



# CRUSER • NEWS

Consortium for Robotics and Unmanned Systems Education and Research

FROM TECHNICAL TO ETHICAL...FROM CONCEPT GENERATION TO EXPERIMENTATION

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## Navy Equips Unmanned Boats with Non-Lethal Weapons for Fleet Experiment

By U.S. Fleet Forces Public Affairs

U.S. Fleet Forces Command (USFF) directed a two-part fleet experiment at the end of January off the shoreline of Fort Eustis to explore the potential of unmanned surface vessels (USVs) to deploy non-lethal weapons and understand the capability of multiple armed USVs to coordinate actions during maritime security and force protection operations. More than 100 successful runs were completed over the course of the week. Experiment control collected geo-positional data from the boats, surveys from fleet users and observer logs from subject matter experts. The results are expected to drive recommendations to Navy decision makers.

Rear Adm. Scott Craig, USFF Deputy Chief of Staff for Fleet Policy, Capabilities Requirements, Concepts, and Experimentation explained the experiment's multi-faceted relevance.

"Equipping unmanned surface vessels with non-lethal weapons will further expand the capabilities of our Naval forces to confront an increasingly complex set of threats," Craig said. "Results from this experiment will be relevant not only to the U.S. Navy, but also to other Services, coalition partners and allies."

One part of the experiment was a follow-on limited objective experiment, wherein a pair of small militarized boats was equipped to employ a directional acoustic hailer, eye dazzling laser and flash-bang munitions operated in autonomous and semi-autonomous modes. Each non-lethal weapon was carefully-orchestrated to respond to a set of threatening behaviors from intruder vessels. This follow-on experiment built on findings from Trident Warrior 2011, held last July, that validated the USVs' ability to autonomously react to vessels traveling in protected waterways.



*An unmanned surface vessel shifts into autonomous patrol mode during a January 2012 fleet experiment off the coast of Fort Eustis, Virginia. The USV ran through a set of behaviors, ending with firing a series of warning munitions across the bow of an unmanned intruder vessel. Photo by Mass Communications Specialist 3rd Class Betsy Knapper.*

In the other part of the experiment, two armed USVs employed onboard sensors and remotely controlled maneuvers to investigate – and where necessary – interdict multiple small boat intruders through simulated engagements with the USVs' weapons systems that included a short range missile and two different gun systems. Command and control of the USV team was conducted afloat onboard the experiment boat Stiletto. Observations and feedback indicated that the USVs were able to effectively react to intruders and perform coordinated maritime security operations to neutralize small boat threats.

Cmdr. Mike Frantz, USFF's Director for Fleet Experimentation, explained the importance of experimenting with real assets in an operational environment.

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**CRUSER Technical Continuum: 7-10 May 2012**

[HTTP://CRUSER.NPS.EDU](http://CRUSER.NPS.EDU)

## DIRECTOR'S CORNER

As new robotics technologies emerge, it becomes important to explore where we should cost-effectively employ unmanned systems. In the CRUSER two-year event thread composed of last fall's concept generation workshop, May's Technical Continuum, and ending in next year's experimentation; augmented by faculty and student research, we hope to make a contribution in answering that question for the community. Please join that thread by attending the CRUSER May Technical Continuum in coordination with the TENTH International Mine Warfare Technical Symposium.

**CAPT Jeff Kline, USN (ret)**  
**CRUSER Director**



### Sure you can create an underwater robot, but can you teach it to do tricks in La Spezia Harbor?

By Edward Lundquist

Students studying science, technology, robotics or engineering can put their knowledge and skills to the test at the Student Autonomous Underwater Challenge – Europe.

Held since 2006, the SAUC-E competition challenges the next generation of engineers to design and build an autonomous underwater vehicle (AUV) capable of performing realistic missions.

“The event is designed to encourage students to think about underwater technology and related applications while fostering innovation and technology,” says Vladimir Djapic, a scientist at the NATO Undersea Research Centre (NURC) in La Spezia, Italy, and technical director for the SAUC-E 2012 competition. “It also aims at getting young engineers and scientists to consider careers in the field.”

Participating teams must consist of 75% student members and have a faculty advisor. SAUC-E '12 will take place 6 July - 13 July at NURC in La Spezia. The competition will run Friday to Friday.

Djapic says that the boat basin at NURC is a very realistic and challenging environment, open to the sea and the elements. “It is not a pool. Participants must contend with wave action, variable visibility, salinity, and tidal conditions.”

“Following some spectacular nose dives into the bottom last year—and the resulting reduction of UW visibility making it extremely difficult to find and recover the vehicles—we’re asking the teams to install strobe lights on their vehicle. At least this way I have a fighting chance to dive and recover them if they go rogue!” says Royal Navy Lt. Cmdr. Nick Gwatkin, the SAUC-E event coordinator.

Another development for 2012 is the creation of a NATO Engineering Support Team (NEST), which will increase the engineering capabilities of the students designing AUVs by letting students ask questions, share ideas, solutions and even hardware, sensor and software designs and code, and allow them to ask experts for advice. There will also be advice to prepare teams to operate in the real-

world environment found in the NURC basin. “This will lead to an increase in the state-of-the-art in AUV design and will also enable teams to develop algorithms for more advanced systems,” Djapic says.

Djapic says NEST will also establish a hardware library where student teams can borrow equipment such as acoustic modems. In return, the students will be expected to share the sensor integration code and sensor data they developed with the loaned gear on the NEST web page.

Not only will NURC's NEST experts be available to provide assistance where possible, they hope to also conduct some onsite visits to help teams at their school laboratories. “We have NEST experts who can assist with software engineering, sensor signal processing, mechanical/naval architecture, and control theory, all of which are directly applicable to AUV design,” Djapic says.

Teams of students from universities all over Europe compete using vehicles they have designed and built themselves, and competing on a course where they must complete a series of predefined tasks. Teams are judged on the ability of their AUVs to complete these tasks, as well as technical merit, craftsmanship, safety of design, and fund-raising efforts.

The SAUC-E 2012 event offers sponsorships. Sponsoring organizations will be recognized through co-branding on all SAUC-E publicity including the official website <http://www.sauc-europe.org/>, posters, brochures/flyers and banners during the competition itself. “We are open to suggestions from organizations interested in becoming actively involved in SAUC-E '12,” Djapic says.

Major sponsors for SAUC-E 2012 are the Office of Naval Research and ONR Global.

**For more information about the competition, visit [www.sauc-europe.org](http://www.sauc-europe.org)**

## CONTINUED FROM PAGE 1 - FLEET EXPERIMENT

“The Fleet Experimentation program allows the Navy to partner with commercial and government organizations to address and obtain solutions where critical maritime capability gaps exist,” said Frantz. “We each have a different piece of the solution and while laboratory experiments form the foundation of the technology development, the ability to experiment with that technology, at sea, in realistic scenarios, is crucial if you want the end result to be relevant to the Fleet Commander’s need.”

The next step for experimenting with these USVs will be this summer, as the Fleet Experimentation plan continues with the start of the annual Trident Warrior experimentation series. This year’s Trident Warrior is multi-phased and will be integrated with several large joint and multinational exercises in West Coast operating areas.

“No one is firing at us here in Virginia, nor are they trying to detonate any explosives near our ships, but these types of malicious scenarios drive our requirement to be prepared for the next time they do,” Frantz said. “Getting this defensive capability into the hands of warfighters to counter that aggression will be a game-changer for our forces when they are operating in dangerous waterways.”

Participants for this event included USFF, the Navy acquisition community, several components of Naval Sea Systems Command, commercial industries and academia.

For more information on the U.S. Navy’s Fleet Experimentation program, contact [FLEX@navy.mil](mailto:FLEX@navy.mil)

**Robotic Systems Joint Project Office (RSJPO)  
Releases UGV Interoperability Profiles (IOPs)**  
<http://www.rsjpo.army.mil/>

## 2nd Annual Robots in the Roses Research Fair

Thurs 10 May 2012 from 1400-1700

*The NPS Rose Garden & Roman Plunge*

Building on the success of last year’s inaugural research fair highlighting UxS activity on the NPS campus, the primary mission of this **2nd Annual Robots in the Roses Research Fair** is to offer the CRUSER community of interest (CoI) an opportunity to share research and educational opportunities in the areas of unmanned and robotic systems. We hope to reach a greater audience with this year’s event, expand the CRUSER CoI, provide NPS students the opportunity to explore potential thesis topics involving emergent technology, and inspire younger students to approach their formal education in science, technology, engineering and math with zeal.

- **DoD Organizations** are invited to showcase your research and recruit NPS students to work on graduate level research
- **Industry** is invited to showcase their latest research or unmanned systems to demonstrate their capabilities

To help non-local CoI members maximize their travel resources, this year’s **Robots in the Roses Research Fair** is scheduled to complete a series of concurrent UxS related events in Monterey. **The TENTH International Mine Warfare Technical Symposium** will take place from 7-10 May at the Embassy Suites, just down the road from the NPS campus. Integrated into the **Mine Warfare Symposium** schedule is the inaugural **CRUSER Technology Continuum**. These events will both conclude by noon on Thursday, so exhibitors and visitors will have plenty of time to catch the shuttle bus over to the NPS Rose Garden. Please note that the **Robots in the Roses Research Fair** is open to everyone – **CRUSER Technical Continuum** attendance is not required.



See you at Robots in the Roses!

<http://CRUSER.nps.edu>



## LIBRARIAN’S NOTES

The staff of Dudley Knox Library at the Naval Postgraduate School are pleased to be involved in CRUSER-related research. Please let us know how we can assist in your efforts by contacting librarians Andrea Davis & Jeff Rothal at [libcruser@nps.edu](mailto:libcruser@nps.edu).

Some links of interest this month:

- Drone Warfare: Costs and Challenges <http://bit.ly/l39kiF>
- Inside Defense’s Unmanned Systems Page (subscription required): [http://insidedefense.com/index.php?option=com\\_customproperties&view=show&tagId=9&Itemid=102](http://insidedefense.com/index.php?option=com_customproperties&view=show&tagId=9&Itemid=102), NPS users: <http://bit.ly/wcUtw3>
- Role of DoD Unmanned Aerial Vehicles for Homeland Security <http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA519898>
- Unmanned Aerial Systems: A Historical Perspective <http://usacac.army.mil/cac2/cgsc/carl/download/csipubs/OP37.pdf>
- Naval War College Library Guide: Unmanned Vehicles: <http://usnwc.libguides.com/content.php?pid=95481&sid=714066>
- **NPS Unmanned Systems Library guide <http://libguides.nps.edu/unmanned>**

Answer to last month’s library contest: *The computer and fashion date to 1989, (stamped on the back of the photo), courtesy of Irene Berry.*

**This month’s question:**

What are your top 5 resources/journals/databases/listservs/etc that you’d take with you to a deserted island to stay up on Unmanned Systems? Let us know--at [libcruser@nps.edu](mailto:libcruser@nps.edu)!

## Faculty Explore Defensive 'Swarming' Strategies to Counter UAVs

By Amanda D. Stein

Unmanned systems have proven valuable and are well integrated into offensive mission sets – from gathering ISR (intelligence, surveillance and reconnaissance) to delivering payload. While researchers at the Naval Postgraduate School are examining a wide variety of these and other uses of unmanned systems, NPS faculty have also begun looking into expanding the use of Unmanned Aerial Vehicles (UAVs) in defensive missions as well.

“Research into concepts and tactics to counter unmanned systems is as important to military operations as research into our use of these systems,” explained retired Navy Capt. Jeff Kline, Senior Lecturer in NPS’ Operations Research department and Director for the Consortium for Robotics and Unmanned Systems Education and Research (CRUSER). “Many of our potential adversaries have advanced unmanned capabilities that present real challenges to our operating forces.”

NPS Assistant Professor and Director of Research and Education for CRUSER, Dr. Timothy Chung, is working on developing a way to test swarm versus swarm tactics to counter an adversary’s UAVs. He is the Principal Investigator on a project titled, “A System-of-Systems Testbed for Counter Unmanned Systems Tactics Development and Research,” which looks at creating a competitive environment for swarm UAV testing.

“Swarming is the notion of having multiple agents that work in a coordinated manner to achieve some sort of objective,” explained Chung. “It is relevant in our work here at NPS because with the presence of unmanned systems, we need to start thinking about scenarios where we or an adversary might start using large groups of these unmanned systems in a combined way.”

CRUSER’s research in swarm UAV tactics is, in part, in support of a classified research report known as Project Jason, established by Kline. Project Jason attempts to characterize and understand the threats posed by swarms of UAVs, such as the Harpy, an unmanned aerial vehicle produced by Israel Aerospace Industries. Project Jason has led to a number of classified student theses projects exploring these threats.

“These Harpy UAVs are deployed in large numbers, and they typically zero in on a particular high value target and dive bomb it,” explained Chung. “Project Jason is essentially studying the problem of defeating the Harpy threat.”

One of the obvious challenges in operating swarms of UAVs is getting the systems to coordinate themselves and maintain their mission capabilities even in the event that one or some of the vehicles malfunctions. Chung noted that the solutions to these challenges cannot be solved by only one discipline or department, and his research has and will continue to draw from the expertise of various departments across campus. He cites a recent example which includes the university’s MOVES Institute to explore the human component of unmanned systems.

“What are the limits of a human operator’s attention?” Chung said. “When something in a complex system of systems goes wrong, how do you deal with it? You don’t want the operator to have to drop everything. You don’t want the shepherd to ignore the entire flock if just one sheep goes astray.”

“So the swarm system needs to be smart enough to adaptively reconfigure to adjust for that loss,” he continued. “Or if I send in reinforcements, they should be absorbed by the swarm without explicit direction by the operator. They should deduce and respond to changes themselves. And that’s where the autonomy research and the artificial intelligence of these systems comes into play.”

The CRUSER team sees NPS as the ideal place to implement such multidisciplinary research in unmanned systems. Since unmanned systems dominance remains a top priority across the services, Chung is working to establish a grand challenge competition dubbed Aerial Battle Bots, which would put the students’ experience and education to the test with live-fly experiments involving 50 versus 50 UAVs. His goal is to have the competition operational by 2015, and open for NPS and interested teams to “duke it out over the skies of Camp Roberts,” referring to the site of active NPS field experimentation efforts.

One of Chung’s key research visions is to inspire researchers and students at NPS and beyond to explore the operational potential of swarming unmanned systems and innovations in tactics they will require. The emphasis is in employing these systems to enhance the



*NPS students and faculty – from right, Marine Corps Maj. Thomas Dono, research associate Michael Day, Turkish Navy Lt. Umit Soyulu, Assistant Professor Tim Chung and Tunisian Air Force Capt. Riadh Hajri – hold five of NPS’ swarm of unmanned aerial vehicles being used to test ‘swarming’ and other counter UAV tactics.*

defense of the Fleet and armed forces; however, the Aerial Battle Bots competition highlights the need to pursue both sides of combat.

“Despite the real-world threat that swarm UAVs could pose, we cannot just study defense,” he said. “Defense is closely integrated with offense, so combining those two in kind of a competition environment allows both teams to develop both offensive and defensive tactics.”

In DoD, academic and industry contexts, large-scale experimentation of swarming aerial robots has yet to mature significantly, although recent projects have begun to push the envelope. Such a swarm test-bed presents several challenges for researchers looking to get 100 or more five-foot wingspan UAVs into the air at one time – as would be the case in the Aerial Battle Bots competition.

“The way UAVs are currently operated, you could probably have one person operating three or four vehicles, but you would still need people to help launch and people to take over in the case of an emergency,” explained Chung. “Right now, the requirements typically are one or more people per platform, which is clearly infeasible with 100 UAVs. We need to develop the capabilities and the tech-

nology to be able to manage larger numbers.” Understanding the full implications of these system-of-systems also calls for analysis of issues such as maintenance and manning, test and evaluation, and even total ownership costs.

There are plenty of basic and applied research challenges, let alone logistical ones, presented when trying to conduct a mission employing many UAVs in the sky simultaneously, but Chung feels that NPS is uniquely equipped with the initiative, resources, and expertise to be the first to fully explore the potential of these future defensive unmanned system swarms.

On this point, “the greatest assets are the students themselves,” remarks Chung. “Our students are operationally seasoned with incredible real-world experiences. In fact, many of them have performed missions with existing unmanned systems, if not innovated their employment tactics themselves.” He goes on to say, “these students are the forerunners of the next generation of military leaders of the robotics era.”

With future concepts and experimentation efforts such as the Aerial Battle Bots competition, Chung hopes to educate and inspire further generations to come.

## CENTER FOR UNMANNED AERIAL SYSTEM EXPLOITATION (CUE)

Sensor Systems Division, University of Dayton Research Institute

The CUE was established in September 2009 under a Third Frontier grant from the Ohio Department of Development with matching capitalization from collaborators in academia, industry and the Department of Defense. The CUE is physically co-located with its primary collaborator, the AFRL Center for Rapid Product Development, at the 24,000 square foot Wright Brothers Institute Tec^Edge Works facility in Dayton, Ohio.

CUE’s mission is to accelerate the development, integration and test of new technologies for military and commercial UAVs.

The CUE is composed of seven engineering workcenters: rapid prototyping/precision fabrication, onboard sensing & computing, communications & navigation, propulsion & power, control systems, modeling & simulation, and software development.

CUE collaborators encompass a multi-disciplinary team of recognized subject matter experts in aeronautics, advanced materials, high-speed computing, sensors, systems integration, network architectures, and test & evaluation (T&E).

CUE has a full spectrum of fixed- and rotary-wing air vehicles to support flight test of client subsystems.

The Center is directed by CAPT(ret) Rick Scudder, a 28-year Naval Aviator who specialized in T&E of aircraft and weapons.

CUE Flyer available on CRUSER’s Wiki at:  
<https://wiki.nps.edu/display/CRUSER/CRUSER+News+Articles>

NATIONAL  
**Robotics** WEEK

7-15 April 2012

<http://www.nationalroboticsweek.org/>

## WRITER’S CORNER

### What’s in an Acronym? “underwater versus undersea”

*Lyla Englehorn, MPP*

In this article, I take a closer look at a common acronym that is expanded inconsistently – UUV. There are two common expansions:

- 1) **unmanned underwater vehicle**
- 2) **unmanned undersea vehicle**

Perspective seems to dictate which expansion is used. As an emerging COI, we have the opportunity to clear up these annoying inconsistencies early and often. How will you expand UUV, and why? I welcome your comments on this issue, and suggestions for future columns. Please submit your ideas to [cruser@nps.edu](mailto:cruser@nps.edu).

For the full article please see the **Writer’s Corner** Wiki page at:  
<https://wiki.nps.edu/display/CRUSER/Writer%27s+Corner>

## STUDENT CORNER

**STUDENT:** Mr Michael Day, Research Associate, Computer Science Curriculum

**TITLE:** Multi-Agent Task Negotiation Among UAVs to Defend Against Swarm Attacks

**ABSTRACT:** This research uses a multi-agent based simulator to model a large (up to 150 member) group of adversarial UAVs attacking a high value surface target and groups of friendly UAVs responding to thwart the attack. Defender UAVs must cooperatively negotiate which red systems to engage to maximize the number of aggressor systems destroyed. Using an optimal centralized task assignment method as a baseline, some distributed methods are examined for efficiency and effectiveness. Other factors are also examined and evaluated as to their effect on the number of aggressor UAVs destroyed. These factors include number of defenders per aggressor, effectiveness of the defender weapon systems, speeds of aggressors and defenders, arrival times of aggressors, and dispersion of aggressors.

## COBRA team meets with South Korean Defence Scientists

by Alanah Duffy

Fredericton – The University of New Brunswick's COBRA team (COLlaboration Based Robotics and Automation) met with defence scientists from South Korea on Dec. 7, 2011. The three scientists travelled to Fredericton on behalf of the Agency for Defense Development, the organization that is responsible for all defence tactics in South Korea.

UNB is the oldest English language university in Canada and the first public university in North America. In 1854, UNB became the birthplace of engineering education in Canada. COBRA, which was established at UNB in 2009, has been conducting groundbreaking research in the field of unmanned vehicles. The group, which has six members and is led by Dr. Howard Li, has developed unmanned land, aerial, and underwater vehicles. Their work has attracted the attention of organizations such as Defence Research and Development Canada. COBRA researchers have developed autonomous behaviours, path planning algorithms, multiple robot SLAM algorithms and navigation control strategies for unmanned systems. COBRA has transferred research results to the Department of National Defence. The team has established collaborations with Dalhousie University, McGill University, Massachusetts Institute of Technology, University of New South Wales, the University of Toronto Institute for Aerospace Studies, etc. The research results were reported by news papers and TV news, such as the Telegraph Journal, the Daily Gleaner, CBC (Canadian Broadcasting Corporation), and the Discovery Channel. General public as well as government officials (Minister of Energy, New Brunswick, Director General of Defence Research & Development Canada Atlantic) are very pleased to see the achievement of New Brunswick universities.

“The meetings with the Agency for Defense Development went well,” said Dr. Li. “It was an opportunity for us to showcase the exciting research that we have been conducting at UNB with a large organization. The meetings were a chance to discuss possible ways to move COBRA into the future.”

The COBRA team has had a chance to showcase their work before. In November, the team travelled to the 2011 Unmanned Systems Canada Conference in Halifax, where they were able to network with experts in the unmanned systems technology. Carl Thibault, a COBRA member, demonstrated an unmanned aerial vehicle called Draganflyer X8 in front of a large crowd.

The hard work that the team put into the conference in Halifax was a great learning experience to prepare for their South Korean visitors. “We were able to apply knowledge that we had learned at the 2011 Unmanned Systems Canada competition and use it when we presented our research to the Agency for Defense Development,” Dr. Li said.

Full article at <https://wiki.nps.edu/display/CRUSER/CRUSER+News+Articles>

## CALENDAR of EVENTS

The CRUSER Calendar of Events is located on our Wiki:

<https://wiki.nps.edu/display/CRUSER/>

## CRUSER Coordination Group

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