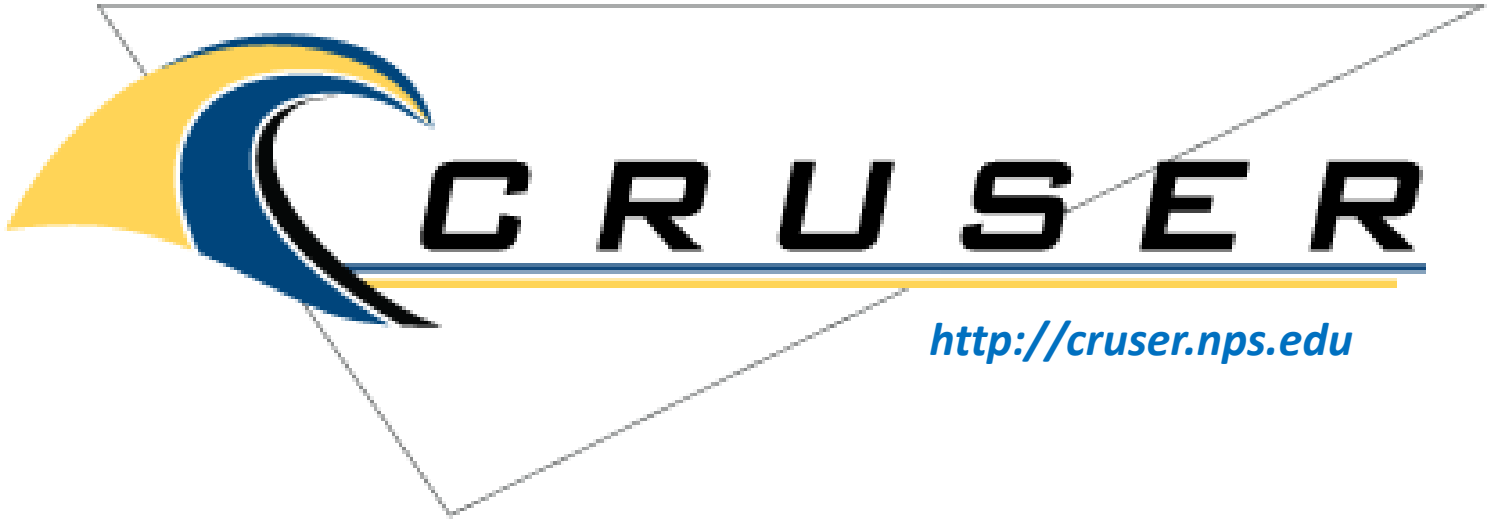


Dr. Ray Buettner

Director

CRUSER Mandate

THE UNDER SECRETARY OF THE NAVY
WASHINGTON DC 20350-1000

February 1, 2011

MEMORANDUM FOR DISTRIBUTION

SUBJECT: Secretary of the Navy Unmanned System Goals and the Consortium for Robotics and Unmanned Systems Education and Research (CRUSER)

Pursuant to the Secretary of the Navy's Unmanned Systems Goals outlined in the attachment, the Naval Postgraduate School is authorized to establish the Consortium for Robotics and Unmanned Systems Education and Research (CRUSER) to shape generations of naval officers through education, research, concept generation and experimentation in maritime application of robotics, automation, and unmanned systems. CRUSER will also provide a DoD-wide community of interest to exchange research and experimentation results.

The Office of Naval Research (ONR) will have funding responsibility for CRUSER efforts and will ensure CRUSER is supported in future resource plans, beginning in POM 12.

The Secretariat lead for Unmanned Systems goals is Mark Gorenflo, who can be reached at (703) 614-0199, or email at Mark.L.Gorenflo@navy.mil.

Robert O. Work

Why we exist

In support of SECNAV's unmanned systems goals CRUSER is established to…

"…shape generations of naval officers through education, research, concept generation and experimentation in maritime applications of robotics, automation and unmanned systems……."

"…provide a DoD-wide community of interest to exchange research and experimentation results"

Under Secretary of the Navy Robert O. Work – 1 Feb 2011

Who we are

Oversight

- **Sponsor**
  SECNAV
- **Oversight**
  ONR
- **Advisory Committee**

Coordination

- **Dr. Ray Buettner**
  Director
- **Dr. Timothy H. Chung**
  Deputy Director
- **Steve Iatrou**
  Director, Strategic Communications
- **Lyla Englehorn**
  Director, Concept Generation
- **Lisa Trawick**
  Operations Manager

Community of Interest

- NPS Faculty/Students: 277
- DoN:618
- Industry: 947
- Other Government: 188
- Academia: 204
- USA/USAF: 103
- General Public: 71
- International: 56

2464 Members and growing

How we do it

Two year innovation threads consisting of

Concept Generation

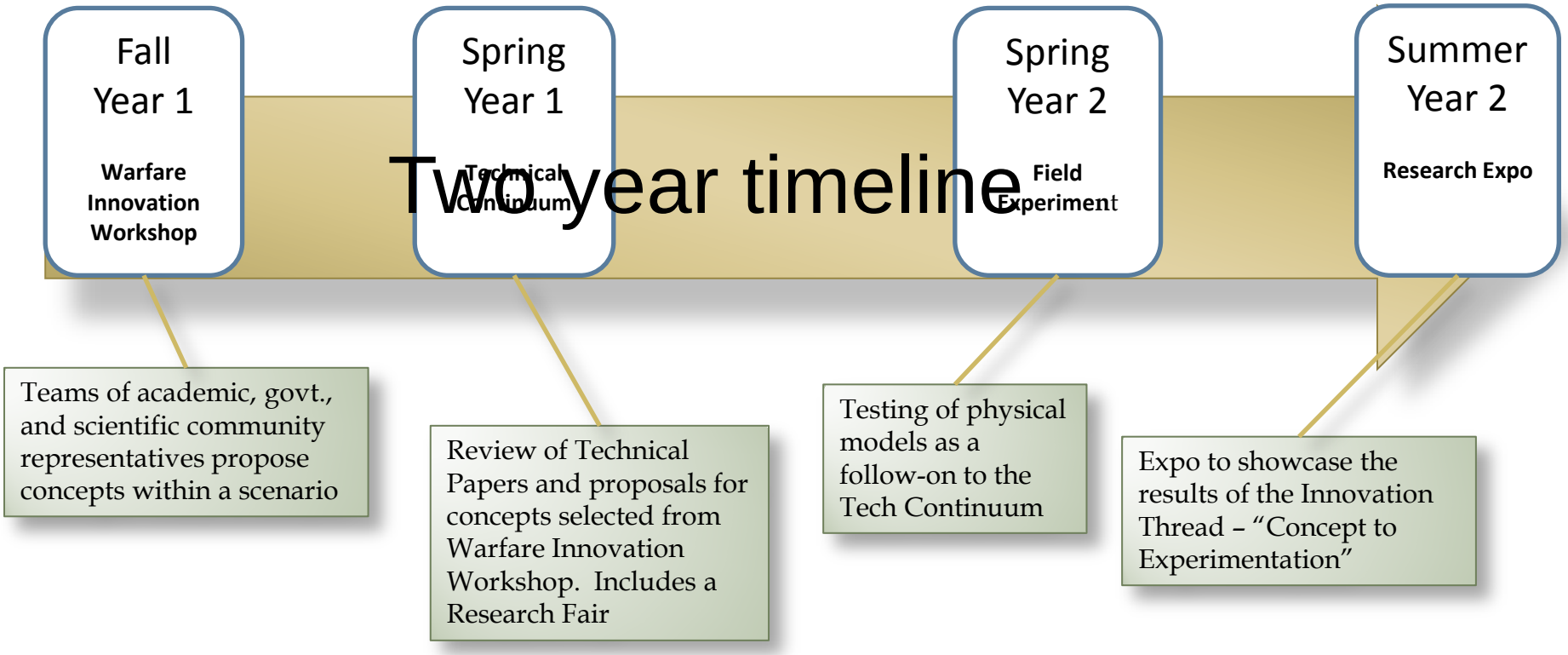
Experimentation Program

Education Venue

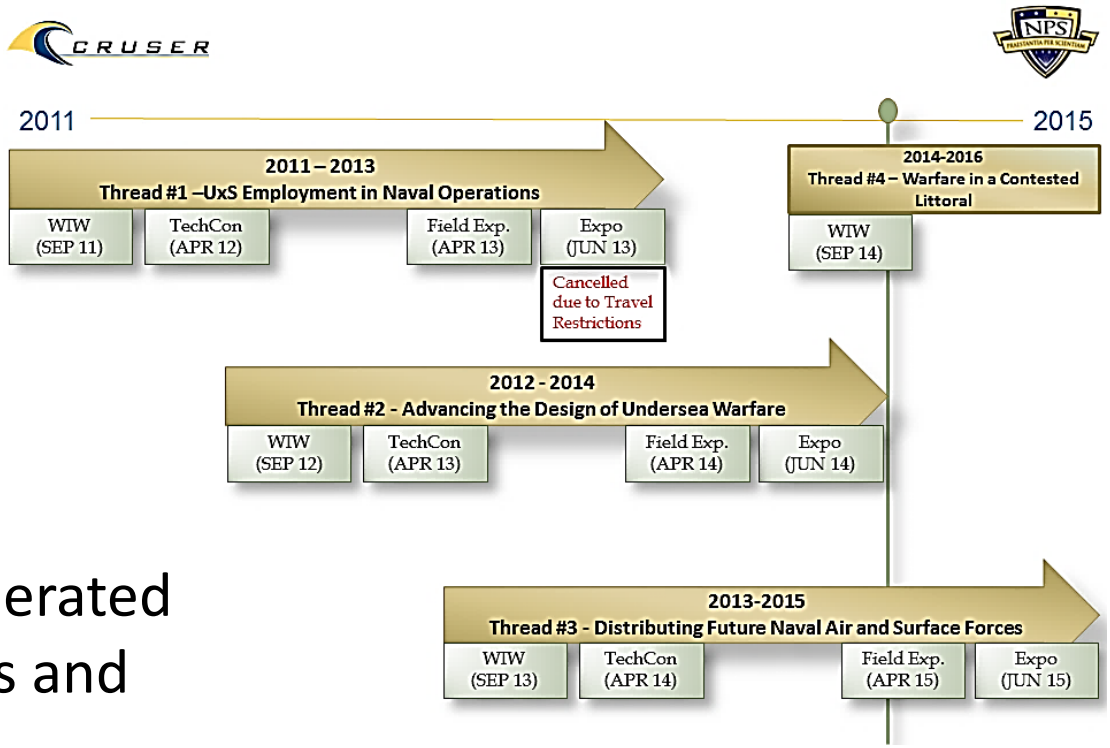
DoD-wide forum for collaboration

How we do it

A two-year event thread begins with a Warfare Innovation Workshop (WIW) and culminates with a research presentation at ONR showcasing the results



CRUSER Innovation Thread



Since 2011:

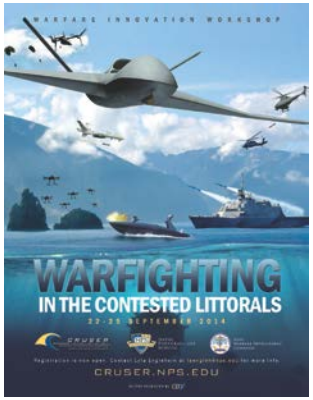
- ❑ Over 400 concepts generated
- ❑ Over 200 presentations and proposals reviewed
- ❑ Over 15 education projects funded
- ❑ Over 62 research projects funded
- ❑ Over 100 theses supported
- ❑ Over 20 major activities executed

Concept Generation: The Warfare Innovation Workshop

Warfighting in the Contested Littorals

22-25 September 2014

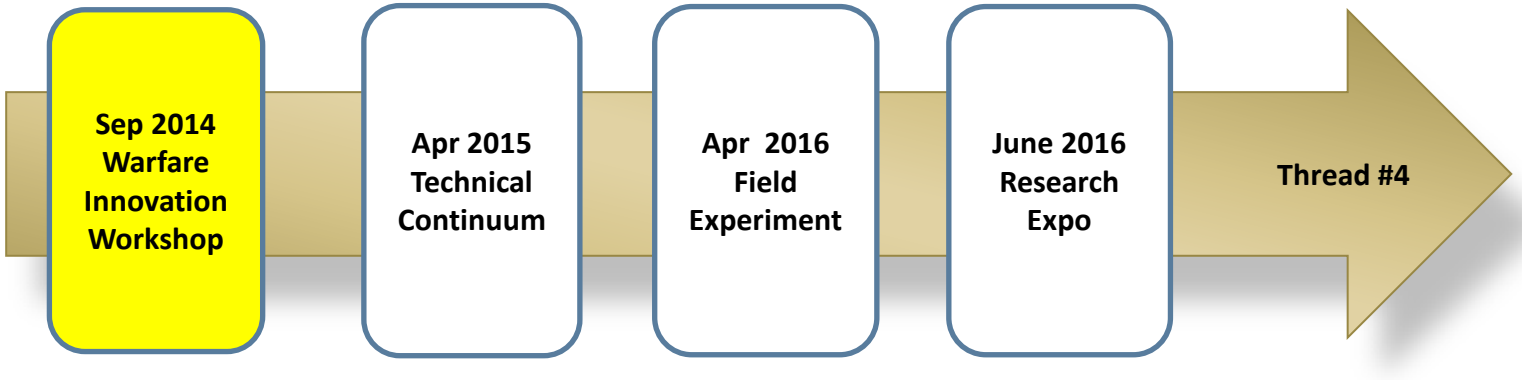
"Will emergent technologies (unmanned systems, advanced computing power, automation, advanced sensor capabilities, laser weapons etc.) allow us to fight effectively in the complex and an electromagnetically contested littoral environment against sea denial forces?"



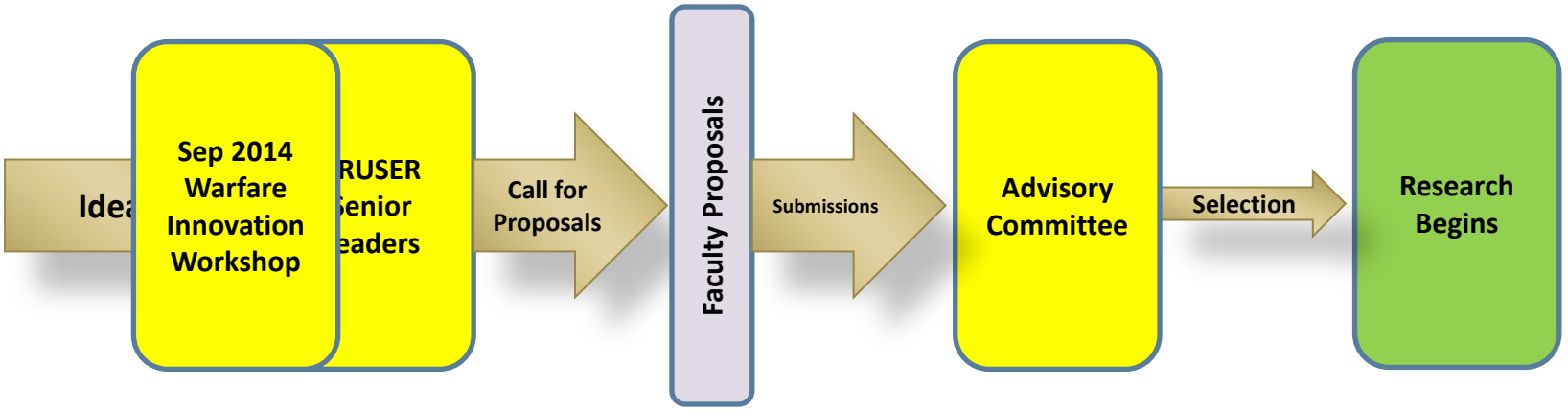
- Electromagnetically contested environment of the littoral
- Address opportunities in swarm ISR to support tactically offensive operations, expeditionary mining and marine raid concepts, alternative methods of ship to ship communications in a Network Optional Warfare concept, laser weapons in defense, and other related research topics.

Sep 2014 Warfare Innovation Workshop → **Apr 2015 Technical Continuum** → **Apr 2016 Field Experiment** → **June 2016 Research Expo** → **CRUSER Thread 4**

Concept selection



Concept selection



Technical Continuum & Research Fair

Technical Continuum

- Thirty presentations on selected technologies identified in Sept 2014 Warfare Innovation Workshops
- Concepts will be selected for continued development and field experimentation in FY16

5th Annual Robots in the Roses Research Fair

- Displays of current research by NPS Faculty and NPS Students
- Hands-on demonstrations of current technology
- High School Robotics Team demonstrations
- S.T.E.M Activity

Sep 2014 Warfare Innovation Workshop → **Apr 2015 Technical Continuum** → Apr 2016 Field Experiment → June 2016 Research Expo → CRUSER Thread 4

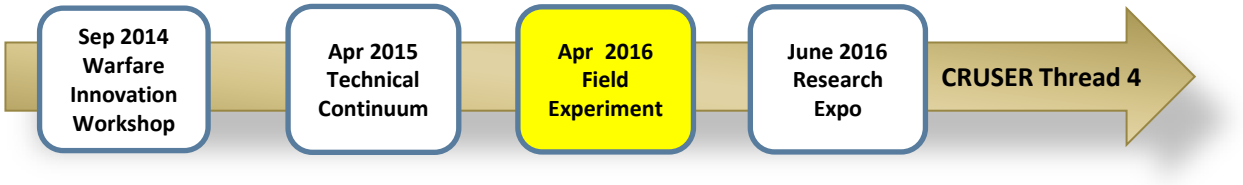
Innovation Thread #3
Next Steps

Spring 2016

Conduct Field Experimentation on selected presentations from the CRUSER Technical Continuum

Summer 2016

Expo at ONR to showcase research



Funded Research

FY 15 (part I)
Funded Research Proposals

- Glider-Measured Underwater Bioluminescence for Submarine Minefield Navigation
- Robo DoJo
- Agent Library of Unmanned Vehicles
- Testing Small Multi-Rotor Unmanned Aerial Systems as Platforms for Atmospheric Measurements
- Short Range Wireless Power Transfer (WPT) for UAV/UAS Battery Charging – Phase II
- Applications of a mobile acoustic source for Tactical Oceanography
- Towards Persistent ISR missions by teams of Autonomous Gliders
- Computational Solutions for Real-time Optimal Maneuvering of Unmanned Vehicles
- Irregular, Hybrid and Asymmetric Warfare: Functional Analysis & Automation for Sustaining and Supporting Dispersed Operations of Dismounted Infantry
- UAS IFC Phase III
- C2 Models of Next Generation Unmanned Aircraft Systems
- Using Small Unmanned Aerial Systems as Electronic Warfare Platforms - Providing the Tactical Ground Commander the Electromagnetic Advantage
- LDUUV Life Cycle Management

FY 15 (part II)
Funded Research Proposals

- Stratified wakes induced by submerged propagating objects: detection using Unmanned Underwater Vehicles.
- Autonomous Aerial Vehicles with Robotic Manipulation Capability
- CRUSER Data Farming Workshops
- Investigating the Navy's Logistics Role in Department of Defense International Humanitarian Assistance Activities
- Combined Unmanned Underwater Vehicle Efforts in a Large-Scale Mine Warfare Environment
- Robotic system software engineering classroom case study: a series of educational modules that result in the development and acceptance of an actual working robotic system
- Real-time undersea networking using acoustic communications for improved UUV positioning and collaboration
- Using Autonomous Wave Gliders to Quantify Near-Surface Turbulence and EM Ducting Conditions
- Development of instructional tutorials, online wiki, and videos in support of Robotics and Rapid Prototyping
- Rapid FDC Resupply Using a Projectile-Launched Guided Parafoil
- Development of Control System Course Content for Interdisciplinary Applications in Robotics

FY 14 (part I)
Funded Research Proposals

- Innovating for the Swarm vs. Swarm Grand Challenge Competition
- Development of Very-Small Multi Rotor Aircraft as Platforms for Atmospheric and Sea Surface Measurement
- Aqua Quad
- Diver and Unmanned Vehicle Networking-by-Touch
- A Robot Control Ontology Supporting Ethical Mission Execution
- UUV Path Planning for ASW/MIW Using Navy's Ocean Data
- An Integrated Indoor Unmanned System Experimentation Facility for Campus-wide Teaching and Research
- Joint Human/Robot Operations in Extreme Environments
- Robotic Outposts to Support Persistent AUV Operations
- A Manual for the Model-Based Design and Assessment of Robotics and Unmanned Systems
- A Teleoperative Sensory-Motor Control Platform (TSMCP)

FY 14 (part II)
Funded Research Proposals

- A Student built Autonomous Ground Vehicle as a Course Project for the Benefit of the CRUSER Community
- Tropical Cyclone Reconnaissance with the Global Hawk: Assessment of Initial Results and Use in Improving Forecasts of Tropical Cyclone Intensity and Structure
- Short Range Radiative Wireless Power Transfer (WPT) for UAV/UAS Battery Charging
- Glider applications in Tactical Oceanography
- Introduction to Big Data and Analytics Course Development
- Defense against Swarms: A Key Naval Capability
- UAS IFC Phase II: BBN Based Hazard Risk Analysis Toolset
- Autonomous Systems C2 Modeling & Analysis
- Real-time undersea networking using acoustic communications for improved AUV positioning and collaboration
- Environmental Data Collection Using Autonomous Wave Gliders

FY 13
Funded Research Proposals

- The Use of Unmanned Systems for Environmental Sampling and Enhanced Battlespace Awareness in Support of Naval Operations
- Tactical Long Endurance Unmanned Air System (TaLEUAS)
- Networked Unmanned Systems Formation for Rapid Detection, Interdiction, and Expert Reachback in Maritime Interdiction Operations
- Support for NPS Seaglider Operations
- Comparative Analysis of X-47 UCAS & F-18 Squadron Manpower
- A Collaborative Diver Assistant for Underwater Operations
- Corporation of Navy's Ocean Data into UUV Path Planning with Obstacle Avoidance
- Experimental Unmanned Aircraft System (UAS) Interim Flight Clearances
- UAS Training and Pilot Certification Program

FY 12
Funded Research Proposals

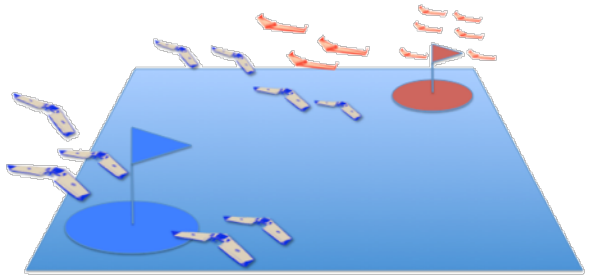
- Passive UxV Navigation using Visual Sensors
- Tropical Cyclone Reconnaissance with the Global Hawk: Operational Requirements, Benefits, and Feasibility
- Joint Optimization of Sensing and Sampling with Unmanned Undersea Vehicles
- Roadmap for Reduction of Total Ownership Cost (TOC) to Support Acquisition Decisions of Unmanned Autonomous Vehicle - Phase I
- Programming the Laws of Armed Conflict (LOAC) for Unmanned Systems
- Autonomous Multi-vehicle Tactical Surveillance and Support for Maritime Visit, Board, Search and Seizure Operations

Funded Experimentation

Aerial Combat Swarms:
Swarm vs. Swarm UAV Competition

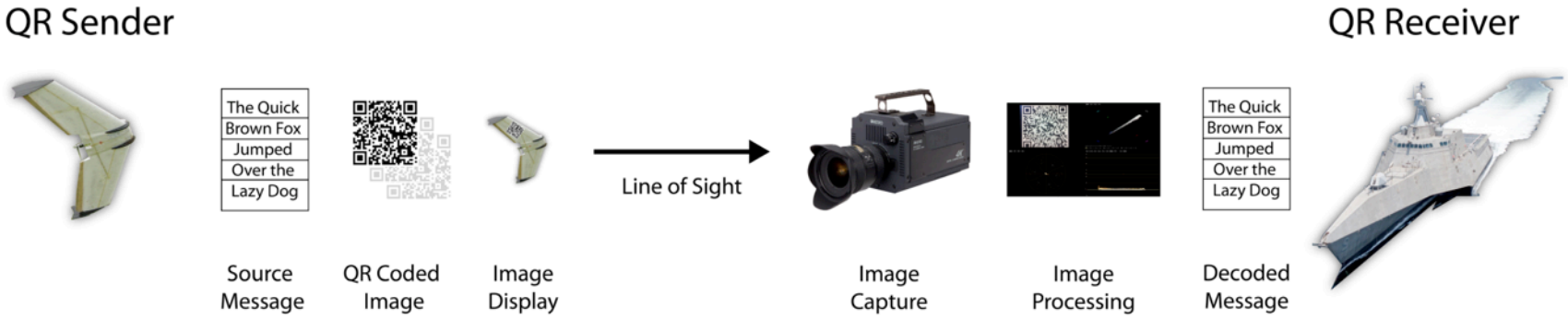
A grand challenge where *tactics drive the technology*

- Develop enabling capabilities for **attacking** the opponent's aerial bots and their home base while actively **defending** own home base
- Conduct **live-fly, outdoor competition** in tournament-style event
- Seek **innovations** in tactics, concepts of operations, autonomy algorithms, hardware platforms, etc.
- Provide **common standards** and infrastructure for rapid evolution



Digital Semaphore

Developing Novel Approaches to Quick Response Code (QR Code) Image Acquisition using 4K Ultra-high Resolution Video for Fleet Tactical Communications with Unmanned Systems



Initial results: Demonstrated QR codes can be extracted at distances at least 500 times farther than typical (600' versus 1-1.25').

Recommendations: Continued Research Warranted - Adaptive Optics to Extend Range past 10K yards, Software for Encode/Decode and Image Processing, Continued Field Testing with Unmanned Systems

Maritime In Situ Sensing Inter-Operable Network

Joseph Rice, Naval Postgraduate School

Objectives

- Study noisy underwater environments
- Achieve acoustic communications through adverse channels
- Integrate U.S. "Seaweb" and Singapore "UNet" networks

Deliverables

Demonstrate *in situ* sensor networks in Singapore Strait

Milestones

- MISSION 2012 sea trials
- MISSION 2013 sea trials

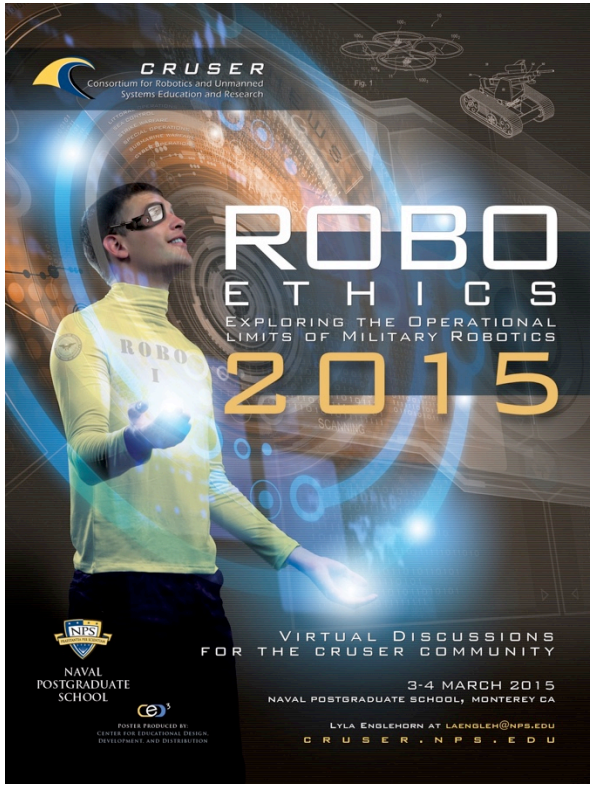
Accomplishments to Date

Developed bilateral project plan with National University of Singapore

Payoff to the Navy

Enable distributed wireless architectures for Maritime Domain Awareness and Under-Sea Warfare

Robo-Ethics continuing education series



January 2012

- Four panels over 2 days
- Over 100 participants from the DC area
- Commands represented included: ONR, OSD, NAVAIR, NAVSEA, USNA, NPS, NWC, PEO LCS, NRL, DOS, JGRE, Navy Staff

September 2013

- Enrichment Week event open to entire campus/Live Stream/Video
- 2-hour panel discussion on UxS ethical issues related to distributing future Naval air and surface forces

March 2014

- San Diego Event with VTC Participants from Pentagon, NPS, NSWC Panama City, and USNA
- 3-hour panel discussion providing a commander with guidance on ethical dilemmas embedded in a South China Sea scenario in the year 20YY

April 2015

- Teams of junior officers from NPS, USNA, & SSC Pac working remotely to explore the operational limits of military robotics

Collaboration

Monthly Meetings

- In-person, Dial-in, or remote viewing
- 1-2 Presentations
- Open Discussion

NPS Students regularly completing Unmanned Systems/Robotics related theses/projects

Collaboration

Monthly e-Newsletter

"CRUSER News"

Articles by CRUSER Members

http://CRUSER.nps.edu

Unclassified Website

Calendar of Events

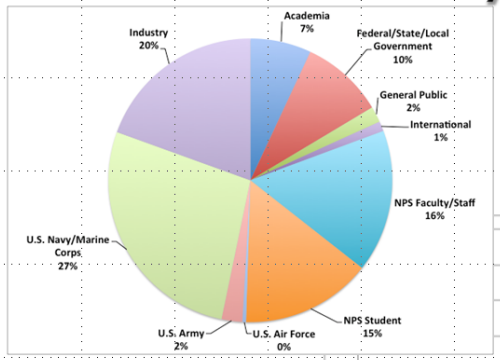
http://my.nps.edu/web/cruser/cruser-sponsored-events

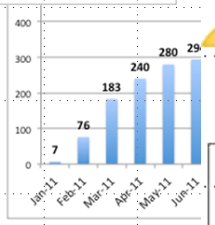
Classified Website

https://cruser.nps.navy.smil.mil

Community of Interest

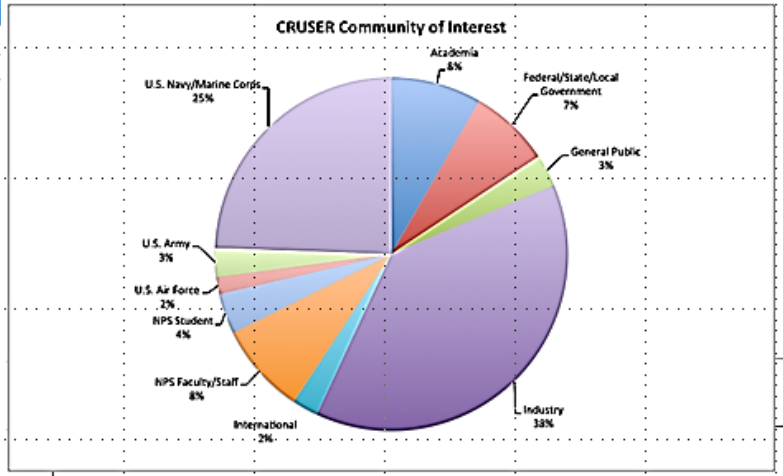
JULY 2012





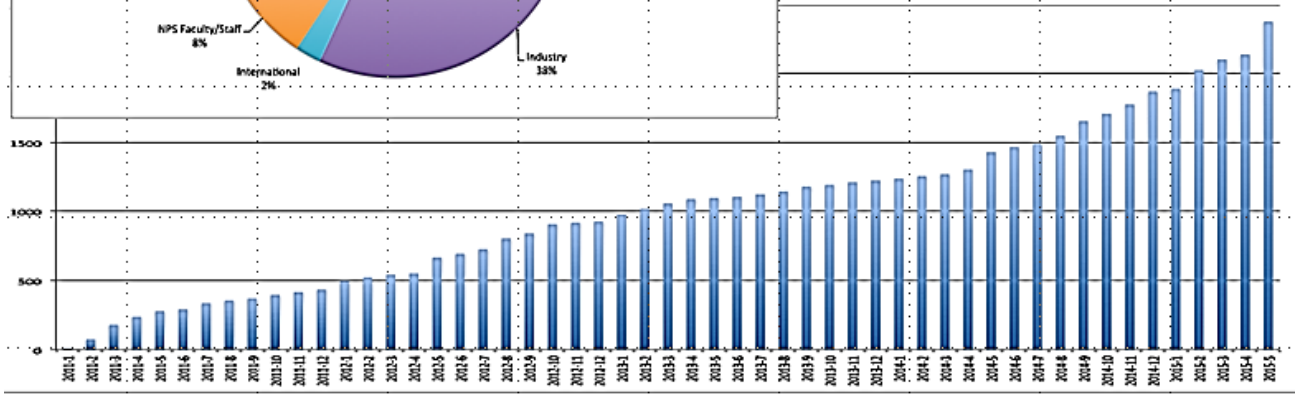
- 720 Members and growing

Community of Interest

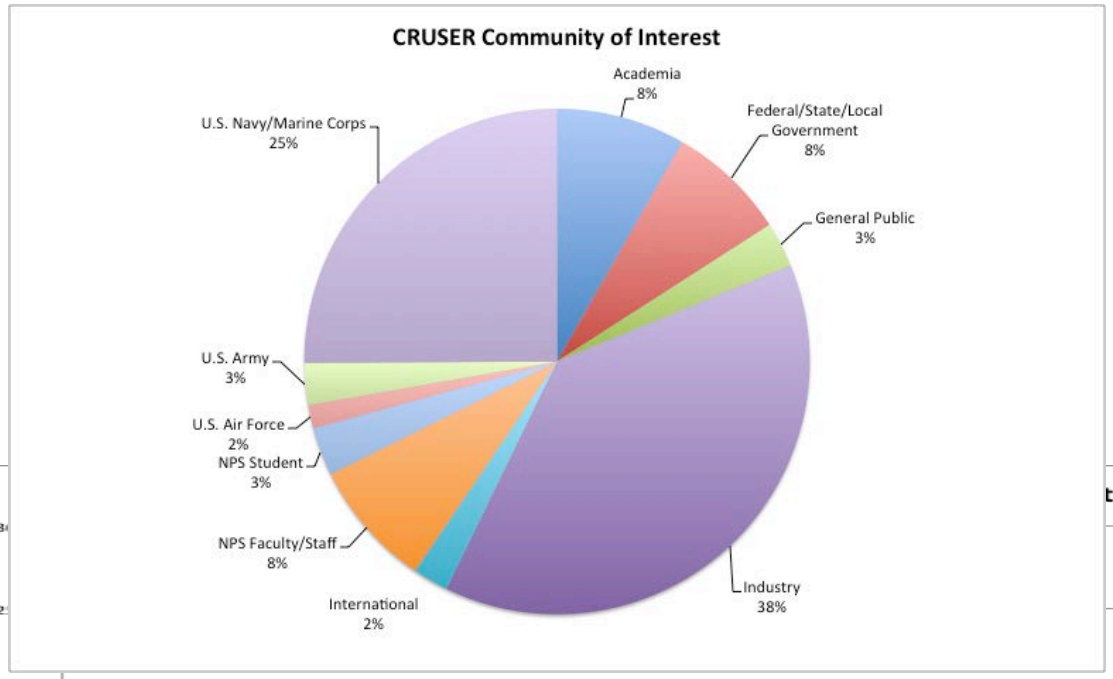


2377 Members and growing

(as of 29 May 2015)

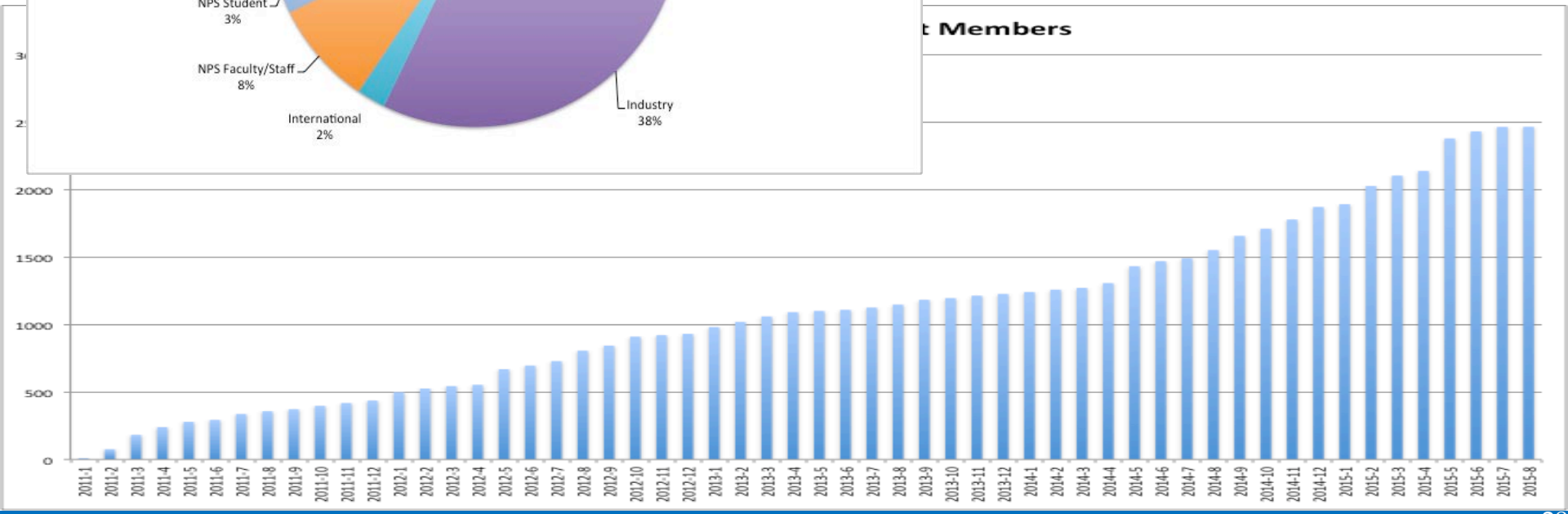


Community of Interest

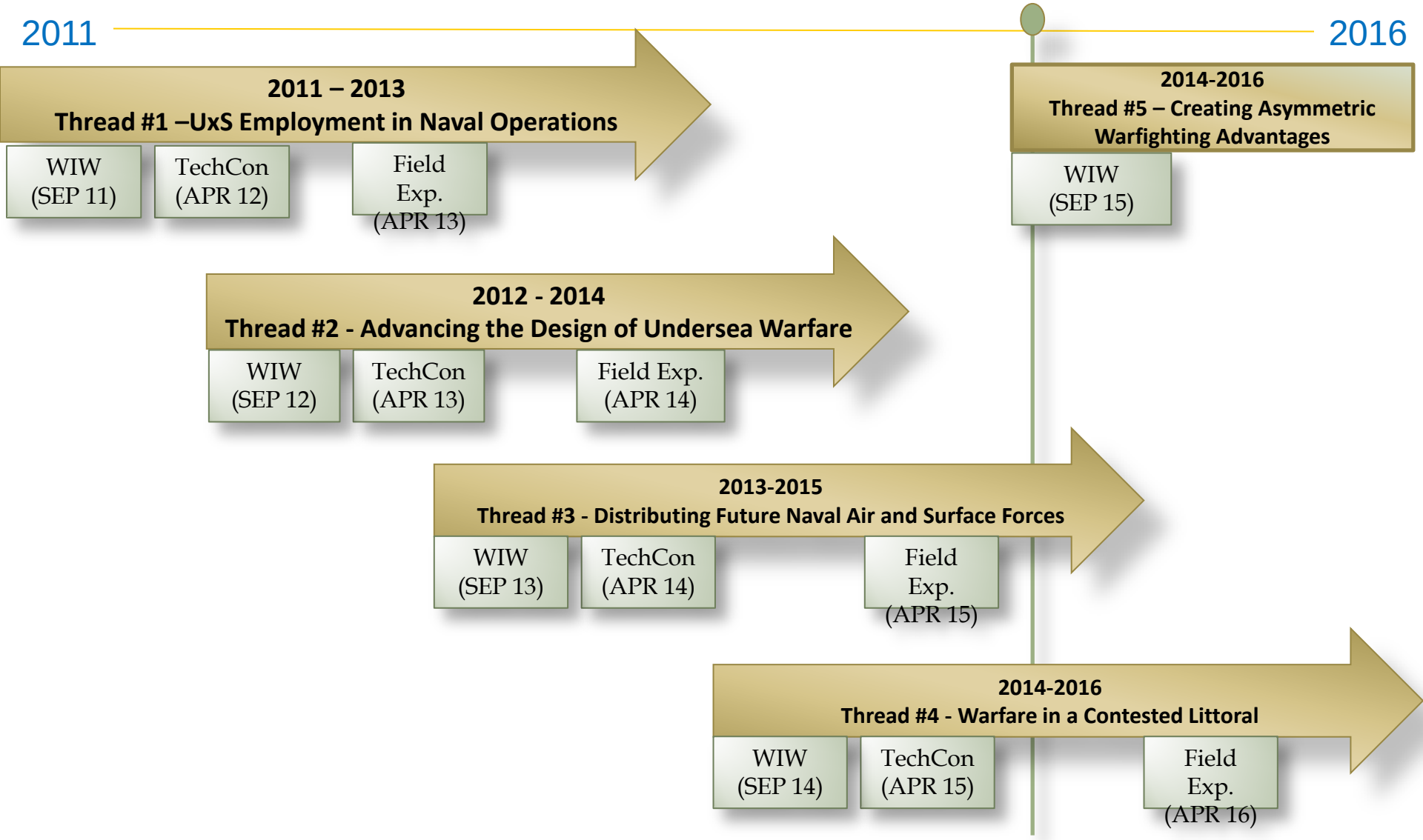


2464 Members and growing

(as of 5 Aug 2015)



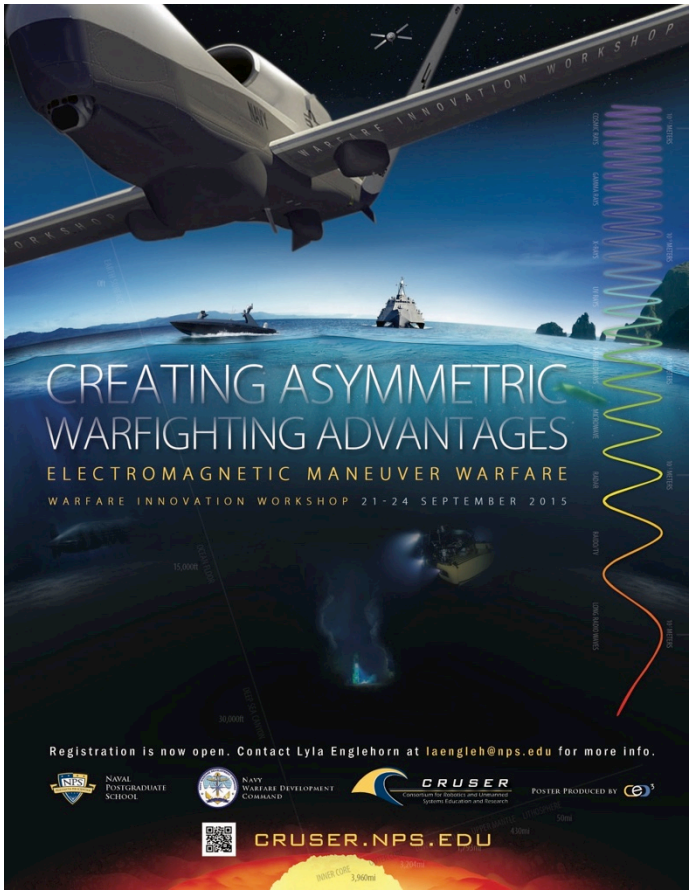
Weaving the threads



September 2015
Warfare Innovation Workshop

sponsored by NWDC and CRUSER

This year's Warfare Innovation Workshop will focus on advancing the CNO's concept of Electromagnetic Maneuver Warfare (EMW) and leveraging unmanned systems to enhance cross domain operations. Small teams of NPS U.S. officers, junior engineers from Navy labs and industry, and fleet junior officers will propose technologies and employment concepts in scenario based discussions. Teams will brief their conclusions to sponsors, industry executives, and senior officers the final morning and these results will be disseminated to fleet commands.



Sep 2015 Warfare Innovation Workshop → Apr 2016 Technical Continuum → Apr 2017 Field Experiment → June 2017 Research Expo → Thread #5