South China Sea region.

Traditional AIS data output does not give a very clear indication of potential networks (*see Figure 17*). Applying social network analysis results in a more useful output to identify relationships and connections between stakeholders such as vessels, owners, and operators (*see Figure 18*).

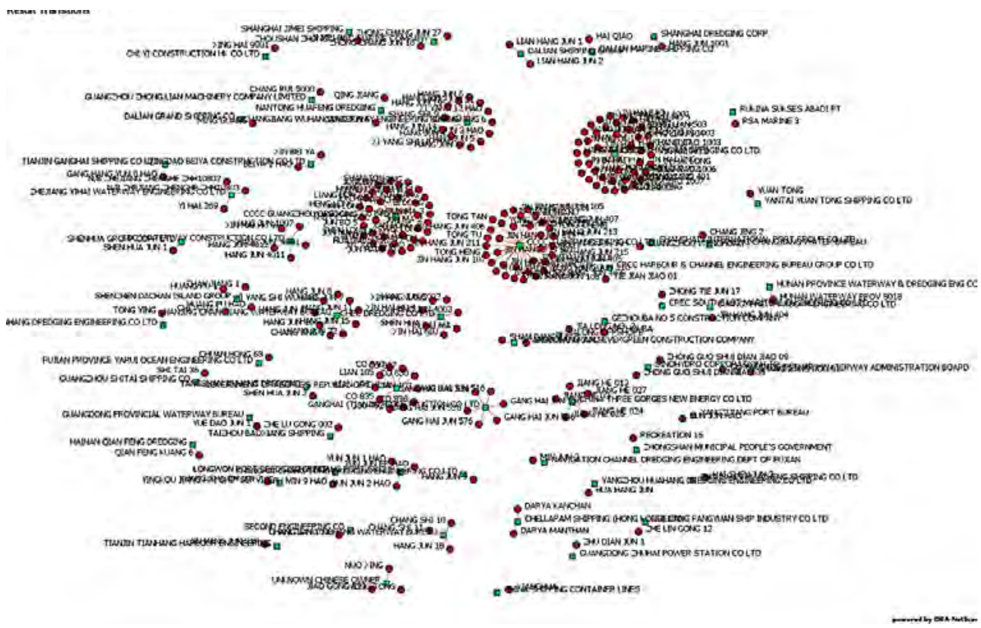

Figure 18. Social network analysis of Chinese reef enhancement vessels (*red*) and owners (*green*).

This work also compared networks over time to identify regions of increasing activity (*see Figure 19*).

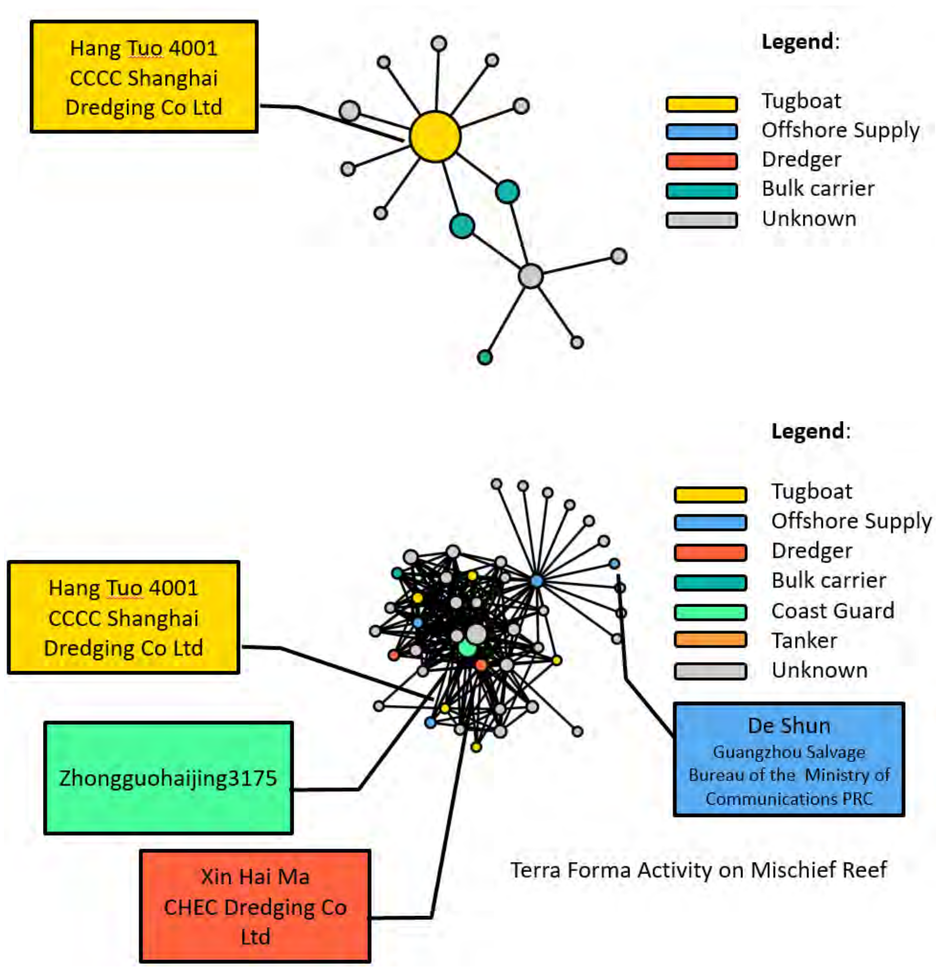

Figure 19. Trend analysis example of terra forma activity on Mischief Reef in JAN 2015 (*top*) and again in MAR 2015 (*bottom*).

Also demonstrated by this work is the capability to display ships geopatially, and identify shipping co-location networks. Based on the location and time information from AIS data, reserarchers can connect ships to other ships if they come within a certain distance (1.5 km) of each other. With a network, researchers can see which ships play central roles, and size nodes by centrality metrics. In this case they are sized by betweenness centrality. Resulting analysis shows where the different ships fit within the network, as well as what attributes they have such as ship type and company affiliation. Once ships owned or operated by the same company are identified the plots collapse ships so that the node represents their company, with companies being connected to other companies if they have had ships connected to each other. Nodes sized by betweenness. Finally, unknown companies are removed in order to see which companies are central to operations in the South China Sea according to ship activity.

Combining several data analysis tools in this way provides future forces with a novel view of not only force activity in the region, but demonstrates potentially exploitable relationships. A relational analysis that includes not only the humans in a social network, but the vessels, vessel owners, operators, ports, cargos, or other actors or nodes or groups in the network may result in a more useful analysis. The most effective course of action to counter an adversary is often not a direct kinetic action against a particular actor or agent, but an operation to influence the network to change actor behavior.

3. Partner Nation Perspective

Commander Scott Craig of the Royal Australian Navy (RAN) presented a partner nation perspective on DMO. With operational experience as a navy diver, Commander Craig now serves as the RAN Assistant Naval Attaché to the U.S. at the Australian Embassy in Washington DC. LCDR Grant Hamilton, a RAN Principal Warfare Officer, who also worked on a concept generation team for this workshop, assisted Commander Craig at the podium for this presentation.

Figure 20. A comparison of the land mass of Australia overlaid on the continental U.S.

To better understand their perspective, Commander Craig began by giving participants an overview of Australia, the RAN force structure and responsibility. Australia is the sixth largest country with the third lowest population density per square mile. With a national population of 24 million, compared with the 20 million people who live in the state of New York State alone, the land mass of Australia is comparable to that of the continental U.S. (*see Figure 20*). The continental U.S. has just over 12 thousand miles of coastline. Australia has 16 thousand miles of coastline to patrol and defend, however most of the land on the eastern coastline is uninhabitable which provides a natural defense. However, the total RAN fleet is quite small to defend a coastline of that magnitude. The total RAN fleet is comparable to the assets that comprise the U.S. 7th Fleet (*see Table 1*). They anticipate the number of RAN submarines to double over the next 30 years, and the total pier-side length and total tonnage is also likely to double in the next 20 years.

Table 1. Comparison of total RAN Fleet with USN 7th Fleet.

RAN FLEET	USN 7TH FLEET
11 FF/DDG	1 CVN, 2 CG, 7 DDG
3 Amphib, 6 MCM	3 Amphib, 4 MCM
6 SSK	3 SSN

With the third largest exclusive economic zone (EEZ) in the world, the RAN's area of responsibility is nearly half the global oceans. The size of the fleet in comparison to their area of responsibility makes DMO essential for the RAN. Primary areas of interest for the RAN (*see Figure 21, green shaded areas*) beyond border protection in their immediate EEZ include regional patrols with partners such as Fiji, New Caledonia, and Papua New Guinea. To be a good global partner the RAN also supports counter-terrorism and other such missions as far North as Japan, directly East to Madagascar, and West to Hawaii.

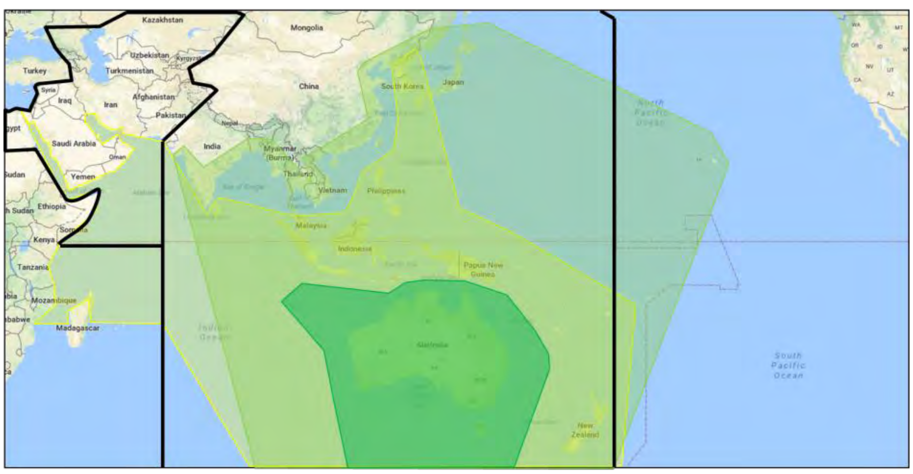

Figure 21. USN delineation of command responsibility (*black lines*) compared with RAN primary areas of interest (*three green shaded areas*).

The RAN has moved away from a traditional carrier strike group (CSG) construct, decommissioning their last aircraft carrier in 1983. Since then they have engaged in task group operations[7] and single ship deployments. The 2017 India-Pacific Endeavor (IPE 2017) was the first RAN engagement to move from this task group mentality to DMO, with air force and army support, and strategic support from government policy stakeholders.

[7] Examples of RAN task group operations include Fiji (1987), Gulf War I (1991), Solomons (1998), East Timor (1999), and Gulf War II (2003)

By necessity, DMO is key for RAN, and they have worked very hard over the last several years to increase interoperability with the USN. Interchangeability is a current near-term goal. One of the fundamental premises of DMO is multiple entities in pursuit of one common objective. However, in coalition or joint operations there are often multiple missions to accomplish in the same resource space. Recognizing that partners are not all the same may be the key to successfully working together. In a denied environment, DMO is premised on commanders at all levels having skills, attributes, knowledge, authority, and confidence to execute the tactical objective to meet the strategic outcome.

4. Prototyping, Testing and Implementation

Once generated and developed, useful concepts need to evolve into an implementable form. This often requires rapid prototyping and testing.

Implementing Concepts

The General Manager of Caterpillar International's Digital Laboratory in San Francisco, Mr. Aaron Kline of presented a case study on the development of his construction technology startup Yard Club to demonstrate the value and utility of the design process to turn ideas into reality. Creating something from nothing requires *agility* and *resilience*, and the best way to be agile and resilient is to embed those principles into how an organization operates through declared core values. Essential to any new endeavor, core values ultimately guides how an organization creates and develops teams, builds relationships with stakeholders, and makes tradeoffs when faced with difficult decisions.

The story of Yard Club started as a class project for Stanford University's Lean Launchpad course. Yard Club was initially peer-to-peer sharing for construction equipment – "*Airbnb for bulldozers*." Equipment rental is a fairly well established industry, allowing those who have a need to leverage idle equipment possessed by others maximizing the utility of the system as a whole. After piloting the project for the class, Yard Club got seed funding from several area venture capital firms, and was then built out into the greater Bay Area. Caterpillar International started working with Yard Club to incorporate the peer-to-peer sharing with their existing equipment rental business. Yard Club transitioned into CAT Digital Labs when acquired by the larger company to better reflect what the project had evolved to be. The mandate of CAT Digital Labs is twofold. First, the lab rapidly prototypes and iterates on customer-facing applications for Caterpillar's global customer base. Second, the lab tests new software technologies throughout Caterpillar's greater corporate ecosystem.

How did this idea become a reality and achieve such success? Yard Club started with one person with one phone moving a bulldozer, and grew very quickly to a team of 15 managing over $120m in transactions for 2,500 construction professionals in 2016. The values commonly inherent in the "startup mentality" were key to success:

- Steak over Sizzle
- Relish Uncharted Waters
- Embrace Failure
- Leaders Transcend

Really knowing your customers and focusing on delivering them value first is at the core of the "Steak over Sizzle" tenet. Observing end customers directly to get a 360-degree view of customer needs is key to success. Don't get distracted by "Sizzle" such as internal feedback, broad surveys, or decks of PowerPoint slides extoling the value of the company. Letting revenue or profit goals to drive decisions on what product to build for the customer is generally not successful. Months of market surveys and product development is often less effective than getting real products to real customers and analyzing usage. Get out in the field and watch customers use the product rather than relying on indirect feedback from sales teams. Yard Club customers wanted real time information on their rented equipment usually only available to owners – Yard Club designed a software product to meet that need (*see Figure 22*), resulting in huge gains in the rental market share. Only after value is delivered to the customer will the company be able to capture value for itself.

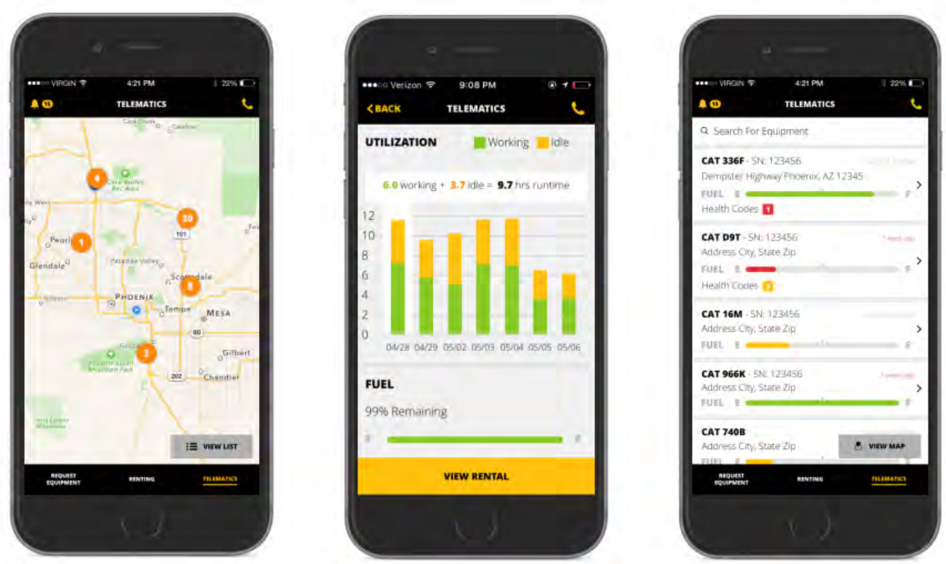

Figure 22. Yard Club's software tool developed in response to stated and observed user needs.

To relish uncharted waters, a company with a startup mentality will move fast and move first – prototyping early and often.

> *…[M]ost decisions should probably be made with somewhere around 70% of the information you wish you had. If you wait for 90%, in most cases, you're probably being slow. Plus, either way, you need to be good at quickly recognizing and correcting bad decisions. If you're good at course correcting, being wrong may be less costly than you think, whereas being slow is going to be expensive for sure. –* ***Jeff Bezos, Amazon, 2016 letter to shareholders.***[8]

Yard Club used a two-week sprint cycle to listen, observe, build, and measure new features. Anchored to customer and supplier feedback gathered in the field, this cycle relies on data analytics. The first prototype was a website – pictures, simple text, and a phone number. Responding to an investor request they built the website overnight, and their first handful of transaction were all by phone. Their

[8] Source: Jeff Bezos, Amazon "2016 Letter to Shareholders" 12 April 2017. Last accessed 18 December 2017 at https://www.amazon.com/p/feature/z6o9g6sysxur57t

first transaction delivered a piece of equipment emblazoned with a competitor's logo to a job site. When the site manager objected, their intern quickly taped a Yard Club logo over the offending graphic and the transaction proceeded successfully. This rapid reaction to user needs is essential to bringing ideas into reality and demonstrates agility. If you are comfortable with operating with 50-70% of the required information the biggest risk is making something no one wants. However, if you can get something in the user's hands quickly and get real feedback you shorten the iteration cycles to achieve success more quickly toward success.

Figure 23. The process of taking an idea into reality requires experimentation and willingness to embrace failure.[9]

Resilience comes through experimentation, embracing failure, and pivoting to a new iteration (*see Figure 23*). Embracing failure is a key element of this process. An idea leads to a hypothesis, prototyped very quickly this is then tested with the user through experimentation. If it doesn't work you must be disciplined enough to scrap it and start again. However, too many companies do not have the discipline to abandon a project. As an idea takes longer to prototype and test, the escalation of commitment makes it very hard to let go when the experiment fails. Yard Club's rental platform, although it had a very high retention rate for established users, they were having trouble attracting initial users to download and use the application for the first time. By riding along with sales reps they discovered that increasing sales rep comfort with the platform was key to adding new users. The obstacle was not the platform but the conduit to the user, and this pivot to leverage the conduit rather than persevering with platform-focused solutions led to a rapid increase in new user adoption.

When leaders model the right behaviors, take ownership of any situation, and enforce the principles of agility and resilience from day one they foster an environment for success. The best leaders coach team members privately and praise them publicly, and always assume responsibility for shortcomings and

[9] Source: Alexander Cowan, UVA Darden "Your Lean Startup" Venture Design. Last accessed 18 December 2017 at https://www.alexandercowan.com/creating-a-lean-startup-style-assumption-set/

work actively to find solutions. When principles like agility and resilience are embedded in core values, it drives how a company hires, develops teams, and makes decisions and tradeoffs.

Rapid Prototyping and Testing

Mr. Jamie Hyneman, one of the duo who brought us "Mythbusters" that ran for nearly fifteen years on the Discovery Channel, shared his recent work (*see Figure 24*) with workshop participants to demonstrate the value of rapid prototyping and testing to address militarily relevant challenges. The recipient of three honorary doctorates, he made science and engineering fun for an entire generation through his work on his very popular television program. His company M5 Industries has been working with several security and defense stakeholders including the Office of Naval Research (ONR) and other DoD stakeholders to address needs and gaps.

Figure 24. Mr. Jaime Hyneman presenting his recent work to demonstrate the value of rapid prototyping and testing, September 2017

Fourteen years shooting "Mythbusters" honed his rapid prototyping skills. To keep to the production schedule the team had four days to address the challenge posed in each episode. "I don't see this as rapid prototyping, what I learned how to do. It was more just learning how to manipulate things to my will." They covered such a broad range of materials and processes that he now finds delight experimenting with a breadth of materials and equipment. The process they developed allows him to extrapolate answers to questions that he had no direct experience with – it allowed him to make much greater intuitive leaps. Failure just provided them another tool in their toolkit. Without failure, they did not move forward. They shared their failures on television – and he credits those failures with the success of the show.

Making rockets out of plumbing parts or balloons out of lead is not the important part of the work. Rather, completing these tasks helped to build a foundation of useful knowledge to address future challenges. During the run of "Mythbusters" a representative from the National Reconnaissance Office (NRO) with a tagging and tracking challenge contacted him to consult on possible solutions. Several months later they were experimenting, testing prototypes. M5 Industries has continued working projects for the NRO on a variety of mission challenges, and the NRO asked Mr. Hyneman to present a talk on disruptive innovation. He is now doing some shipbuilding work with Naval Special Warfare (NSW) at Command Virginia Beach. Much like the duct-tape boat they created on Mythbusters, the NSW challenge requires building a boat out of non-traditional materials. To better understand the challenge, the group design process starts with ride-alongs to see what the Special Warfare Operators (SEALs) are actually doing.

On the value of prototyping, Mr. Hyneman extolled the value of rapid and iterative prototyping starting with very rudimentary, rough prototypes rather than jumping first to the 3D printer. Good design is informed by the failure of early prototypes, so rapid iteration is essential to get to where you want to go. The knowledge gained through building prototypes by hand provides a much more profound understanding of materials. If you skip that step, you miss developing important parts of your toolkit. The scientific process they used on “Mythbusters” to approach a design challenge aligns nicely with storytelling – there is a beginning premise, a body of work in the middle, and you have a conclusion. Tell the story and everything will likely fall into place, and parts of your story may come from the experience with materials you had while addressing different challenges. All experiences become knowledge. Do not discount the value of exploration – tangents are important. “Sometimes the most important things you run across are things that you weren’t actually looking for.”

5. Stakeholder Perspectives

All retired Navy Captains, George Galdorisi, Karl Hasslinger, and William Glenney shared their perspectives on the distributed maritime operations design challenge.

Issues in Autonomy

A retired Navy helicopter pilot, Captain George Galdorisi has now been with SSC-PAC as a technologist for 17 years. He started this section of the workshop by sharing salient points from the DoD plan for autonomous systems, the need for offset strategies, and the challenges inherent in developing autonomous systems.

> *There is no question that unmanned systems must also be an integral part of the future fleet. The advantages such systems offer are even greater when they incorporate autonomy and machine learning… Shifting more heavily to unmanned surface, undersea, and aircraft will help us to further drive down unit costs. –* ***Admiral John Richardson, Chief of Naval Operations***[10]

DoD Unmanned Systems Integrated Roadmap FY2013-2038 states that the *“DoD envisions unmanned systems seamlessly operating with manned systems while gradually reducing the degree of human control and decision making required for the unmanned portion of the force structure.”*[11] In a quick review of U.S. DoD strategic planning, Galdorisi pointed to the “New Look” strategy of the 1950s and the

[10]ADM John Richardson, USN CNO (2017). *“The Future Navy”* White Paper released 17 May 2017. Last accessed 19 December 2017 at http://www.navy.mil/navydata/people/cno/Richardson/Resource/TheFutureNavy.pdf

[11] *DoD Unmanned Systems Integrated Roadmap FY2013-2038.* Approved for open publication, reference #14-S-0553. Last accessed 19 December 2017 at http://archive.defense.gov/pubs/DOD-USRM-2013.pdf

initial "Offset Strategy" of the 1970s. He then introduced today's strategy, the *Defense Innovation Initiative*[12] that some refer to as the "Third Offset" strategy.

> *As a competitive strategy, we will try to approach this problem without trying to match our potential competitors tank for tank, airplane for airplane, missile for missile [or] person for person. We will try to offset their strengths in a way that gives us an advantage.* ***- The Honorable Robert Work, Deputy Secretary of Defense***[13]

The "Third Offset" is about more than technology, but the technology component is quite compelling as it centers on human-machine collaboration and combat teaming. The game *AlphaGo*[14] is the most celebrated recent example of autonomous deep learning systems as the system's wins against human competitors received global attention, not just in the technology realm but also on the business pages. The joint strike fighter is the most notable example of the U.S. investment in human-machine collaboration. Assisted human operations include things like the exoskeleton in development by the U.S. Army. Advanced human-machine combat teaming such as the P-8 teaming with Triton, and the H-60 teaming with the Firescout. Network-enabled semi-autonomous weapons such as enhanced Tomahawks are also on the horizon. However, one of the most significant challenges to the development of unmanned systems in the DoD currently is one of the largest cost drivers in the DoD budget – manpower.

> *A significant amount of that manpower, when it comes to operations, is spend directing unmanned systems during mission performance, data collection and analysis, and planning and replanning. Therefore, of utmost importance for DoD is increased system, sensor, and analytical automation that can not only capture significant information and events, but can also develop, record, playback, project, and parse out those data and then actually deliver "actionable" intelligence instead of just raw information. -* ***FY2013-2038 DoD Unmanned Systems Integrated Roadmap***[15]

The "dark side" of autonomy features prominently in current popular culture and science fiction films so designing the right degree of autonomy will be an important consideration as we look to the future. The public has been slowly introduced to autonomy through films such as Stanley Kubric's 1968 film *2001: A Space Odyssey*, an adaptation of Arthur C. Clarke's short story "*The Sentinel" (1948).* Recent films such as *Her (2013)* and *Ex Machina (2015)* have taken this sub-genre into a more nuanced realm where the relationship between human and machine grows increasingly more disturbing. With this cultural thread

[12] SECDEF Chuck Hagel (2014). "The Defense Innovation Initiative" *Memorandum for Deputy Secretary of Defense* 15 November 2014. Last accessed 19 December 2017 at http://archive.defense.gov/pubs/OSD013411-14.pdf

[13] Hon. R. Work (2016). Remarks at the "Securing Tomorrow Forum" presented by The Washington Post on 30 March 2016. Summary of forum last accessed 19 December 2016 at https://www.defense.gov/News/Article/Article/708827/work-great-power-competition-aims-for-deterrence-not-war

[14] *"AlphaGo is the first computer program to defeat a professional human Go player, the first program to defeat a Go world champion, and arguably the strongest Go player in history."* https://deepmind.com/research/alphago/

[15] *DoD Unmanned Systems Integrated Roadmap FY2013-2038.* Approved for open publication, reference #14-S-0553. Last accessed 19 December 2017 at http://archive.defense.gov/pubs/DOD-USRM-2013.pdf

underpinning DoD development of autonomy, there is much justified caution as the Navy moves forward.

> *The Department Defense is working through the problems of future robotic weapon systems–so-called thinking weapons. We're not talking about cruise missiles or mines, but robotic systems to do lethal harm–a Terminator without a conscience. Our job is to defeat the enemy, but it is governed by law and by convention. We have insisted on keeping humans in the decision-making process to inflict violence on the enemy. That ethical boundary is the one we've drawn a pretty fine line on. It's one we must consider in developing these new weapons.* ***- General Paul Silva, Vice Chairman of the Joint Chiefs of Staff***[16]

Mr. Galdorisi closed his remarks with a discussion of where he believes the DoD is headed in the development of autonomy. Rather than AI commonly understood as artificial intelligence, he posited that we are more likely heading for AI as augmented intelligence to maximize the utility of military UxS. A human operator would always be looped into the system – whether it be "in the loop" activity or "on the loop" supervision – and autonomous assets will enhance the human's capabilities.

Integrating Assets

In a presentation titled "Integrating Allied Undersea Systems" retired Navy Captain Karl Hasslinger focused his talk on missions, operational concepts, communications, autonomy, and support. A retired submarine warfare officer who now leads the Washington DC office of a major DoD contractor, he started his remarks citing the budget as the issue that keeps him up at night. "The trend in the DoD that is going to destroy us – or limit our capability – is continued deficit spending and our national debt." When he was Chairman of the Joint Chiefs of Staff,[17] ADM Mullen cited the budget as the greatest threat to our national security. Future coalition operations are possible and likely as we are going to need to fight as a coalition now and in the future to afford the increasingly sophisticated assets required. To counter evolving threats requires technology that is ever more exquisite. Currently, assets are valued by the pound magnified by the density of electronics.

Unmanned systems (UxS) have potential to perform many missions, and the U.S. has many allies with developed UxS capabilities such as Australia, Japan, and Singapore. Potential coalition missions include:

- Countermine operations in major chokepoint straits like Malacca, Lombok, Luzon, Taiwan, and Tsushima
- ASW operations off Yulin, Luzon Strait, Yellow Sea
- Cyber and EW missions against Chinese ports and airfields
- Seabed warfare against Chinese systems
- ISR missions throughout the theater

[16] "Innovation in the Defense Department" *Military Strategy Forum*. Center for Strategic and International Studies, talk presented on 25 August 2016. Last accessed 19 December 2017 at https://www.csis.org/events/innovation-defense-department-general-paul-selva

[17] U.S. Chairman of the Joint Chiefs of Staff, 1 October 2007 – 30 September 2011

How might we work with allies in this future scenario? An ally could contribute unilaterally to achieve mission objectives, for instance deployment of a nearshore fixed seabed system and limited range vehicles by a regional nation. Allies could operate as a true coalition as a combined force in situations when water space management and prevention of mutual inference are not required. Cascading operations, where platforms deploy UxS of another allied nation, allow coalition partners to share capabilities that one nation may lack such as REMUS vehicles. UxS swarms may also be magnified in a coalition force.

Probably the greatest challenge in terms of physics and security, communication is a long pole for coordinated operations especially for less autonomous systems. When he worked for Secretary of Defense Rumsfeld[18] one of their first discussions was about network-centric warfare. "Everything is networked. Every slide I see has one hundred lightning bolts on it." They agreed that network communications built into future assets is a vulnerability exposing future forces to a range of EW threats. If forces are not able to function without these networks – "*we can't reach back, we can't make decisions"* – this will be problematic. Submariners like to say that we do not have a communications problem we have a stealth problem. Currently, we trade off power and communications with stealth. If the satellites are no longer available in the battlespace how does that impact mission effectiveness? Autonomy could partially mitigate this challenge.

FDECO-like systems, fixed or mobile, could help with endurance and communications challenges. Towing UUVs with submarines could extend their endurance while maintaining stealth, and data relay could extend communication range. However, to achieve these solutions nations need to start looking at developing standards.[19] In theatre repair is also a support issue that requires attention. For example, submarine rendezvous in theater is risky and even special submarines could only take small unmanned vehicles (UxVs) aboard.

In closing, he encouraged teams to think big. "*We never built a ship large enough to carry all the sensors, systems, weapons and alterations we developed over time*." UUVs are likely to grow to meet payload capacity, power, endurance, reliability and survivability needs. Larger UxS could cascade smaller, niche systems. In the world we are heading toward, we will likely want larger vehicles to deploy on longer missions to achieve more objectives with fewer humans placed in harm's way.

Ideas into Reality

Finally, retired Navy Captain William Glenney shared his perspective from many decades working in Naval innovation. How does an idea generated in a workshop such as this make it to the fleet? The quality of the ideas generated will correlate directly to the number of team members actively involved. If you find yourself designing a new ship, a new aircraft or radio circuit, stop. Force yourself back into the operational problem space. "What is the operational utility of this concept? Why should the JTTF commander care?" Answers to these questions will help scope down your concepts and begin to explore the tactical and technical details. Work to remove all possible constraints, challenge your perceptions

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[18] U.S. Secretary of Defense, 20 January 2001 – 18 December 2006

[19] For example USB or BlueTooth® standards

and assumptions, and do not be afraid to make mistakes. Learn from those mistakes as you move your ideas forward. Never underestimate the contribution of any individual to this process, and do not underestimate your own ability to innovate. Good ideas have no rank.

Explore the realm of the adjacent possible. “If this is true, then what else might be true?” Use the technique of “Yes, and…” to build on the ideas of others to climb to a new space. Explore the problem from this new vantage point. You may be amazed at what you discover. There is a key principal that most powerful innovations emerge from a combination of operational, organizational, and technological factors. People tend to fixate on technology, but it is not just about technology. Every problem cannot be solved merely with a new technological fix. Focusing on technology may also cause you to miss factors that inhibit innovation, and may be a strategy for failure. The U.S. no longer holds the global technological edge. Consider all three factors.

View innovation at three different levels: 1) individual, 2) social or group, and 3) bureaucratic or organizational. Good ideas originate at the individual and group levels, and good opportunties emerge at the group and organizational levels. Each of these levels at scale are at play throughout the entire innovation process, and are key to taking an idea to implementation. If any of these three levels is not functional the innovation process will suffer. Although it is amazing how much the creative constraint of time can foster the innovation process, seeing an idea through to reality takes time. “You will not solve the Fleet’s problem this week. You are going to set the stage for solving the Fleet problem sometime in the future.” The innovation process generally does not fit into a strict timeline. Innovation requires concerted effort on a continued basis.

Successful innovators train themselves to think broadly, think in an unconstrained manner, and explore different perspectives. Diversity of thought and experience is exposed by questions such as “What do you read? What blogs to you participate in? Who are your friends and colleagues, and what do they think and do? Like the Capital One slogan “What’s in your wallet?” to find an innovator ask *What is on your bookshelf? What is bookmarked in your favorites? Who is in your network? Who are your social media friends? Where are you weak signals coming from?* These are often the early indicators of innovation. Seek out alternative views.

In terms of innovation, what is success? It is often less about immediate action, but indirect time latent results. Measures of success are not straightforward and require significant personal and professional maturity. At an individual level one must give up “ownership” of the concept and think of their work as a contribution to a greater whole. In the Navy we often require nearterm results, but the time required to make the innovation successful does not always comply with this culturally imbeded timeline. We have to develop the maturity to wait for an idea to develop. How long will it take to see your idea acted on by the CNO and others at that level? It may not be detectable for years. Be patient.

Also consider the scope of the idea. While your generated concept may be rather small in scope it may precipitate a larger change as it spreads throughout the Navy. Some innovations are a single prompt jump such as the the nuclear powered submarine or the submarine launched balistic missile. The USS

Nautilus (SSN-571)[20] launched in 1954. The earliest we started thinking about nuclear powered submarines at ONR was 1943, so it took eleven years for this idea to mature into reality. That is fairly quick. Other innovations, such as carrier aviation, may be the result of a series of smaller steps. The first notion of putting an aircraft on a ship was just after WWI (1914-1918), but it took over twenty years to really understand what it might take and it took until WWII (1939-1945) to reach this goal.

False, failed innovations, are very good and solid concepts that are killed by the internal organizational culture such as in-air refueling of aircraft. In 1917 we kept an aircraft airborne for seven days, but we did not adopt in-air refueling as a standard practice until the late 1940s. We proved that the idea was valid but organizaitonal culture impeded the idea reaching reality. Fleet adoption of UxS is experiencing similar cultural impediments.

From nearly 20 years as the Deputy Director of the CNO's Strategic Studies Group (SSG) Mr. Glenney shared many examples of ideas that made it to reality, and many examples of ideas that got crushed in the process. Each SSG cohort produced a set of operational, organizational, and technical concepts – and UxS were prominent in these concepts from 1998 forward. The notion of modularity was also key to many of the concepts generated. It is time to stop building assets with hardwired capabilities locked in. If you think of the platform as a truck with interchangable payloads it provides the required flexibility to address a range of threats in an uncertain future. In response to tasking by ADM Johnson,[21] the 1999 SSG cohort proposed a concept called Sea Strike. Employing families of manned and unmanned systems, Sea Strike enabled the Navy to have direct decisive influence in a land campaign anytime anywhere. The notion of Sea Strike started moving forward but was interrupted by the 11 September 2001 attack and the DoD pivot to respond. Development of the electromagnetic gun, a technical component of Sea Strike, continued to develop slowly against scientists saying it can't be done, budgeteers who said it can't and won't be done, and folks at ONR saying we can't possibly do it. The SSG kept the pressure on and in 2004 ONR acquiesced and funded a very small project. Today we have an EM gun that is functional at half the energy that the SSG originally envisioned.

ForceNet was a concept developed by the SSG over five years to bring the Navy into the network-centric warfare world. ADM Clark, CNO at the time,[22] championed ForceNet and signed out the document with the Commandant of the Marine Corps. By 2003 the Navy was adopting what had begun in the SSG as the idea of ForceNet. About five years after ForceNet, the SSG addressed the vulnerability inherent in the network-centric warfare embedded in ForceNet.

The SSG also succeeded in the realm of Navy personnel recruiting and talent development. SSG ideas impacted Navy education, recruiting, and boot camp within a matter of weeks following their final brief. The SSG failed in the alternative energy realm. In 2006 the SSG briefed the Navy synthetic fuel program

[20] *USS Nautilus was the first nuclear-powered submarine. Electric Boat Company in Groton, Connecticut—the same company that had sold the U.S. Navy its first submarine in 1900—laid her keel 14 June 1952. She was launched 18 months later and commissioned in September 1954.* (SOURCE: National Museum of American History http://americanhistory.si.edu/subs/history/subsbeforenuc/revolution/nautilus.html)

[21] ADM Jay L. Johnson served as Chief of Naval Operations from 2 August 1996 – 21 July 2000

[22] ADM Vern Clark served as Chief of Naval Operations from 21 July 2000 – 22 July 2005

to get the entire Navy off dead dinosaurs in a decade. The program was slow-rolled by OPNAV staff and DoD, and the oil industry opposed it. Eleven years down the road we have made no significant progress toward Navy oil dependence. In 1996 the SSG proposed a concept called In-Stride Sustainment to lessen the stranglehold of logistics. Free form fabrication, now called 3D printing or additive manufacturing, was key to this concept. It failed, and the Navy is still not a huge proponent of this technology. Talent management was again explored by the SSG in 2014, and they proposed the concept of career credits. Although there were initial hesitation, the idea was well received and gained momentum but was shut down when it hit Capital Hill where the drive to make a bunch of personnel changes did not garner support.

Distributed maritime operations emerged out of a notion called distributed lethality. For 18 years the SSG has been exploring the concept of disbursed, distributed, disagregated forces – refered to as D3. This concept is included in many of the SSG cohort final reports. The seeds of DMO have matured in their own time to the topic we are tasked with addressing today. Some say innovation is about opportunity, but in the realm of warfighting innovation the opportunity the timelines to embrace concepts may be quite extensive. In 1998 it was clear that UxS were militarily viable and valuable on a broad scale. Here we are 20 years later and the Navy has only embraced UxS to support limited ISR missions. But don't give up. The evidence of success may not be obvious for some time, but know that the ideas generated at workshops such as these have value. Don't underestimate the ability of groups such as these to generate clear and compelling ideas that transition into reality.

6. UxS Design Principles

Figure 25. Deputy Assistant Secretary of the Navy (DASN) for Unmanned Systems retired USMC Brigadier General Frank Kelley presented the keynote address for workshop participants.

The Deputy Assistant Secretary of the Navy (DASN) for Unmanned Systems retired Marine Corps Brigadier General Frank Kelley participated in the entire WIC Workshop, and gave guidance to the concept generation team members in his keynote address to start the second full day of the workshop. DASN Kelley, the SECNAV's designated CRUSER lead in the Pentagon, spent 32 years in the USMC and transitioned to civil service in 2015. He began his remarks sharing the status on unmanned systems in the hierarchy of the DoD within the Pentagon. He structured his guidance to the workshop participants around the following ten UxS design principles:

1) Sophisticated sensors and networks
2) Rapid fabrication and assembly
3) Modular open architecture platforms
4) Leveraging forward-deployed bases and supplies
5) Vehicle endurance
6) Robust organic communications networks
7) Expendable vehicles
8) Motherships
9) Organic precision, navigation and timing (PNT) capabilities
10) Commander's intent, and acceptable use of autonomy

He noted that of the three primary military armed services – the U.S. Army, the U.S. Air Force, and the U.S. Navy – only the USN operates in the four traditional physical domains of air, ground, surface, and undersea. The USN operates in the emerging domains of space and cyber as well. "*We are everywhere*." In light of this vast range of responsibility, sophisticated sensors and networks will be essential to maintain an accurate common operational picture (COP). Rapid fabrication and assembly will also be essential to future forces, and is included as one of the ten fundamental design principles. Modular open architecture platforms is also included as a fundamental design principle as modularity will allow the flexibility to respond to a dynamic threat environment and continue to incorporate emerging technologies as they develop. Infrastructure components are also included on the list of fundamental design principles for UxS – key among these are leveraging forward-deployed bases and supplies, vehicle endurance, and robust organic communications networks. The Forward-Deployed Energy Communication Outpost (FDECO)[23] is an excellent example of a UxS concept that incorporates all these essential infrastructure components. One of the biggest discussions inspired by FDECO in the Pentagon right now is when it might become an installation. "Who is going to own this?" Program and asset ownership is culturally ingrained.

The fact that these assets do not carry humans completely changes the way we think about UxS. If they are designed as expendable vehicles, when they are destroyed in combat "we can just build more." This changes the way we engage adversaries. As we proved in preparation for WWII, our nation is quite capable of mobilizing our industrial base in response to a threat. Expendable vehicles also present a problem for our opponents. DASN Kelly shared a few examples of assets in development that fall into the category. The "mothership" asset configuration will also be important in the design of UxS, and DASN Kelley shared the example of a USV beaching to launch an unmanned ground vehicle (UGV) from a

[23] *The Forward-Deployed Energy and Communications Outpost, or FDECO, is an Innovative Naval Prototype program launching in fiscal year 2016. The technology will equip underwater unmanned vehicles, or UUVs, with communications and energy refueling options for extended endurance, range and mission capabilities.* (SOURCE: ONR Facebook post 22 May 2015. Last accessed 21 December 2017 at https://www.facebook.com/officeofnavalresearch/posts/10152858080995998)

recent field experiment.[24] Another design principle derived from field experimentation is organic precision, navigation and timing (PNT) capabilities. The NPS swarming experimentation conducted at Camp Roberts in February 2017 demonstrated the importance PNT – "*not only do you need to know where you are, but you need to know where your partners are, you need to know where your enemy is*." To do cooperative EW requires that your assets have robust PNT.

What will artificial intelligence look like in the future? Elon Musk and other have warned us about the artificial intelligence (AI) of the future, but what if AI could augment and extend the range of one of our submarines? Employing the "mothership" design principle, once in the battlespace a Large Displacement Unmanned Undersea Vehicle (LDUUV) could deploy several smaller UUVs. Taking a page from the Navy Meteorology and Oceanography (METOC) playbook, what if the LDUUV deployed hundreds of even smaller UUVs as well, or the LDUUV could take "command" of the hundreds of assets already in the battlespace. DASN Kelley proposed a future where we even might remove the LDUUV from that future configuration. The final design principle involves commander's intent. What is the appropriate use of autonomy? What will the command structure of the future look like? How far are we willing to go?

Before he took the DASN Unmanned position, Mr. Kelley considered the obstacles inherent in the military culture will likely impact adoption of UxS and asked CNA to conduct a study. The resulting *Cultural and Organizational Impediments to Unmanned Systems in the Department of the Navy*[25] surfaced the following key ingredients that increase the probability of UxS adoption:

- A concrete military problem
- An empowered officer corps
- Bureaucratic acceptance
- Consistency of message and purpose
- A cadre of warriors at all ranks
- Short-term wins
- A military culture of honest study
- Reflection and projection

If you establish a combination of these initial conditions, moving toward UxS adoption will still be hard but may be possible. The Department of the Navy employed UxS and elements of autonomy in the 1960s and 1970s, and most of our warfare centers and labs have been researching and experimenting with UxS for quite some time. Today's warfighters easily integrate UxS into exercises and operations because it is familiar technology. "We know how to do this." Our senior leadership is supportive of the adoption of UxS.

[24] ANTX Newport 2017, a NSWC IHEDDTD/Carderock collaboration

[25] M.F. Stumberg, R. Reesman, S. Klein (2017). Cultural and Organizational Impediments to Unmanned Systems in the Department of the Navy, Center for Naval Analyses (CNA) July 2017 released December 2017 UNCLASSIFIED/FOR OFFICIAL USE ONLY

> *The nation needs a more powerful Navy, on the order of 350 ships, that includes a combination of manned and unmanned systems – ADM John Richardson, CNO*[26]

Advocates in leadership is one of the most important elements for adoption, and others in leadership have echoed the need to incorporate UxS in the future force. In the future UxS will operate in every domain, an UxS element will always be an option in any plan, and Fleet UxS will be at their best when teamed with Sailors and Marines.

B. Concepts of Interest

Key criteria used by the CRUSER selection committee to select concepts from all those proposed for further development were:

1) Is the concept feasible (physically, fiscally)?
2) Is the concept unique?
3) Is the concept testable?

The following taxonomy of systems was developed from selected concepts presented by each team, as well as additional concepts submitted but not developed. Identified categories of interest include:

1) **Autonomy in Support of Operations & Logistics:** this topic area includes autonomy concepts that provide direct support to warfighters in a battlespace. Concepts of interest in this topic area include *Strategic Operational Resource Meteorological and Environmental Renderer (StORMER), Autonomous Track Assess Report Intercept (ATARI), Message Traffic to Operations Center Display, Distributed UxV C2 Architecture*, and some counter-UAS concepts.
2) **Man-Machine Teaming:** this topic area includes robotics and autonomy concepts to support warfighters throughout their careers. Selected concepts in this category include *Soldier-size node for HUMINT via Augmented Reality and Body Worn Sensors (SeNTAuR), Watchstander AI Teaming,* the *Modern Day 300* career spanning man-machine teaming, and gravitational sensing.
3) **Organizational Change & Adoption:** rather than purely autonomy related concepts, this topic area includes recommendations for change at the organizational level to better leverage the capabilities that autonomy may offer in the future. Parts of the *Modern Day 300* concept fall into organizational change and adoption, and additional concepts warranting further exploration presented in this category include some aspects of gravitational sensing, and a proposed *"FORM-BOT"* designed to autonomously complete standard forms alleviating a common administrative burden.

Unclassified details of these concepts as presented are included in Appendix A of this report.

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[26] ADM John Richardson, USN CNO (2017). "The Future Navy" White Paper released 17 May 2017. Last accessed 19 December 2017 at http://www.navy.mil/navydata/people/cno/Richardson/Resource/TheFutureNavy.pdf

III. WAY AHEAD

Of all the ideas generated through the facilitated design process, each team selected concepts to further explore and present in their final briefs. Following the final briefs on 21 September 2017, CRUSER leadership identified ideas with potential operational merit that aligned with available resources. In brief, identified concepts fell into three primary topic areas:

1) Autonomy to support operations and logistics
2) Man-machine teaming
3) Adoption and organizational change

In addition to the concepts and technology proposals, the September 2017 workshop also supported other equally vital elements of CRUSER's charter: 1) the advancement of general unmanned systems knowledge among the participants; and 2) a greater appreciation for the technical viewpoints for officers, or the operational viewpoint for engineers. The information interchange and relationship building that occurred during this event were characteristic of the workshop venue, and also support CRUSER’s overall intent.

A. Warfare Innovation Continuum (WIC)

The Warfare Innovation Continuum (WIC) encompasses the successful research, education, and experimentation efforts, which are currently ongoing at NPS and across the naval enterprise. The goal of the continuum is to align regularly scheduled class projects, integrated research and special campus events into a broad set of coordinated activities that will help provide insight into the opportunities for future naval air power and evolving the littoral combatant ships variants. Exploring a new topic area each fiscal year, the WIC is a coordinated effort to execute a series of cross-campus educational and research activities that share a central theme. Classes, workshops and research projects are synchronized to leverage and benefit from prior research that results in a robust body of work focused on each annual topic area.

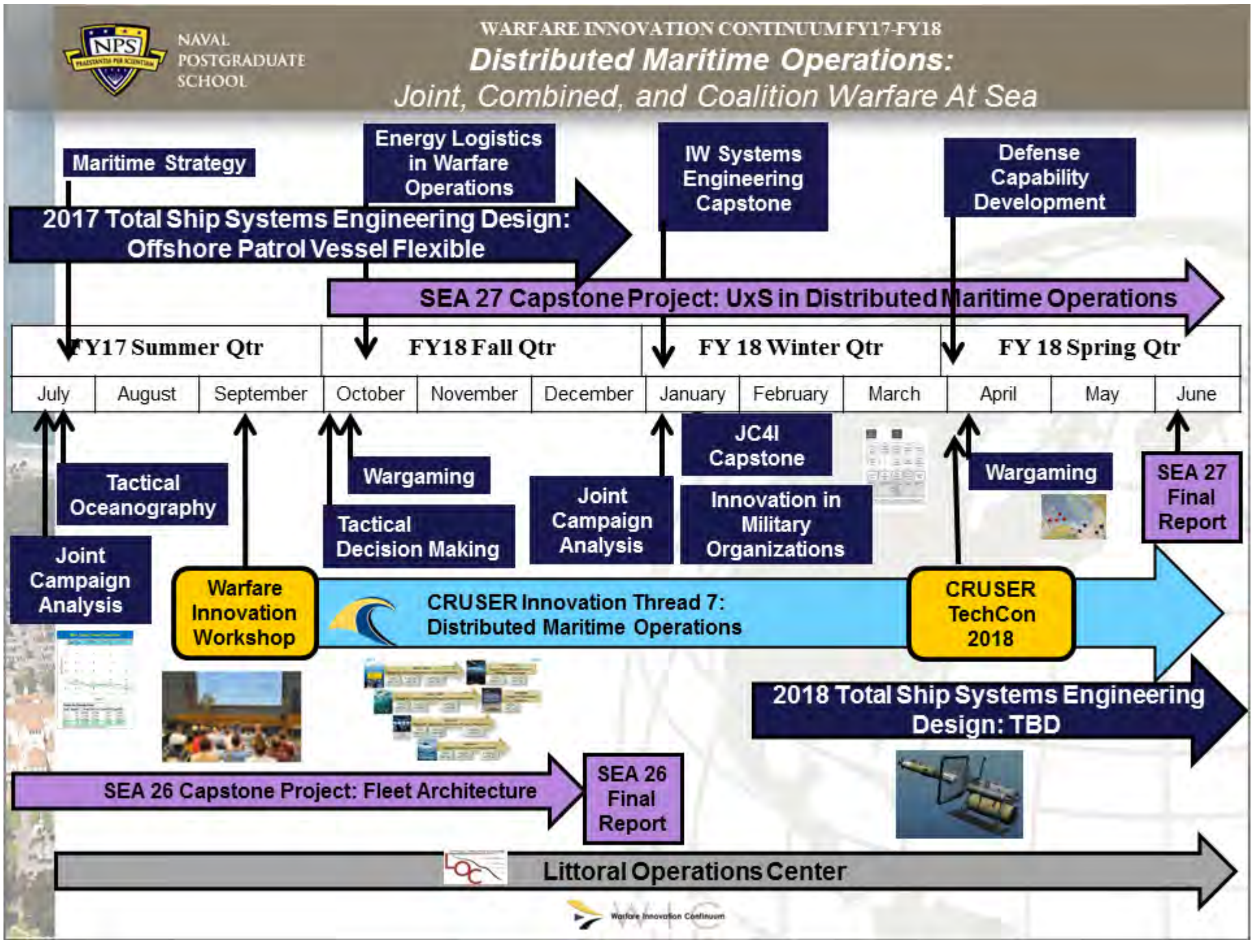

Figure 26. FY17-18 NPS Warfare Innovation Continuum (WIC).

The FY17-18 WIC, "Distributed Maritime Operations" (*see Figure 26*), is focused on the evolution of the distributed lethality concept first proposed by Vice Admiral Rowden COMNAVSURFOR in a January 2015 article in *Proceedings Magazine*[27]. The WIC consists of a series of coordinated cross-campus educational and research activities with a central theme. By incorporating topics of fleet interest into established academic courses and by supporting student thesis project research, students and faculty promote research that aligns with fleet priorities while simultaneously achieving the educational requirements for the graduate students. Final reports are available for all prior continuums dating back to 2013.

[27] Vice Admiral Thomas Rowden, Rear Admiral Peter Gumataotao, and Rear Admiral Peter Fanta, USN (2015). "Distributed Lethality," *Proceedings Magazine* – January 2015 Vol. 141/1/1,343. Last accessed 20 NOV 2017 at https://www.usni.org/magazines/proceedings/2015-01/distributed-lethality

B. CRUSER Innovation Thread

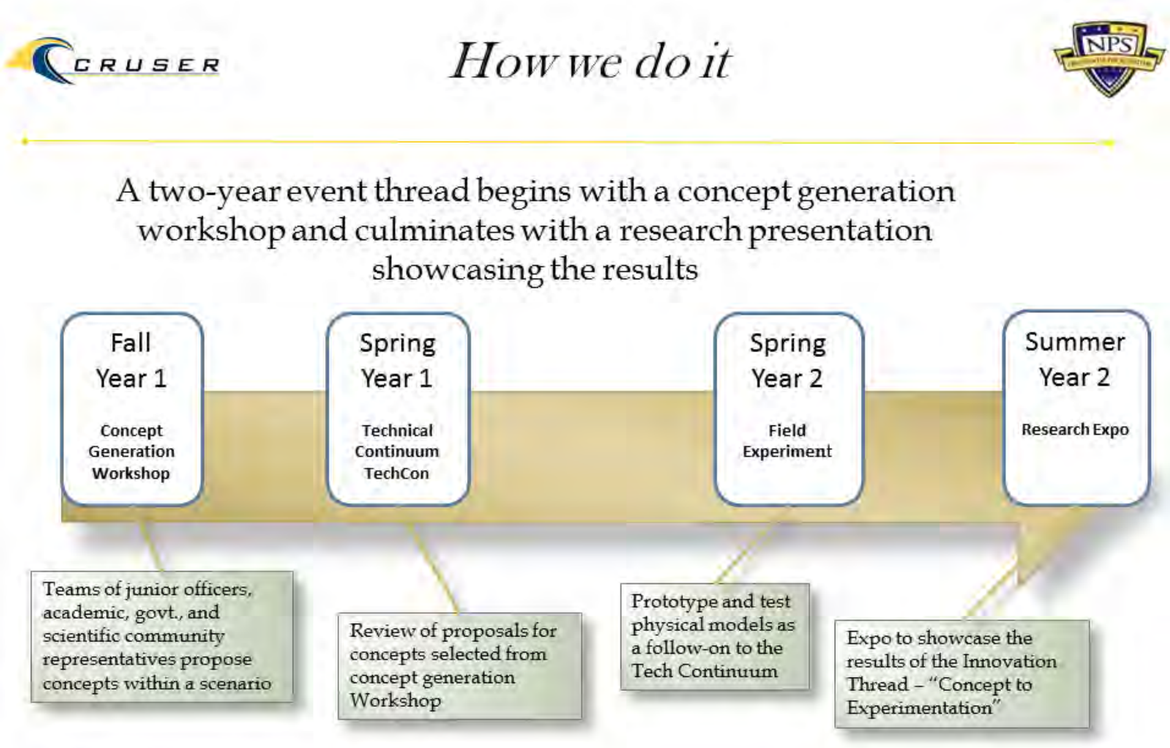

Figure 27. CRUSER Innovation Thread structure.

CRUSER organizes activities around a programmatic Innovation Thread structure (*see Figure 27*) in parallel with the Warfare Innovation Continuum thread. Each innovation thread starts with a concept generation workshop traditionally in September each year. Concepts of merit are identified, and technical members of the CRUSER community of interest are asked to submit proposals on how these concepts might actually work. Proposals are presented at an annual Technical Continuum (TechCon) or demonstrated at the annual NPS CRUSER research fair, and then several are selected to take to field experimentation. Finally, results of field experimentation are presented to CRUSER sponsors and other community of interest members.

Since 2011 CRUSER has made progress along seven innovation threads (*see Figure 28*). The first five Innovations Threads are complete, the sixth thread is underway, and Innovation Thread #7 is just underway with this September 2017 Warfare Innovation Workshop will finish in FY19.

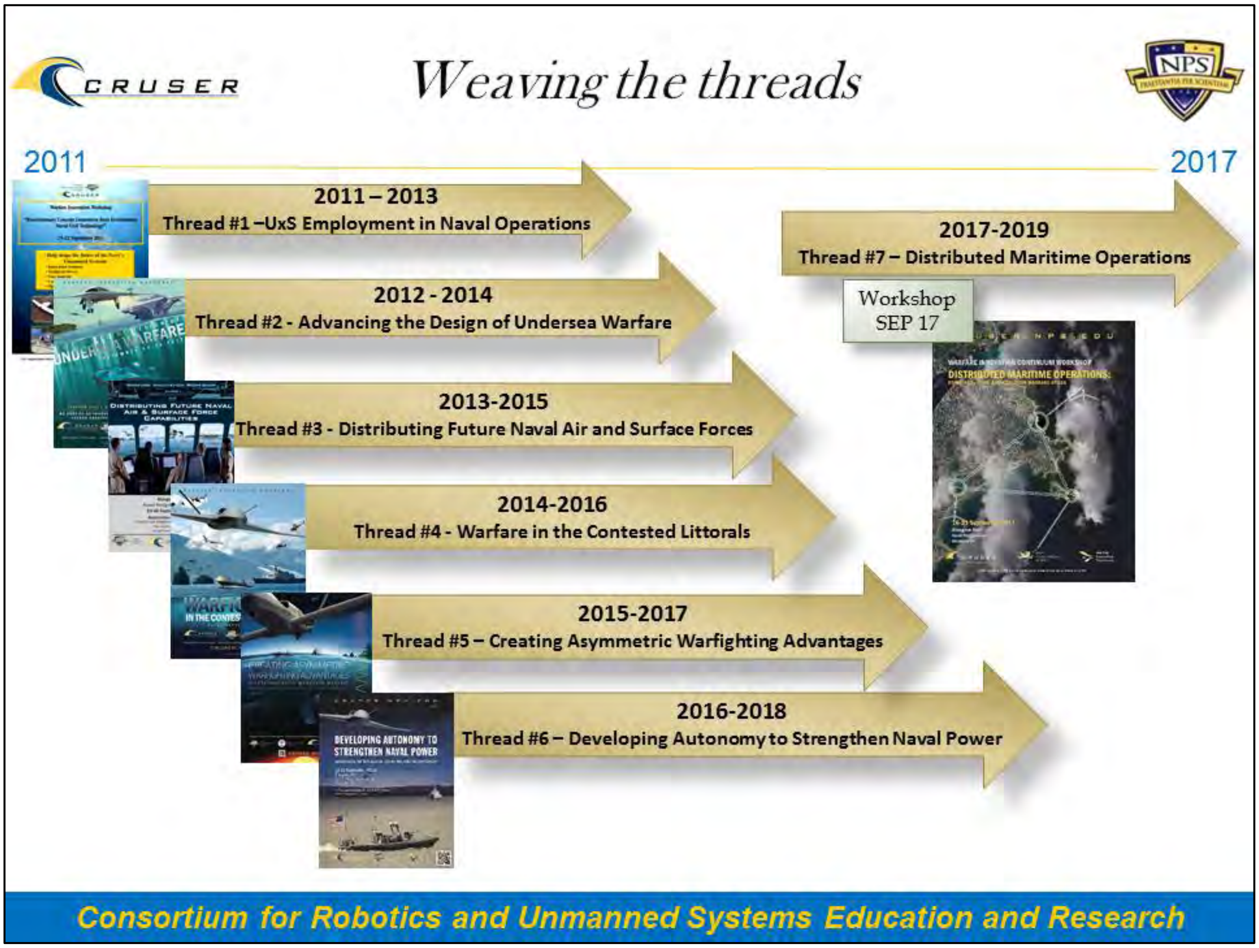

Figure 28. CRUSER Innovation Thread overview, September 2017.

APPENDIX A: Final Concepts

All five teams presented their final briefs on Thursday 21 September 2017, and were given 15 minutes to present their most developed and promising concepts. In addition, the mentor team also presented the concepts they generated through the facilitated design process. The following concept summaries detail these final presentations. These summaries are unclassified and are included in the order presented.

A. Team Pegasus

Figure 29. Members of Team Pegasus (*pictured from left to right*): LT Carlos Maldonado USN, LT Joe Newman USN, Katrina Magalotti, Joshua Hogge, Brian Siela, LCDR Grant Hamilton RAN, LT Dave Alessandria USN, and Brett Vaughn.

The members of this team (*see Figure 29 and Table 2*) included four junior officers and three early career engineers, and the team was facilitated by a senior military civilian.

Table 2. Members of Team Pegasus (*alphabetical by last name*)

NAME	PERSPECTIVE	AFFILIATION
LT Dave Alessandria USN	aviator	NPS
LCDR Grant Hamilton RAN	aviator	Royal Australian Navy
Joshua Hogge	human systems	NAVAIR PMA 262
Katrina Magalotti	computer science	JHU/APL
LT Carlos Maldonado USN	surface warfare officer	NPS
LT Joe Newman USN	surface warfare officer	NPS
Brian Siela	aerospace engineer	NAWC China Lake
Brett Vaughn	*facilitator*	N2N6FX

1. Problem Statement

Team Pegasus addressed the design challenge through the following problem statement: *How might we best combine unmanned systems and artificial intelligence for effective mission accomplishment in a hybrid or Distributed Maritime Operation environment?*

2. Proposed Concepts

The proposed concepts included:

- StORMER: Strategic Operational Resource Meteorological and Environmental Renderer
- SeNTAuR: Soldier-size Node for HUMINT via Augmented Reality and Body Worn Sensors
- JARVIS: human command, machine control

a. StORMER

Usually when expressing sensor coverage it is accompanied by a coverage radius which is graphically represented by a full circle surrounding a ship or other asset or area of interest. Most assume that this view displays anything within that area of circular coverage. However, electromagnetic propagation is heavily dependent on environmental conditions and changes when the environmental conditions change. Although often oversimplified to a circle of coverage, there are usually blind spots caused by the differential bending of sensor waves at a certain range. Electromagnetic interference will often bend the sensor waves and cause them to bounce differently before they return to your sensors. The side-view illustration (*see Figure 30 top*) shows what may happen with electromagnetic propagation in certain conditions. These gaps in coverage are then lost when the sensor data is translated into the overhead view below (*see Figure 30 bottom*). Temperature, pressure, humidity, salinity, and gradient thereof will change seasonally, monthly, daily, or even hourly, and could alter sensor function. Physical obstacles such as an antenna or superstructure of some sort might also obscure the senor readings. The resulting 20NM sensor output will then include constantly varying gaps, and a variable outer edge. How do you arrange a whole fleet in a DMO configuration to maximize total coverage and minimize blind spots? With continuous inputs from constantly changing meteorological and environmental effects these coverage profiles could be analyzed and ship positioning could be optimized automatically to suggest stationing and operations.

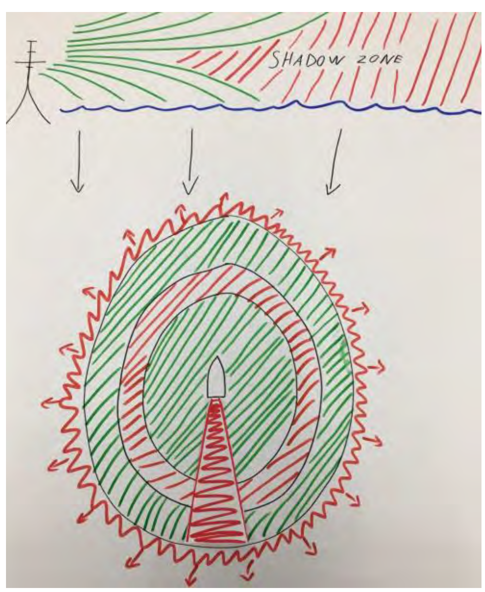

Figure 30. Traditional sensor display where sensor coverage is green and shadow zones in red illustrating gaps in coverage hidden by "circle of coverage" displays, side-view (*top*) and overhead view (*bottom*).

To address this gap, Team Pegasus proposed the strategic operational resource meteorological and environmental renderer (StORMER). StORMER would take all the varying inputs from organic sensors on the ships and from UAVs dropped into the battlespace for ISR, and process them into a more accurate representation of the current environment. Using algorithms designed to accommodate constantly varying meteorological and environmental conditions, StORMER would reduce the gaps and blind spots in current sensor outputs. This system would also allow tailoring for mission priorities such as air warfare, surface targeting, and individual ship coverage and would then identify optimal fleet positioning for maximum coverage. Fleet metric effects include maximization of fleet-wide sensor coverage thereby improving detection time, increasing probability of detection, and improving target classification accuracy.

b. SeNTAuR

To detect insurgents in riverine environment Team Pegasus proposed a soldier-size node for human intelligence (HUMINT) via augmented reality and body worn sensors (SeNTAuR) providing the "*super power you get when you add decision aids in the DMO environment.*" In a large population, it can be hard to pick out persons of interest like the adversary amongst civilians and Latvian government officials in the given hybrid war scenario. As a result, there is a need to leverage human-to-human communications intelligence (COMINT) on the ground, social networks, HUMINT, and electronic intelligence (ELINT) to provide a God's-eye view of multiple sensor nodes giving feedback from the command center for operational decisions quickly back to the operational nodes or soldiers.

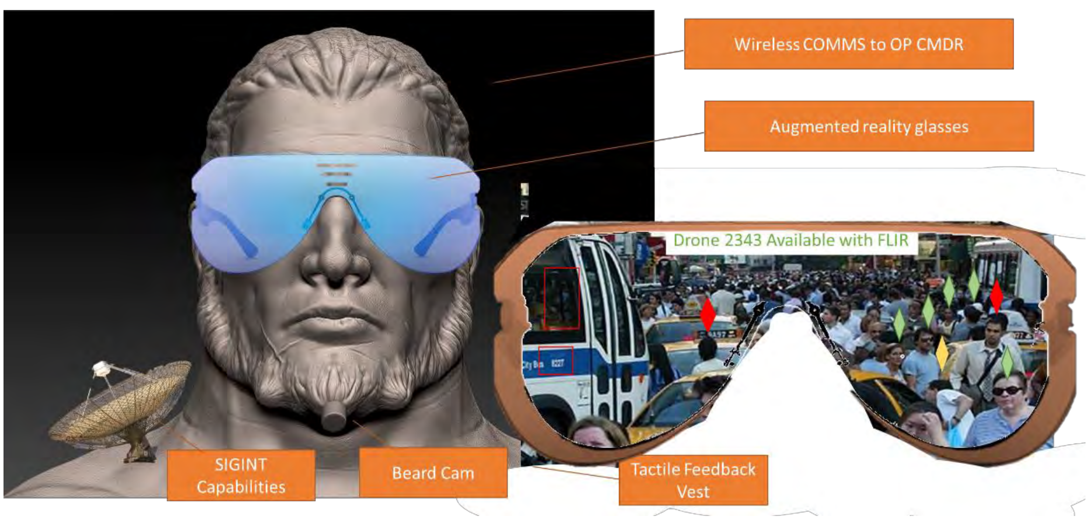

Figure 31. Soldier-size node for HUMINT via augmented reality and body worn sensors (SeNTAuR)

The team envisioned a set of accessories worn by the warfighter to enhance capabilities in the field (*see Figure 31*). Augmented reality (AR) glasses would give the warfighter in situ data processing capability, real time facial and vehicle recognition, and target identification. Wireless communications with the command center, localized signals intelligence (SIGINT) receivers, a "beard-cam", and tactile feedback vest to offset heavy visual input comprise the rest of SeNTAuR.

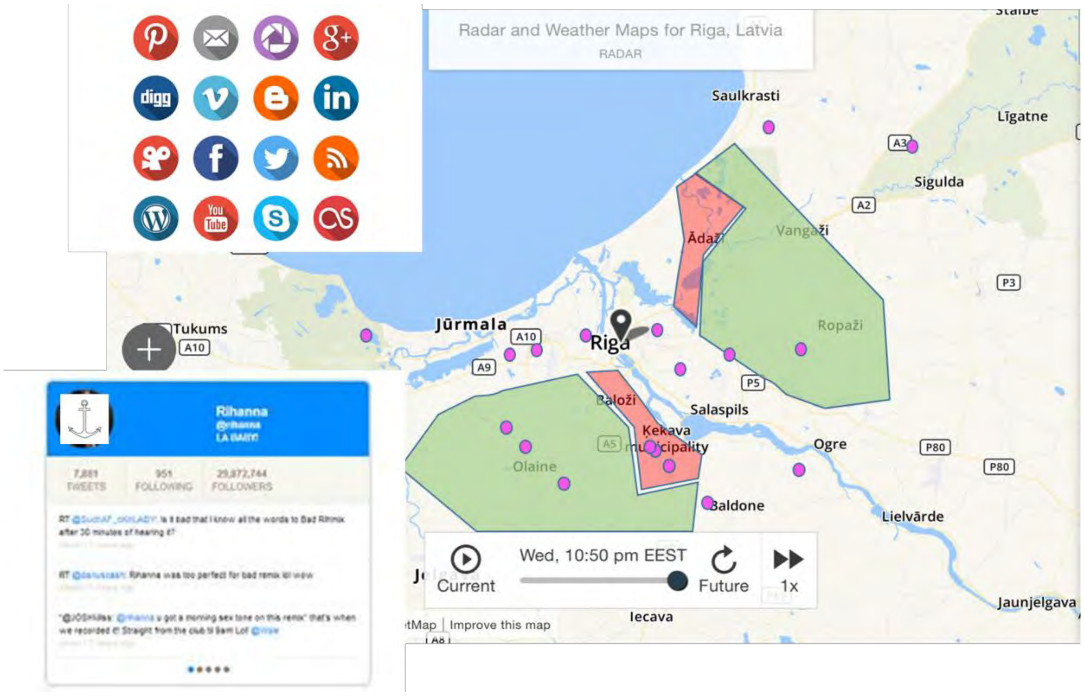

Figure 32. Information "God's-eye" display envisioned for SeNTAuR operator.

SeNTAuR provides sensor integration into the populace for identifying current and near-future threats. In coordination with other assets in the battlespace, the aggregated data input from the SeNTAuR nodes (*see Figure 32*) may give operational commanders the ability to predict likely adversary action. Stakeholders impacted by SeNTAuR include operational commanders, tactical commanders, "boots on the ground" operators, and civilian enterprise.

There is a technical risk associated with SeNTAuR. Although likely feasible in the near future, most technology included in this concept is still in development. Vulnerabilities will become clearer once the technology is field tested, but the assumption is that all wireless technology is vulnerable to cyber threats. Metrics to measure success might include accuracy and reliability.

c. JARVIS – human command, machine control

The JARVIS concept is based on a "Scalpel and the Axe"[28] future operating concept for future fleet design. If we talk in terms of command and control, we can start to solve the accountability and responsibility question of autonomous or semiautonomous unmanned systems. A manned system *must* be able to defend itself in all spheres of warfare by either people, AI or a combination thereof. The problem there is that with a focus on defense manned ships and aircraft will not be able to focus on delivering effects against an adversary. That is where the scalpel comes in. An unmanned system could be designed for a specific purpose, and similar systems should have as many common components as

[28] The "Scalpel and Axe" operating concept was described as understanding the value of assets in terms of precision effects, the "Scalpel" asset delivering the highest precision effects where an "Axe" asset will deliver effects with a lower precision but higher intensity. A small, unmanned asset will generally be on the higher end of the precision effect scale. The team advocated using the right tool for the effects desired – *"use a scalpel when you need a scalpel, not an axe."*

possible to drive cost down, which means the issue of the effect-delivery platform returning is less of a concern.

> *AW de T Unknown Aircraft 050 ZZ 120 Turned hot k*
>
> *W de AW –Air warning Red I make force track 0203 hostile based on AH1, T push 04F take track 0203 with CAP k*

Is spoken as:

> *"Alpha Whiskey this is Tango. Unknown aircraft zero five zero Zulu Zulu one two zero turned hot over. Whiskey this is Alpha Whiskey. Air warning red. I make force track zero two zero three hostile based on Alpha Hotel one. Tango push zero four Foxtrot take track zero two zero three with CAP over."*

This vignette illustrates air warfare as it is known today. This cryptic exchange is one person in command of a ship pushing a message out through multiple people and a patrolling aircraft (Tango E2/E7) to the operator – a "trigger puller" pilot and the aircraft (Taco/Nav). Team Pegasus proposed a simplified future C2 in anti-air warfare (AAW) where command is human and control is machine. Command carries responsibility and accountability and therefore should be held by a human in a highly charged battlespace. However, this command augmented with automated or machine control mechanisms in the battlespace will enhance C2. In this envisioned Theme C2 environment the above exchange would be:

> *[Hook track right click on track 0203 select take]*

Where one person in command of a ship right clicks on a target, selects a unit in proximity, selects the target, and then right clicks again to detect the target's track to complete the task. The commander is requesting instant replay of wide area surveillance (Tango) directly from the semi-autonomous vehicle in the commander's battlegroup resulting in the information needed for a command decision. This eliminates the need for a cryptic message communicated through several relay points in a highly charged battlespace. The same task is accomplished through a digital message to a semi-autonomous machine that does exactly what it is taught or programmed to do.

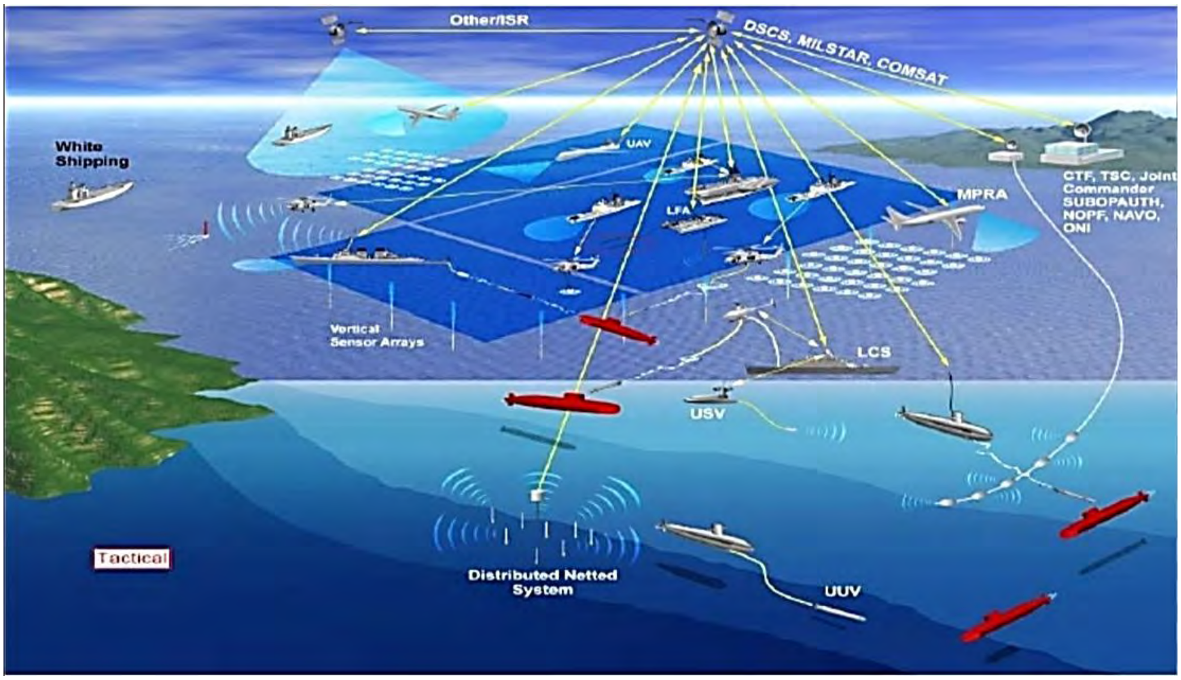

Figure 33. Cross-domain employment envisioned in JARVIS high-level operational concept (OV-1).[29]

Although the team presented this concept using an air warfare example, JARVIS is capable of employment across domains as long as a human retains the command functions and the control aspects are delegated to machines (*see Figure 33*). In addition, when offense and defense are co-located as is often the case in a tense battlespace the team proposed that in a division of effort between defense and offense that human focus should remain on defensive mission sets while machine tasking would be most effectively focused on offensive mission sets – especially more inexpensive and expendable unmanned assets. “You have a scalpel and an axe where the axe is the manned platform in command and the scalpel is the unmanned platform designed to deliver a specific effect in a specific sphere of warfare.” Use them accordingly.

There are risks involved, but there is no need to change how we are currently operating. If current location data is available to these unmanned platforms – the same information currently available to manned platforms – they will know where allied stakeholders are in the battlespace and will operate accordingly. If it encounters unexpected assets it the unmanned platform will relay that information back to a human in command for an operational decision.

Offence is the best defense. However, when your offence and defense is co-located it is almost impossible to regain the initiative which our adversary will almost always have given the our constraints of maintaining the moral high ground and following rules based global order. In this scenario, the ship is in command and has the ability to defend itself organically. However, simultaneously the task group organic unmanned assets and strategic and operational unmanned assets under this tactical control are

[29] Source: SPAWAR Systems Center Atlantic (SSC LANT)

used offensively to seize and regain the initiative in a low risk high payoff manner. Fighting this way will reduce the orientation to decision time within the OODA loop[30] significantly.

B. Team Taurus

Figure 34. Members of Team Taurus (*pictured from left to right*): LT Peter Winstead USN, CAPT Tony Nelipovich USNR, Katrin Mierfrankenfeld, Wes Rankin, Andre Douglas, and Matt Moore (*not pictured CDR Erik Cyre USN and Kristen Tsolis*).

The members of this team (*see Figure 34 and Table 3*) included one junior officer, one senior officer, three early career engineers, a PhD student from Germany, and a junior NPS faculty member. A senior officer from the USN reserves facilitated the team.

Table 3. Members of Team Taurus (*alphabetical by last name*)

NAME	PERSPECTIVE	AFFILIATION
CDR Erik Cyre USN	aviator	OPNAV N501
Andre Douglas	mechanical engineer	JHU/APL
Katrin Mierfrankenfeld	psychology	NPS (Germany)
Matthew Moore	electrical engineer	LMCO
CAPT Tony Nelipovich USNR	*facilitator*	ONR
Wes Rankin	systems engineer	Draper Labs
Kristen Tsolis	software development	NPS
LT Peter Winstead USN	surface warfare	NPS

1. Problem Statement

Team Taurus addressed four separate but related problem statements with their three proposed concepts:

1) How might we provide persistent, covert ISR capability in littoral areas for mine clearance?
2) How might we influence populations using cyber techniques?

[30] OODA: *observe, orient, decide, and act* decision cycle defined by Col John Boyd USAF

3) How might we improve the operational awareness of a Surface Action Group through autonomous tracking, monitoring and engagement of surface and subsurface threats in a littoral environment?

a. R&D Ecosystem

Although not presented in their final concepts, the team also spend time addressing the problem statement *"How might we improve long-term interaction, collaboration, and knowledge transfer between industry professionals and government science and technology workforce?"* During the team's discovery phase of the process this challenge was one of the most mentioned obstacles to long-term progress.

Cross-pollination between industry and government labs would likely influence industry research and development (R&D) investment in toward problems of significant government interest and better target limited government funds. The team identified several implementation opportunities including:

- Industry participation in short-term wargames or exercises such as the Advanced Naval Technology Exercise (ANTX)
- Fellowships (1-2 years). Example: SECDEF Corporate Fellowship Program (small scale)
- Liaison Offices in Industry (especially autonomy)
- Targeted government investment in industry like the Defense Innovation Unit Experimental (DIUx)
- Create new Autonomous Systems Agency (ASA) to interface with industry. Board with oversight of industry development. Example: Missile Defense Agency to address particular concerns or roadblocks
- Hire and leverage industry experience. Example: Ellen Lord, former CTO at Textron Systems and now Under Secretary of Defense for Acquisition, Technology and Logistics[31]

Identified obstacles included concerns about the administratively mandated intellectual *firewall* between government and industry, and unintended consequences of long-term sponsorship and sustained funding.

b. Metrics

The team also spent time addressing the wildcard tasking to identify candidate metrics that reflect combat capability and capacity of a future naval fleet composed of manned and unmanned systems capable of delivering both kinetic and non-kinetic effects – *Does a "355 ship" fleet mean anything anymore?*

Team Taurus suggested the following as candidate metrics to reflect combat capability and capacity of a future naval fleet:

- *Does this system reduce operational risk?*

[31] The USD(AT&L) is the principal staff assistant and advisor to the Secretary of Defense and Deputy Secretary Defense for all matters concerning acquisition, technology, and logistics. https://www.acq.osd.mil/

- *Does this system improve coverage factors, probability of kill, probability of detection, reduce vulnerability (RCS, noise, detection, etc.)?*
- *Does this system improve international relations?*
- *Does this system provide a cost-effective alternative?*

2. Proposed Concepts

The proposed concepts included:

- Enhanced Biological Swarms
- Influencing Populations using Cyber Techniques
- Autonomous Track Assess Report Intercept (ATARI)

a. Enhanced Biological Swarms

The complex littoral environment surrounding Riga is hard to assess completely with current ISR assets. Addressing the problem statement *"How might we provide persistent, covert ISR capability in littoral areas for mine clearance?"* the team proposed enhanced biological swarms. Sensors and processors attached to fish could convert a school of living fish into a UUV swarm providing covert, non-invasive detection of mines and increased situational awareness in the area of operation (*see Figure 35*). These enhanced fish could provide underwater imagery to expose locations of mines, underwater objects of interest, and other potential hazards in the underwater topography. Leveraging the natural environment by attaching hardware to biological assets already in the area of operation will improve ISR and minimize risk to the warfighter.

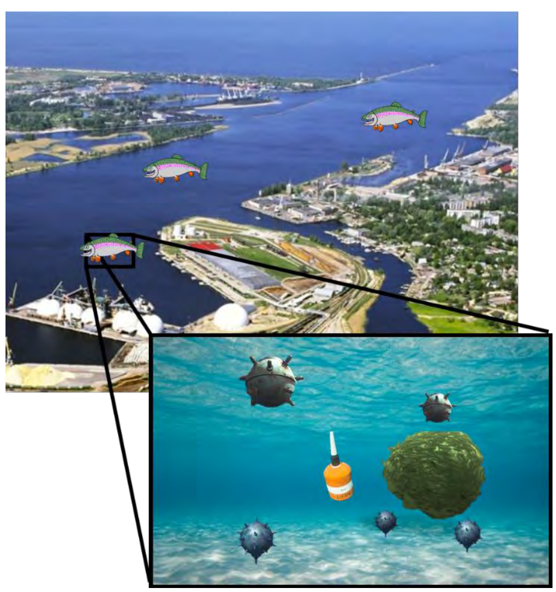

Figure 35. Biological swarm concept.[32]

[32] Image sources: http://www.dredgingtoday.com/wp-content/uploads/2014/05/Dredging-Brings-Benefits-to-Port-of-Riga.jpg and https://www.dreamstime.com/royalty-free-stock-photography-underwater-mines-image7619007

Each fish will be equipped with sensors and a processor (*see Figure 35 top*) and has three primary functional modes:

1) **Sensing Mode:** the system is sending out EM energy to the environment
2) **Recharge Mode**: the system draws energy to the sensor using the kinetic energy of fish motion
3) **Data Processing Mode**: the system processes information collected by external fish for transmission

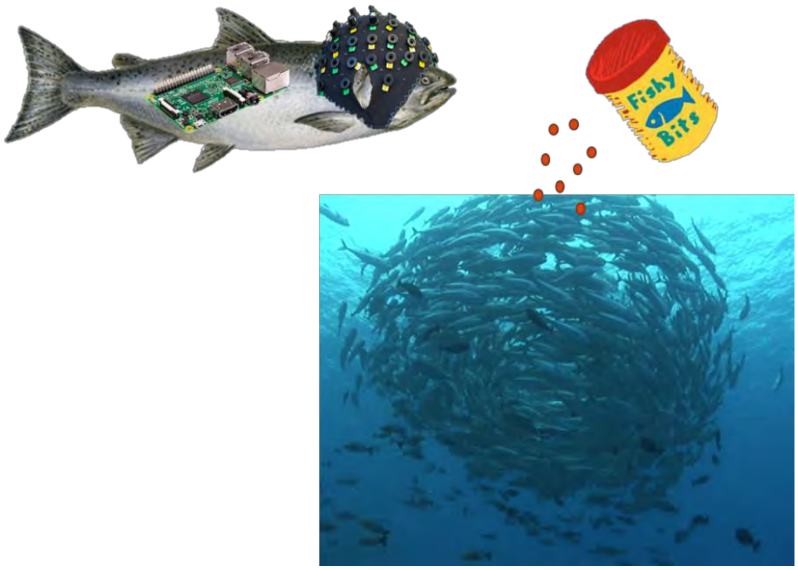

Figure 36. Biological swarm individual units (*top*) and full swarm (*bottom*).

Within each swarm the fish are tasked by their position in the swarm, either as an *outside fish* or an *inside fish*. An *outside fish's* primary functions are search, target, and classify. The primary functions of an *inside fish* would be data processing, energy collection (eating), and transmitting. Enabled to interact with existing DMO assets, the biologic swarm could provide blockage, extend the range of other DMO assets, and provide decoy interference.

The *inside fish* in the inner part of the swarm ball form a distributed "hive-mind" processor while the *outside fish* on the outer ring (*see Figure 35 bottom*) are doing object recognition. Key technologies include some sort of brain-machine interface, kinetic energy recovery to power the sensors and processor, ingestible computer processors, and a biological database of host animal characteristics related to their suitability to carry hardware. Interference with natural animal behaviors is a risk with unexplored consequences, and different populations exist in different regions and have a unique place in their own biosphere. Most fish in a littoral environment are quite small and could likely only carry a limited payload or capability. These sensors would also be environmentally limited. Next steps include leveraging existing bio-mechanical and bio-electric R&D to develop enabling technology, further research to understand animal swarming behaviors, and then progress to incremental experiments in controlled environments.

b. Influencing Populations Using Cyber Techniques

How might we influence populations using cyber techniques? The team identified three population sets of interest which might be mixed in place:

1) Populations who are already adverse
2) Populations who are neutral yet might become adverse
3) Populations who are friendly

The team proposed to monitor and disrupt adverse populations. Populations who are neutral yet might become adverse will be targeted for active influence to prevent them from becoming adversarial. Finally, they recommended monitoring and support of friendly populations.

To monitor adverse populations the team first suggested mining of social media data and tracking website traffic. Develop compromised smart devices to sell inexpensively in targeted regions (*see Figure 37*).

Figure 37. Compromised smart phones distributed on "sale" to adverse populations to enable monitoring.

In addition, the team proposed launching "free" apps to gain control of smart devices allowing allied forces to track and record movements of targeted adversaries using the global positioning system (GPS) features. The team also suggested hiding devices in plain sight disguised as features of the natural environment – such as antennas hidden in trees disguised as branches.

To disrupt this population, the team considered digitally infiltrating social media groups. Once an escalation is predicted through chat room banter, the compromised devices could be disabled which would likely hinder the adversary at a critical point.

Figure 38. Targeted social media ads to influence neutral populations.

To prevent neutral populations from joining the adversary the team recommended monitoring for new connections to known adversaries through social networks and communications, and mine data to identify trends in website visits and information gathering. This approach might help allies determine the motivations and design more effective means to influence these vulnerable populations. Targeted social media ads (*see Figure 38*) were suggested. The team also proposed to target new websites and prime comment threads with preferred actions, solutions, ideas. Finally, games should be developed for smart devices where the "good guys" always win may also influence neutral populations.

Monitoring social media and website traffic of populations already friendly to the allied forces may help identify any frustrations with the adversaries enabling allied forces to mitigate concerns and solidify support. Once example given was to provide for basic needs such as food and medicine (*see Figure 39*).

Figure 39. Military members providing humanitarian assistance.[33]

A means of feedback to support groups would also solidify support. Targeted ads, movies, and games to promote their way of life may also validate and encourage friendly populations.

Discovery, incorrect identification of population groups, incorrect interpretation of frustrations, and poorly designed or executed assistance are all risks of employing cyber influence techniques. The public perceptions of social engineering is a powerful incendiary force and could incite more unrest and inadvertently escalate the conflict.

c. ATARI

To improve the operational awareness of Surface Action Groups through autonomous tracking, monitoring, and engagement of surface and subsurface threats in a littoral environment, the team proposed the Autonomous Track-Assess-Report-Intercept (ATARI). ATARI is comprised of two assets working in tandem, an autonomous subsurface and rigid-hull inflatable boat (RIB) surface vessel (*see Figure 40*) – a "smart torpedo" and "smart RIB" respectively – designed to track, monitor, assess and engage threats such as IEDs and suicide bombers. The primary objective of ATARI is to increase situational awareness thereby increasing operational effectiveness, while reducing operational risk.

[33] Image source: http://www.aitonline.tv/pix/NewsImages/14493.jpg

Figure 40. Proposed elements of the autonomous track assess report intercept (ATARI) system.

ATARI would augment the fleet by expanding ISR and providing a virtual expansion of any vessel's magazine capacity without adding or designing a new ship. Barrier protection, deterrence, layered defense, securing sea lines of communication (SLOC), sea control, tracking, mine operations and intelligence gathering are all force-multiplier functions ATARI could offer to the DMO force.

Key to the ATARI concept is quantity and expendability – many inexpensive assets working in tandem ensure cost effectiveness and utility for the fleet while reducing risk to personnel. All assets in ATARI are simple, rechargeable, and ultimately disposable. Intended for forward deployment by amphibious means, air-dropped, or maybe via an littoral combat ship (LCS) module, the team envisioned a payload of explosive ordinance and a minimum of 24-hour endurance.

Risks include rules of engagement (ROE) challenges associated with a forward deployed "smart RIB" or "smart torpedo" – there may be *identification-friend-or-foe* (IFF) issues. In addition, explosive capabilities – especially for an unmanned platform – might increase risk of unintended escalation should the asset detonate upon capture. The size capacity versus available sensor packages may expose ATARI to *requirement creep* as the concept is developed causing ATARI to exceed initial cost expectations.

d. Undeveloped Concepts

Per the guidance given to all teams, Team Taurus presented their top few concepts and included a listing of their generated but undeveloped concepts in their presentation. The following 22 concepts were generated in the room but not selected for further development and presentation:

1. Unmanned survey collection ships
    - Observational
    - ISR
    - Weather
    - Ground/beach layout
2. Uninhibited sensor placement throughout country to determine "way of life"; data collection
3. Sound transducers in sewer system implemented with autonomous devices (mimic sewer creatures). Use to establish a reference and then detect environmental changes.
4. Pre-position one-time/few-time use devices to act as decoys / emit signatures. (use of palm trees is one example)

5. Use UUV to attach parasite (loud device/emitter) to submarine to force return to port (for removal).
6. Use mothership UUV at port entrance to deploy micro-UUV that transmit ship position (enable tracking).
7. “Beacon app”. Tracking device for vessels to better network enemy / friendly / unknown contacts and way of life.
8. Microdot labeling of ships. Used on all printers already. Could be concealable identifier on fishing boats.
9. Low-cost UxS to identify/tag objects of interest for later use or reference.
10. Autonomous evacuation via air or surface assets. Large payload to evacuate personnel.
11. Evacuation routing. Autonomous vehicles take indirect routes to maximize load efficient and distribute people from enemy targeting.
12. Decoys deployed by primary domains to mislead enemy “offensive operations”. Autonomous patterns with active noise or radar cross-section.
13. Unmanned docking station for UAVs to land/recharge/etc. No conflict with collision and fouling.
14. Food with synthetic biology “tags” (to track or identify population).
15. Develop/morph organisms/creatures into targeted sensors.
16. Gravity waves for communication technology.
17. Building chaos into complex systems (“learning to let go”).
18. Prevent adversary UxVs from operating.
19. Create automated robot that “destroys weapons”.
20. Build UUV that can reconfigure to fly or float.
21. Show of force (example quadcopter).
22. Use autonomy to protect material, sensors, people.

C. Team Hercules

Figure 41. Members of Team Hercules (*pictured from left to right*): Leon Tan, Shrey Shaw, Kevin Kaplansky, Sarah Rigsbee, LTJG Sydney Stone USN, Brian Wihl. Chris Vatcher, and LT Eric Clow USN.

The members of this team (*see Figure 41 and Table 4*) included two junior officers, three early career engineers, a junior military civilian, and a military student from Singapore. A human systems integration engineer facilitated the team.

Table 4. Members of Team Hercules (*alphabetical by last name*)

NAME	PERSPECTIVE	AFFILIATION
LT Eric Clow USN	surface warfare officer	NPS
Keven Kaplansky	electrical engineer	Battelle
Dr. Sarah Rigsbee	*facilitator*	JHU/APL
Shrey Shaw	electrical engineer	NSWCPD Code 433
LTJG Sydney Stone USN	surface warfare officer	NPS
Leon Tan	systems engineer	NPS (Singapore)
Chris Vatcher	cyber architect	LMCO
Brian Wihl	electrical engineer	LLNL

1. Problem Statement

The mission set provided in the Riga portion of the Maritime War 2030 scenario, including expeditionary strike group defense, mine countermeasures, and evacuation all have capable mission systems that exist today, and will continue to be acquired, refined, and maintained in to the fleet of the future. If this mission were to occur today, the US Navy would persevere at the cost of manpower, capital, and time. Manpower is a finite asset. In light of the recent collisions at sea, Team Hercules believes manned-unmanned teaming might maximize the efficiency of current manpower levels while allowing for greater mission effectiveness. Autonomy power is gaining efficiencies in executing missions, collecting and processing data, and providing natural language responses to decision makers. The team presented their concept for the *Digital Watchstander* to address their primary problem statement: *How might we accelerate the adoption of autonomous and artificial intelligence systems in the DoD, and make the hand off of AI as comfortable as handing off to a co-worker?*

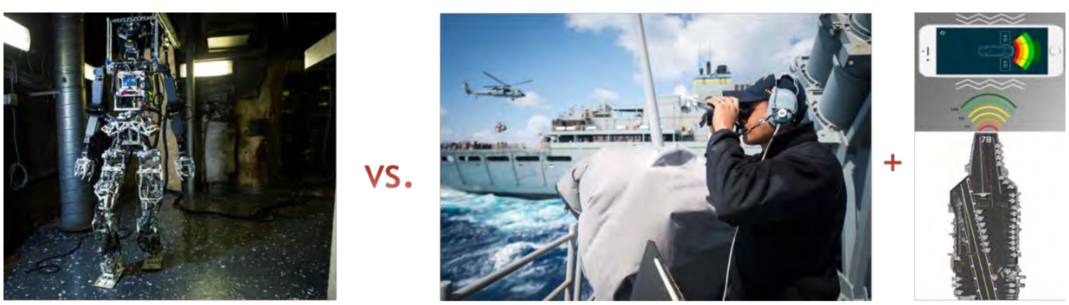

Figure 42. Current misconception of a robotic watchstander (*left*) versus a man-machine team with a human watchstander with digital assist (*right*)

Where a shipboard firefighting humanoid robot might be too much for the DoD to handle (*see Figure 42 right*) the team proposed a man-machine team (*see Figure 42 left*) leveraging technology and AI that could be trained by the personnel conducting the tasks not the engineer who designed the code. To measure combat potential based on effects not platforms, Team Hercules generated metrics to assess combat capability and capacity or a future naval fleet composed of manned and unmanned systems capable of delivering both kinetic and non-kinetic effects.

Generated metrics include:

- Optimize training for collective and individual
- Increased total “people” to stand watch
- Increased “force multiplier”… (2 people + 2 AI = > 2 “individual” force units)
- Create a normalized unit to compare
- Decrease watch standing needs / times / requirements
- Decreased manning interruptions
- Increased warfighter effectiveness
- Increased sleep, increased awareness
- Agility of Response
- Flexible and rapidly responding unit
- Quality metrics vs. resource metrics
- Shorten deployment cycle
- Decreased cost
- Decrease health impacts
- Increased retention
- Reduce workload
- Competence
- Survivability
- ISR Coverage factor, Strike destructive power

2. Proposed Concept

Team Hercules proposed one overarching concept they called the *Digital Watchstander* where the AI serves side-by-side with a human watchstander. Based on their interviews of subject matter experts, the team identified trust as a significant obstacle, especially when giving AI potentially lethal kinetic capabilities. Watchstanding responsibilities seemed a good fit for AI, especially teamed with a human watchstander. Although their presentation focused mainly on a surface warfare example, this concept is applicable to all services. Rather than development of technology, the concept focuses on building infrastructure for training and policy to augment the warfighter with an AI device.

Figure 43. Potential components of the *Digital Watchstander* system.

In the *Digital Watchstander* concept, the AI is intended to work side-by-side with a single human counterpart augmenting whatever mission the sailor is assigned such as watchstanding. For example, a new surface warfare officer (SWO) would be assigned an AI component with their commission. Both the sailor and the AI component will begin training together for the new assignment, learning their new shipboard responsibilities and progressing through boards and quals together. Initiating this man-machine relationship early in a sailor's career will improve trust in the technology, increase likelihood of use, and thereby increase overall effectiveness. This technology does not need to be a humanoid robot, but could be as small as a chip to insert into a device of the sailor's choice such as a watch or other mobile device (*see Figure 43*).   This enabled chip would listen and learn along with the sailor to eventually control systems. For example, everything an engineering department is responsible for is controlled through a console. If the *Digital Watchstander* chip is plugged into the engineering console when the human sailor is assigned to the engineering unit the trained AI will be able to direct other human unit members to take oil samples or replace parts based on analyzed system inputs. The *Digital Watchstander* will also monitor the health and well-being of its human team member based on learned attributes, and will be able to address needs should their human team member experience trauma and anticipate choices based on experience as a team.

The implementation pipeline (*see Figure 44*) is essential to adoption of the *Digital Watchstander*. Fully integrated implementation by training together will give sailor's ownership encouraging personalization of each AI unit, as the sailor is truly responsible for training and maintaining their individualized unit.

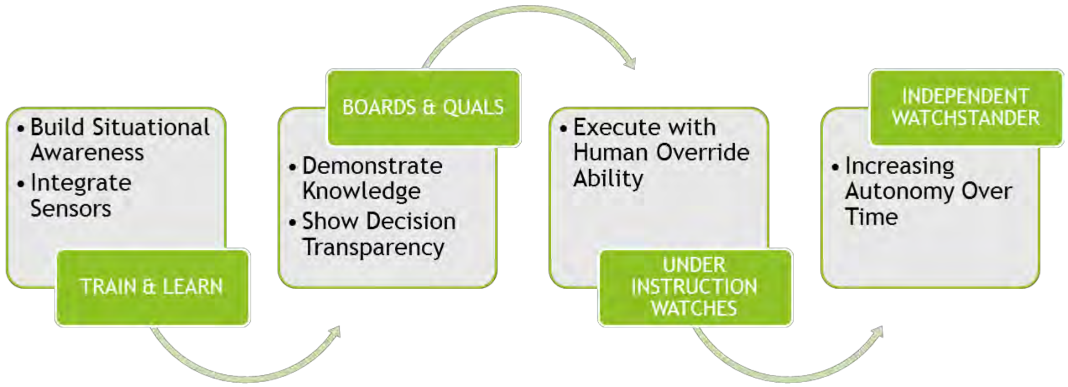

Figure 44. *Digital Watchstander* implementation pipeline.

Observability and task complexity are two integral factors that impact trust (*see Figure 45*). When the relationship is new the sailor will likely task their AI with a low complexity task and carefully observe the result. As expectations are met the sailor will likely assign the AI tasks of increasing complexity, and will not feel obliged to observe the execution of the task quite so closely allowing the sailor to complete separate and parallel tasks – thereby increasing the overall productivity of the man-machine team.

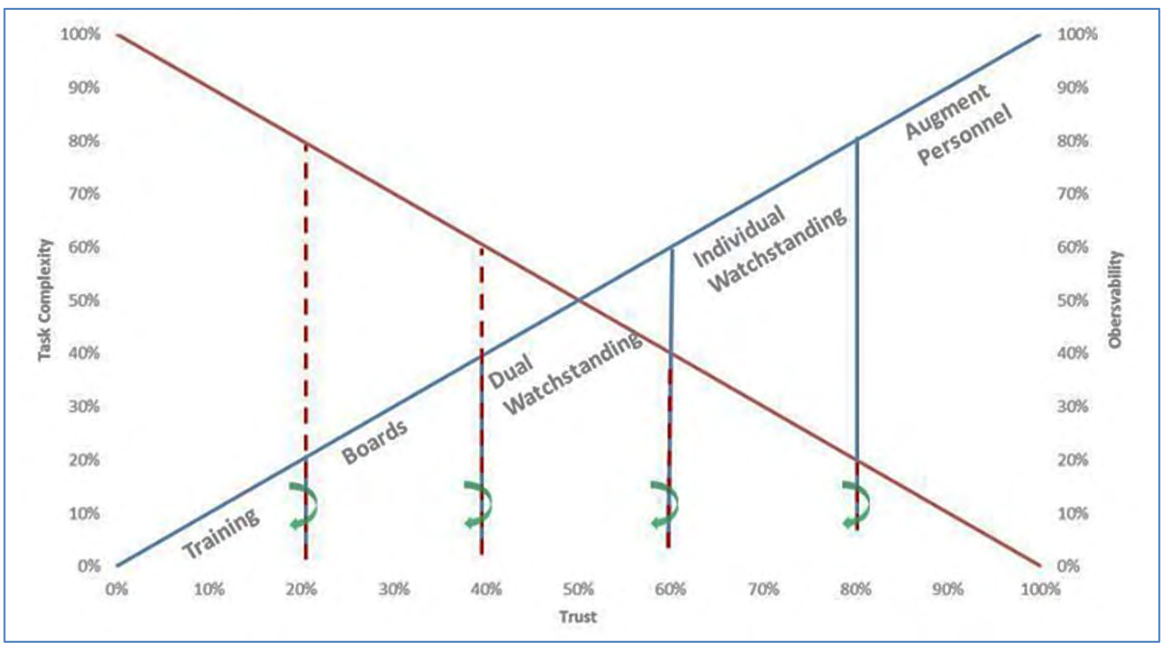

Figure 45. Observability and task complexity as compared to trust in autonomy.[34]

Transparency and feedback are essential to building trust in AI. The user wants to know why AI made a particular choice in a particular set of circumstances or when given a particular instruction, especially in situations with increasing risk such as a battlespace. The *Digital Watchstander* man-machine team will only thrive with constant feedback throughout the Plan - Brief - Execute - Debrief (PBED) process. Routine debriefs will allow both the sailor and the AI the opportunity to learn more about their teammate's decision making process thereby allowing them both to anticipate future decisions. The

[34] "Chart of Trust" created by Team Hercules

ability to retrain and communicate uncertainty is also key to building trust in this relationship with technology. Like their human counterparts, the AI component is not going to be perfect right out of the gate. When things go awry, an ability to retrain or reprogram responses could allow for course correction as well as the flexibility to adapt to changing conditions and environments. The future is an inherently uncertain place. Finally, plain language discussion of probability and likelihood calculations must be integral to any successful design.

Over time, the individualized AI component might incrementally increase knowledge as the relationship with their particular human counterpart progresses. Offering technical manuals when the human team member is faced with a faulty pump or instant access to "Rules of the Road" to address a navigation issue are examples of initial interaction between human and machine. As the trust in the relationship increases, the AI component could be enabled to make recommendations such as *"there is ship off your starboard side so I recommend a hard turn starboard to avoid collision.*" However, if the human team member has direct command from a superior officer to turn to port the recommendation of the AI component will be disregarded. The AI component is also expected to develop baseline knowledge and capability for a specific type of warfighter such as a SWO. If the man-machine team has successfully passed their quals and boards, this knowledge base of a service category may allow future AI components to be more effective for their future human counterparts should that knowledge base be shared forward.

Trustworthy interactions are key to successful development and implementation. *"If you don't trust it you are not going to use it."* The *Digital Watchstander* experience must be "sticky" like your smart phone or Facebook – if you use it once successfully you will likely incorporate it into your routine. Although the team focused their examples in the SWO community, the Digital Watchstander will augment human warfighters in all services. To increase mission success while reducing risk may be as simple as allowing more sleep for the human warfighters. A trained and trusted *Digital Watchstander* might result in a more well rested crew. Might a more well rested crew have been able to avoid the recent collisions in the South China Sea? Possibly.

The ability to listen and understand like a human – natural language task input – is an essential enabling technology for the success of the *Digital Watchstander*. The next step would be emotion classification to recognize non-vocalized cues such as doubt or anger. Equally important is natural language report generation, or talking like a human. Intelligent selection of appropriate visualizations to communicate the decision process must be incorporated, as well as domain isolation mechanisms when the AI component handles classified and unclassified information, only sharing when appropriate. Techniques to identify adversarial sensor input is an essential cybersecurity consideration, and network capabilities on and off board.

Cybersecurity is a vulnerability for all networked technology. The *Digital Watchstander* concept also has a risk of inadvertently creating interdependency leaving the human counterpart vulnerable. To mitigate this risk, the AI and human teammates should be required to pass their boards separately. Overconfidence in AI is also a risk, and if the AI fails repeatedly to pass training what is the remedy?

Next steps include policy development such as required interaction, appropriate level of oversight, and joint interoperability standards. Operational partners must also be ready to accept the level of man-machine teaming to ensure the success of future joint and coalition missions.

D. Team Aries

Figure 46. Members of Team Aries (*pictured from left to right*): LT Chris Popa USN, LT Timbo Uchida USN, LT Steve Bremer USN, Lance Lowenberg, Dr. Andrew Winn, LT Rob McClenning USN, and Troy Schideler (*not pictured LCDR Kristen Wheeler USN*)

The members of this team (*see Figure 46 and Table 5*) included four junior officers, three early career engineers, and the team was facilitated by a mid-level officer.

Table 5. Members of Team Aries (*alphabetical by last name*)

NAME	PERSPECTIVE	AFFILIATION
LT Steve Bremer USN	intelligence officer	NCWDG
Lance Lowenberg	robotics engineer	SSC-PAC
LT Rob McClenning	surface warfare officer	NPS
LT Chris Popa USN	aviator	NPS
Troy Schideler	political science	SPA Inc
LT Timbo Uchida USN	surface warfare officer	NPS
LCDR Kristen Wheeler USN	*facilitator*	NOSC San Jose
Dr. Andrew Winn	electrical engineer	SSC-LANT

1. Problem Statement

The team spent a lot of time in the divergent phase of their design process, and generated close to 200 concepts – including a submarine that passes gas to send tactical signals and unmanned vehicles designed to hijack enemy radar signals. As they worked through their tasking, they found that many of their ideas addressed the challenge of sorting through massive volumes of information in a complex information-riddled battlespace. Might autonomy help translate that massive amount of information into knowledge to inform decisions increasing mission effectiveness and reducing risk to the warfighter?

The problem statement addressed by Team Aries was *How might we build the relationship between humans and AI so that we may enhance and advance the warfighter's goals?*

2. Proposed Concept

Team Aries proposed one overarching concept – *The Modern Day 300* subtitled *"meet the human machine team that won in Riga!"* Storytelling conventions best communicated their concept so they chose to share a series of fictional characters and vignettes.

Ssgt Brad Hikleman and KITT

The first story was that of Staff Sargent Brad Hikleman and his AI, KITT. Like any other radio controlman out there, Ssgt Hikleman is tasked with maintaining and controlling the networks and communication arrays that allow ships and different platforms to talk to each other. Several days before the Battle of Riga he is running through his typical checklist making sure all the radios and secure comms are up, and crypto looks good.

Figure 47. Aggregation and analysis of data scraped off social media sites in advance of planned action to identify trends of interest.

Meanwhile, through data-scraping social media sites, aggregating and analyzing that data (*see Figure 47*) KITT has been able to identify potential threats. For example, individuals identified as EW experts may be mobilizing – their geo-tags are different, and they are all taking pictures in different areas. They seem to be coming together, and KITT predicts from this data that there is an 85% chance that adversaries in Riga are planning to employ EW in the coming conflict which is a higher likelihood than originally predicted. KITT recommends to Brad that they come up with a more secure way to share information. Brad replies "Sure, KITT. What have we got?" KITT suggests they deploy a swarm of UAVs as a communications array to pass information in the battlespace via light signals. This has never been done before. It is mission specific, easily scalable, and it is secure. Brad agrees and tasks KITT with operationalizing this innovative concept. Sure enough, when the Battle of Riga begins allied forces discover that their UHF and RF areas are compromised. They have no way to communicate. KITT seamlessly integrates into the swarm of UAVs to pass information and the opposing human users are completely unaware of the alteration. They are only aware that all allied stakeholders have secure comms.

FC2 Jennifer Jimenez and TARS

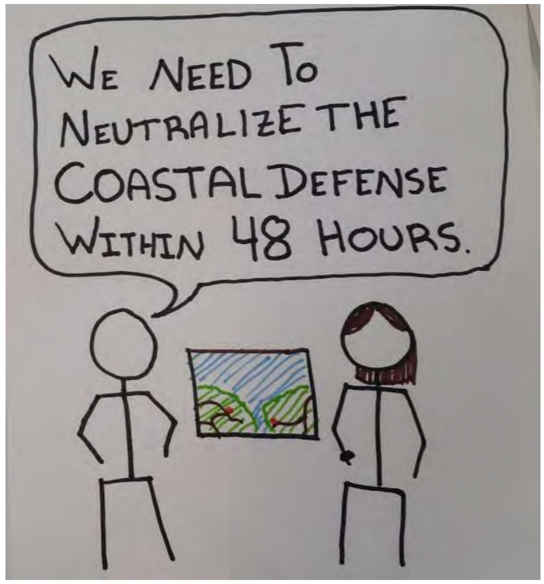

Figure 48. The commanding officer (*left*) shares guidance for the upcoming Battle of Riga with FC2 Jimenez (*right*).

This is the story of Fire Controlman Second Class Jennifer Jimenez and her AI, TARS. Referring to the border at the mouth of the Port of Riga, her commanding officer states that, “We need to neutralize the coastal defense within 48 hours” (*see Figure 48*).

Figure 49. FC2 Jimenez tasks TARS with computing COAs to meet the mission while she walks to her workstation.

Jennifer immediately interfaces with her AI, and says, “TARS, we need to compute COAs[35] to eliminate CDCMs[36]” (*see Figure 49*). As she goes back to her workstation, TARS begins work using links into the ship’s systems to access the information required, such as pertinent ISR data, to calculate COAs. By the time she reaches her workstation, TARS has completed required calculations and on her screen are all the possible COAs to consider along with likely consequences. Rather than a “tell me what to do and I will do it” type of relationship, TARS and Jennifer have an interactive exploratory relationship, so she is able to ask questions about several presented COAs and TARS replies with additional required information accessed from all the systems integrated within the ship and the full battle group. Her questions include “Why did you think it was a good idea to send that many units?” or “What if instead of this we did that? What are the ramifications? Does that alter the collateral damage?” This discussion with her AI guides Jennifer to a “lightbulb moment” (*see Figure 50*) where human ingenuity results in an idea that data analysis alone would not generate independently. However, without the rich initial input from TARS and the resulting discussion the human ingenuity alone would not have reached that solution in the limited time available in advance of a conflict.

Figure 50. FC2 Jimenez discusses COAs presented by TARS resulting in a "lightbulb moment"

The AI units would have access to all available theater ISR and other intelligence information on the region. In this example, TARS is tasked specifically with countering the CDCM threat and is able to rapidly access all required information about available assets, ranges, requirements, and capabilities. TARS is also capable of calculating the COAs (*see Figure 51*) much more quickly than any human counterpart.

[35] COAs = courses of action
[36] CDCMs = coastal defense cruise missiles

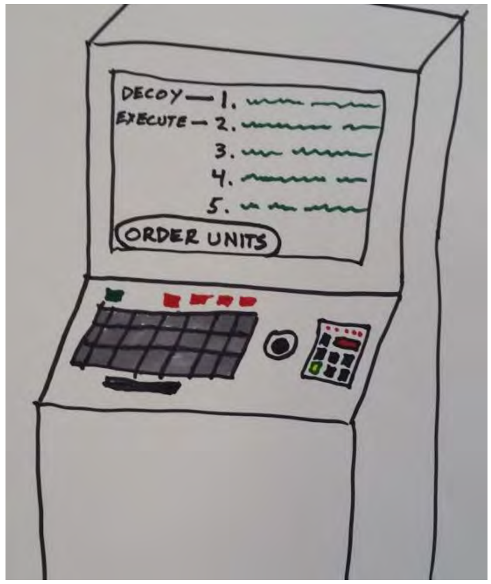

Figure 51. AI provided knowledge derived from information rapidly aggregated from many sources.

The AI component makes recommendations based on analysis of the data available. However, the human adds the key elements of intuition and judgement to make the final decision after reviewing the AI crafted suggestions. The human may choose to combine suggestions (*see Figure 52*). The team re-emphasized that the AI will augment not replace the human.

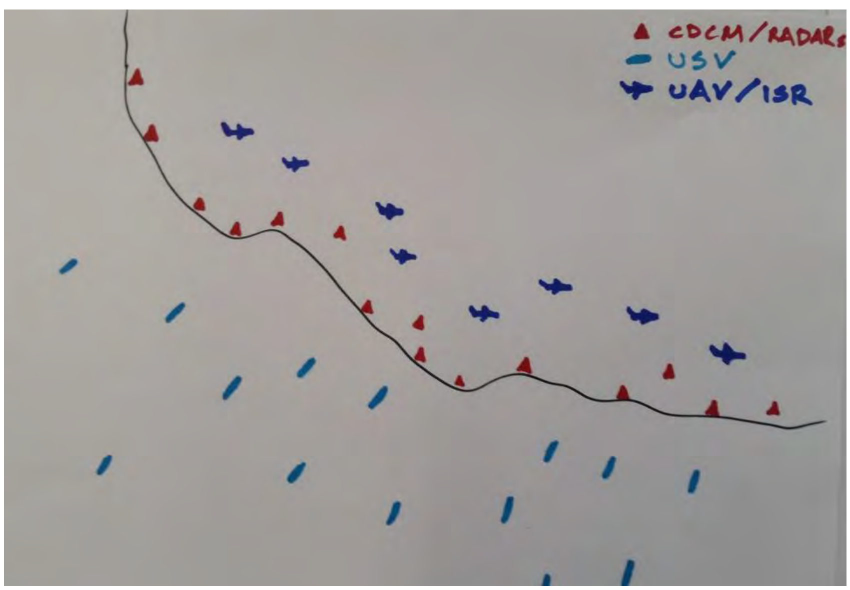

Figure 52. A combination of three AI suggested COAs (*red, light blue, navy blue*) is the AI augmented human chosen COA.

LT Kyle Sapporo and BENDER

The final vignette shared was the story of Lieutenant Kyle Sapporo and his AI unit, BENDER. Kyle grew up not knowing a world without AI and WiFi and test screens. He enrolled in a competition in his STEM high school and won a scholarship to study at the Faber College of AI where he earned his Bachelor of Science degree in AI. Upon graduation and ROTC commissioning, Kyle was assigned an AI unit to follow him throughout his career.

Figure 53. Upon commissioning, LT Kyle Sapporo is assigned an AI unit, BENDER, to follow him throughout his career.

Upon successful completion of their commissioning program, Kyle and BENDER were selected for the Explosive Ordnance Disposal (EOD) program (*see Figure 53*). Going through their basic EOD pipeline Kyle learned the basics of combat such as riflery, hand-to-hand skills, insurgency tactics, and basic explosives disarmament. BENDER was systematically uploaded with different databases from electrical engineering to historical IED placement and civil engineering vulnerabilities.

Figure 54. Basic EOD training for Kyle involved combat training (*right*) and for BENDER involved downloading manuals, databases, and other pertinent information sets (*left*).

Following successful completion of basic training, they were deployed together as the “rookies” in their tactical level unit. BENDER was able to access the organic assets provided to the advanced warfighter such a “Smart Soldier” system or Talos[37] envisioned for the near future. By accessing the embedded cameras in combination with aerial drone feeds, BENDER was able spot a disguised improvised explosive device (IED) that Kyle missed, alert him in time and saved his life (*see Figure 54*).

[37] TALOS = tactical assault light operator suit. SOURCE: E. Bryce (2016). “Soldiers of the future will be augmented and indestructible,” WIRED 29 December 2016. Last accessed 12 DEC 2017 at http://www.wired.co.uk/article/smart-soldiers-technology

Five years later, BENDER and Kyle are on their third deployment. Building on their career experience together, augmented by BENDER Kyle is now able to coordinate many systems together throughout the platoon conducting riot suppression, counterinsurgency (COIN) operations, and IED detection. Meanwhile, BENDER is providing direct support by scraping social media sources such as Facebook and other social media, closed-circuit television (CCTV) feeds throughout Riga, and FitBit data to surface trends and identify potential insurgent gathering points in the city to target the efforts of Kyle's platoon (*see Figure 55*).

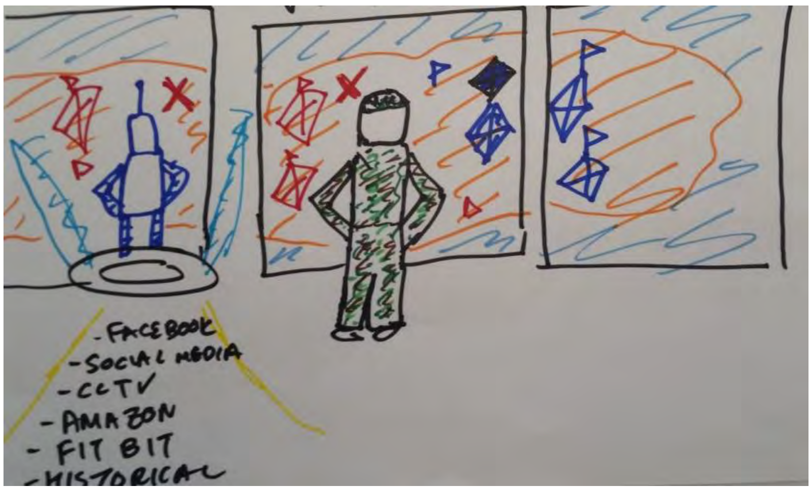

Figure 55. Kyle and BENDER on their third deployment in command of a platoon.

BENDER is watching heat signatures in the areas where people are beginning to gather and identifying spikes in heartrates. If the human operators, guided by BENDER's analysis, are able to identify individual insurgent leaders, they may be able to avert riots and de-escalate the conflict quickly.

Pioneers in Human Machine Teaming

Next, the team identified fictional advocates, champions, and visionaries required to achieve this AI vision of the future. These archetypes fell into the three realms of academics, the military, and industry.

<u>ACADEMICS</u>

Alexia Kannapolis: the first AI Department Chair at NPS developed the first AI degree program for human students. She was a major proponent of the *AI Games*, an annual human-machine team competition in Monterey, and an advocate for a DoD-sponsored common AI interface.

Dr. Stephen Kongberg: a professor of human-machine ethics at Harvard and author of the book *<u>The Human-Machine Team</u>*, he was the first to define the limits of AI. He socialized the concept of human augmentation and enhancement, rather than replacing humans with AI.

<u>MILITARY</u>

VADM Michael O'Doyle: considered the father of the UxV and AI warfighter community, he simplified the command structure through the creation of the human-AI response team (HART) based on the work of Dr. Kongberg. He also supported changes to the acquisition system to allow modular capability delivery.

INDUSTRY

Asimov Bradenton: the visionary leader of the company Amazon Defense Industry (ADI) pioneered the *on demand* delivery of UxVs to the warfighter (*see Figure 56*). Leveraging additive manufacturing, ADI developed a modular assembly system to quickly develop capability. Aerial and underwater warehouses placed the assembly mechanism closer to the battlefield to maintain effective response time.

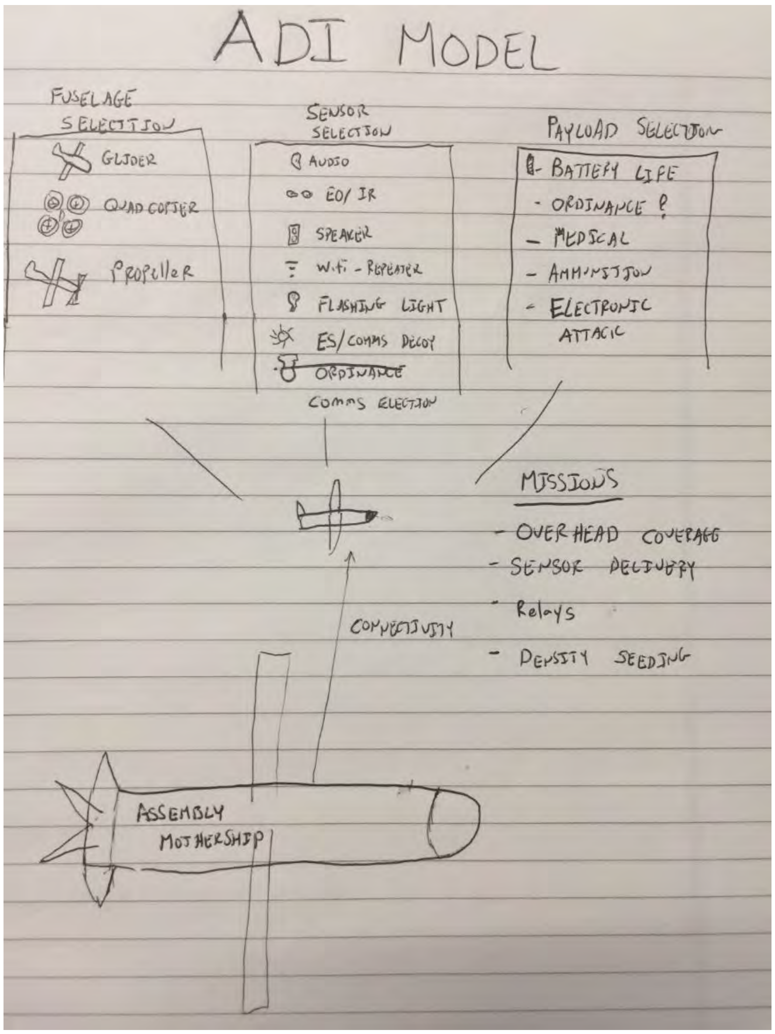

Figure 56. The fictional Amazon Defense Industry (ADI) modular on-demand asset delivery model.

Team Aries closed their presentation with five take-aways:

1) ***Human-Machine Teams:*** Humans alone are not the future of warfare. Machines are not the future of warfare. Humans and machines working in teams will take us into the future by enhancing each other's strengths and negating each other's weaknesses.

2) ***AI as a Force Multiplier:*** In an operation where you previously needed seven ships and 5,000 men, in the future you will need seven men and 5,000 inexpensive UxVs. This dramatically increases the capabilities of a very small force, and significantly reduces the manpower, logistics and supply requirements.
3) ***Previous Scenarios + Data Analysis = AI Predictions:*** We live in a world of *Big Data* – data is everywhere! We have thousands of years of history to pull from, and millions of small events happening across the globe every day. AI can use all of this historical information in combination with analysis of real time data to provide more accurate predictions of near future events that may impact future warfighters one hour from now, one week from now, or one year from now.
4) ***Redundancy through Massive Deployment of Inexpensive UxVs:*** If you have a small selection of very powerful complex systems, loss of one of those systems results in a significant loss of capability and coverage. However, if you launch a swarm of 1,000 UAVs and you lose 100 you have only lost 10% of your outlay, so that leaves 90% coverage of your area of responsibility. Also, if these swarming aerial units are able to communicate amongst each other via RF or light signals in a comms-denied environment you could have the vehicles reorganize to fill gaps and return to full coverage. *"If you cut the head off a snake, the snake dies. But if you cut an arm off a starfish it grows another."*
5) ***Simplify Tasks and Amplify Capability:*** There are so many tedious, routine tasks and processes that currently completed by humans that are time-consuming and unnecessarily difficult. Leveraging machine learning an AI unit could likely accomplish many of these tasks more efficiently than humans, allowing the humans to focus on other issues.

E. Team Gemini

Figure 57. Members of Team Gemini (*pictured from left to right*): Emily Hall, Daniel Sotingco, LT Jeremiah Medina USN, Rachel Florea, Andrea Leichtman, LT Brandon Nichols USN, and LT Isa Aljawder RBNF (*not pictured CDR Dan Cain USN*)

The members of this team (*see Figure 57 and Table 6*) included two junior officers, one naval officer from Bahrain, and three early career engineers. The team was co-facilitated by a senior officer and a visiting engineer who was a concept generation team member in two prior workshops.

Table 6. Members of Team Gemini (*alphabetical by last name*)

NAME	PERSPECTIVE	AFFILIATION
LT Isa Aljawder RBNF	foreign military	NPS (Bahrain)
CDR Dan Cain USN	*facilitator*	NPS
Rachel Florea	systems engineer	SPA Inc
Emily Hall	*facilitator*	Battelle
Andrea Leichtman	computer engineer	JHU/APL
LT Jeremiah Medina USN	surface warfare officer	NPS
LT Brandon Nichols USN	aviator	NPS
Daniel Sotingco	mechanical engineer	Draper Labs

1. Problem Statement

Team Gemini noted to start their presentation that their process diverged and converged several times over the course of the two concept generation days (*see Figure 58*). Their “ah ha” moment came during their initial pitches on the second morning. BGen Kelley asked for an Alexa for his fleet. How might we set ourselves up for BGen Kelley’s “Navy Alexa” future? “NAlexa, I need eyes on Yemen. What is available?” Evolved to the problem statement *How might we better utilize information to effectively maintain battlespace control?*

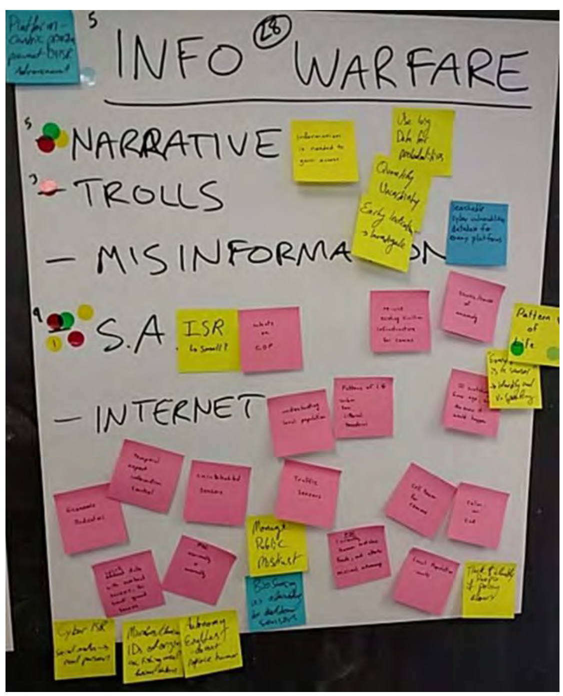

Figure 58. Team Gemini design process artifact.

The team stated up front that although they did not create the NAlexa, they have generated key pieces of the concept as a foundation from which to move forward. These pieces address an anti-access area denial (A2AD) environment, quality situational awareness, and means to control the narrative with the populace and media to counter the impact of cyber “Trolls” the region.

Team Gemini provided the following metrics:

- **Manpower Intensity –** increase capability with a corresponding decrease in man-hours to field (flying, fixing, monitoring, maintaining)
- **80 Hour Work Week** – currently averaging 108hrs on CRUDES, "doing more with less".
- **Time To Accomplish Specific Tasks –** improved computations in the field
- **Campaign Level Expendability** – on a 1 to 100, black wing is a 1 and a carrier is a 100; fleet average can be used to assess fleet
- **Sensor/Weapon Coverage Ratio** (NM^2)
- **Firepower** (average, total)
- **Combat effectiveness** – of unit in network-denied environment (e.g. human is high, GPS-dependent drone is low)

2. Proposed Concepts

The proposed concepts include:

- Command Ticketing System
- Operations Center Display
- UXV Activity Manager
- Distributed UXV C2 Architecture

a. Command Ticketing System

Commanding a combined force of autonomous and manned units is inconsistent and cumbersome. The proposed *Command Ticketing System* is a software system that will allow a battlefield commander to easily issue commands to a large distributed force of manned and unmanned units, and receive relevant updates from diverse and dispersed units in a timely manner without being overloaded by too much information. The system will issue tasks in a ticket-style order system like that in GitHub[38], an open-source software solution currently used by engineers to coordinate development across large teams dispersed across the globe. Taking inspiration from a current social media giant that allows people to receive notifications on chosen topics of interest and an app that allows customers to call cabs from their cell phones, the proposed system will also allow users to receive notifications like in Facebook, and to call a required UxV support like in Uber.

[38] GitHub is a Web-based Git version control repository hosting service. It is mostly used for computer code, but is being used increasingly for other shared document types. It offers all of the distributed version control and source code management functionality of Git as well as adding its own features.

Figure 59. The *Command Ticketing System* is much like a traditional restaurant ticketing system for line cooks to plan their tasks to meet customer demand.

The term "ticket" – from the IT and software engineering community – is a record of a desired task. Like a waiter posting a ticket for a line cook (*see Figure 59*), or a ticket submitted for technical support; the *Command Ticketing System* will review current tickets to plan lines of effort in a complex battlespace based on urgency and assets available.

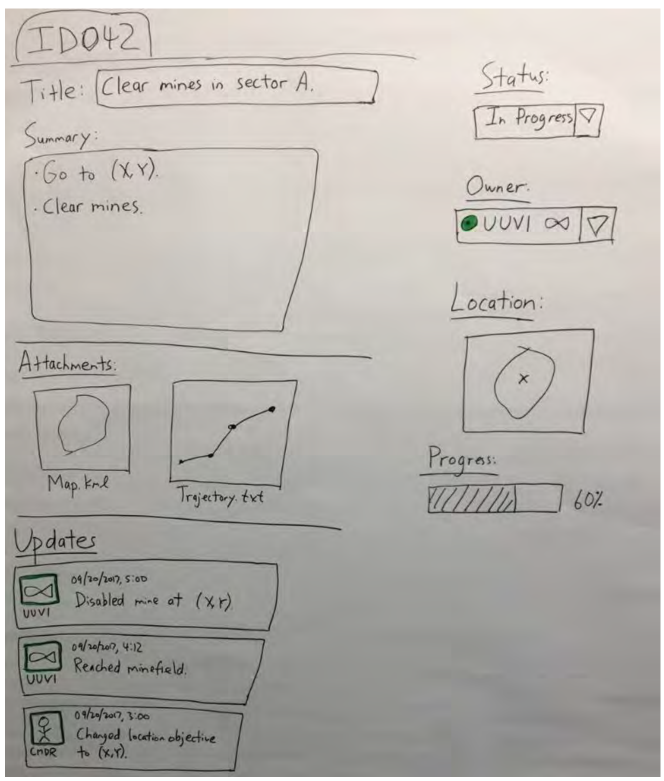

Figure 60. A sample mission ticket in the *Command Ticketing System*.

To order an autonomous system to perform a mission (*see Figure 60*) the commander fills out a title and summary description, attaches relevant information such as maps, and assigns the ticket to the desired unit. As the unit performs the mission, their progress appears as updates to the ticket, such as location, target identification, and other pertinent milestone events.

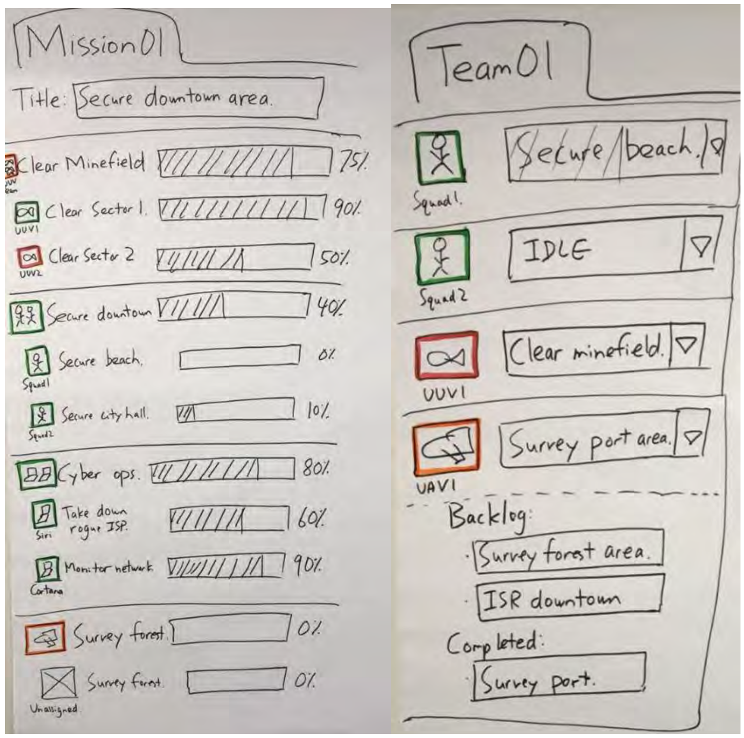

Figure 61. A sample mission pane (*left*) and team information pane (*right*) displaying success (*green*), pending (*orange*), or concern (*red*).

The mission pane of the Command Ticketing System (*see Figure 61 left*) allows the commander to view all relevant tasks associated with a mission. Each task display is accompanied by an overall progress bar, subtask progress, and the designated task owner – either manned or autonomous. A team information pane (*see Figure 61 right*) displays the members of a team including both autonomous and manned units, and current status – current task, idle, or in distress. The commander can click or touch to display the backlog of tickets assigned to that unit, as well as a log of completed tasks. Unit profiles are color-coded to indicate their health status. For instance, a unit may be colored green to indicate that it is functioning well, yellow to indicate that it has taken combat damage, or red to indicate that it has been destroyed or has not checked in for a long time.

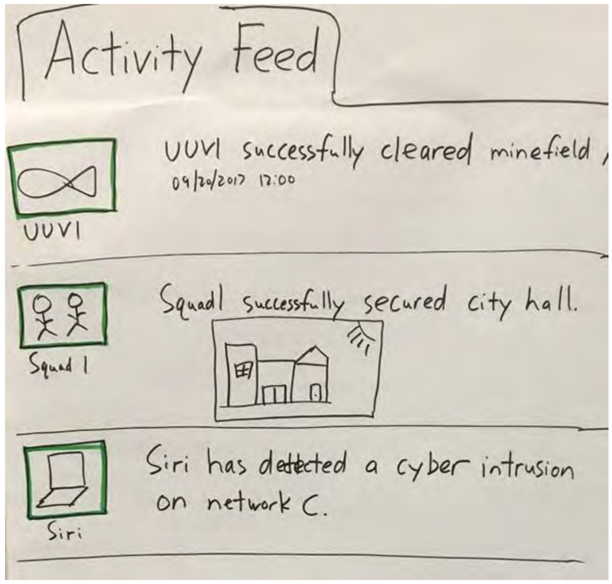

Figure 62. A sample activity feed indicating a cleared minefield (*top*), a photo of a secured building (*center*), and a detected cyber intrusion (*bottom*).

As each unit reaches milestones, updates are displayed on both the associated ticket and the dynamically-populated activity feed (*see Figure 62*) that aggregates the activity from all units the commander is monitoring.

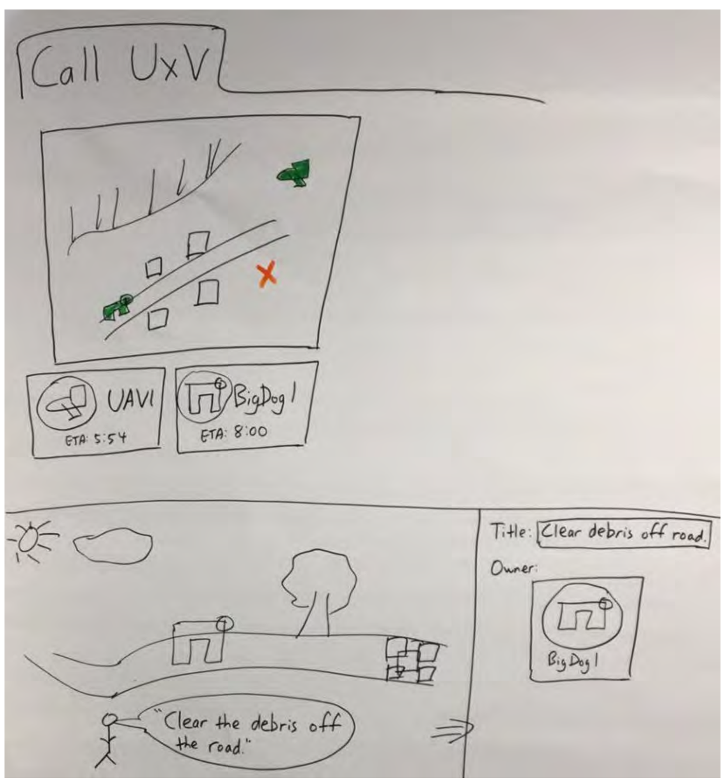

Figure 63. A sample call pane displaying available assets and estimated time of arrival (*top*), and notes interface mode (*bottom*) such as voice.

In the same way that you would call an Uber, the commander is able to call for UxV support in the field. The call pane (*see Figure 63 top*) shows available UxVs and estimated time of arrival to the mission site. Tickets may be entered manually or voice activated (*see Figure 63 bottom*). For example, a squad commander may order a UGV to clear some debris off the road. This auto-creates a ticket in the system and updates progress so that the fleet commander has visibility into what is happening.

b. Operations Center Display

Unit status information is currently available via message traffic displayed in an unwieldy form. There is a lot of useful information available in message traffic, but the text format makes it extremely cumbersome (*see Figure 64*). Situational awareness through human reading of message traffic is time intensive. To remedy, the team proposed an intelligent status display distilled from accepted reporting standards.

```
----OFFICIAL INFORMATION DISPATCH FOLLOWS----
RTTUZYUW RUCCBWF0132 2572340-UUUU--RHMCSUU
ZNR UUUUU
R 141211Z SEP 17 ZYB
FM COMNAVPERSCOM MILLINGTON TN
TO NPS MONTEREY CA
TACRON TWELVE DET WESTPAC ALFA
TACRON TWELVE
PERSUPP DET PENSACOLA FL
COMNAVPERSCOM MILLINGTON TN
PERSUPP DET LEMOORE CA
PERSUPP DET NORTH ISLAND CA
PERSUPP DET OKINAWA KADENA JA
INFO COMTACGRU ONE
COMNAVFORJAPAN YOKOSUKA JA
BT
UNCLAS FOUO //N01321//
PASS TO OFFICE CODES:
FM COMNAVPERSCOM MILLINGTON TN//PERS432/PERS455//
TO NPS MONTEREY CA//JJJJJ//
TACRON TWELVE DET WESTPAC ALFA//JJJ//
TACRON TWELVE//JJJ//
PERSUPP DET PENSACOLA FL//JJJ//
COMNAVPERSCOM MILLINGTON TN//JJJJ//
PERSUPP DET LEMOORE CA//JJJ//
PERSUPP DET NORTH ISLAND CA//JJJ//
PERSUPP DET OKINAWA KADENA JA//JJJ//
INFO COMTACGRU ONE//JJJ//
COMNAVFORJAPAN YOKOSUKA JA//JJJ//
MSGID/GENADMIN/COMNAVPERSCOM//
SUBJ/BUPERS ORDER//
RMKS/
 BUPERS ORDER: 2577   XXX-XX-1234/1310  (PERS-432H)
   OFFICIAL CHANGE DUTY ORDERS FOR
   LT DOOR, WT,  USN  IN CARRYING OUT/PROCESSING THESE ORDERS, BOTH PA
    MUST BE READ AND LISTED INSTRUCTIONS COMPLIED WITH
           FOR OFFICIAL USE ONLY              P A R T   O N E
        ------ DETACHING ACTIVITY /M/ ------
WHEN DIRECTED BY REPORTING SENIOR, DETACH IN DEC 17   EDD: DEC 17
FROM STU PG MONTEREY                        UIC: 31405
PERMANENT DUTY STATION  CA, MONTEREY
FROM DUTY UNDER INSTRUCTION IN A FLYING STATUS NOT    ACC: 342
   INVOLVING FLYING
- PERSONNEL ACCOUNTING SUPPORT: PERSUPPDET LEMOORE
                          UIC: 43077
```

```
      ------ INTERMEDIATE (01) ACTIVITY /M/ ------
REPORT NET 13 JAN 18 BUT NLT 15 JAN 18          EDA: 15 JAN 18
TO TACRON 12                          UIC: 55135
LOCATION: CA, CORONADO
FOR TEMPORARY DUTY UNDER INSTRUCTION IN A FLYING     ACC: 341
   STATUS INVOLVING FLYING
FOR APPROXIMATELY 5 DAY/S/
- PERSONNEL ACCOUNTING SUPPORT: PERSUPPDET NORTH ISLAND
                              UIC: 42827
TO INCLUDE 5 DAY/S/ AT TACRON TX
CLASS:   CONV: 180115 GRAD: 180119      CDP:
UPON COMPLETION OF TEMPORARY DUTY UNDER INSTRUCTION IN A FLYING
 STATUS INVOLVING FLYING
AND WHEN DIRECTED, DETACH.                   EDD: 19 JAN 18
- REPORT NOT LATER THAN 0730 15 JAN 18 AND NOT EARLIER THAN
13 JAN 18. REPORTING PRIOR TO NOT EARLIER THAN DATE WILL
TERMINATE LEAVE STATUS AND RESULTS IN NON-PAYMENT OF PER DIEM FOR
PERIOD PRIOR TO THE NOT EARLIER THAN DATE SPECIFIED UNLESS AUTHORIZED
UNDER MILPERSMAN 1320-140.
- UNDER CIRCUMSTANCES NOT PERMITTING TRAVEL BY USUAL MEANS OF
TRANSPORTATION IN AND AROUND SAN DIEGO, CA.
A SPECIAL RATE MTMC/DOD LOWEST COST RENTAL CAR IS AUTHORIZED FOR
OFFICIAL BUSINESS UNDER JTR, PAR. U3415, U3510-C, AND U3505-B.
RENTAL VEHICLE MUST BE OBTAINED THROUGH COMMERCIAL TRAVEL OFFICE
(CTO). CTO RESERVATION INFORMATION MUST BE PROVIDED WITH REQUEST
FOR ADVANCE.
      ------ INTERMEDIATE (02) ACTIVITY /M/ ------
REPORT NET 18 JAN 18 BUT NLT 20 JAN 18          EDA: 20 JAN 18
TO TACRON 12 DET WESTPAC ALFA                 UIC: 55623
LOCATION: JAPAN, WHITE BEACH N
FOR TEMPORARY DUTY UNDER INSTRUCTION IN A FLYING     ACC: 341
   STATUS INVOLVING FLYING
FOR APPROXIMATELY 37 DAY/S/
- PERSONNEL ACCOUNTING SUPPORT: PERSUPPDET OKINAWA
                              UIC: 43385
TO INCLUDE 37 DAY/S/ AT TACRON TX
CLASS:   CONV: 180120 GRAD: 180225      CDP:
UPON COMPLETION OF TEMPORARY DUTY UNDER INSTRUCTION IN A FLYING
 STATUS INVOLVING FLYING
AND WHEN DIRECTED, DETACH.                   EDD: 25 FEB 18
- REPORT NOT LATER THAN 0730 20 JAN 18 AND NOT EARLIER THAN
18 JAN 18. REPORTING PRIOR TO NOT EARLIER THAN DATE WILL
TERMINATE LEAVE STATUS AND RESULTS IN NON-PAYMENT OF PER DIEM FOR
PERIOD PRIOR TO THE NOT EARLIER THAN DATE SPECIFIED UNLESS AUTHORIZED
UNDER MILPERSMAN 1320-140.
```

```
      ------ INTERMEDIATE (03) ACTIVITY /M/ ------
REPORT NET 24 FEB 18 BUT NLT 26 FEB 18          EDA: 26 FEB 18
TO AF CMD AND CTL WARRIOR SCHOOL              UIC: 64106
LOCATION: FL, HURLBERT FIELD
FOR TEMPORARY DUTY UNDER INSTRUCTION IN A FLYING     ACC: 341
   STATUS INVOLVING FLYING
FOR APPROXIMATELY 17 DAY/S/
- PERSONNEL ACCOUNTING SUPPORT: PERSUPPDET PENSACOLA
                              UIC: 43081
TO INCLUDE 17 DAY/S/ AT IAOC2C
CLASS:   CONV: 180226 GRAD: 180314      CDP:
UPON COMPLETION OF TEMPORARY DUTY UNDER INSTRUCTION IN A FLYING
 STATUS INVOLVING FLYING
AND WHEN DIRECTED, DETACH.                   EDD: 14 MAR 18
- REPORT NOT LATER THAN 0730 26 FEB 18 AND NOT EARLIER THAN
24 FEB 18. REPORTING PRIOR TO NOT EARLIER THAN DATE WILL
TERMINATE LEAVE STATUS AND RESULTS IN NON-PAYMENT OF PER DIEM FOR
PERIOD PRIOR TO THE NOT EARLIER THAN DATE SPECIFIED UNLESS AUTHORIZED
UNDER MILPERSMAN 1320-140.
- UNDER CIRCUMSTANCES NOT PERMITTING TRAVEL BY USUAL MEANS OF
TRANSPORTATION IN AND AROUND HURLBURT FIELD, FL.
A SPECIAL RATE MTMC/DOD LOWEST COST RENTAL CAR IS AUTHORIZED FOR
OFFICIAL BUSINESS UNDER JTR, PAR. U3415, U3510-C, AND U3505-B.
RENTAL VEHICLE MUST BE OBTAINED THROUGH COMMERCIAL TRAVEL OFFICE
(CTO). CTO RESERVATION INFORMATION MUST BE PROVIDED WITH REQUEST
FOR ADVANCE.
- MEMBER ADVISED: NO PERDIEM/LODGING REIMBURSEMENT AUTHORIZED AT ANY
INTERMEDIATE STOP/S/ IN THE SAME GEOGRAPHIC LOCATION AS THE ULTIMATE
DUTY STATION. EXCEPTION TO THIS POLICY IS ARDUOUS SEA DUTY IDENTIFIED
IN JTR U5120D AND LISTED IN OPNAVINST 4650.17.
- MEMBER DIRECTED: FOR EACH INTERMEDIATE STOP, IF GOVERNMENT
QUARTERS ARE AVAILABLE (BQ/SHIPBOARD BERTHING) AND THE BASE HAS A
GOVERNMENT MESS APPROPRIATED FUND FOOD SERVICE ACTIVITY/GALLEY
AVAILABLE TO THE TRAVELER, USE OF THE GOVERNMENT MEAL PER DIEM
RATE IS DIRECTED. IF GOVERNMENT MESSING IS NOT AVAILABLE OR IS
PARTIALLY AVAILABLE, OBTAIN AN ENDORSEMENT TO THAT EFFECT FROM THE
HOST COMMAND. JTR PARA U4400 APPLIES.
```

Figure 64. Current text format message traffic.

Generally, a room full of junior officers are assigned to read all incoming message traffic for hours each day to pull out a few nuggets of information each day to pass on to their skipper at the daily OPS/INTEL brief. A data management system that “reads” all message traffic could display unit status information graphically, potentially as icons on a global or regional layout providing rapid situational awareness to operators and decision-makers.

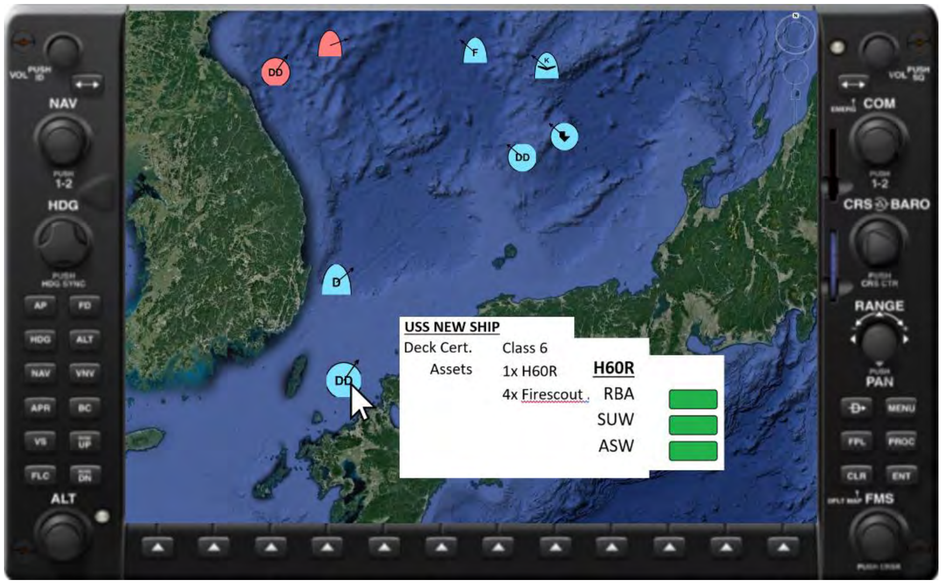

Figure 65. Proposed *Operations Center Display* of message traffic information.

Translating this message traffic into a graphic display gives the human operator a much quicker view of the area of interest, with nearby assets and targets of interest geo-located on a simple regional map display (*see Figure 65*). In this proposed *Operations Center Display,* the operator might simply click on any ship to get key information, and then expand the selection to explore more detail. The proposed system would incorporate a "click-for-information" feature like Google Maps, with results that might be easily searchable using Boolean queries or simple browsing.

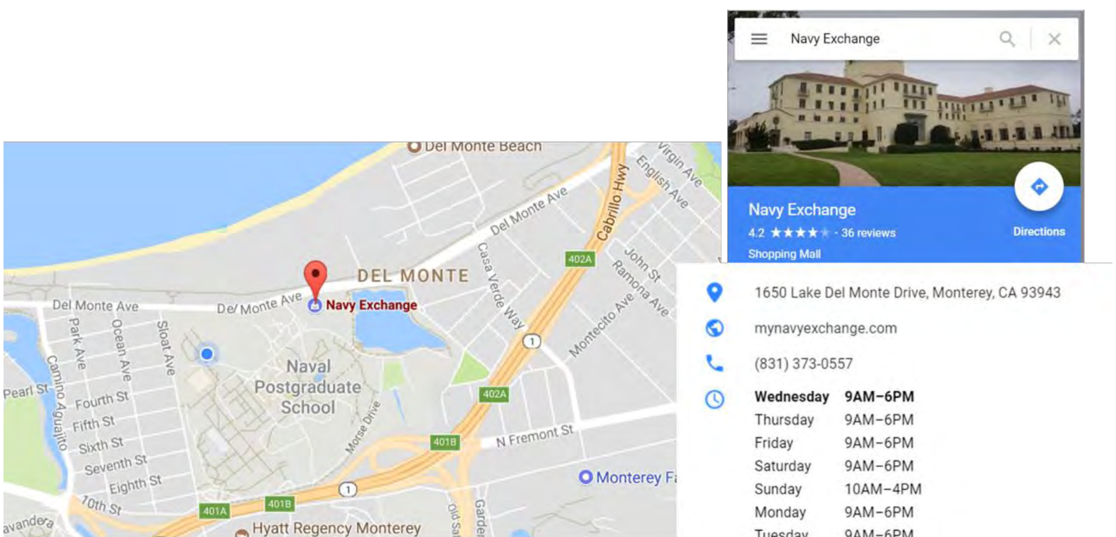

Figure 66. Proposed operations center display to replace current message traffic system.

Imagine the following situation (*see Figure 66*): you are on travel from your command and arrive on the NPS campus with a nearly empty travel toothpaste tube. You note a break in your WIC Workshop schedule and you search for options to replenish your toothpaste. The first thing you do is open Google Maps and find stores nearby. You see Navy Exchange (NEX), and click on it to see if it is open. You want to go on your way home, so although the first screen confirms that the NEX is open now you expand the selection to see the full display of open hours. *"It's open until 6– better go before beers at the Trident room!"*

Google Maps pulled this information from websites, user updates, and other available open-source databases. How does the U.S. Navy respond to similar information requests now? Three to six junior officers read all message traffic and generate a PowerPoint slide. This very time intensive process does not always produce required results as the information may aggregate at a different level. Message traffic is simple light information – it is just text. The problem is ***not*** the message traffic – it is a robust, consistent means of communications that can work at all levels from a newly stood-up forward operating base to the full Military Sealift Command (MSC)[39]. Historically, in a complex information environment the message traffic generally makes it through. The team emphasized that this concept does not require a change in the message traffic, only a change in the interface using current fleet accepted standards.

c. UxV Activity Manager

Ships have limited range ISR. It is possible to extend this range using UxVs, but the limited endurance of such enhancement platforms and the current manpower required to field these assets is an obstacle. To mitigate this obstacle, Team Gemini proposed an *UxV Activity Manager* with a variety of preprogrammed actions to enhance mission support. This system's outputs might assign activities to unmanned assets rather than assigning human operators to control UxVs. Rather than assigning officers to review incoming data, the UxV would alert the user to data feed anomalies freeing manpower for other tasks.

For instance, to support an ISR mission multiple UxVs might automatically conduct elliptical orbits relative to a manned asset, and provide pictures back to the command node. An AI system might also conduct pattern recognition, and alert a watchstander to an anomaly so the human is not needlessly tasked to review all returned data. For ease of use, a watchstander might re-task one UxV to track a particular contact by either drawing on a touch-screen, or using a more traditional "point and click" method. If the watchstander does not give an updated track command, the UxV would default to a loiter setting. Rather than each unmanned asset requiring several human operators, the *UxV Activity Manager* is intended to allow one human operator to control multiple UxVs – each assigned different tasks.

[39] "Military Sealift Command exists to support the joint warfighter across the full spectrum of military operations. Our mission is timeless and essential. Regardless of the challenge, we prevail! Working seamlessly with key partners to master the maritime and cyber domains, MSC provides on-time logistics, strategic sealift, as well as specialized missions anywhere in the world, under any condition, 24/7, 365 days a year." (http://www.msc.navy.mil/mission/)

Figure 67. Notional interface for tasking single drone showing common operational picture with the drone (*DD at center*), a commercial vessel (*pink at right*), and a UAV and USV (*blue at bottom left*).

Team Gemini presented a notional interface for tasking a single drone by displaying a common operating picture (*see Figure 67*).

Figure 68. Notional workflow where the user selects the UAV to task (*pink circle left of center*) and then selects pre-defined tasking from left navigation bar (*grey box at top left*).

To demonstrate a notional workflow, the user might later select a UAV to task (*see Figure 68 pink circle*). The user then selects a pre-defined tasking such as an elliptical patrol (*see Figure 68 left*). The UAV will then automatically begin to patrol and follow the ship. As the mission progresses the common picture is updated to show the UAV's progress on elliptical patrol (*see Figure 69*).

Figure 69. Mid-mission tasking of a UUV (*pink circle*) to investigate (*left*) a suspected commercial vessel (*red*).

As mission needs change, an operator could then task a UUV to investigate a commercial vessel by selecting the UUV and the suspected commercial ship as the target, and then selecting "Investigate" on the left navigation bar (*see Figure 69 left*).

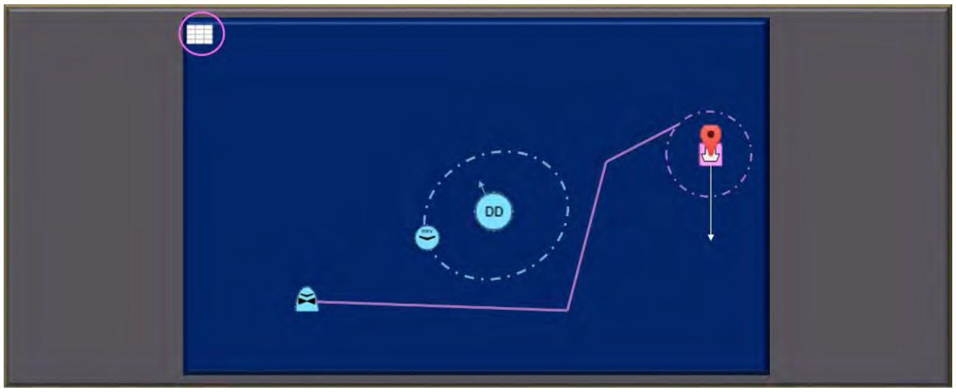

Figure 70. Full mission display updates to reflect additional tasking, and proposed target (*red*) investigation path (*pink line*). Note table icon (*pink circle top left corner, see next figure*).

Again, the display updates to show the auto-determined path for target investigation (*see Figure 70*). Like in current navigation programs, the operator can change the investigation path at any time.

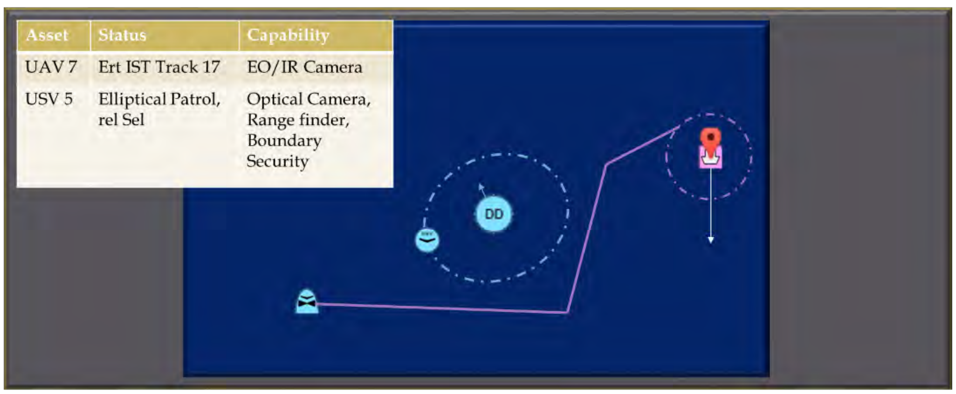

Figure 71. Table icon at top left of the previous figure displays current tasking in a report format.

The table icon allows the operator to review current tasking, and produce a report of existing recourses in play (*see Figure 71 top left*).

Figure 72. The system screens and reports useful and actionable information when available.[40]

Rather than assigning human operators to monitor feeds continuously, the *UxV Activity Manager* screens and reports tips to human operators when useful, actionable information is available (*see Figure 72*). Based on that information, the human user is then able to take direct action to alert or re-task the UxVs currently assigned within the mission.

d. Distributed UxV C2 Architecture

Team Gemini's final concept involves alternative communications between nodes in an unmanned swarm. As currently envisioned, all assets in a UxV swarm are in line of sight (LOS) of the human operator peer-to-peer communication between UAVs is lacking. If network communications and ISR are expanded the UxV swarm's is more robust. The proposed Distributed UxV C2 Architecture tasks a select number of "smart comms" UAVs to pass orders and maintaining network coverage. *"A few, select unmanned craft carry the burden of communications for the swarm."* In a single swarm unitsmaller, light-task UAVs are used for ISR and kinetic effects and are tasked by larger UAVs.

[40] Image source: http://i.dailymail.co.uk/i/pix/2016/03/16/article-doc-8s4g7-4zEDfY2awi238572c972670cc05e-547_634x423.jpg

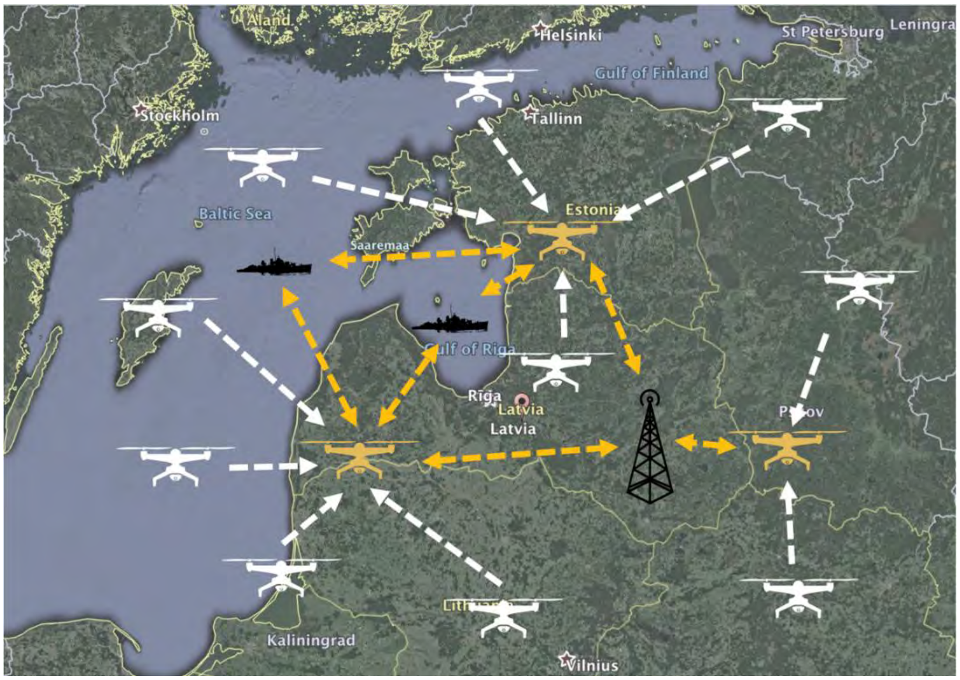

Figure 73. An OV-1 of the Distributed UxV C2 Architecture concept depicting proposed lines of communications between select assets within a swarm. The ten assets responsible for ISR (*white*) pass data to the three assets (*orange*) responsible for relaying the data back to the three control stations (*black*).

Within a standard architecture for an envisioned UAV swarm (*see Figure 73*) a handful of assets have ISR responsibility – simply gathering sensor data and relaying it to the assets responsible for passing the data back to control stations. The two ships and the tower represent the control stations in the figure above. In this architecture, all the UxVs are visibly identical with different responsibilities. The three orange assets can patrol areas to maximize coverage and alleviate the need to maintain line of sight distance from white assets to the control stations. All that is required is a shared data link and integrated communication structures.

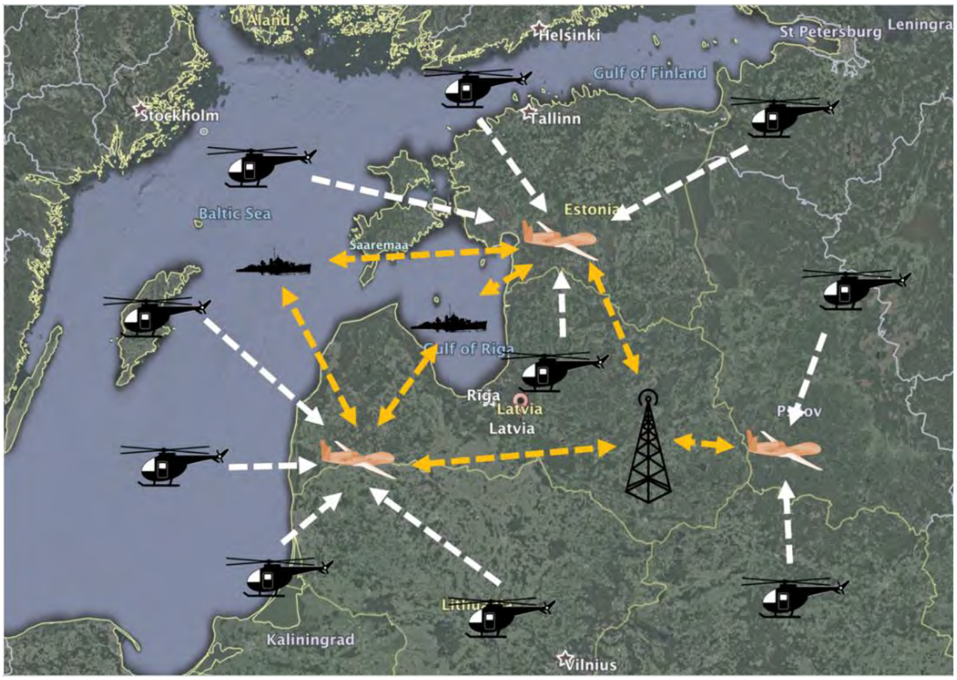

Figure 74. The same C2 architecture employed within a heterogeneous swarm of unmanned assets.

The same architecture could be employed even if the swarm is not homogeneous (*see Figure 74*). The ISR units might be of one variety, while the relay units are another. The only requirement is that all UxVs have the ability to communicate peer-to-peer via a common data link.

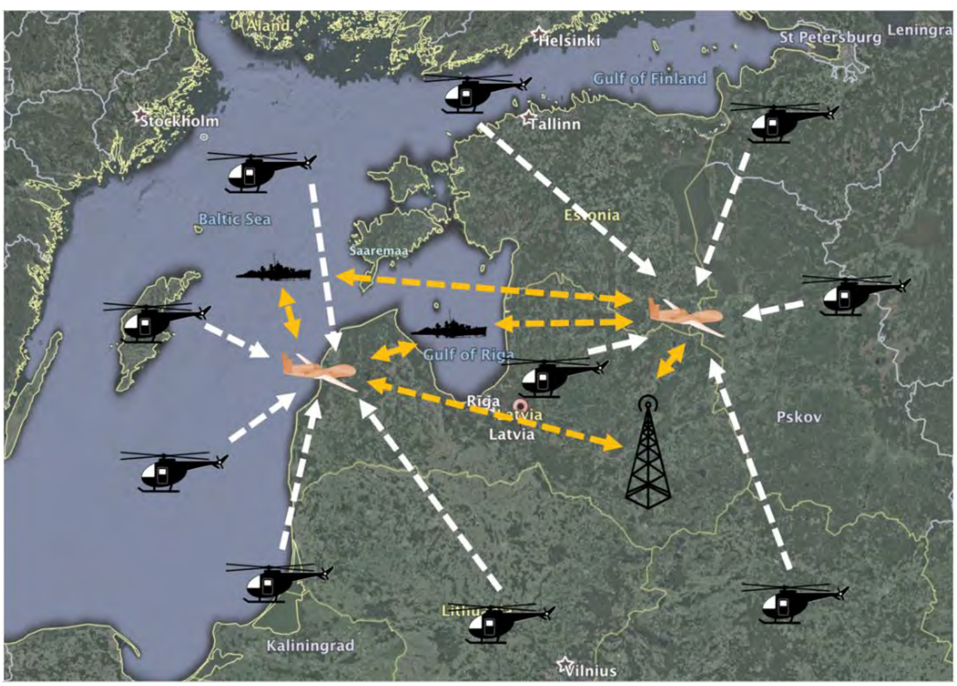

Figure 75. Swarm tasking and groupings can change as this scenario proceeds, so flexibility of C2 architecture is required.

In the event that one ISR asset loses comms through malfunction or attack, the C2 architecture will allow relay assets to adjust their location to maximize links with the remaining ISR assets to fill the gap while comms are reestablished with the lost assets (*see Figure 75*). The relay assets could solve an optimization algorithm to maximize the area communication coverage while minimizing their distances from ISR UxVs and control stations.

e. Undeveloped Concepts

The following concepts were generated but not developed:

Crab Bots

Problem Addressed: Undersea domain control
Description: walk or swim, swarm or individual – scalable, ISR or kinetic

Area Kill Switch

Problem Addressed: Narration control and enemy communications denial
Description: Set emissions control (EMCON) throughout Latvia, drone jammers, synchronize with Link 16

IW AI-Cloud

Problem Addressed: Pattern Recognition and Analysis of public forums
Description: Similar to targeted advertising, find bad guys, find susceptible populace – provide alternate narrative, autonomously executed cyber-attacks (single order from Commanding Officer)

IW AI-Unit Level

Problem Addressed: More data is not necessarily better data for a human
Description: pattern recognition in ISR – this boat squawks “fishing vessel” on AIS, but video identification has a 50 cal -> warning for watchstander, anomaly detection in ISR, opportunity for bio/chem ISR, tie-in option for UXV swarm

Stingray UAVs

Problem Addressed: Pattern of Life Info
Description: sniff cell phones, mimic cell tower – police employment example, commercial off-the-shelf (COTS) technology and redeployment, developed for military – we should use all the technology we have, plugs into pattern recognition AI to find Red

Auto Page 2 Verifier

Problem Addressed: warriors in the field waste time on Navy Admin, which degrades situational awareness and readiness
Description: button on EVERY PAGE OF NSIPS that takes you to the verify function

Underwater Gas Station

Problem Addressed: limited UUV endurance – not unlimited-endurance nuclear power
Description: provide a recharge station for UUVs (geothermal, vibration, wave, or nuclear)

Modular Mission Drones

Problem Addressed: flexibility
Description: common airframe, modular mission suit, IRS drone returns – swap out for kinetics and send out for strike

Drones Repairing Drones

Problem Addressed: manpower requirements for maintenance

Description: go watch the *Empire Strikes Back*…seriously, drones do PMS and standard assessment and repair, lowers manpower requirement to one inspector vice several maintenance men

3D Print Replacement Parts

Problem Addressed: limited storage space; outdated technology

Description: older technology (i.e. 76mm on a Hazard FFG) has high cost replacement parts due to not being made anymore, 3D print circuit. Save Space. Save Money. Planned maintenance system (PMS) easier. Less casualty reports (CASREPS). Yay!!! (plastic, metal, circuits)

Video Game UX

Problem Addressed: Training is expensive and time consuming

Description:

Leverage existing user interface expertise in the video game industry to make operations and UXS command intuitive

- Training takes less time
- Less manpower for mission accomplishment
- Leverage existing skill sets – most recruits already play video games

APPENDIX B: Scenario

Developed by retired Navy Captain and Professor of Practice in the NPS Operations Research Department Jeff Kline, the following scenario was the environment given for the design challenge:

Hybrid War in an Urban Littoral Environment
Maritime War 2030
Riga, Latvia

In 2030, while increasing tensions in the Pacific in the South and East China Seas has the attention of the United States, certain intelligence leads indicate Russia's plans to conduct a lighting occupation of Gotland and the Aland Inlands in the Baltic. Sweden and Finland react immediately by mobilizing their armed forces and establish defenses on the sea, air and land. The United States sends an expeditionary strike group with a battalion-sized Marine Air-Ground task force toward the Baltic.

And then, nothing happens.

For six months Swedish and Finnish forces remain at a high state of readiness while the U.S. amphibious readiness group visits various northern European cities. Russian forces are not deployed, nor do any Russian Baltic exercises occur during that time. Swedish and Finnish forces begin to stand down. The U.S. naval forces return home. Everyone agrees that the Russians were deterred.

Then gradually, Russian "trolls" on Baltic social internet sites begin to inspire social unrest between immigrants, liberals, and radical conservatives resulting in riots in Stockholm and Helsinki. Cyber attacks against personal and business financial accounts begin as well as periodic power outages across both countries. As internal security becomes a challenge, the Russian fishing fleet sails escorted by Russian Border Control Maritime Ships and close the sea lanes surrounding Gotland and the Aland Islands. As the same time, a Russian container ship steaming near Visby, Gotland suddenly reports an engineering casualty.

These activities have the European press and intelligence agencies' attention. Too late they notice the slow build-up of Russian conventional ground forces on Latvia's eastern border. Across Latvia, ethnic Russians begin to protest the "suppressive" Latvian majority. While these developed into riots in Riga, "rebels" begin to take control of Jekabpils, Rositten, Ludza, Orge and other towns on the Daugava River. Other towns on the Baltic coast like Salacgriva fall under ethic Russian "rebel" control.

Figure 76. The urban littoral environment of Riga, Latvia.

Within three weeks the “rebels” control all approaches to Riga (*see Figure 76*), upriver on the Daugava or Western Dvina, and threaten the Baltic approaches with small armed boats and maritime IEDs. Rebels are believed to be integrating into Riga’s 650,000 inhabitants. Power, food, and water become scarce and violence is increasing across the city. Riga International Airport is still operational, but the other two airports have been shut down. Latvia’s government is still functioning inside Riga, but requests immediate NATO assistance.

In response, the North Atlantic Treaty Organization (NATO) sends the five battalions (5000 troops) of the Very High Readiness Joint Task Force (VJTF) to Riga. Their missions are to:

- Defend Riga and provide internal security until follow-on forces arrive,
- Protect critical infrastructure, particularly the airport and port facilities,
- Protect government leadership in Riga,
- And, if necessary, evacuate NATO and government personnel from Riga.

In support, the United States sends an expeditionary strike group composed of a three-ship amphibious readiness group, one Marine Expeditionary Unit, 2 DDGs, and 3 Frigates. Their mission is to support the VJTF, be prepared to sweep maritime IEDs from Riga’s port approaches, and be prepared to assist in the evacuation if executed.

APPENDIX C: Workshop Schedule

The three and a half day workshop started on Monday morning with a series of knowledge leveling briefs, followed by initial team meetings. Both Tuesday and Wednesday started with full group technical inject sessions followed by a full day of team generation work. Teams presented their final concepts on Thursday morning and the workshop adjourned by noon to accommodate outgoing travel.

MON – 18 September

0800	Registration	**GLASGOW 102**
0830	CRUSER Overview	Dr. Ray Buettner, NPS CRUSER Director
0845	NPS Warfare Innovation Continuum & Scenario	CAPT Jeff Kline USN (ret), NPS Chair of Systems Engineering Analysis (SEA)
0915	Distributed Maritime Operations	CDR Jason Canfield USN, NWDC
0940	Future Fleet Design	CDR Erik Cyre USN, OPNAV N501 Future Fleet Design & Architecture
1005	Autonomous Data Collection	Dr. Lori Adornato, DARPA
1030	**BREAK**	
1040	MDUSV	Mr. David Trask, NPS Professor of the Practice for MASINT Studies
1105	Maritime Dark Networks	Dr./CAPT Wayne Porter USN (ret), NPS Littoral Operations Center Director
1130	Partner Nation Perspective	CMDR Scott Craig, Royal Australian Navy
1150	Team Introductions	Ms. Lyla Englehorn, NPS CRUSER Associate Director
1200	**LUNCH**	
1300	Welcome	VADM Ronald Route USN (ret), NPS President
1310	Implementing Concepts: an industrial technical example	Mr. Aaron Kline, Caterpillar International
1345	Rapid Prototyping & Testing	Mr. Jamie Hyneman, M5 Industries
1445	Tasking	CAPT Jeff Kline USN (ret), NPS SEA Chair
1515	Initial Team Meetings	**BREAKOUT ROOMS**
1600	Icebreaker	**TRIDENT ROOM**

TUES – 19 September		**GLASGOW 102**
0800	Welcome	Dr. Ray Buettner, NPS CRUSER Director
0810	Keynote Address	Brigadier General Frank Kelley USMC (ret), DASN Unmanned
0900	Process	Ms. Lyla Englehorn, NPS CRUSER Associate Director
0930	Discovery Interviews – ***Mentors***	**BREAKOUT ROOMS – *Mentors meet in Glasgow Courtyard***
1100	Concept Generation – **Divergent**	**BREAKOUT ROOMS**
1200	**LUNCH**	
1300	DASN Panel on Issues in Autonomy – ***Mentors***	**GLASGOW 102**
1430	Executive Time – ***Mentors***	
	Concept Generation – **Divergent to Convergent**	**BREAKOUT ROOMS**

WED – 20 September		**GLASGOW 102**
0800	Welcome	Mr. Carl Oros, NPS CRUSER Associate Director
0810	Issues in Autonomy	CAPT George Galdorisi USN (ret), SSC-PAC
0835	Asset Integration	CAPT Karl Hasslinger USN (ret), General Dynamics Electric Boat
0900	Ideas into Reality	Mr. William Glenney, Institute for Future Warfare Studies
0930	Concept Generation – **Convergent**	**BREAKOUT ROOMS**
1000	MBARI Tour – ***Mentors***	***van departs for Moss Landing @0930***
1030	Directors & Chairs Rotation	**BREAKOUT ROOMS**
1200	**LUNCH**	
1300	Concept Development – **Final Push**	**BREAKOUT ROOMS**
1400	NPS Lab Tour – ***Mentors***	***Guided tour leaves from Starbucks***

THUR – 21 September		**GLASGOW 102**
0800	Team Photos & Evaluation	
0830	Final Briefs	
1200	**ADJOURN**	

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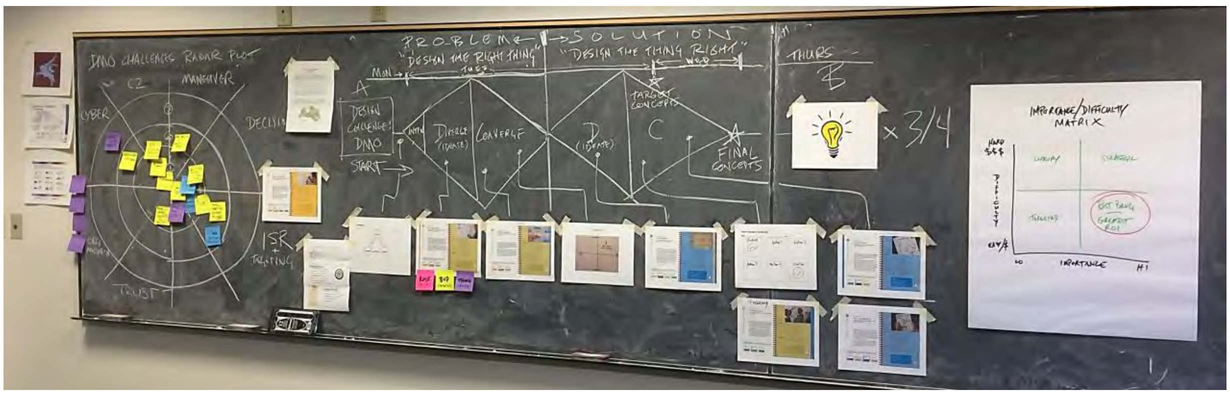

ACKNOWLEDGMENTS

Thank you to all those who made this workshop a success:

- To retired Marine Corps Brigadier General Frank Kelley, the Deputy Assistant Secretary of the Navy for Unmanned Systems for his valuable input and his willingness to share his time with workshop participants. Our outcome was absolutely impacted by his active participation.

- To our embedded design facilitators Mr. Brett Vaughn, CAPT Tony Nelipovich, Dr. Sarah Rigsbee, LCDR Kristen Wheeler, Ms. Emily Hall and CDR Dan Cain. All your work and expertise was absolutely reflected in the outstanding outcomes.

- To our visiting subject matter experts, mentors and observers; and to our resident subject matter experts Dr. Ray Buettner, and Professor Jeff Kline for sharing their time and expertise with the participants to better prepare them for their work.

- To all the participants for your time, professionalism, input based on your unique experience and expertise, and especially your willingness to help shape the future of our Navy.

LIST OF ACRONYMS AND ABBREVIATIONS

A2AD	anti-access area denial
AAW	anti-air warfare
ACTUV	ASW Continuous Trail Unmanned Vessel
AI	artificial intelligence
AIS	automatic identification system
ASuW	anti-surface warfare
ASW	anti-submarine warfare
ATARI	Autonomous Track Assess Report Intercept
C2	command and control
CASREPS	casualty reports
CCTV	closed-circuit television
COIN	counterinsurgency
CNO	Chief of Naval Operations
COLREGS	collision regulations
COMINT	communications intelligence
COP	common operational picture
COTS	commercial off-the-shelf
CRUSER	Consortium for Robotics and Unmanned Systems Education and Research
CSG	carrier strike group
DARPA	Defense Advanced Research Projects Agency
DASN	Deputy Assistant Secretary of the Navy
DMO	Distributed Maritime Operations concept
DoD	U.S. Department of Defense
EEZ	exclusive economic zone
ELINT	electronic intelligence
EMCON	emissions control
EO/IR	electro-optical infrared
EOD	Explosive Ordnance Disposal
EW	electronic warfare
FDECO	Forward-Deployed Energy Communication Outpost
GPS	global positioning system
HUMINT	human intelligence
IDM	integration, distribution, and maneuver
IED	improvised explosive device
IFF	identify friend or foe
IMO	International Maritime Organization
ISR	intelligence, surveillance, and reconnaissance
JHU/APL	The Johns Hopkins University Applied Physics Laboratory
LCS	Littoral Combat Ship

LDUUV	Large Displacement Unmanned Undersea Vehicle
LOS	line of sight
MCM	mine countermeasures
METOC	Navy Meteorology and Oceanography
MICA	multi-parameter inorganic carbon analyzer
MIW	mine warfare
MSC	Military Sealift Command
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NCWDG	Navy Cyber Warfare Development Group
NEX	Navy Exchange
NPS	Naval Postgraduate School
NRL	U.S. Naval Research Laboratory
NRO	National Reconnaissance Office
NSW	Naval Special Warfare
NTTL	Naval Tactical Task List
NWDC	Navy Warfare Development Command
ONI	Office of Naval Intelligence
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
PBED	*plan - brief - execute - debrief* process
PMS	planned maintenance system
PNT	precision, navigation and timing
RAN	Royal Australian Navy
RAS	robotic and autonomous systems
RF	radio frequency
RFI	request for information
ROE	rules of engagement
SCAMP	Sequester Carbon with Anaerobic Microbial Populations
SEALs	NSW Special Warfare Operators
SECNAV	Secretary of the Navy
SeNTAuR	Soldier-size Node for HUMINT via Augmented Reality and Body Worn Sensors
SIGINT	signals intelligence
SLOC	sea lines of communication
SPA	Systems Planning and Analysis, Inc.
SPAWAR	Space and Naval Warfare Systems Command
SSC	SPAWAR Systems Center
StORMER	Strategic Operational Resource Meteorological and Environmental Renderer
SWO	surface warfare officer
TTPs	tactics, techniques and procedures
UAV	unmanned aerial vehicle
UGV	unmanned ground vehicle

USMC	U.S. Marine Corps
USN	U.S. Navy
USV	unmanned surface vehicle
USW	undersea warfare
UUV	unmanned undersea vehicle
UxS	unmanned systems
UxV	unmanned vehicle
VJTF	NATO’s Very High Readiness Joint Task Force
WIC	NPS Warfare Innovation Continuum

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