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CRUSER • NEWS

Consortium for Robotics and Unmanned Systems Education and Research

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

Contents

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Flying Miniature Quad-Rotor Unmanned Aerial Systems over the Arctic Ocean

by Peter Guest, NPS Faculty, pguest@nps.edu

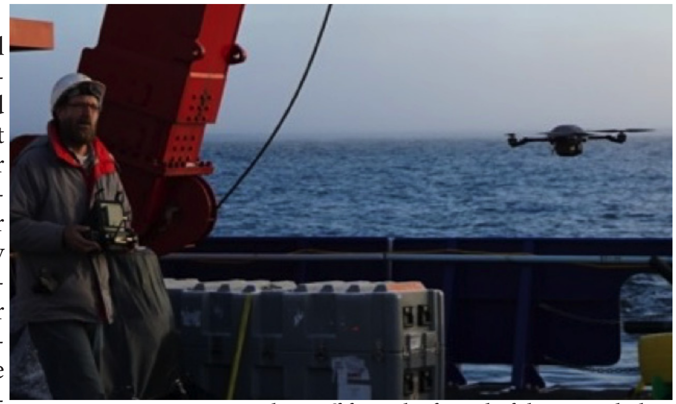


Figure 1: InstantEye taking off from the fantail of the R/V Sikuliaq

This article describes meteorological measurements over the Arctic Ocean using a Miniature Quad-Rotor Unmanned Aerial System (MQRUAS). With support from the CRUSER program, the author and students have been testing the concept of using MQRUASs as platforms for measurements of temperature, humidity and pressure in the lower atmosphere using a radiosonde as a sensor. The author performed a series of tests at Camp Roberts that involved flying the InstantEye MQRUAS alongside a calibrated meteorological tower to test the accuracy of the measurements. These tests determined that such measurements were of sufficient accuracy and reliability to be used for scientific and operational studies of atmospheric structure near the surface.

An Office of Naval Research directed research initiative entitled "Sea State and Boundary Layers in the Emerging Arctic Ocean" (abbreviated as "Sea State") provided the first opportunity for the author to use the MQRUAS to address scientific (rather than just feasibility) issues. The overall goal of the Sea State project was to understand the physics of the interaction between the atmosphere, the ocean and sea ice in the Arctic Ocean. Before about 10 years ago, the Arctic had been mostly ice-covered all year and therefore few surface waves were present. But recently, ice cover has dramatically decreased and as a result waves now exist where they did not previously and this is having significant effects on various physical processes such as ice formation, ocean mixing and shore erosion in the Arctic Ocean. The primary platform for this project was the R/V Sikuliaq, a newly-commissioned icebreaker operated by the University of Alaska, Fairbanks. The specific goals of the author in the Sea State project during the 1 October to 10 November 10, 2015 cruise was to quantify the role of the atmosphere in generating waves, creating and destroying ice and transferring heat, moisture and momentum to the surface. This was accomplished, in collaboration with other meteorologists, with a suite of measurements which included the MQRUAS/radiosonde system.

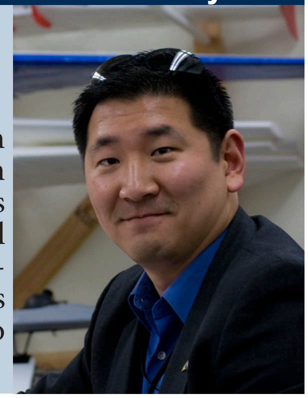
The MQRUAS meteorological measurements were the first of their kind in any polar region, to our knowledge. Also this was the first time the author has flown an MQRUAS from a vessel at sea and from sea ice floes. Flying in such an extreme and different environment presented several challenges. One challenge was to obtain the required interim flight clearance (IFC) for operation from vessels at sea and flying in international air space, neither of which had been performed by NPS researchers with any type of UAS. This was obtained just before the start of the Sea State cruise, not in time to perform any at sea testing before the Sea State cruise. Other challenges were operating (1) in cold conditions, (2) in potentially icing conditions and (3) where the magnetic field is nearly vertical due to proximity to the magnetic North Pole. The latter challenge was crucial because the navigation and control of the InstantEye depends on accurate compass readings.

There were three goals to the MQRUAS measurements:

1. Testing the feasibility of such measurements in Arctic Ocean conditions
2. Quantifying the fine-scale atmospheric structure of the lower atmosphere
3. Quantifying the amount of heat and moisture coming from leads (openings in the ice pack)

Director's Corner

Tim Chung, CRUSER Deputy Director



As we kick off a new year, we look forward to another year of incredible and exciting growth in unmanned systems and robotics technologies, capabilities, and accomplishments! In this new year, we can anticipate witnessing the continued expansion of unmanned systems employment not only in new domains but across multiple domains, additional operational efforts with robotics in numerous sectors beyond military applications, and an acceleration of further transition and/or commercialization of robotics technologies. 2016 looks to be another exciting year for robotics and unmanned systems, and CRUSER is eager to continue riding the wave towards this future! Happy New Year from the CRUSER team!

Figure 2: The author flying the InstantEye over a large ice flow in the Arctic Ocean.

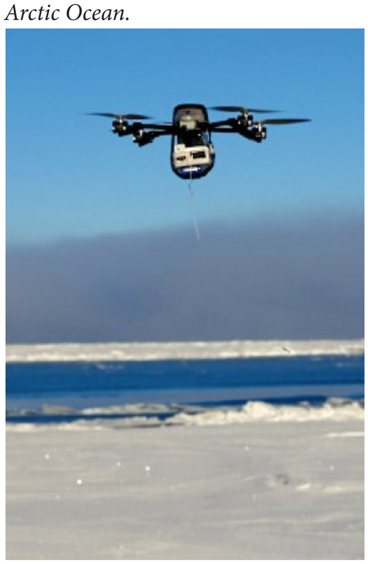


Figure 3: Close up of the InstantEye, with radiosonde instrument package attached underneath, over ice in the vicinity of a lead (seen in the background).

The latter accomplished by comparing profiles of temperature and humidity upwind and downwind of a lead. The author performed flights from the deck of the Sikuliaq (Figure 1) and from ice floe surfaces (Figures 2 and 3). The flights involved horizontal transects over and on both sides of leads and also vertical profiles (up to 300 meters). A total of 18 MQRUAS 10 - 15 minute flights were performed. We choose to fly in periods with relatively light winds (less than 8 kts) and temperatures ranges from -3 C to -20 C (28 F to -3 F).

There were some operational issues encountered. During some of the flights over open water, ice crystals formed on the MQRUAS rotors. However, these did not appear to significantly affect performance and were easily cleaned off while changing batteries between flights. The cold conditions reduced the battery life from the usual 25-30 minutes to 12 - 15 minutes, at least as indicated by the control screen; we suspect the battery life was actually more than indicated. A more serious issue was compass performance. During three of the flights, the control screen indicated "Compass Error" and the MQRUAS became hard to control. In one case, when the MQRUAS was launched from the ship fantail, control became difficult and the author had to land on some thin ice alongside the ship. As the ship moved to recover the MQRUAS, it cracked the ice and the MQRUAS was pushed off into open water and sank before it could be rescued. (We had spares.) We believe the compass errors were a result of being so close to the magnetic North Pole, resulting in almost vertical magnetic force lines. Also the magnetic field generated by the ship may have caused distortions in the magnetic field

Despite these issues, overall the experiment was a success. The meteorological data from the MQRUAS and fixed-wing UAS flights appeared to be accurate and we were able to quantify lead heat fluxes and also the fine scale-structure of the lower atmosphere and how it varies horizontally and temporally. These results are still being analyzed and will be published in a scientific journal article. Challenges remain, but the author believes that the MQRUAS shows great potential as a platform for scientific and operational meteorological measurements and he plans to continue testing the system in various marine environments including international waters off the coast of California in 2016 and in the seas surrounding Antarctica during a 2017 cruise.

Librarian's Corner

Best Practices for Protecting Privacy, Civil Rights & Civil Liberties In Unmanned Aircraft Systems Programs (Dec 18, 2015)
http://www.dhs.gov/sites/default/files/publications/UAS%20Best%20Practices.pdf

These Are the Drones You are Looking for: Manned-Unmanned Teaming and the U.S. Army
http://www.ausa.org/publications/ilw/DigitalPublications/Documents/nsw15-4/index.html

Unmanned Systems and the Homeland Security Enterprise
http://www.anser.org/Unmanned_Systems

The Marketplace of Ideas at War: Issues, Elites, and Public Support for American Drone Strikes
http://www.lawschool.cornell.edu/cornell-IL-IR/upload/Kreps_Wallace_Drones_16Jan-2.pdf

New DoD Robotics and Autonomous Systems Strategies for 2016- More Details Emerge

by Matt Dooley, Principal Consultant, Robotics and Autonomous Systems | JHNA, Inc., matt.dooley@jhna.com

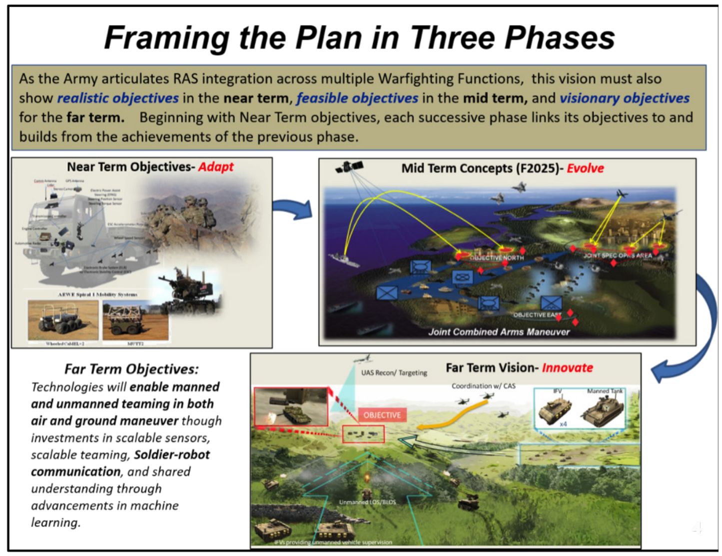
"... there is going to be an increase in what we call human-machine collaboration…this is human-centered autonomy... this is about allowing machines to help human decision-makers make decisions at the campaign and tactical level which will be either faster or better than the adversaries"

- Deputy Secretary of Defense Bob Work, Whitehall, London, September 10, 2015

The U.S. Department of Defense has accelerated its efforts to chart a unified way ahead for robotics and autonomous systems (RAS) across the Services. The Joint Staff (J7/J8) is currently writing a Joint Concept for Robotic and Autonomous Systems due for publication in the summer of 2016. Simultaneously, the U.S. Army is working to staff its own new RAS strategy document. While the Joint Staff grapples with clarifying defense policies, overarching goals, and areas where common efforts for RAS may be achieved, the Army's document pursues its own agenda to provide more detail for how Army RAS platforms will operate across all formations and Warfighting Challenges. The efforts of the Joint Staff and the Army are collaborative and promise to define clear endstates for RAS capabilities, feasible concepts for their integration, and acquisition paths that can reasonably be executed over the next 25 to 30 years. This effort strikes at more than simply publishing concepts of employment to be tested but also seeks to articulate how Department of Defense funded experiments in science and technology will combine with use of RAS in training exercises and real world operations to bring more robotic capabilities into the force.

A Joint Vision for RAS in the Future (Courtesy Joint Staff J7/J8)

For its own part, the U.S. Army's new RAS strategy will articulate how RAS will function across all three domains (land, sea, and air). While previous strategies over the years have focused on merely illustrating methods of employment for Unmanned Aerial Systems (UAS) or Unmanned Ground Systems (UGS) alone, the Army's new strategy will also explore how RAS may be integrated as combined, human-machine collaborative teams that will provide combat formations with true differential advantages over their adversaries. To make this ambitious and innovative style of warfighting feasible, the RAS strategy will also outline the non-RAS capabilities needed to realize this vision. Areas like mission command, intelligence gathering integration, cyber defense, cyber offense, and seamless data streaming will all be essential to managing a future battlefield swarming with robotic and autonomous formations.



The Army's Three-Phased Picture for RAS Integration (Courtesy TRADOC, ARCIC)

The Army's RAS strategy paints its vision in three distinct, clearly discernable phases that sustain and integrate current RAS capabilities across the force, replace obsolete systems, develop new capabilities, and build upon earlier successes. The vision for RAS shows realistic objectives in the immediate future, but also encourages increased investments now to make enhanced capabilities, like autonomy and human-machine teaming, more feasible by 2025. Lastly, the Army's RAS strategy will provide separate annexes for discussion of innovative technologies and truly visionary concepts.

CRUSER Calendar

1 Feb (1200 PST) - Monthly Meeting
9-12 Feb 2016 - JIFX
7 Mar (1200 PST) - Monthly Meeting
5-6 Apr - CRUSER TechCon

details at http://CRUSER.nps.edu

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

STUDENT CORNER

Student: Capt Joshua S. Lum, USMC

Title: Utilizing Robot Operating System (ROS) in Robot Vision and Control

Curriculum: Electrical Engineering

Link to Completed Thesis: https://calhoun.nps.edu/handle/10945/47300

Abstract: The Robot Operating System (ROS) is an open-source framework that allows robot developers to create robust software for a wide variety of robot platforms, sensors, and effectors. The study in this thesis encompassed the integration of ROS and the Microsoft Kinect for simultaneous localization and mapping and autonomous navigation on a mobile robot platform in an unknown and dynamic environment. The Microsoft Kinect was utilized for this thesis due to its relatively low cost and similar capabilities to laser range scanners. The Microsoft Kinect produced three-dimensional point-cloud data of the surrounding environment within the field-of-view. The point-cloud data was then converted to mimic a laser scan. The odometry data from the mobile robot platform and the converted laser scan were utilized by a ROS package for simultaneous localization and mapping. Once self-localization and mapping were achieved, a ROS navigation package was utilized to generate a global and local plan, which translated to motor velocities in order to move the robot to its objective. The results demonstrated that simultaneous localization and mapping and autonomous navigation can be achieved through the integration of ROS and the Microsoft Kinect.

Multispectral Imaging – Eye On The Commercial Market

by David Harrison, Business Development Manager, Materion Precision Optics, David.Harrison@materion.com

During last August's Unmanned Aircraft Systems (UAS) West Symposium, a wide range of speakers noted a common theme running through the presentations. It was the increased need for multispectral data. Why particularly this type of data? To answer that question calls for a basic understanding of the function of multispectral imaging.

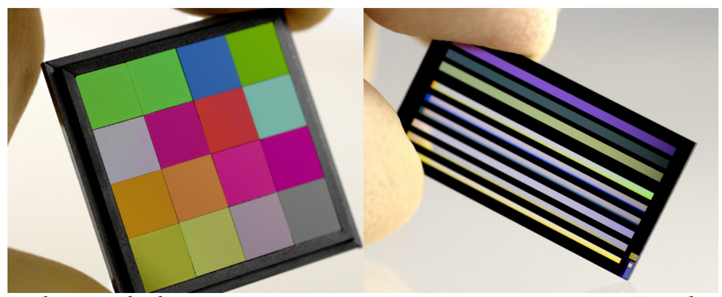
Advantages of Multispectral Imaging

A multispectral image is one that captures image data at specific frequencies across the electromagnetic spectrum. The wavelengths may be separated by filters or by the use of instruments that are sensitive to particular wavelengths. This includes light from frequencies beyond the visible light range, such as infrared. Originally developed for space-based applications, spectral imaging can extract additional information that the human eye fails to capture due to its limited receptors for red, green and blue. This offers insight on its potential benefits and uses.

Because multispectral imaging allows for the fusion of multiple images combining different wavelengths, it is able to provide much more accurate information for use in real-time decision making. For that reason, multispectral imaging has long been the cornerstone of earth observation and remote sensing satellites. In the past, this technology was extremely expensive to build and reserved for large space- based programs such as Landsat, VIIRS and others. However, with the expansion of applications (picosats, machine vision, etc.) this technology is moving towards more commercially affordable options.

Traditional Use

In today's industrial camera market only a handful of vendors manufacture CCD (charge-coupled devices) and CMOS (complementary metal-oxide-semiconductor) imagers, making it difficult for camera vendors to differentiate their products based on sensor performance alone. While most of the imagers available today use the Bayer mosaic to allow color images to be captured, some sensor and camera manufacturers now offer custom filters that can be added to sensors and cameras to target specific application areas. One of the benefits of using such multispectral filters is that they can be used to reduce the size, weight and power of the aircraft. Traditionally, such multispectral imaging systems have employed filter wheels equipped with multiple filters to perform these tasks.



Multispectral Filter Array Materion *ArrayTec Select*

Emerging Commercial Applications

Employing multispectral filters with CCD or CMOS Imagers can certainly be used in commercial systems. There are multiple potential applications for UAV-based multispectral imaging such as, ISR, agriculture monitoring, disaster recovery and geographic mapping to name a few. To obtain appropriate filters to fulfill a specific task, imaging developers will require the technical expertise of such companies as Materion Precision Optics.

In the past, multispectral filters were built to customer-specific requirements in either butcher block or checkerboard formats. These were then shipped to the customer for mounting onto either linear or area array imagers. For space-based applications, Materion has worked closely with Ball Aerospace (Boulder, CO) for example, to develop a custom nine-band multispectral filter for the LANDSAT 8 satellite. The on-board imager fitted with the filter instrument provides 49ft panchromatic and 98ft multi-spectral spatial resolution along a 115 mile-wide swath, allowing the entire Earth to be imaged every 16 days.

While Materion continues to offer custom capabilities, customers now have the option to choose commercial off-the-shelf (COTS) filter arrays or semi-customized filter arrays. While the COTS arrays are pre-assembled with sizes up to 2in square and eight 1mm wide imaging bands, developers requiring semi-customized filters can choose from eight filters in the visible and short wave infrared bands.

By offering several filter options, the cost of developing multispectral camera systems will be reduced. This in turn allows for expanding viable alternatives for the commercial UAV market.