Defense Systems Information Analysis Center

DSIAC TECHNICAL INQUIRY (TI) RESPONSE REPORT

Using sUAS for Coastal and Forestry Assessments

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ABOUT DSIAC

The Defense Systems Information Analysis Center (DSIAC) is a U.S. Department of Defense Information Analysis Center sponsored by the Defense Technical Information Center. DSIAC is operated by SURVICE Engineering Company under contract FA8075-14-D-0001.

DSIAC serves as the national clearinghouse for worldwide scientific and technical information for weapon systems; survivability and vulnerability; reliability, maintainability, quality, supportability, and interoperability; advanced materials; military sensing; autonomous systems; energetics; directed energy; and non-lethal weapons. We collect, analyze, synthesize, and disseminate related technical information and data for each of these focus areas.

A chief service of DSIAC is free technical inquiry (TI) research, limited to 4 research hours per inquiry. This TI response report summarizes the research findings of one such inquiry. For more information about DSIAC and our TI service, please visit www.DSIAC.org.

ABSTRACT

The Defense Systems Information Analysis Center (DSIAC) received a technical inquiry requesting information on techniques and sensors for use on small unmanned aircraft systems (sUAS) for shoreline mapping, coastal beach management, and forestry monitoring. DSIAC performed a search using open sources for relevant publications and research projects to determine different UAS methods, documented their findings in a table of light detection and ranging (LIDAR) sensors designed for sUAS, and provided information on organizations that could potentially be interested in collaboration. The most promising techniques identified include LIDAR, photogrammetry, and multispectral imaging.

Contents

List of Figures

List of Tables

1.0 TI Request

1.1 INQUIRY

What information is available on the use of small unmanned aerial vehicle (UAV) light detection and ranging (LIDAR) for coastal mapping beach management, coastal damage assessment, and forestry assessment?

1.2 DESCRIPTION

The inquirer requested relevant articles and opportunities for potential collaboration efforts, as well as information on technologies better than LIDAR/laser detection and ranging. The inquirer identified that they had seen LIDAR and blue/green laser systems for oceanographic and topographical mapping, but these systems are too big for and focus more on commercial-grade UAV systems.

2.0 TI Response

The Defense Systems Information Analysis Center (DSIAC) completed a search using open sources for relevant publications and research projects to determine different unmanned aerial system (UAS) methods. DSIAC staff compiled the findings in a table of LIDAR sensors designed for small UAS (sUAS). DSIAC also included information on an organization that might be able to further collaborate in this area. This response contains publicly-available reports of sUAS and drone uses of LIDAR, or other sensor payloads, for imaging coastal and forested areas.

2.1 LIDAR-EQUIPPED sUAS

LIDAR is used to create high-resolution digital elevation models with a vertical accuracy as good as 10 cm by a laser scanner, global positioning system, and inertial navigation system. The laser scanner transmits pulses such that the distance is calculated by the time it takes for the pulse to be reflected off the ground and received back by the scanner. As these sensors need to be airborne to collect such data, the sensor payload is generally mounted on small aircraft [1]. Secluded and dense areas in nature can prove difficult to acquire such data, so the potential of LIDAR equipment being mounted on sUAS is both desirable and becoming more feasible [2].

The typical max payload of a sUAS is about 10 lbs, while mini-drones (Class 1) have a payload capacity ranging from less than a pound to about 8 lbs, as seen in Figure 1. Typically, sUAS have a weight limit of 55 lbs (25 kg) [3].

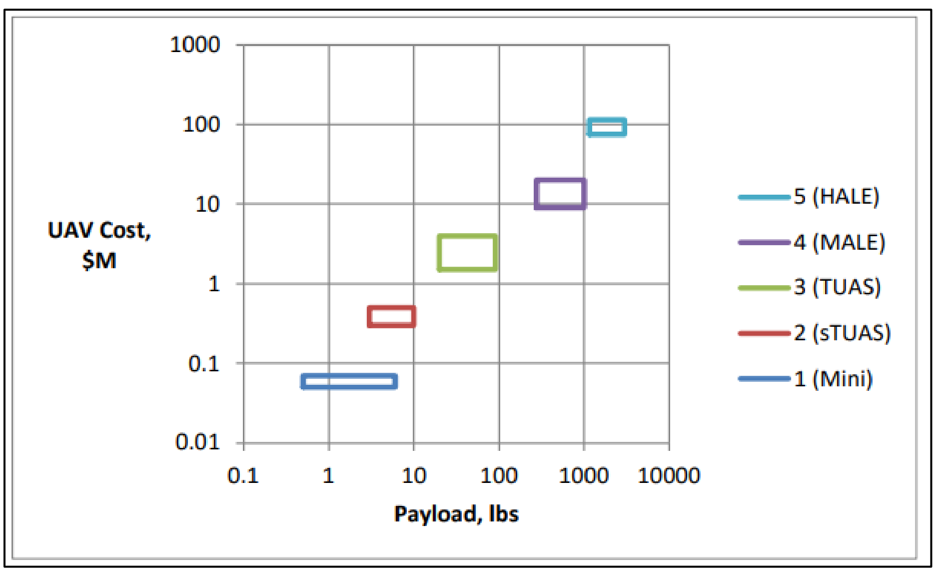

Figure 1: Vehicle Cost and Payload Capacity Ranges for Department of Defense UAS Groups [3].

2.2 UAS PAYLOADS FOR COASTAL ASSESSMENTS

Multiple government and environmental agencies have utilized UAS, specifically sUAS, and various sensor payloads for examining coastlines and beaches, as well as the changes that occur from natural disasters. As noted in the National Estuarine Research Reserve System's roadmap [4], the benefits of sUAS mapping far outweigh the costs. Based on the reports summarized next, the sensor used most prevalently includes LIDAR; another option is using photogrammetry techniques on aerial images.

The National Oceanic and Atmospheric Administration (NOAA) used LIDAR drone technology to map dense marsh areas for gaining a better understanding of marsh vulnerability to sea-level rise in 2018. The detail from the drone imagery provided finer delineations of habitats, with spatial accuracy specifications set at 10-cm root mean square error (RMSE) vertically and 15-cm RMSE horizontally [2]. The final report from this work provides further information on the whole process of imaging and evaluating the data [5]. The project utilized a variety of UAS's, including the DJI Matrice 600 hexacopter and PrecisionHawk Lancaster 5 fixed-wing with either YellowScan systems integration of a Velodyne Puck and Velodyne Puck VLP-16 based LIDAR system, depending on location being surveyed. The study includes a list of lessons learned, which includes adhering to Federal Aviation Administration regulations and the possible limited surveying area in single operation of an sUAS due to battery life. NOAA compared the drone data with manned imagery and data collection [5]. A presentation of this work by the contracted UAS users, Precision Hawk and Quantum Spatial, showcases more on the payload sensors and other equipment integrated with the UAS [6]. LIDAR was also used in a United States Geological Study (USGS) project in Alabama for identifying shoreline changes and calculating sand volume changes from hurricanes [7].

The National Centers for Coastal Ocean Science funded work that mapped shallow, near-shore areas using inexpensive drones and the Structure from Motion (SfM) software to convert two-dimensional images into three-dimensional (3-D) habitat maps. The data from the drone software are compared with LIDAR data in Figure 2, which shows the mosaic overload on LIDAR depths for a reef where the yellow transect corresponds to the depth profile; the green line represents the software data; and the blue line represents the LIDAR data [8].

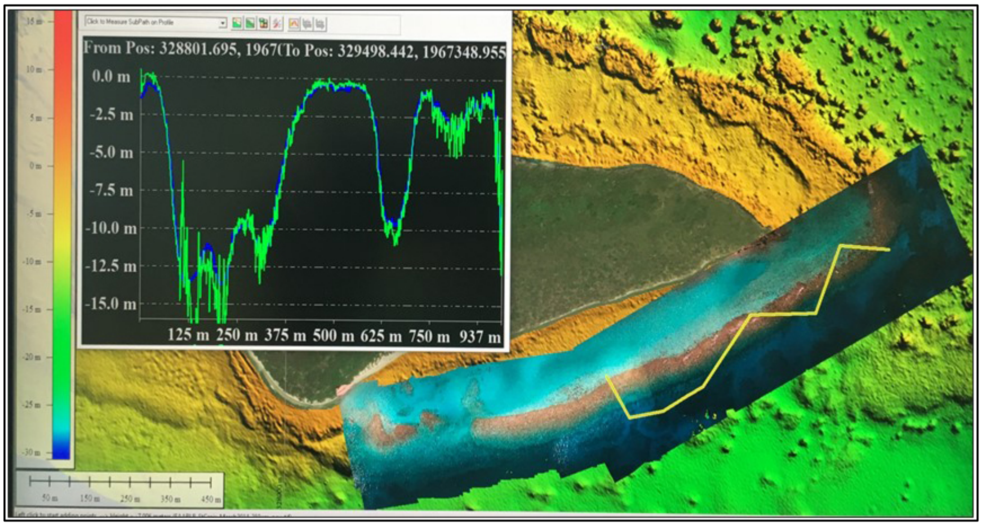

Figure 2: Drone Photo Mosaic Overlaid on LIDAR Depths [8].

Another method of mapping and tracking beach and coastline elevations and erosion problems can be investigated with a technique called photogrammetry, which uses control points on the ground and aerial photographs to form maps with horizontal resolutions of 5–10 cm and vertical precision within 8 cm. This process was used by the USGS at the Woods Hole Coastal and Marine Science Center in Massachusetts to study coastal erosion, sediment transport and storm response, habitat classification biomass mapping, and marsh stability. The center has multiple 3DR Solo quadcopters and a Birds Eye View FireFly6 Pro fixed-wing drone. The resulting images are processed with Agisoft Photoscan and PiX4D software packages. Using photogrammetry, researchers can create maps that are comparable in quality to LIDAR surveys at a fraction of the cost. Additionally, drones can be equipped with multispectral cameras to classify vegetation or identify invasive species [8]. Photogrammetry was found to be a more accurate imaging method, with several hundred measurements per square meter vs. the one to two points per square meter acquired from LIDAR by O. Cohen et al. in the presentation “Mapping Coastal Dunes Morphology and Habitats Evolution Using UAV and Ultra-High Spatial Resolution Photogrammetry” [9]. This project utilized a DJI Phantom IV Pro quadcopter with ground control points to obtain very precise geo-references of the beachfront and sand dunes to create a model.

Post-processing drone images have been used for bathymetric measurements, or measuring water depths, in multiple studies. In one study, a DJI Phantom 2 drone was equipped with a consumer-grade camera with a modified lens to capture overlapping images processed with SfM algorithms. The result was a bathymetric digital elevation model that compared favorably with the LIDAR dataset at a lower cost in favorable conditions [10].

2.3 UAS FOR FORESTRY ASSESSMENTS

Just as the combination of sUAS and imaging techniques has been used for coastal assessments, drones have been used with various payloads to map out areas affected by pathogens. In the reports examined next, the UAS's were equipped with either multispectral or very near infrared (VNIR) cameras to distinguish between healthy and infected trees of various species.

Potentially, the most relevant publication is "Aerial Mapping of Forests Affected by Pathogens Using UAVs, Hyperspectral Sensors, and Artificial Intelligence," by Sandino et al. [11], where hyperspectral imaging sensors are mounted on a UAS to detect and segment the deteriorations by fungal pathogens in natural and plantation forests in Australia. This is explored with the case of myrtle rust on paperbark trees in New South Wales. The authors concluded that the combination of UAS, hyperspectral imaging, and artificial intelligence (coding) resulted in detection rates of 97.24% for healthy trees and 94.72% for affected trees.

In the report "UAV-Based Multispectral Data for Tree Species Classification and Tree Vitality Analysis" [12], a UAS equipped with a 6-band multispectral camera was used to classify trees by species and identify infections of ash dieback disease and the European spruce bark beetle in Austria. It was concluded that the species classification approach was sufficiently accurate and reliable, although the infection identification could be improved.

In the article "Unmanned Aerial Vehicles (UAV) for Assessment of Qualitative Classification of Norway Spruce in Temperate Forest Stands" [13], an investigation in the Czech Republic used drone-equipped VNIR imaging for species and spruce tree health identification. Analysis was based on normalized differential vegetation index and point dense cloud raster.

2.4 SENSOR PAYLOADS FOR UAS

With the increased desire for UAS imaging for applications in areas such as agriculture, forestry, corridor mapping, topography, resource management, shoreline and storm surge modeling, and digital elevation models, it has been important to design and engineer smaller LIDAR sensors specifically to fit drone payload restrictions. A list of LIDAR sensors designed specifically for smaller UAS systems is compiled in Table 1.

Table 1: LIDAR Sensors for UAS

Manufacturer	Model	Range (m)	Weight (g)	Source
LeddarTech	Vu8	215	75	[14]
Velodyne	Puck VLP-16	100	830	[14]
Velodyne	Puck Lite	100	590	[14]
Velodyne	Puck Hi-Res	100	830	[14]
Routescene	UAV LidarPod	100	2500	[14]
YellowScan	Surveyor	150	1600	[14, 15]
YellowScan	Surveyor Ultra	340	1700	[15]
Geodetics	Geo-MMS	—	—	[14]
Geotech	Lidaretto	100-200	<1500	[16]

To receive photogrammetry data, a UAS and good camera are needed because a minimum of one photo every 2 s is required. A few cameras notable for use on smaller UAS's include the Canon S110 and SX260; the Sony QX1, DSC-RX100 A7R, A7, A7S, NEX-6, NEX-5R, NEX-5T, and A5100; and the Panasonic GH3. Specifically, a camera must function well at altitudes above 120 m to get decent results and attach to the drone system, such as a DJI series system [17]. The third portion of technology needed is 3-D photogrammetry software, which is discussed in the DoneZon article "12 Best Photogrammetry Software For 3D Mapping Using Drones" [18].

2.5 SUBJECT MATTER EXPERT (SME) ORGANIZATION

A good organization to contact for further SME assistance or possible collaboration is Georgia Tech Research Institute (GTRI). The Sensors and Electromagnetic Applications Laboratory (SEAL) at GTRI investigates and develops prototype radio/microwave frequency sensor systems, with emphasis on radar systems engineering, measurement and signal intelligence, radar system performance modeling and simulation, advanced signal and array processing, and sensor fusion. The GTRI SEAL website includes the current contact information for the laboratory director and business development contact [19]. According to the Chief of Program Development Operations in the Sensors and Intelligent Systems Directorate, GTRI had previously done work on battle damage assessments using LiDAR and therefore has experts that would have relevant experience [20].

REFERENCES

[1] U.S. Geological Survey (USGS). "What is LIDAR data and where can I get more information?" https://www.usgs.gov/faqs/what-lidar-and-where-can-i-get-more-information?qt-news_science_products=7#qt-news_science_products, accessed 3 April 2019.

[2] Vierra, K. "NOAA Evaluates Using Drones for Lidar and Imagery in the National Estuarine Research." National Oceanic and Atmospheric Administration (NOAA), https://uas.noaa.gov/News/ArtMID/6699/ArticleID/796/NOAA-Evaluates-Using-Drones-for-Lidar-and-Imagery-in-the-National-Estuarine-Research, 19 November 2018.

[3] Fladeland, M., S. Schoenung, and M. Lord. "UAS Platforms." White Paper, National Center for Atmospheric Research (NCAR)/ Earth Observing Laboratory (EOL) Workshop, https://www.eol.ucar.edu/system/files/Platforms%20White%20Paper.pdf, February 2017.

[4] NOAA. "The Way Forward: Unmanned Aerial Systems for the National Estuarine Research Reserves." https://uas.noaa.gov/Portals/5/Docs/Library/The-Way-Forward-UAS-for-NERRS-2016.pdf, 2016.

[5] Waters, K. "Unmanned Aircraft System Lidar and Imagery in the National Estuarine Research Reserve System." Final Report, NOAA, https://uas.noaa.gov/Portals/5/Docs/Projects/FINAL_REPORT--OCM_UAS--08-01-2018.pdf?ver=2018-11-08-145328-793, June 2018.

[6] Faux, R., and M. Coleman. "Small UAS-Based LiDAR Acquisition and Processing Considerations for Natural Resource Management." Presented at Coastal GeoTools, Quantum Spatial, https://coast.noaa.gov/data/docs/geotools/2017/presentations/Faux.pdf, 9 February 2017.

[7] Ebersole, S., and B. Cook. "Topographic Maps and LiDAR in Field Mapping and Research at the Geological Survey of Alabama." Presented at Digital Mapping Techniques (DMT) 2018, Lexington, KY, https://ngmdb.usgs.gov/Info/dmt/docs/DMT18_Ebersole.pdf, 20–23 May 2018.

[8] USGS. "Aerial Imaging and Mapping." https://www.usgs.gov/centers/whcmsc/science/aerial-imaging-and-mapping?qt-science_center_objects=0#qt-science_center_objects, accessed 8 April 2019.

[9] Cohen, O., A. Cartier, and M.-H. Ruz. "Mapping Coastal Dunes Morphology and Habitats Evolution Using UAV and Ultra-High Spatial Resolution Photogrammetry." Presented at International Workshop "Management of Coastal Dunes and Sandy Beaches," Dunkirk, https://www.researchgate.net/profile/Olivier_Cohen/publication/326059214_Mapping_coastal_dunes_morphology_and_habitats_evolution_using_UAV_and_ultra-high_spatial_resolution_photogrammetry/links/5b35dc29a6fdcc8506db7745/Mapping-coastal-dunes-morphology-and-

habitats-evolution-using-UAV-and-ultra-high-spatial-resolution-photogrammetry.pdf, 12–14 June 2018.

[10] Casella, E., A. Collin, D. Harris, S. Ferse, S. Bejarano, V. Parravicini, J. L. Hench, and A. Rovere. "Mapping Coral Reefs Using Consumer-Grade Drones and Structure From Motion Photogrammetry Techniques." In *Coral Reefs*, vol. 36, no. 1, pp. 269-275, https://link.springer.com/article/10.1007/s00338-016-1522-0, March 2017.

[11] Sandino, J., G. Pegg, F. Gonzalez, and G. Smith. "Aerial Mapping of Forests Affected by Pathogens Using UAVs, Hyperspectral Sensors, and Artificial Intelligence." In *Sensors (Basel),* vol. 18, no. 4, p. 944, https://www.mdpi.com/1424-8220/18/4/944/htm, April 2018.

[12] Kampen, M., S. Kederbauer, J.-P. Mund, and M. Immitzer. "UAV-Based Multispectral Data for Tree Species Classification and Tree Vitality Analysis." ResearchGate, https://www.researchgate.net/profile/Max_Kampen2/publication/331895337_UAV-Based_Multispectral_Data_for_Tree_Species_Classification_and_Tree_Vitality_Analysis/links/5c921f1a92851cf0ae89d417/UAV-Based-Multispectral-Data-for-Tree-Species-Classification-and-Tree-Vitality-Analysis.pdf, accessed 8 April 2019.

[13] Brovkina, O., E. Cienciala, P. Surovym, and P. Janata. "Unmanned Aerial Vehicles (UAV) for Assessment of Qualitative Classification of Norway Spruce in Temperate Forest Stands." In *Geo-spatial Information Science*, vol. 21, no. 1, pp. 12–20, https://www.tandfonline.com/doi/full/10.1080/10095020.2017.1416994?scroll=top&needAccess=true, 2 January 2018.

[14] Corrigan, F. "12 Top Lidar Sensors For UAVs and So Many Great Uses." DroneZon, https://www.dronezon.com/learn-about-drones-quadcopters/best-lidar-sensors-for-drones-great-uses-for-lidar-sensors/, 26 January 2019.

[15] YellowScan. "Overview." https://www.yellowscan-lidar.com/products, accessed 8 April 2019.

[16] Small Unmanned Aerial System (sUAS) News. "Lidaretto." https://www.suasnews.com/2019/04/lidaretto/, 1 April 2019.

[17] Corrigan, F. "Introduction to UAV Photogrammetry and Lidar Mapping Basics." DroneZon, https://www.dronezon.com/learn-about-drones-quadcopters/introduction-to-uav-photogrammetry-and-lidar-mapping-basics/, 10 December 2018.

[18] Corrigan, F. "12 Best Photogrammetry Software for 3D Mapping Using Drones." DroneZon, https://www.dronezon.com/learn-about-drones-quadcopters/drone-3d-mapping-photogrammetry-software-for-survey-gis-models/, 3 March 2019.

[19] Georgia Tech Research Institute. "Sensors and Electromagnetic Applications Laboratory (SEAL)." https://www.gtri.gatech.edu/laboratories/sensors-and-electromagnetic-applications-laboratory, accessed 1 April 2019.

[20] Georgia Tech Research Institute Chief of Program Development Operations. Personal communication, 15 May 2019.