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Executive Summary

The capabilities of Unmanned Aerial Systems (UAS) for marine science and conservation applications are growing rapidly at the local, regional and global levels. On June 29-30 2015, Duke University Marine Laboratory hosted a marine science UAS workshop to:

- Better understand technological advances in UAS
- Enhance collaboration with the extraordinary unmanned aerial systems expertise in North Carolina and the eastern coast of the US
- Develop a strategy for educating the public on unmanned aerial systems use in marine science
- Draft a plan of actions and milestones for creating a UAS facility; this facility would serve the unique needs of UAS research in the local marine sciences community and beyond

The workshop provided a forum to assess current challenges and discuss ideas and initiatives to advance adoption of UAS technologies. The workshop had a diverse agenda and an equally diverse group of over 50 experts from government, academia, commerce and civic groups.

A vast array of UAS marine science applications were discussed including:

- Emergency response
- Identifying and analyzing marine debris
- Monitoring protected and endangered species and their habitats
- Supporting fisheries stock assessments, effort surveys and habitat assessments
- Supporting marine animal entanglement and stranding efforts
- Monitoring effects of climate change, coastal erosion and sea level rise
- Monitoring sea grass and marsh health

Key takeaways from the workshop include:

- There is significant opportunity for eastern North Carolina to lead the nation in marine science UAS engineering, applications and training.
- There is significant potential to partner with NOAA and other federal entities that use UAS capabilities and/or require UAS support along the east coast.
- Workshop participants indicated that a UAS facility should support not only local initiatives, but provide support for regional, national and global marine science efforts as well.
- Marine science UAS operators must work diligently to stay within FAA constraints and work closely with DoD and NC DOT airspace authorities when airspace restrictions apply.
- Partnerships could follow the Duke University/University of North Carolina Oceanographic Consortium (DUNCOC) model for resource sharing/allocation.
- Public outreach is a critical aspect of any UAS initiative and key to sustaining good will with local citizens, schools and businesses.

During the workshop, there was enthusiastic support for a marine science UAS facility. As a result, Duke University will move forward to create, from an existing building, a facility that will:

- Meet state and FAA training requirements for marine scientists seeking to employ UAS
- Train scientists to employ UAS in marine and coastal systems, and facilitate marine data analysis
- Engage with engineers to develop new platforms, sensors and software systems applicable to marine science applications
- Provide equipment services for researchers and natural resource managers seeking to use UAS in their workflows
- Increase UAS knowledge and marine research public outreach

Ideally, the facility will meet the needs of the local community and collectively build on the strengths of partnerships, the nature and structure of which will be carefully defined. This UAS facility will provide a great opportunity for NSF researchers to move their programs forward, and will also provide a nexus for fund raising from other agencies.

Workshop by the Numbers

Introduction

Advances in microelectronics, sensors and integrated software systems have resulted in an proliferation of Unmanned Aircraft Systems (UAS) available to the general public. These systems are comprised of autonomous or remotely piloted aircraft (often with a camera) linked to some form of ground control station for control purposes. Many require hands-on flight control, although they are increasingly capable of autonomous flight based on pre-programmed missions. The use of UAS in science applications is growing, and the availability of sophisticated yet affordable commercial hardware and software solutions is now facilitating their use by marine researchers. The use of UAS in terrestrial commercial and science applications is now wide-spread and transforming spatial ecological science. These devices are used regularly to reduce costs and boost knowledge of key agricultural parameters through aerial spectroscopy. Small UAS are also used to assess progress and environmental compliance in mining operations and occasionally to study the terrestrial habitats and aggregations of wildlife. However, these devices have not been used extensively in marine systems. Indeed, the application of this technology in marine and coastal systems has lagged behind its adoption in terrestrial systems, despite the fact that many of these platforms represent significant data collection opportunities for marine scientists. One factor that is limiting adoption of this technology into marine science programs is the lack of guidance and support for scientists seeking to incorporate this technology.

To address this gap, a multi-agency workshop was convened at the Duke University Marine Laboratory with the purpose of scoping the creation of a local facility to meet the needs of coastal researchers seeking to exploit UAS technology in their research programs. The two-day workshop started with an overview of marine science applications that employ UAS and was followed by a participant-driven exploration of the needs, expectations and concerns about creating a UAS facility in our community.

Specifically, the workshop aimed to 1) help local stakeholders better understand technological advances in UAS, 2) enhance collaboration with the extraordinary unmanned aerial systems expertise in North Carolina, 3) increase local capacity for conducting marine research using UAS technology and 4) develop approaches for educating the public on unmanned aerial systems use in marine science. To do this, the workshop was focused particularly on scoping a plan of action and milestones for creating a UAS facility in our community; a place that would serve the unique needs of UAS research in the local marine sciences community and beyond.

Workshop Participants

The workshop was designed to be outwardly looking, marine-centric and focused on engaging with partners beyond faculty and staff within Duke University that have interest in this topic. A significant effort was made to invite participants from all aspects of the coastal community that would be interested in using this technology to achieve their specific missions, to include small business owners, educational or research institutions, natural resource management agencies, military units or community groups. The workshop was well attended, with over 55 participants representing more than 25 agencies and institutions. A detailed list of attendees can be found in Appendix 1.

Workshop Format and Agenda

The workshop was split into two sections, divided between two days and capped with demonstration flights of both fixed-wing and multicopter unmanned aerial vehicles (UAVs). The initial portion of the workshop was comprised of briefings from experts on 1) UAS integration in the national airspace, 2) future developments and engineering challenges for UAS in marine environments and 3) a select set of case studies of current employment of UAS in marine science by both government agencies and academic institutions. The remainder of the workshop was dedicated to a focused discussion—often directed by participant questions—on the needs, expectations and concerns regarding the development of a UAS facility in coastal Carolina. The promotional material for the workshop and the final agendas are included in Appendix 2.

Formal Briefing Summaries

Opening Remarks – David W. Johnston, Duke University Marine Laboratory

The workshop commenced with a short presentation by Johnston on the growing opportunities presented by small and affordable robotic aircraft with low-cost yet high-quality sensors. This technology is readily adaptable to many applications in marine environments (commercial and academic), yet there is little guidance on safe, efficient and ethical use. Johnston also presented data from a recent AUVSI report on the economic opportunities presented by this rapidly changing technology. Taken together, this information presents an opportunity for our region to lead in the use of UAS in marine applications. Johnston finished his briefing with a brief description of the type of facility he hoped to scope through the discussions held at the workshop including meeting educational goals, supporting UAS research in the region, and engaging with local communities to raise awareness of the utility of UAS.

The Roadmap for UAS in NC - Tom Zajkowski, NextGen Air Transport Group (NGAT), North Carolina State University

Tom Zajkowski provided a presentation on the status of the State of North Carolina's NextGen Air Transport Group (NGAT) at North Carolina State University. The NGAT was "created to develop and evaluate improvements to air traffic control, airspace management, airport and airspace system capacity, surface traffic management, and flight safety, specifically as it relates to the integration of Unmanned Aircraft Systems (UAS) into domestic airspace. The center was designed as a non-profit partnership of academia, industry, and government agencies to provide a research and application oriented, technology transfer-focused organization for conducting technology development, investigations, and field trials as North Carolina prepares for a modern air transportation system". Zajkowski delineated the timeline for NGAT's entry into UAV flights and provide details on the number and scope of missions currently being undertaken by the group. At present the group has four UAS platforms and is conducting weekly flights across 17 different locations. Their research is currently focused on airspace integration issues, agriculture and surveying operations and control and communication systems. The NGAT has obtained clearance from the FAA for several projects and is currently undertaking a petition for exemption from Section 333 of the FAA Modernization and Reform Act of 2012 to conduct commercial UAS operations using both fixed-wing and multicopter UAVs. Zajkowski also provided details on the operational goals of the NGAT, including collaborating with NGAT members, supporting research at 16 universities, providing NC agency service, and sharing collected data. The NGAT consulting service goals were also discussed, including development of standard operating procedures, and crafting permit applications.

Engineering and the Future of UAS - Larry Silverberg, Mechanical and Aerospace Engineering, North Carolina State University

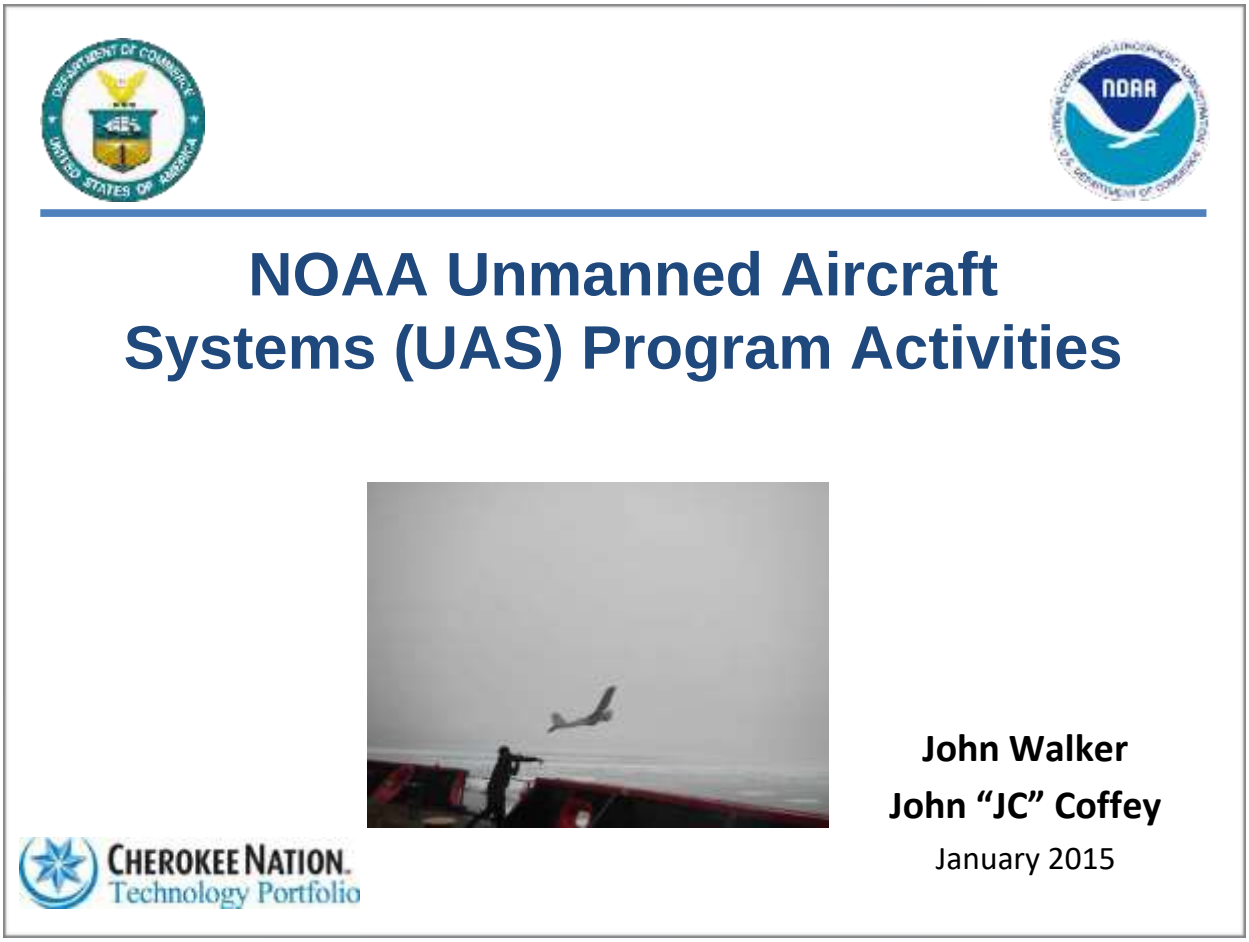
Larry Silverberg provided an overview of previous efforts that he, along with NCSU faculty and staff, have made to push forward UAS engineering technologies including vehicle design, the development of sensors and actuators, advances in autonomy and communication systems. From these examples, Silverberg indicated that NC as a state was likely developing and operating more UAS than other states. Silverberg's research program is currently focused on emerging problems associated with high-density air traffic, operating swarms of UAVs safely, real-time object identification from sensor output and creating systems that can fly safely in obstacle-rich environments. Silverberg also indicated that there is a great opportunity in our coastal region to become a hub for UAV projects that span agriculture, mines and culture, renewable energy construction along with environmental projects—even bird watching.

Toward Domain Agnostic Unmanned Vehicles - Matthew Bryant: Mechanical and Aerospace Engineering, North Carolina State University

Matthew Bryant provided a briefing that focused on how strategies apparent in nature—used by birds, squid, fish, and insects—could be applied to developing more efficient UAVs. Using this biomimetic approach, Bryant has been working on an unmanned system that spans habitats, allowing the transition from aerial operations to aquatic operations and back, a project that required significant engineering. For underwater operations, the system must be high strength with the ability to control buoyancy. Conversely, for air operations, the system must be fast and light in weight. While the details remain classified, Bryant was able to confirm that he has developed a UAS that can both swim and fly efficiently.

NOAA Unmanned Aircraft Systems (UAS) Program - John J. Coffey NOAA

John J. Coffey provided a high-level overview of the NOAA UAS program. This program recognizes that UAS observations are poised to become essential components of the NOAA observing program, allowing the agency to greatly enhance its ability to provide timely, actionable and reliable environmental intelligence to end users and decision-makers. Specifically, Coffey indicated that UAS were integral for missions in locations that can be described by the four Ds: dull, dirty, dangerous and denied (i.e., remote). Coffey also noted that the use of UAS in NOAA missions enhances its ability to conduct operations in a more efficient, effective, economical and environmental-friendly manner. Coffey indicated that NOAA is prepared to take advantage of recent advances in propulsion (energy, batteries), computing (command and control), and miniaturization of electronics (improved sensors). Coffey indicated that UAS are now used by NOAA in weather assessment, protected species surveys and polar science using a combination of both fixed-wing and multicopter platforms. Coffey also provided a framework for assessing the readiness of a technology for deployment, which can be useful for tracking platforms and sensor payloads when contemplating new missions. Finally, Coffey indicated that from NOAA's perspective UAS are wildly successful and a regional approach to developing competence is critical—although there are plenty of issues to address such as lagging regulations, limited program management assets, and administrative hurdles to cooperation and asset pooling.



Multi-copter platforms for Photogrammetry and Sampling Individual Animals - Michael Moore: Woods Hole Oceanographic Institution

Michael Moore provided an overview of his collaborative work that uses multi-copter platforms to assess the body condition and health status of large marine vertebrates. The briefing focused on work conducted with sperm whales and blue whales using a APH 22 UAV (hexacopter platform) with an Olympus camera system useful for photogrammetric studies. Moore provided imagery that illustrated body condition and reproductive status of blue whales in Chile, imagery that impressed participants with the potential uses of UAVs for this type of work. Moore also provided experimental success of collecting whale breath samples (and associated whale snot) using a small quad-copter system built for use in marine ecosystems. Moore provided data from dive plots that indicated whales did not appear to change their diving behavior when studied via UAVs, an important consideration for both permitting and data quality control. A publication detailing methods used for this work is available here: http://www.nrcresearchpress.com/doi/pdf/10.1139/juvs-2015-0020.

Mapping Macro Marine Debris with UAS – David W. Johnston, Duke University Marine Laboratory.

David Johnston provided a briefing on the use of fixed-wing UAVs to survey shoreline marine debris in conjunction with the Race for Water Odyssey. This project seeks to circumnavigate the globe in less than 300 days and survey beaches in all oceans for plastic pollution. Johnston provided details on the magnitude of the problem and demonstrated the use of the senseFly eBee for beach surveys and developing new techniques to identify debris and estimate its distribution and density. Johnston and his colleagues are seeking to detect macro-plastic debris through UAVs fitted with RGB, near-infrared, red edge and thermal cameras. Experimental work is aimed at combining spectral reflectance from these cameras to detect and distinguish marine debris objects of varying sizes. Johnston also provided information on the challenges faced so far with the project including non-standard flight conditions, inconsistent ground sampling resolution and data management issues, as large amounts of storage are required.

Surveying Seal Colonies with UAS and Thermal Imaging - Julian Dale, Duke University Marine Laboratory.

Julian Dale briefed participants on the use of UAVs to count gray seals at colonies in Canada. Dale introduced the importance of population assessments and provided details on the costs, efficiency and risk factors associated with traditional approaches that require manned aircraft (e.g., fixed wing planes and helicopters), noting that UAV-based approaches were better across these factors. Dale detailed the environmental conditions in which surveys were conducted: snow and ice-covered terrestrial habitats, -20°C air temperatures and high winds of up to 20 mph. Dale also outlined the advantages of using the senseFly eBee for this project including lower survey costs, lower disturbance of animals, and lower risk for both observers and animals. Dale's approach provides a model for less-invasive research opportunities, and the simple workflow allows for rapid data processing. Dale also noted that many challenges for safe and consistent data collection remain for UAS surveys conducted in these types of extreme environments.

Mapping Sea Grass Beds with UAS in the Bahamas - McCain McMurray, New Fields

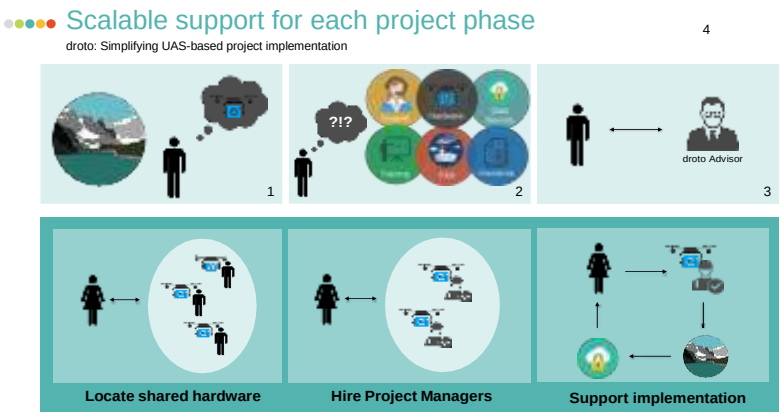
McCain McMurray provided details on a proof-of-concept sea grass mapping application conducted by McCain McMurray in the Bahamas. McCain utilized the senseFly eBee for these surveys and conducted operations at 300m to reduce artifacts of wind-driven surface chop and glare. McMurray conducted 14 flights, usually in 20 kts of wind, that resulted in reduced flight time for the UAV. Aerial imagery was stitched into an orthomosaic, compared with in situ samples of sea grass density collected from boat-based surveys and assessed with Coral Point Count with Excel extensions (CPCE software). The results of UAS imagery and CPCE assessment were used in an object-based classification analysis in the eCognition software package to identify seagrass habitats within the final orthomosaic. McMurray's proof–of-concept indicates that sea grass mapping can be conducted in challenging conditions using readily available software. (Presented by Johnston).

NewFields

UAS Survey

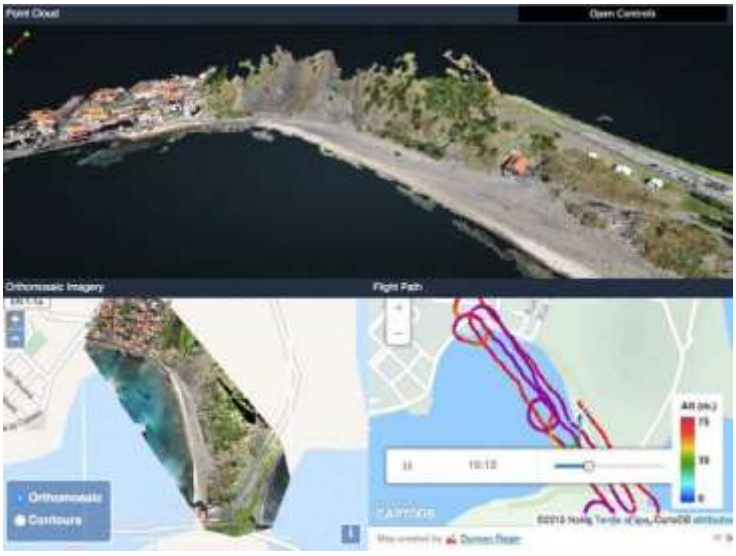
- 14 flights conducted over three days of surveying
- Six flights, 465 total images, used in production of the final orthomosaic
- Flights flown at approximately 300 m altitude in attempt to reduce distortion effects caused by waves and glare on the water surface
- The spatial resolution of the 16 megapixel camera at 300 m was approximately 10 cm

droto – Simplifying UAS-based Project Implementation - Sidney McLaurin, Duke University



Sidney McLaurin provided a briefing on a new business startup focused on the growing need for integrated project management for UAS commercial ventures. McLaurin described the gaps between users and providers of UAS technology and services, and outlined an internet-based commercial approach that would connect academic, industry and government partners with crowd-sourced UAS rentals and UAS-savvy project managers. While much of the market is focused on agriculture and mining, droto would focus on projects with ecological/environment vertical market and supporting longer term, more specialized projects conducted outside urban settings.

Visualizing UAS data – Open Source Software and Open Access Data - Colin Stief, Duke University Marine Laboratory



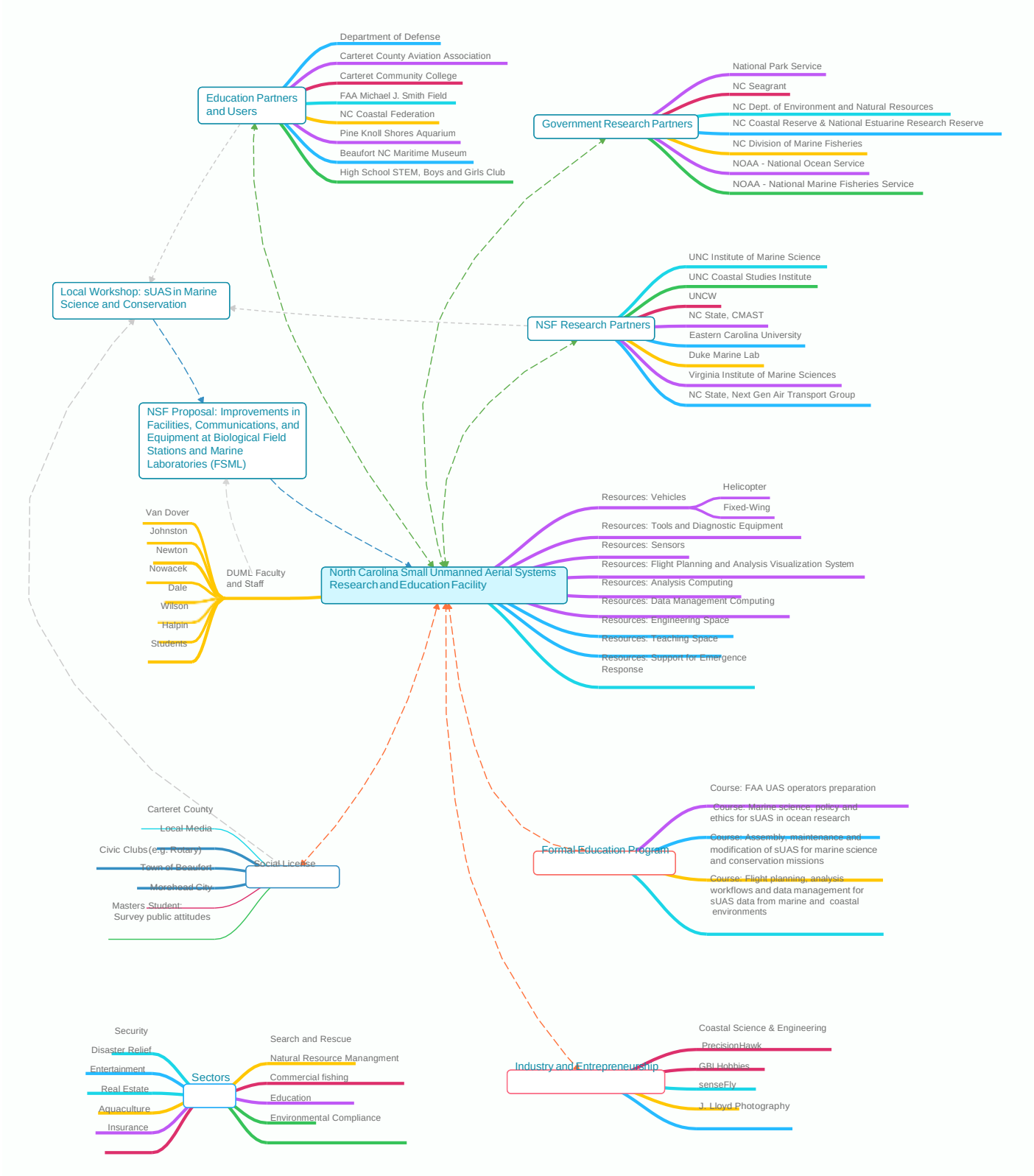
Colin Stief provided details on an open-source visualization application for UAS data. Stief's application addresses both the density of data collected from visual sensors onboard UAVs and its typically inaccessible nature by integrating it into an easy to navigate web-browser interface. This UAS data viewer presents orthomosaics, spectral reflectance data, 3D point clouds, elevation contours, and UAV flight path information and allows for direct data downloads. The viewer application is built on several open access software packages. It uses Potree, a WebGL based point cloud viewer for very large datasets, to present 3D imagery and serves imagery data from a local GeoServer and UAV flight paths from a cloud-based CartoDB mapping system. Stief indicated that the presented layout, and others like it, can be utilized for research, outreach/ education and commercial purposes. (Presented by Johnston).

Envisioning a Facility for UAS in Marine Science

The proposed UAS facility will host resources for teaching, research, and outreach and will be connected to local partners across sectors. It will produce formal educational programs for undergraduate, graduate and professional students and scientists and will conduct outreach in the local community through relationships with informal educational institutions and community leaders. These resources and relationships are summarized in the mindmap figure on the following page. Facility resources include both teaching and research assets and support for emergency response action. The facility will hold periodic formal education programs that address the needs of scientists planning UAS research programs and managers seeking to ensure compliance with regulatory restrictions. Local science and education partners have been identified for research and outreach collaborations, and stakeholders from local businesses will be engaged to encourage entrepreneurship and support facility needs in terms of platforms, customers and supplies. All of the above stakeholders were invited to participate in this 2-day workshop to review the state-of-the-art in UAS marine science research and education and scope the needs, expectations and concerns of users of the facility locally. This report will form the seminal document for a proposal to the National Science Foundation's Improvements in Facilities, Communications, and Equipment at Biological Field Stations and Marine Laboratories (FSML) program (due December 2015) to develop the facility, including Boathouse renovation, scoring new platforms and sensors, installation of visualization systems, and development of data management platforms. Finally, special attention is being paid to developing the "social license" for the facility within the Beaufort community. We are aware of concerns expressed in news media regarding the use of drones; as such the facility will continue to actively engage with community leaders to develop evidence of a social license to operate in the local area.

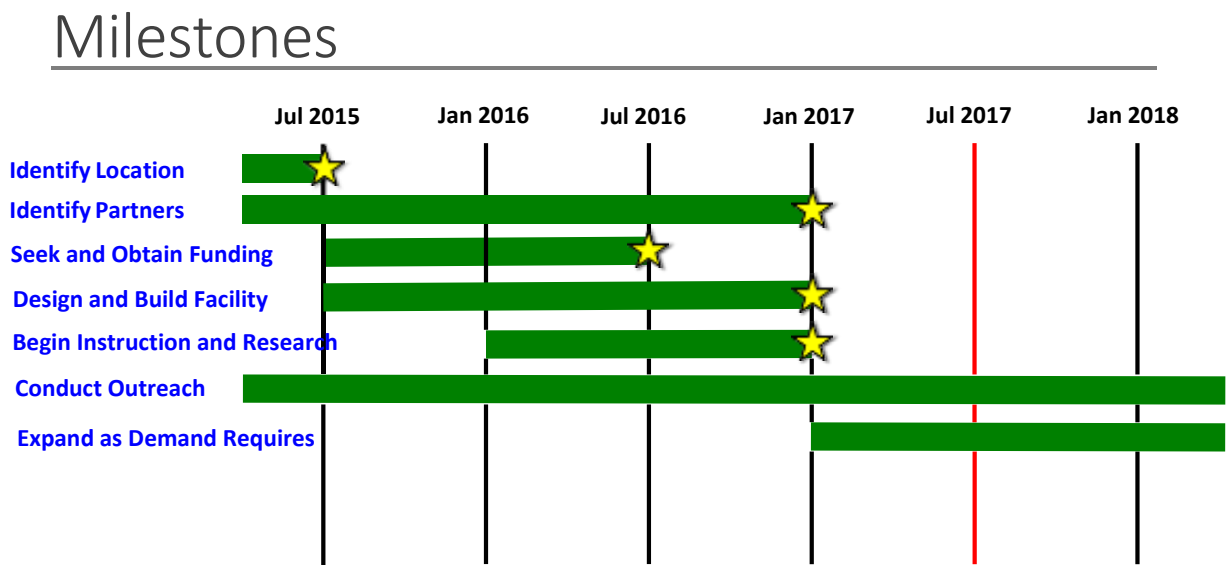
The Duke faculty and staff involved in the development of the facility and deployment of its programs are listed in the mindmap below as well. The faculty involved bring a range of applicable expertise to the program, including science and mission planning for autonomous vehicles in the marine environment (Van Dover, Johnston, Nowacek), photogrammetry and behavioral ecology (Nowacek), geospatial analysis (Halpin), and population assessments (Johnston and Nowacek). Specifically, Van Dover has extensive experience planning and executing science missions with autonomous vehicles in marine environments, and brings strong leadership skills to the facility. Johnston and Nowacek are trained ocean glider pilots and have experience planning and executing UAS missions for marine vertebrate science. They also bring experience in oceanography, movement analysis, behavioral ecology and the study of marine populations and habitats. Halpin is the leader of the Marine Geospatial Ecology Laboratory and brings extensive experience in dealing with the analysis and management of geospatial datasets generated from platforms such as UAS. Staff leaders provide expertise in program management (Newton) aviation, aviation training (Newton, Wilson) and hardware engineering of UAS (Dale, Newton). Specifically, Wilson is a trained commercial pilot with experience in marine environments and Dale is a trained systems engineer with skills in building and maintaining marine electronics including the development and modification of UAS platforms for marine conditions. Newton retired as a Colonel from the US Air Force in

2011 following a 28-year career that included leading-edge engineering, F-15E Strike Eagle leadership and assignments as an Arabic foreign area officer. Newton has extensive experience designing, building, operating and maintaining unmanned aerial vehicles. Johnston will be the lead PI for the facility, and it is expected that Newton will be the first Program Manager. (Presented by Johnston).



Timeline for a UAS Facility at Duke Marine Lab

Newton presented a briefing to workshop participants on the location, timeline and milestones currently under consideration for a UAS facility at the Duke Marine Lab. The facility would ideally be located in the Boathouse, an iconic but at present unused building at the base of the academic quad at the DUML campus. This structure would need renovation to support the facility. Specifically, this renovation will create a modern teaching space outfitted with a visualization system for flight planning and data analysis; permitting will require addition of a bathroom compliant with ADA standards. The facility will also host an engineering space that will allow students and researchers to assemble, maintain, and repair UAS hardware and to begin work on sensor integration and development. Teaching space would be located in the easternmost section with engineering space located centrally adjacent to the breezeway. Newton indicated that initial partners for the facility and potential funding sources had already been identified, and he set out future milestones for the project including having initial operational capability (IOC) by fall 2015, acquiring NSF funding by summer 2016 for renovations and establishing our first course taught for summer 2016. This is good timing, as it is anticipated that new regulations for commercial use of UAS will be introduced during summer 2016. We expect that the facility would establish a Center of Excellence and be ready to expand within five years of achieving full operational capability (FOC) in late 2016. Newton also noted the incredible outreach potential provided by a UAS facility in our region that will advance marine science education across age ranges and provide information on security, privacy and safety issues to the local community.



Day 1 of Participant Discussions

After individual briefings the workshop was opened up for a participant-led question and answer period. This provided opportunity for participants to provide their ideas, expectations and concerns regarding the development of a UAS facility in our region. There was much discussion amongst participants, and key messages are provided below.

Many marine science and conservation applications for UAS were discussed over the course of the day, and included:

- Identifying and analyzing marine debris
- Monitoring protected and endangered species and their habitats
- Supporting fisheries stock assessments, effort surveys and habitat assessments
- Supporting marine animal entanglement and stranding efforts
- Monitoring effects of climate change, coastal erosion and sea level rise
- Monitoring sea grass and marsh health
- Conducting post-storm damage assessment

Captain Guy Nelson, a US Marine Corps UAV pilot, started the session with a briefing. Nelson applauded efforts to develop a facility and noted the timeliness of the efforts. He also provided useful information on how to structure roles within a facility, such as establishing explicit workflows and responsibilities for engineers, operators and analysts, and addressing the lack of basic aviation knowledge in many operators. Nelson also provided useful models for risk mitigation and avoidance that are standard techniques in military operations. Nelson also raised the issue of extensive military airspace in the region that will likely factor into when and where UAS can be flown for science, management or emergency response missions. There was good discussion about this by workshop participants and it was made clear by those attending from military units that they were excited about this endeavor and ready to work with the facility on airspace issues to help achieve missions wherever possible.

Jarod Lloyd, a local photographer, videographer and nature reporter, provided an important perspective regarding UAV-use in film and other art forms. Lloyd indicated that UAVs had revolutionized photography and videography, especially as it pertains to nature and wildlife. He was excited about the opportunities presented by a facility in the region that could support efforts to further develop UAV-based photography and videography techniques, and indicated the great potential to boltser science communication through this type of approach.

Pat Kenney, the National Park Service Superintendent of Cape Lookout National Seashore provided details on current policy on UAV-use in US National Parks. He reminded participants that flying UAVs from park land is currently prohibited, but that the permitting system provided opportunity for research focused UAV projects. Kenney noted that while most permits for research in National Parks are approved locally, the use of UAVs in research is vetted at the National Park Service headquarters. Kenney and other NPS staff attending the workshop noted the potential for UAS to replace traditional forms of research currently being employed (e.g. manned aircraft surveys) for

sea turtles, invasive plants, horse monitoring, and inspections of infrastructure such as lighthouses.

Dave Plummer (Regional Military Airspace Coordinator) and Major Hernandez (US Marine Corps Air Traffic Controller) provided more detail about military airspace in the region, how it is controlled, and the need to communicate awareness of ongoing air operations as UAS missions start to grow. They indicated a great willingness to work together to navigate airspace issues, exemplified by their desire to facilitate, not eliminate operations across the region. Plummer also indicated that the development of memoranda of understanding (MOU) amongst agencies may be helpful regarding UAS operations in some portions of military airspace.

Steve Fegley, faculty at University of North Carolina's Institute of Marine Sciences, expressed excitement about having a local facility to help develop UAS research in marine sciences and provided important perspectives about communication amongst partners. Fegley indicated that a framework of MOUs amongst participating organizations would be essential for the facility to support multi-agency research. He also pointed out that rapid success could lead to conflicts for access to platforms and other facility resources. Workshop participants noted that a well-designed communications plan and the development of MOUs could address part of these concerns, and that in terms of platforms it would be relatively easy to scale availability, especially compared to ship resources.

Amy Hapeman from the NMFS Protected Resources Division provided input regarding permitting for UAS operations around protected species (marine mammals and sea turtles). Hapeman was encouraged by the concept of having a regional education facility that would provide training for operators to conduct missions safely and with little disturbance to animals. Hapeman noted that permit applications for UAV flights over protected species were rising rapidly, creating new challenges for permitting officers in determining who is qualified to operate UAVs around these animals, and how these qualifications would be obtained. Hapeman indicated that there was great need for training programs that would explicitly address protected species issues, and hoped that the proposed facility would develop a standardized training program and best practices applicable to qualifying pilots for flights over protected species. Several workshop participants indicated that would be relatively easy to achieve with the proposed facility, and that there was enough expertise in protected species in the region to build a comprehensive approach to this type of training. This ended day one of the workshop. (Facilitated by Johnston and Newton).

Scoping a UAS Facility - Day 2 of Participant Discussions

Day 2 of the workshop opened up with a recap of the previous day's activities by Johnston and an overview of workshop participants by Newton. Newton's overview of the diversity of participants was evidence of significant interest in the local community, academic organizations, military stakeholders and natural resource managers in the region. Many workshop participants agreed it was encouraging how many sectors were represented by those attending.

Johnston provided an overview of the previous day's main points and indicated that the feedback provided by workshop participants revolved entirely around how best to develop a facility in the region, and that no major concerns were raised about embarking on developing it. Johnston reiterated key points about 1) integrating with military airspace, 2) agency regulatory concerns (both internal and external) relating to the confusing FAA process, 3) the incredible potential for various applications, 4) a broader community effort with thoughtful communication and agreements amongst partners, 5) the growing need for educational offerings to support partner and agency needs and 6) the need to recognize opportunity to integrate art and science through aerial videography via UAS.

The remaining portion of day 2 of the workshop was conducted as open discussion, allowing participants to revisit key points and bring up new ideas and issues that may have germinated overnight. Reide Corbett from East Carolina University raised the potential of using an existing agreement amongst agencies to support the development of the facility. Corbett was referring to the Duke/University of North Carolina Oceanographic Consortium (DUNCOC). This consortium included all local academic partners in the area and was focused on administering the R/V *Cape Hatteras*, a UNOLS vessel that supported oceanographic work in the region. Corbett also noted that the DUNCOC model brought people together to discuss research, created a broader community of users and data producers and that the DUNCOC model has an established record of success. Corbett also voiced frustration about increasing occurrences of inappropriate non-commercial use of UAS and hoped that a regional facility may help in addressing these concerns locally through education and by acting as a conduit for reporting infractions.

Michael Moore from the Woods Hole Oceanographic Institution suggested that a survey of hobbyists (perhaps through developing connections with regional air clubs) could determine the number of flyers, what is being flown and where flying occurs would be useful. This type of information would provide context for the contribution of science-based UAS operations to overall activity in the area. Moore also indicated that the facility would provide an information node for directing people to fly safely in appropriate locations. Dave Plummer followed this discussion with strong advice that the proposed facility have a proper communication plan with key messages for

the public ready and available. Corbett indicated support for these ideas and presented a local example where knee-jerk reactions to bad behavior had resulting in a community considering a ban on the use of UAS. Corbett expected that a UAS facility could be the community voice and advocate as it relates to UAS use, creating the needed connections to prevent knee-jerk reactions and informing the broader community about who they can talk to when complications arise. The response from various workshop participants was that the proposed facility should have a core group of identified representatives to approach this issue. Participants indicated that the next step is to get the word out there that the facility is emerging. Nelson pointed out that several training centers already exist, some which purport to be accredited by the FAA. Warren Lloyd from PrecisionHawk noted that they have an established research connection with the FAA, and that he was interested in developing training for UAS pilots, perhaps through community colleges. He indicated that reaching out to established programs would be beneficial, including the North Dakota UAS test site. Tom Zajkowski reminded workshop participants that the FAA rule remains uncertain, making the development of a training program somewhat challenging. Several workshop participants indicated that the proposed rule provided enough information to develop a program that would surpass FAA requirements. Zajkowski agreed, and also pointed out that Wichita State University has an education program for UAS training. Larry Silverberg noted that much of this would remain in flux until the final UAS rule was published, but having looked at the proposed rule it would not be difficult to develop a comprehensive course. Silverberg also noted that he and his colleagues had grant money to help community colleges develop a UAS training program. Moore indicated that the proposed training facility has broad appeal, and would be a resource for others nationally and likely internationally. Johnston indicated that a mixed approach to training that included a distributed component of online courses with a practical session at the marine lab was one model that had been under consideration. Keith Rittmaster rounded up the discussion about education with a call for some immediate resources for locals, including seemingly simple but incredibly useful things like a glossary which would provide definitions for the growing array of complicated concepts and acronyms associated with UAS.

A briefing by Joe Jones, the Michael J. Smith Field Airport Manager, followed the discussion of education programs. Jones indicated strong support for developing a UAS facility and indicated that the airport could be a great partner. Jones provided detailed background on the airport's three active runways (two lighted), 422,000 acres and basing for 72 aircraft which make trips as far as California and Europe. The airport supports 45,000 operations a year but has capacity to support three times the number of operations. He also presented future plans for the expansion of the airport that could support even greater operations. Jones finished his briefing with a suggestion of getting the facility better aligned with the FAA needs as it develops rules to support

commercial UAS operations in the national airspace.

Several workshop participants asked questions about funding and support, and whether the development of the facility was contingent on getting new support from NSF. Johnston responded that NSF support would be a key factor in how quickly the facility developed, but that other sources of support were being investigated. Johnston also indicated that with the current platforms in hand they could support some level of collaborative research, and that the education program would move forward regardless of gaining NSF support. Johnston then asked participants for other examples of research that might be supportable in the short-term. Larisa Avens from NOAA Protected Species in Beaufort indicated her short-term intentions to collaborate on sea turtle surveys locally, and was excited about having a regional facility that would support her research program as it developed new directions. Matthew Godfrey, the NC State sea turtle biologist with the NC Wildlife Resource Commission provided other examples where he could use UAS technology including surveys of difficult areas to reach during breeding season or cold stunning events.

Johnston described several other local projects that had already been scoped with partners in the room.

Lauren Hermley, the Assistant Town Manager of Beaufort, indicated her strong support for the facility, noting that it could be a focal point to bring new and higher paying jobs into the region. She suggested that to prevent knee-jerk reactions it was critical to make sure that town leadership was briefed on potential risks associated with a facility located in the town, provided with a range of scenarios that might transpire for planning purposes, and supported in efforts to ascertain how the community will react to potential problems. She had already started to think about what having a greater concentration of UAS in the area might mean for Beaufort, and had reached out to other communities about processes used for planning of similar things such as airport renovations. She also hoped that the facility would include professionals that are aware of rules and regulation to help provide answers to the kinds of questions that may arise—especially since the Town of Beaufort does not have this type of expertise. Jones indicated that the airport is already fielding calls about UAS in the community.

Johnston then directed participants towards an open discussion about next steps. Johnston indicated that Duke was ready to move ahead with specific partners to develop MOUs associated with airspace access, permitting and educational programs. He indicated that Duke would immediately begin exploring the use of the DUNCOC agreement to support interagency work on the facility. Johnston also noted that Duke would help encourage the development of follow-up meetings within the context of what DUNCOC had done. Johnston noted that Duke was ready to run on a few UAS projects that could be seen as early successes for the facility.

Godfrey pointed out that there was a lack of new technology in government agencies and that many were reluctant or unable to access them. Godfrey indicated that providing case studies or proof-of-concept tests would help agencies embrace new approaches that are more efficient, effective, economical, and safe. Jones indicated that the airport would like to see a schedule of operations online for his purposes of directing the local

airspace but also for coordination amongst users. Johnston responded that they had several examples that could be provided online for participants, and that many of the UAS companies had excellent resources online to explore potential solutions. These resources would be added to the facility.

Jerry Moxley, a PhD candidate at Duke Marine Lab, indicated that sharing UAS data would be an important direction for the facility to take the lead in. This would enable collaborations and provide baselines for future surveys. Moore noted that there was much expertise at Duke for large scale data-sharing, such as OBIS-SEAMAP. Johnston noted that Pat Halpin, the PI for OBIS SEAMAP, was a key participant in the proposed facility. Dale furthered this discussion by noting that a networked approach was crucial not just for data sharing, but for sharing information on UAS platform development, survey design and other knowledge.

One of the next steps discussed was broadening the mission of the facility to included surface and subsurface vehicles. Andrew Thaler from the Virginia Institute of Marine Science provided details on small affordable ROVs that could be a great component for an expanded facility. For example, some micro-ROVs cost less than US $1000 with a 2-hour run time. These platforms can work in 5kts of current, dive to 100 meter depths and the payload can be whatever it needs to be as long as it can be balanced for buoyancy. He indicated that entry into this sector would not be accompanied by significant regulatory issues as with UAS. Several workshop participants indicated support for a facility that focused on UAS initially, but suggested that the facility remain open for future developments in surface and subsurface robots. The meeting then moved on to two presentations by UAS manufacturers: PrecisionHawk and senseFly and was followed by fixed-wing and quad-copter demonstration flights on the Duke Marine Lab campus.

PrecisionHawk –Warren Lloyd

Lloyd started his presentation by indicating that PrecisionHawk was an aerial imagery company, not a UAS company. It was formed 10 years ago to provide UAV and data software for actionable business intelligence. He indicated that their primary platform, the Lancaster, was universal and can be used with various applications. He provided details on their data-mapper application, and provided a video that described the cloud-based workflow of their system. Lloyd also provided details on PrecisionHawk's work with the FAA on a new low altitude tracking and avoidance system (LATAS). Lloyd was queried about costs of the current PrecisionHawk UAS. He indicated that the basic airframe costs US $16,500 without sensors, and that sensors range in price from $2,000 to $90,000 US. Lloyd indicated that the cloud processing capabilities were subscription-based, with opportunities to purchase access to advanced processing algorithms developed with university partners.

senseFly – Adam Zylka

Zylka provided an overview of senseFly products including the regular eBee, the eBee ag (agriculture), the eBee RTK (survey grade mapping) and the new multicopter eXom (close mapping). He introduced participants to the range of cameras used on the eBee UAVs including RGB, near infrared, red-edge, multispectral, and thermal (infrared). Zylka provided details on local processing of data to produce 2D

orthomosaics and 3D point clouds. He also noted that the senseFly fixed-wing UAS can cover large areas at 2.5 cm/pixel with up to 50 minute flight times. The senseFly quad-copter was aimed at providing high resolution inspection surveys of smaller areas with 20 minute flight time. The basic costs for the eBee UAS (2 batteries, wings, RGB and software) was US $25,000, the RTK version was US $50,000 and the eXom package was $45,000. (Facilitated by Johnston and Newton).

Workshop Conclusions

The first workshop for UAS in marine science and conservation was very successful. Participants were highly engaged on both days, providing for excellent dialogue on how best to develop a facility for UAS at Duke, and how to build a broader community through existing models, new collaborations and networked information sharing. The following are the main conclusions of the workshop:

1. There is significant opportunity for eastern North Carolina to lead the nation in marine science UAS engineering, applications and training. At present there are no other agencies or institutions contemplating the creation of a facility as it was discussed at the workshop.
2. There is considerable potential to partner with NOAA and other federal entities that use UAS capabilities and/or require UAS support along the east coast. Duke Marine Lab, and the other agencies and institutions, present a nexus of marine science and education professionals that does not exist elsewhere on the east coast of the US.
3. There is desire from workshop participants that a UAS facility would support not only local initiatives, but provide support for regional, national and global marine science efforts as well. It appears that the facility scoped during the workshop, and the scoping process itself, may present a useful model to be applied in other locations.
4. Marine science UAS operators must work diligently to stay within FAA constraints and work closely with DoD and NC DOT airspace authorities when airspace restrictions apply. Workshop discussions about airspace issues provided participants with a much better understanding of how complex the national airspace is, and how it is affected by restricted military airspace.
5. Partnerships could follow the Duke University/University of North Carolina Oceanographic Consortium (DUNCOC) model. Workshop participants felt that the DUNCOC model would speed collaborative activities and provide a solid base upon which to build a UAS facility.
6. Public outreach is a critical aspect of any UAS initiative and key to sustaining good will with local citizens, schools and businesses, and educating them about the positive uses of UAS. The workshop was attended by several civic leaders and representatives of civic groups. Continued engagement with these participants is key for outreach success.

Considering the above key points, Duke Marine Laboratory will continue to develop a facility for UAS in marine science and conservation, and seek to build a larger collaborative community to support research, education and outreach for UAS applications in marine and coastal environments.