Issue 58 December 2015

CRUSER NEWS

Consortium for Robotics and Unmanned Systems Education and Research

From Technical to Ethical...From Concept Generation to Experimentation

Contents

JOIN the CRUSER Community of Interest
http:\\CRUSER.nps.edu

InfraGard San Diego Unmanned Aircraft Systems (UAS) Symposium

by Matthew E. Miller, San Diego Law Enforcement Coordination Center, matthew.miller@sd-lecc.org

The InfraGard San Diego Unmanned Aircraft Systems (UAS) Symposium was held on 4 Nov 15 at Qualcomm's Irwin Jacob's Hall Auditorium in San Diego.

The last decade has seen a significant increase in the domestic use of Unmanned Aircraft Systems (UAS), commonly referred to as drones. In early 2015, the SD-LECC, San Diego's DHS recognized fusion center, initiated a series of UAS Workshops to explore the local challenges to public safety and critical infrastructure security. The magnitude and scope of both positive and potentially negative scenarios quickly led to the development of a UAS symposium in hopes of reaching a broad audience to exchange ideas among stakeholders from private, commercial, and government entities.

On November 4, 2015, the San Diego Law Enforcement Coordination Center (SD-LECC) in partnership with the FBI San Diego Field Office, the San Diego City Office of Homeland Security, and InfraGard San Diego held an Unmanned Aircraft Systems (UAS) Symposium with more than 300 attendees to address growing concerns and benefits of the domestic use of UAS technology.

As demonstrated throughout the Symposium, a tremendous amount of work lies ahead for all stakeholders – local, state, and federal government and the private sector – in adopting legislation and policies to safeguard all aspects of UAS use. The sharing of information between the government, private sector, and commercial users will be essential ensuring the safe use of UAS and response to inappropriate UAS use. These ideas were highlighted in the opening remarks from Tom Farris, Deputy Director of the SD-LECC; John Valencia, Executive Director of the San Diego City Office of Homeland Security; and Eric S. Birnbaum, Special Agent in Charge of the Federal Bureau of Investigation San Diego Division.

The Symposium's keynote speaker Mr. Thomas Baker, Director of UAS and Counter-UAS Initiatives at NORAD/NORTHCOM, discussed the integration of drones into the national airspace. There is a growing concern/problem over airspace saturation with UAS. Following Mr. Baker's keynote, a distinguished panel of experts convened, including panel moderator Christian Whiton, President of the Hamilton Foundation, and panel members Colonel Dana A. Hessheimer, the commander of the 163d Attack Wing, California Air National Guard; Rusty Sailors, Chairman / CEO of LP3-SecurIT; Robin Snider, Program Director, Electronic Payloads Mission Systems at General Atomics Aeronautical Systems; and Lieutenant John Forsythe, Port of San Diego Harbor Police Department. The topics discussed were relevant, timely, and covered concerns across all spectrums relating to civil-military relations, public safety, civil liberties, potential and current threats, and the benefits of UAS to all stakeholders.

Director's Corner

Lyla Englehorn, CRUSER Director Concept Generation

As the 2015 calendar year draws to a close it is time to look ahead to 2016 – and, as always, CRUSER has exciting plans! During the NPS Thesis & Research Week, 21-24 March 2016, CRUSER plans to host two specialty Warfare Innovation Workshops. The first full week of April each year is National Robotics Week, and CRUSER will be joining the celebration with our annual Technical Continuum. CRUSER TechCon 2016 will be held on Tuesday and Wednesday, 5-6 April, here on the NPS campus. We also plan to make the presentations available remotely via Collaborate for non-resident members of CRUSER. Finally, our sixth Innovation Thread will begin with a Warfare Innovation Workshop at the end of FY16, 19-22 September 2016. Put these activities on your calendars now, and check cruser.nps.edu for more details. Happy December, and may 2016 bring you inspiration and success!

Rapidly Installable Robotic Appliqué Kits

by Troy Takach, President & CEO, Kairos Autonomi, www.kairosautonomi.com, troy_takach@kairosautonomi.com

Rapidly Installable Robotic Appliqué Kits, or RIRAKs, may hold the answer to near term deployment of combat vehicle robotic systems.

The struggle to produce safe, effective, unmanned ground vehicle (UGV) systems for the U.S. Military is at a fever pitch as many competing technologies and approaches strive to find a way around the fact that a "people sensor" does not yet exist. Until such a class of sensors exists with developed, proven software, viable autonomous systems will always be 5-10 years out. On the other hand, automated vehicle systems are here today. Automations are functions and behaviors that assist human operators/controllers of UGVs as they perform missions by executing common tedious tasks. Automated UGVs project the senses and skills of the warfighter while shielding them from the dull, dirty and dangerous.

There are two edges to the autonomous UGV continuum – leading and trailing. Leading edge systems are singular test beds for various technology efforts. These systems expand the envelope of the possible but lack stability and costs required for viable deployment. The continuum trailing edge includes production UGV systems. They contain surviving, effective UGV technologies, limited with focused features and functions driven by cost and reliability. Without the leading edge, the trailing edge does not exist. Without a trailing edge, deployment does not exist.
The robotic appliqué kit market focus is twofold - custom appliqué kits are created to prove new technologies (leading) and production appliqué kits are created to perform specific automations (trailing).

A primary delineator between custom and production appliqué kits is the installation time into the vehicle and the commitment of the vehicle to the appliqué kit. The total cost of an appliqué kit based UGV includes the cost of the vehicle, kit, installation and training. Maintenance is excluded.

If the installation time of the robotic appliqué kit is driven to zero, it can be installed and removed at will. The vehicle is not committed to be a UGV except when required, enabling point-of-use robotics. Total cost of the UGV is significantly reduced because vehicle, installation and training costs fall out of the equation. The cost is fully contained in the RIRAK. The vehicle can be located anywhere.

Short installation times can be fully captured in modern video tutorials. If a RIRAK takes less than 10 minutes to install, the installation video is short. Watch/Execute the video 3 times and you are a self-trained expert – anytime, anywhere.
Using existing or near term RIRAK technologies as point-of-use robotics; the tactical commander is able to remove the human being from harm's way as the mission dictates. This can be done Now!

Video Demonstration:
https://www.youtube.com/watch?v=0C63cbW4rcM

Short articles (up to 500 words) for CRUSER News are always welcome submit to: cruser@nps.edu

CRUSER Calendar

11 Jan (1200 PST) - Monthly Meeting
9-12 Feb 2016 - JIFX
details at http://CRUSER.nps.edu

Joint Interagency Field Experimentation - Call for Experiments for Feb 2016 event

by Tristan Allen, NPS Faculty Associate Research | Field Experimentation, tmallen@nps.edu, http://my.nps.edu/web/fx

The Naval Postgraduate School's Joint Interagency Field Experimentation (JIFX) program is now accepting Experiment Proposals for its remaining Fiscal Year 2016 events:

- JIFX 16-2: 9-12 February 2016 at Alameda, CA
- JIFX 16-3: 9-13 May 2016 at Camp Roberts, CA
- JIFX 16-4: 8-12 August 2016 at Camp Roberts, CA

Interested parties are encouraged to visit the JIFX website(http://my.nps.edu/web/fx) to review the event Request for Information (RFI) document, submit an Experiment Proposal, and review important due dates. The RFI document outlines the parameters for participation and lists the areas of interest for the event. Applications will be accepted that relate to any of the RFI areas of interest.

Development and Testing of the Aqua-Quad

by Dr Kevin Jones, NPS Faculty, kdjones@nps.edu@nps.edu

Under CRUSER funding, a new energy-independent, ultra-long endurance, hybrid-mobility unmanned system has been under development called the Aqua-Quad. Shown in Figure 1, it is a concept platform that combines an ocean drifter with a quad-rotor air vehicle, and is intended to be a "launch and forget" asset, typically deployed in small groups or flocks that work as a team to more efficiently meet mission goals. While there are many mission sets where the Aqua-Quad might be advantageous, one in particular, underwater tracking with passive acoustic sensors, was previously addressed in simulation by LT Dillard (MAE, 2014). This has led to current work by LT Cason (USW, 2015), also with contributions by LT Fauci (SE, 2015).

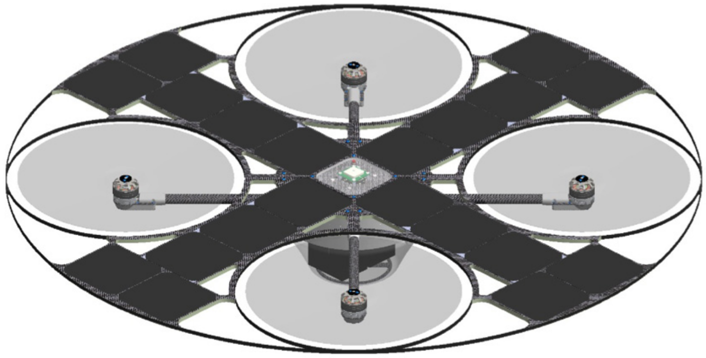

Figure 1: CAD rendering of the Aqua-Quad prototype

As seen in the figure, a 20-cell photovoltaic (PV) array is distributed around the four propeller disks. These monocrystalline Silicon SunPower E60 cells are the only source of energy that the copter has, but are the means to achieve endurances of 3 months or more. In a single day in June in the Monterey Bay, the NREL solar irradiance calculator, PVWatts (http://pvwatts.nrel.gov/index.php), would suggest a total daily energy budget of about 0.5 kWh collected by the PV array, and this energy needs to be divided up amongst avionics, sensors and propulsion for flight. This available daily energy budget will change depending on latitude, weather and other factors, but is representative of the energy available in a 24 hour period for all operational needs of the Aqua-Quad.

One of the most challenging aspects of the program has been identifying materials and manufacturing techniques to construct a device which is water-tight and tough enough to survive at sea, but still light enough to efficiently fly. The prototype weighs a little over 3 kg, including the water-tight enclosure and PV array, and is lifted by four water-tolerant motors spinning 360 mm diameter carbon fiber propellers. The outer ring is just over 1 m in diameter. Flight tests of a stripped down version of the prototype, with most of the water-tight enclosure and the solar array removed, demonstrated stable flight with a required power of about 340 W at full weight, indicating a maximum flight time of about 25 minutes with fully charged batteries. Flights have also been performed with the solar array support structure installed, as there were concerns regarding aerodynamic influences and possibly structural resonance – neither was a problem. The measured Figure of Merit (FOM) for the copter is pretty good, about 9 g/W, operating at roughly the same efficiency as a full size helicopter. The flying prototype with the PV array support structure installed is shown in Figure 2.

Flyable prototype with lower shell removed and feet attached

A test of the solar recharge sub-system was performed on the afternoon of October 18th, a fall day with mixed clouds. With the PV array aligned roughly normal to the Sun light, a maximum power of about 63 W was measured, and with the array aligned horizontally, as it would be in use, an average power of about 35 W was recorded. PVWatts estimates values between about 30 and 45 W for that time of year and time of day, based on an archived year of data from NAF Monterey. During the test, a Genasun Maximum Power Point Tracker (MPPT) was utilized to optimize power output from the PV array and to charge the batteries. The stripped down MPPT weighed about 100g, and was relatively large, with a heavy inductor and several large electrolytic capacitors. The size and weight of the MPPT were known issues, as well as the limited lifespan of electrolytic capacitors. However, during the experiment, it was noted that the compass in the flight control system reported errors whenever the Sun was shining brightly. The running theory is that the inductor creates magnetic interference that is proportional to the current passing through the MPPT, which is proportional to the solar irradiance. The inductor is located just a few inches from the compass, and cannot easily be relocated due to the size of the Genasun MPPT. Fortunately, this last summer, LT Fauci was working with a different MPPT from STMicroelectronics for the TaLEUAS project. It is a newer design with customizable output voltage (meaning that by swapping 4 resistors, we can tune it to act as a charge controller for the batteries). The STM board is actually purchased as a dev-board, with 3 MPPT circuits either connected in series or parallel on a single board. We were able to cut the board into 3rds, obtaining 3 single-array MPPTs. The Genasun and trimmed STM boards are shown in Figure 3. The weight of the STM board is under 25g, and the cost is about 1/10th of the Genasun. While not installed yet, the inductors on the STM board are much smaller, and there are no electrolytic capacitors, so we expect a longer life, and minimal compass interference. Due to its small size, the STM board can easily be relocated further from the compass.

On November 3rd, to gather data for LT Cason's thesis, and with the support of John Joseph, Keith Wyckoff and Tarry Rago, we headed out onto Monterey Bay to perform float tests of the Aqua-Quad in various sea states. There was a small craft advisory posted for the day, with swells expected to reach 11-14 feet at 13 seconds, so a perfect day to make sure the design would stay afloat and keep the solar array above water while floating. We started about 100 m outside the harbor where the swell was around 3 to 4 feet, and everything looked good. As a back-up, the Aqua-Quad was tied off to the buoy shown in Figure 4,

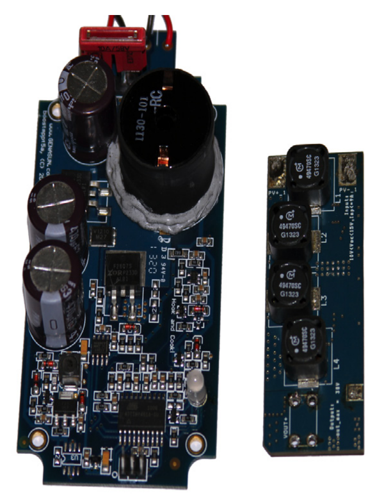

Figure 3: MPPTs from Genasun (left) and STMicroelectronics (right)

and to represent actual fielded use, a dummy Acousonde sensor was hanging below the Aqua-Quad on a 10 m line. It provides a stabilizing effect, like a tail on a kite. After some sounding experiments in the harbor region, we recovered the equipment and moved out to

STUDENT CORNER

Student: **Maj Thomas M. Rice, USMC; Maj Erik A. Keim, USMC; Maj Tom Chhabra, USMC**

Title: Unmanned Tactical Autonomous Control and Collaboration Concept of Operations

Curriculum: Information Sciences

Link to Completed Thesis: https://calhoun.nps.edu/handle/10945/47319

Abstract: There is a perceived problem in Marine Corps tactical units regarding technological advancements and cognitive load; specifically, the almost infinite flow of new information on the modern battlefield is overtaxing the human brain. The development of Unmanned Tactical Autonomous Control and Collaboration (UTACC), an alternative warfare concept, could clarify the relationship between technological advancements and cognitive load. UTACC's purpose is to enhance mission accomplishment while simultaneously reducing the cognitive load on the Marine through collaborative autonomy. This thesis developed a UTACC Concept of Operations that captured the logic, sequencing of operational activities, and initial information exchange requirements for a Marine Corps Warfighting Laboratory provided scenario. Addressing the complexity of UTACC also required an in-depth analysis of collaborative autonomy, human system integration factors, and decision support. This research finds that, in the early stages, UTACC could be most effective as a scalable decision support tool that automates routine planning processes, improving the efficiency of the small tactical unit. Additionally, this research discovers areas for future work, three of which are: measuring capability gaps, common operational picture management/fusion, and security.

rougher seas. At the second location swells were peaking at around 10 feet, and the Aqua-Quad still behaved perfectly.

Ongoing work on the Aqua-Quad includes obtaining an interim flight clearance to allow for autonomous outdoor flights with water launch and recovery tests, new developments on a self-righting capability in case the Aqua-Quad gets tumbled in rough seas, and collaborative behaviors to support realistic mission sets. There are a variety of interesting potential thesis topics, spanning from aerodynamic performance, to flight controls, to circuit design, to complete system optimization and operational applications. There may also be topics in USW, Cyber, and METOC were the Aqua-Quad might be of interest.

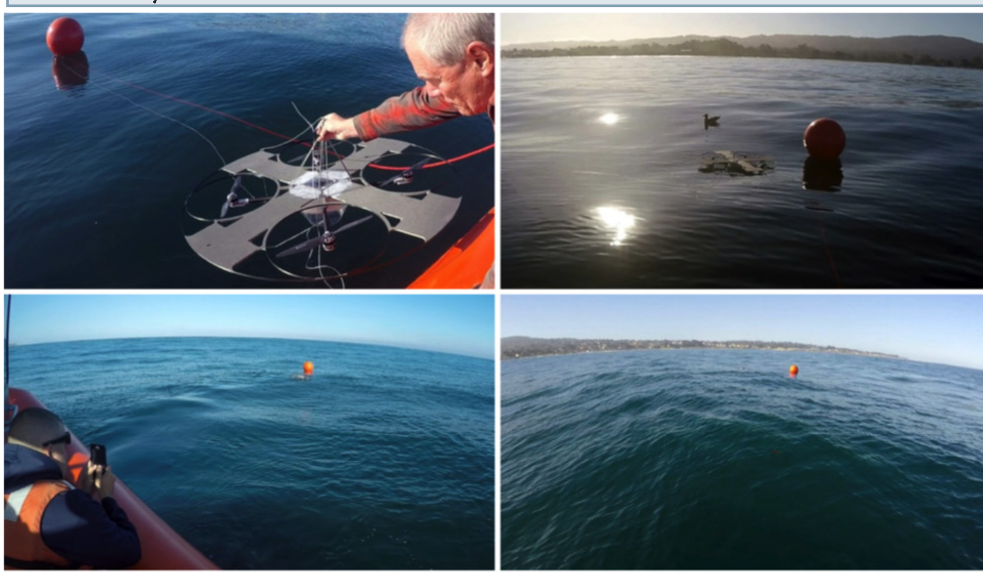

Figure 4: Snapshots of the buoyance experiments in Monterey Bay. Upper left: John Joseph deploying the Aqua-Quad for the first time. Upper right: casually resting in calm waters. Lower left: just deployed in rougher seas. Lower right: riding down the back side of a 10 foot roller

Librarian's Corner

The Disrupter Series: The Fast-Evolving Uses and Economic Impacts of Drones [congressional hearing]
http://energycommerce.house.gov/hearing/disrupter-series-fast-evolving-uses-and-economic-impacts-drones

Seibert, Benjamin. "The Dark Side of Drones: Implications for Terrorism" Combating Terrorism Exchange (CTX), November 2015, v. 5, no. 4
https://globalecco.org/the-dark-side-of-drones-implications-for-terrorism-cpt-benjamin-seibert-us-army

Buchanan, Allen and Robert O. Keohane. "Toward a Drone Accountability Regime." Ethics & International Affairs 29, no. 1 (2015): 15-37.
http://wws.princeton.edu/system/files/research/documents/Toward%20a%20Drone%20Accountability%20Regime.pdf

The Use of Unmanned Aerial Systems for Agriculture in Africa: Can It Fly [Rand]
http://www.rand.org/pubs/rgs_dissertations/RGSD359.html