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

Cross-Domain Operations (CDO)

Warfare Innovation Continuum (WIC) Workshop September 2018

Summary Highlight Report



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for
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NAVAL POSTGRADUATE SCHOOL

10 OCT 2018

Full report available by 31 OCT 2018

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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 17-20 September 2018 on the campus of the Naval Postgraduate School (NPS) in Monterey, California. The three and a half day 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 Vice President of the Defense Acquisition University (DAU), Mr. 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 and work with our industry partners.

The September 2018 workshop "Cross-Domain 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 advancements in autonomy, machine learning, manned-unmanned teaming, emergent technologies, and unmanned systems be employed to enhance cross-domain operations in highly contested environments to accomplish missions more effectively and/or with less risk?* With embedded facilitators, teams had three days to meet that challenge, and presented their best concepts on the final morning of the workshop.

This September 2018 WIC workshop included just over 80 active participants, observers and guests – the full participant pool representing nearly 30 different organizations. Half of the workshop participants were NPS students drawn from over a dozen curricula across the NPS campus. For this workshop, the final roster also included participants from The Johns Hopkins University Applied Physics Lab (JHU/APL), the Naval War College (NWC), Battelle, L3 Technologies, and Lockheed Martin. Fleet commands included OPNAV N2N6FX, Naval Air Systems Command (NAVAIR), Naval Undersea Warfare Center (NUWC) Newport, 12th Flying Training Wing, Space and Naval Warfare Systems Command (SPAWAR) Systems Center (SSC) Pacific, Naval Surface Warfare Center Panama City Division (NSWC PCD), US Fleet Forces, the Office of Naval Research (ONR) the Royal Australian Navy (RAN), and the New Zealand Defence Force.

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 for further research and development. All concepts are described fully in this report, but in summary these concepts include:

- 1) *Counter UxS*: this topic area includes concepts to counter attacks by adversary autonomous assets (real and virtual) in multiple domains envisioned in a future contested region. Examples of specific concepts within this topic area include *Algorithm Capture* and *Weaponized*

Autonomous Sensor Persistence (WASP) – many smaller UxS blocking and/or attacking another UxS.

- 2) *Cross-Domain Connectivity:* this topic area includes concepts to establish robust and resilient communication networks between autonomous manned and robotic assets operating across multiple domains simultaneously in a future contested environment assuming degraded or denied communications. Examples of specific concepts within this topic area include *Underwater Disaggregated Architecture* and *C3PO for Machines – a universal translator*.
- 3) *Human-Autonomy Teaming:* this topic area includes concepts to integrate manned and unmanned assets working as an integrated force in a future battlespace. Examples of specific concepts within this topic area include *Virtual Battlefield Sim* and *Third Eye – a human worn augmented data collector*.
- 4) *Autonomy for Deception:* this topic area includes concepts employing autonomy to spoof, decoy, or otherwise deceive future adversary forces, human and robotic. Examples of specific concepts within this topic area include *Trash Camo*, *Bio Buoys* and the *Submarine Investigation, Revelation, and Exploitation Network (SIREN) - many UxS elements mimicking a high value unit*.

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 FY19 and FY20 Call for Proposals. Technical members of the CRUSER community of interest will present proposals at a technical continuum gathering such as TechCon 2019 to prototype and test concepts of interest in lab or field environments. A final report, the FY19 CRUSER Annual Report, detailing process and outcomes will be released before the end of the 2019 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 2020.

I. BACKGROUND

Sponsored by the OPNAV N9I Chair, Systems Engineering Analysis and the Consortium for Robotics and Unmanned Systems (CRUSER), this WIC workshop was held on campus during Naval Postgraduate School (NPS) Thesis & Research Week, 17-20 September 2018. Participants were asked to propose concepts of operations in a near future global scenario with simultaneous conflicts in several distinct regions.

A. ORIGINS

Innovation and concept generation are key drivers for CRUSER and other NPS research efforts, 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 within a near future conflict in an urban littoral environment.

In the September 2018 WIC workshop focused on cross-domain operations with the design challenge: *How might advancements in autonomy, machine learning, manned-unmanned teaming, emergent technologies, and unmanned systems be employed to enhance cross-domain operations in highly contested environments to accomplish missions more effectively and/or with less risk?* With embedded facilitators, six concept generation teams had three days to meet that challenge, and presented their

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

best concepts at the end of the workshop. Participants from government, industry and academia worked this design challenge and presented over 20 unique concepts. 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, academia and industry. 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 1. September 2018 Warfare Innovation Continuum (WIC) workshop participants

This September 2018 WIC workshop included just over 80 active participants, observers and guests – the full participant pool representing nearly 30 different organizations. Half of the workshop participants were NPS students drawn from over a dozen curricula across the NPS campus. For this workshop, the final roster also included participants from The Johns Hopkins University Applied Physics Lab (JHU/APL), the Naval War College (NWC), Battelle, L3 Technologies, and Lockheed Martin. Fleet commands included OPNAV N2N6FX, Naval Air Systems Command (NAVAIR), Naval Undersea Warfare Center (NUWC) Newport, 12th Flying Training Wing, Space and Naval Warfare Systems Command (SPAWAR) Systems Center (SSC) Pacific, Naval Surface Warfare Center Panama City Division (NSWC PCD), US Fleet Forces, the Office of Naval Research (ONR), the Royal Australian Navy (RAN), and the New Zealand Defence Force.

The six 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 2018 workshop, “Cross-Domain Operations,” leveraged the innovation lessons learned in previous workshops and was designed specifically to inspire innovative concept generation and development.

Scenario

All participants were given an overview of the future scenario titled “Global War 2030” focused on a future global conflict in multiple theaters. Derived from current open source media reports, this scenario reflects published thinking by current global military stakeholders. Teams were tasked with developing concepts of operations to counter multiple threats in a global warfare scenario but were not required to address the conflict in its entirety. 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.

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 six 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 20 September 2018, 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 (*see schedule pp 15-17*). 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. Plenary topics included:

- Cross-Domain Operations
- Emerging technologies – military robotics and autonomy including FDECO and seabed cables
- Seabed environment and geology
- Undersea infrastructure defense
- Fielding unmanned systems in multiple domains
- Rapid concept generation and innovation
- Moving from concept development to fielding – acquisitions

The knowledge-leveling plenaries on Monday included an overview of Cross-Domain Operations from a US Fleet Forces perspective, a portfolio of emerging robotics and autonomy related technologies from a DoD lab and an industry perspective, and an introduction to elements of undersea infrastructure defense by a leading academic. Participants were also encouraged to look at the seabed as topography much as infantry might look at terrain – considering geologic features and other environmental and meteorological elements that might impact battlespace effectiveness. Tuesday and Wednesday morning each started with broader plenary talks before teams were released to their breakout rooms. The keynote address by the new Vice President of the Defense Acquisition University (DAU), Mr. Frank Kelley, detailed his thoughts on how good ideas move through acquisitions to the field. Throughout the plenaries, speakers several examples of military approaches to innovation – some successful, some not – and lessons learned through past efforts.

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) *Counter UxS*: this topic area includes concepts to counter attacks by adversary autonomous assets (real and virtual) in multiple domains envisioned in a future contested region. Examples of specific concepts within this topic area include *Algorithm Capture* and *Weaponized Autonomous Sensor Persistence (WASP) – many smaller UxS blocking and/or attacking another UxS*.
- 2) *Cross-Domain Connectivity*: this topic area includes concepts to establish robust and resilient communication networks between autonomous manned and robotic assets operating across multiple domains simultaneously in a future contested environment assuming degraded or denied communications. Examples of specific concepts within this topic area include *Underwater Disaggregated Architecture* and *C3PO for Machines – a universal translator*.
- 3) *Human-Autonomy Teaming*: this topic area includes concepts to integrate manned and unmanned assets working as an integrated force in a future battlespace. Examples of specific concepts within this topic area include *Virtual Battlefield Sim* and *Third Eye – a human worn augmented data collector*.
- 4) *Autonomy for Deception*: this topic area includes concepts employing autonomy to spoof, decoy, or otherwise deceive future adversary forces, human and robotic. Examples of specific concepts within this topic area include *Trash Camo*, *Bio Buoys* and the *Submarine Investigation, Revelation, and Exploitation Network (SIREN) - many UxS elements mimicking a high value unit*.

Unclassified details of these concepts as presented are included in Appendix A of the full workshop report.

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 four primary topic areas:

- 1) *Counter UxS*: this topic area includes concepts to counter attacks by adversary autonomous assets (real and virtual) in multiple domains envisioned in a future contested region.
- 2) *Cross-Domain Connectivity*: this topic area includes concepts to establish robust and resilient communication networks between autonomous manned and robotic assets operating across multiple domains simultaneously in a future contested environment assuming degraded or denied communications.
- 3) *Human-Autonomy Teaming*: this topic area includes concepts to integrate manned and unmanned assets working as an integrated force in a future battlespace.
- 4) *Autonomy for Deception*: this topic area includes concepts employing autonomy to spoof, decoy, or otherwise deceive future adversary forces, human and robotic.

In addition to the concepts and technology proposals, the September 2018 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 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 operations, fleet architectures and fleet design. 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.

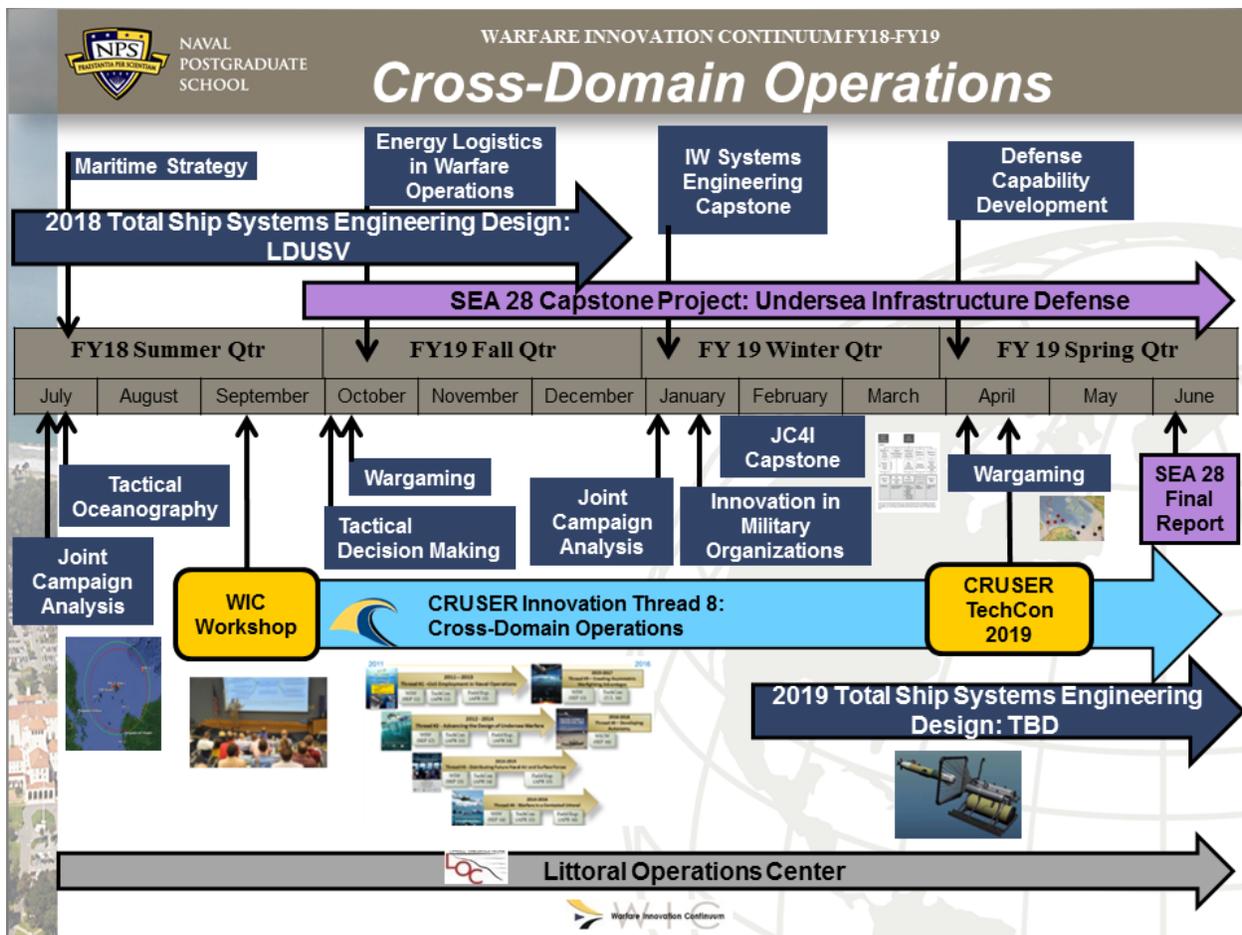


Figure 2. FY18-19 NPS Warfare Innovation Continuum (WIC).

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. The FY18-19 WIC, “Cross-Domain Operations” (see Figure 2), address the question, “How might emerging technologies enhance cross-domain operations?” Final reports are available for all prior continuums dating back to 2013.

B. CRUSER Innovation Thread



How we do it

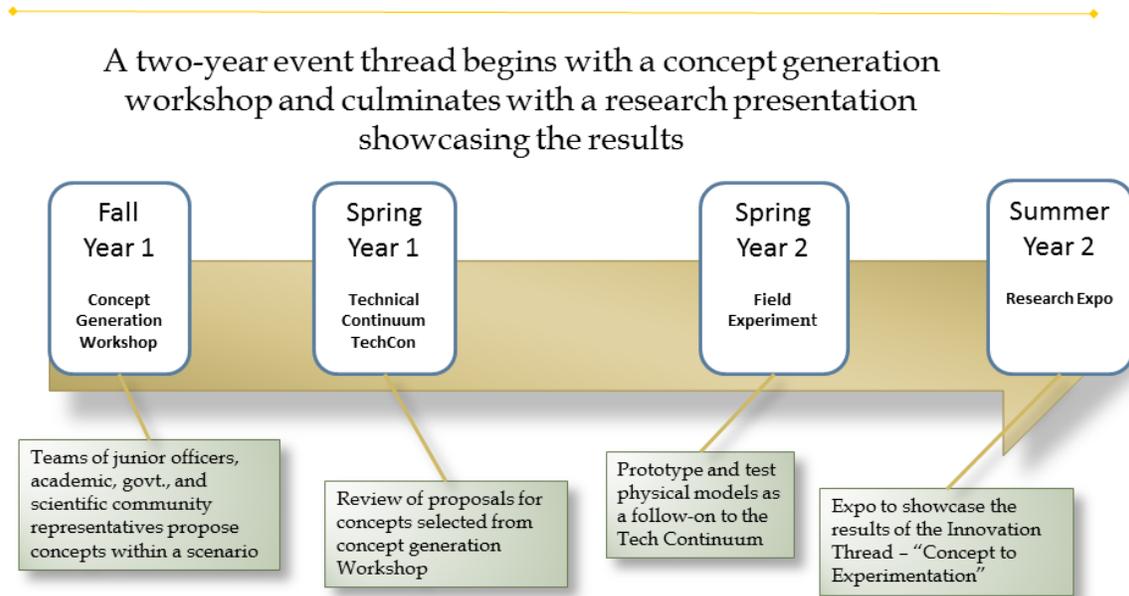


Figure 3. CRUSER Innovation Thread structure.

CRUSER organizes activities around a programmatic Innovation Thread structure (see Figure 3) 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 4). The first six Innovations Threads are complete, the seventh thread is underway, and Innovation Thread #8 started with this September 2018 Warfare Innovation Workshop and will finish in FY20.



Figure 4. CRUSER Innovation Thread overview as of October 2018.

APPENDIX : 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 – 17 September

0745	Registration	<u>GLASGOW 109</u>
0800	Welcome	VADM Ronald Route USN (ret), NPS President
0815	CRUSER Overview	Dr. Ray Buettner, NPS FX Director
0835	NPS Warfare Innovation Continuum & Scenario	CAPT Jeff Kline USN (ret), NPS Chair of Systems Engineering Analysis (SEA)
0915	Cross Domain Operations	CDR Roy Wilson, USFFC N92
0940	Achieving Emerging Technology	Mr. Mike Tall, SSC-PAC
1005	Undersea Infrastructure Defense	Dr. David Alderson, NPS Operations Research
1030	BREAK	
1040	FDECO	Mr. Jose Chavez, SSC-PAC
1105	Seabed Topography	Mr. George Zvara, NUWC Newport
1130	Team Introductions	Ms. Lyla Englehorn, NPS CRUSER Associate Director
1200	LUNCH	
1300	Tools of Design	Ms. Lyla Englehorn, NPS CRUSER Associate Director
1330	Industry Perspective Statement	Mr. Glen Sears, LMCO
1355	Seabed Cables	Mr. Steven Powell, Trans Bay Cable
1420	Tasking	CAPT Jeff Kline USN (ret), NPS SEA Chair
1500	Initial Team Meetings	BREAKOUT ROOMS
1600	Icebreaker	TRIDENT ROOM

TUES – 18 September

[GLASGOW 109](#)

0800	Welcome	Dr. Brian Bingham, NPS CRUSER Director
0810	Keynote Address – Crossing the Valley of Death	Mr. Frank Kelley USMC (ret), DAU Vice President
0900	Innovation Challenges	Dr. Maura Sullivan, FATHOM5 Founder & COO
0925	Lessons Learned in Innovation	Mr. Stephen O’Grady & Mr. Mark Dalton, NUWC Newport
1000	Discovery Interviews – <i>Mentors</i>	BREAKOUT ROOMS – <i>Mentors meet in GLASGOW 128</i>
1100	Concept Generation – Divergent	BREAKOUT ROOMS
1200	LUNCH	
1300	“Just One Thing” launch – <i>Mentors</i>	GLASGOW 128
1300	Concept Generation – Divergent to Convergent	

WED – 19 September

		<u>GLASGOW 109</u>
0800	Welcome	Ms. Lyla Englehorn, NPS CRUSER Associate Director
0810	MTX & SLAMR	Dr. Raymond Buettner, NPS FX Director
0835	On Undersea Infrastructure Defense	Mr. William Glenney, Institute for Future Warfare Studies
0900	Fielding Unmanned Systems in Multiple Domains	CAPT George Galdorisi USN (ret), SSC-PAC
0930	Concept Generation – Convergent	BREAKOUT ROOMS
1000	NPS Lab Tour – <i>Mentors</i>	<i>Guided tour leaves from Starbucks</i>
1030	Directors & Chairs Rotation	BREAKOUT ROOMS
1200	LUNCH	
1300	Concept Development – Final Push	BREAKOUT ROOMS
1300	“Just One Thing” quick look – <i>Mentors</i>	GLASGOW 128

THUR – 20 September

GLASGOW 109

0800 Team Photos & Evaluation
0830 Final Briefs
1200 **ADJOURN**

**September 2018 Warfare Innovation
Continuum (WIC) Workshop: *Cross-Domain
Operations Final Report*
*available after 31 OCT 2018***

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