UAV Manufacturers & Researchers Search for the Optimal Sensor Package for Atmospheric Studies

Anemoment™
Know the Wind

With the increased use of unmanned aerial vehicles (UAV) in atmospheric research and meteorological studies, selecting the optimal sensor package becomes essential to the researcher's success. Below are some case studies looking at how UAV manufacturers and researchers are addressing this challenge and their findings.

TEN TECH LLC (www.tentechllc.com)

Recently, Ten Tech LLC, a provider of aerospace and defense engineering services, announced the launch of its Huracán Multi-Purpose Aerial Drone (MPAD), a quadcopter UAV (unmanned aerial vehicle) flight demonstrator platform designed for sensor testing, environmental data acquisition, communication and processing. The Huracán MPAD (Figure 1) is based on a DJI Phantom 4 drone and has been enhanced with several off-the-shelf sensors and communication modules including Digi XBEE and Anemoment's TriSonica™ Mini Wind & Weather Sensor. The platform is designed to serve as an aerial sensor testbed as well as a proof-of-concept for further tactical, commercial and R&D UAS developments.

Figure 1: Huracán Multi-Purpose Aerial Drone

"One of the difficulties of integrating COTS (Commercial Off-The-Shelf) electronics is evaluating performance under harsh conditions, such as MIL-STD-810," emphasizes William Villers, VP of Engineering, Ten Tech LLC. "Our Huracán quadcopter sensors were validated by simulation. Using MSC Software's Software Cradle CFD STREAM, we can predict thermal performance quickly and accurately (Figure 2)."

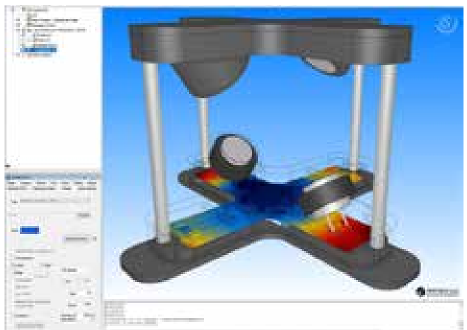

Figure 2: Thermal performance testing of the TriSonica Mini

Extensive Finite element analysis (FEA) was performed on the main airframe structure to ensure survival of the sensors under harsh shock & vibration to MIL-STD-810 standards. Computational fluid dynamics (CFD) were used for aerodynamics studies and flight performance characterization, allowing for an optimized sensor positioning for both balancing flyability and minimizing propeller aerodynamics interference.

"We do a lot of testing virtually before even putting anything together or testing it physically," Villers adds. "We look at the thermal performance of the components and see if we're going to get a hotspot and see how high in temperature we can go, as far as ambient temperature. We do the same thing with vibration, because we have vibration from the structure itself, from the quadcopter and it has a tendency of shaking the electronics and cracking the boards and cracking the components and the solders, so we looked at that in detail too. Eventually we want to be able to function on the field for military stuff usually means less than a 1% failure rate. That's the kind of reliability we need to achieve."

The TriSonica Mini Wind & Weather Sensor was chosen for a number of reasons, weight and size being two key considerations. "The TriSonica Mini is very, very light, and since we put it high up over the structure, the lighter it is, the better it is," states Villers.

While its physical characteristics were important factors in its selection, service and support were equally critical to Ten Tech and Villers. "It has really been a pleasure to deal with Anemoment," Villers says. "The support and the knowledge that Stephen and Liz provided us was important too. It makes a real difference."

Integration of the sensor package on the Huracán, given the variety of components, proved to be challenging, but not insurmountable. "We have some RF sensors, some GPS positioning, some wireless capability, the ultrasonic anemometer, and an RGB camera, which eventually we will replace with most likely an IR camera," said Villers. "Honestly, among all of the sensors that we used, the TriSonica Mini was the easiest to integrate, even though it was the most sophisticated, as far as functionality. The TriSonica Mini was the component we were the most worried about, yet it turned out to be the easiest to integrate."

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The Huracán MPAD successfully passed all functional and operational tests, including both piloted and autonomous flight while recording and transmitting environmental data.

Villers is quick to add, "Good people make good products. Anemoment's products are really good. They do exactly what they're supposed to do. I couldn't ask for more."

AEgis Technology Group (aegistg.com)

Atmospheric research is an expanding science, to say the least. To estimate optical turbulence and boundary layers, researchers have relied on numerical weather modeling. Traditionally, this involves differential temperature sensors installed on a tower (Figure 3) to measure temperature at multiple places simultaneously. These observations provide unquestionable value to meteorological studies. Yet this approach fails to provide detailed profiles of temperature, moisture, and winds within the atmospheric boundary layer (ABL) found above the weather tower.

Figure 3: Tower with sensors installed measuring temperatures.

The introduction of unmanned aerial vehicles has proven to compliment traditional measurements with a unique capability to sample multi-dimensional ABL structure well beyond the height of the tower (Figure 4).

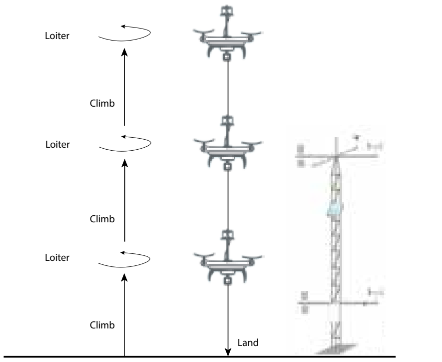

Figure 4: The climb and loiter approach used to capture atmospheric data.

Alex Clark, Senior Engineer at AEgis Technology Group, has assembled a sensor package designed specifically to gather essential atmospheric measurements in the upper ABL. Named the WP-V2 (Weather Payload Version 2), this payload package can be mounted to any number of UAVs and is equipped with a variety of atmospheric sensors and measurement devices enabling real-time weather monitoring (Figure 5).

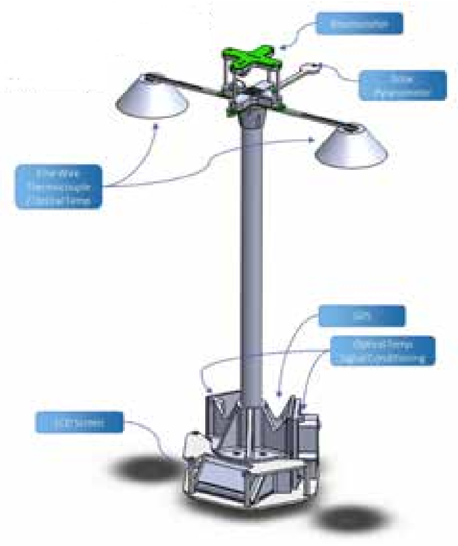

Figure 5: Weather Payload Version 2 (WPV2)

"In the real world, we're trying to limit the size of our airframe, limit the SWaP (Size, Weight and Power), and still collect accurate and meaningful data," says Clark. "Because of its SWaP attributes, the TriSonica Mini is the perfect complement to our payload package."

Platform agnostic, the WPV2 can be mounted on nearly all multi-rotor UAVs. Platforms it has deployed on include the Intense Eye Version II (IEV2), a 750 millimeter quadcopter; the E900, a larger 900 millimeter quadcopter; and the DJI M600, a 1668 millimeter hexacopter (Figure 6)

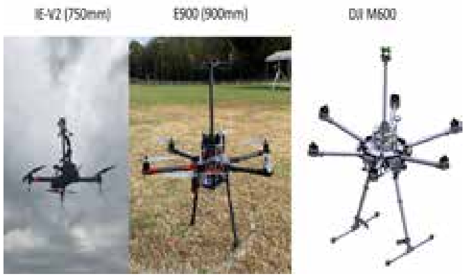

Figure 6: Tested platforms for the WPV2 sensor package.

SPARV EMBEDDED AB
(sparvembedded.com)

UAVs provide a convenient and effective way to sample methane, a gas with a greenhouse effect 84 times stronger than carbon dioxide. Sparv Embedded is helping Linköping University to integrate a high precision CH4 (methane) sensor from Aeris Technologies with the Sparvio system. The sensor has an unprecedented CH4 resolution for its size, measuring variations smaller than one ppb (parts per billion). This is more than enough to map background levels, around 2 ppm.

(Figure 7) shows a quadcopter hovering with the white Aeris sensor attached underneath. The quadcopter also carries a Sparvio sensor system that synchronizes data from Aeris with readings from a the TriSonica Mini ultrasonic wind sensor, GPS and other sensors. Sparvio logs all data and transmits it to a ground station to visualize on a map in real-time. In the end, the combination of all data will be used to calculate not only the location of methane emission sources, but also the quantity of gas flow.

Figure 7: Capturing high resolution methane measurements from a UAS.

"The TriSonica Mini is the lightest 3D wind sensor available," states Anders Petersson, President, Sparv Embedded AB. "This positions the TriSonica Mini to address the blind spot of wind sensing capabilities of small UAV. The TriSonica Mini is a natural addition to our Sparvio sensing platform."

"One thing that we know about fire behavior—and most people neglect this—is that the vertical profile in the wind has been shown to cause erratic fire behavior," says Craig Clements, Ph.D., Professor, Fire Research Laboratory, Wildfire Interdisciplinary Research Center, San Jose State University. "If it's got a strong wind shear, you've got wind blowing at the surface in one direction, and you have wind going above that layer in the opposite direction, you can get erratic fire behavior."

SJSU SAN JOSÉ STATE UNIVERSITY

Under the direction of Dr. Clements, the Fire Weather Research Laboratory has been conducting meteorological profiling of wildfires using UAS, often referred to as unmanned aerial vehicles (UAV) or drones. Their research has demonstrated that a UAS equipped with a sonic anemometer is effective for taking vertical profiles of atmospheric variables, while also being used in place of meteorological tower measurements for sampling the fire environment.

Assisting Dr. Clements in this research was Matthew Brewer, a Graduate Research Assistant in the Fire Weather Research Laboratory. Brewer proved to be a critical asset as he piloted the UAS for this series of wildfire studies.

"I've always thought that there's a good fit for UAS in atmospheric science, especially for high resolution sampling," says Brewer. "That belief and my interests in things like fire weather and downslope windstorms really aligned with what Dr. Clements' research goals were. That's what brought me to San Jose State and it proved to be a really unique opportunity that I wouldn't have had any other place."

Flying a **DJI Matrice 200 (M200)** equipped with a TriSonica™ Mini Wind and Weather Sensor from Anemoment, LLC (Figure 1), the team, working collaboratively with the United States Forest Service (USFS) and the Desert Research Institute (DRI), sampled the vertical wind profiles of 3-dimensional (3D) winds generated by wildfires.

The DJI M200 quadcopter is a commercial, off-the-shelf platform chosen for its ease of use combined with obstacle avoidance measures and ease of maintenance. The sensor package selected records three components of wind speed (u, v, w), wind direction, sonic temperature, humidity, pressure, magnetic heading, pitch and roll rates up to 5 Hz.

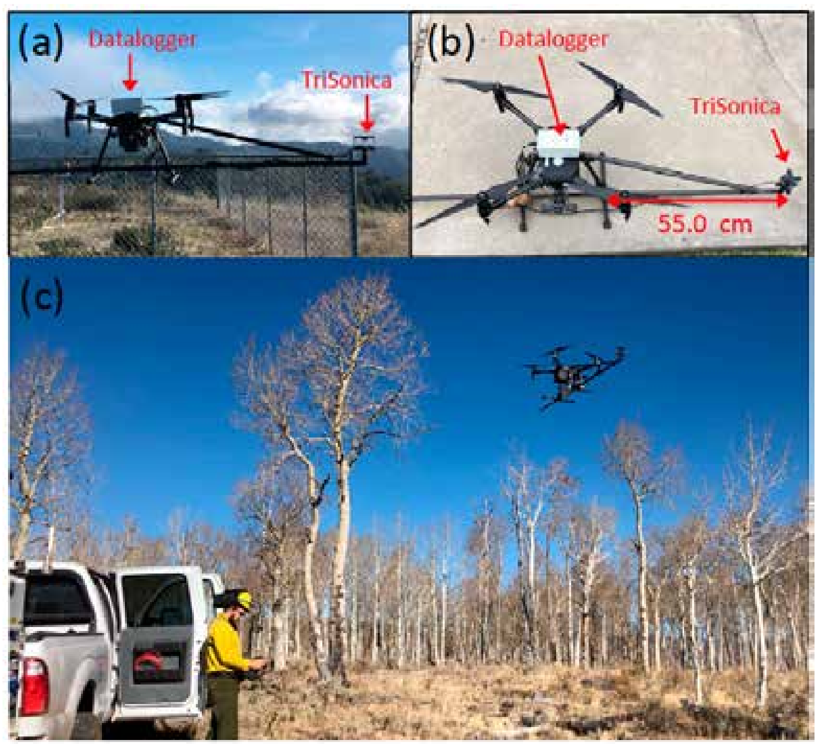

Figure 1: Photos of UAS system to showing system design and operation. (a) Horizontal view of system with hovering. (b) The TriSonica Mini was mounted on a carbon fiber pole extending 55 cm off the body of the UAS with the datalogger fixed to the top of the platform. (c) The profiling flight in the Fishlake National Forest, Utah, 7 November 2019.

"This sensor is ideal for the UAS due to the output of magnetic heading and accelerometer corrections, as well as its small mass of only 50 grams. The really cool thing about the TriSonica Mini is it auto-corrects; it has got an inertial measurement unit (IMU) so it automatically corrects for pitch and roll. That's huge!"

Craig Clements, Ph.D.

Placement of the sensor was critical. Too close to the rotors and the resulting rotor wash could compromise the resulting data. The team saw pictures on the Anemoment web site (anemoment.com) of an octocopter flown by researchers from the U.S. Naval Academy and George Washington University where the sensors were mounted to a boom extending off to the side of the UAS platform. Leveraging this design, the team began to test placement options in an effort to minimize any bias caused by the rotors.

"Our decision to place the sensors off to the side was driven in part by our desire to obtain vertical velocities," clarifies Clements. "The whole point to deploying a 3D sonic anemometer is to take advantage of the capabilities of the device for micrometeorology, where you really want to get tangential (W) velocities, and we determined the optimal placement then was on a boom below the vehicle."

Placing the sensors off to the side of the quadcopter offered another benefit in that the platform can be rotated into the wind so that rotors are downwind of the sensor for even cleaner readings.

After several tests, the team placed the sensors approximately 55 cm (two-times prop width) from the body of the UAS as anything further than this caused the platform to be unstable. They then elected to install Anemoment's data logger to the top of the UAS powered by a 5V USB port integrated into the M200.

Figure 2: Calibration tests conducted with TriSonica Mini and RMY anemometer.

The accuracy and biases of the Anemoment system were evaluated over several flights next to a R.M. Young (RMY) 81,000 3D sonic anemometer (Figure 2), with the resulting data logged using a Campbell Scientific CR1000 data logger. Clements notes, "In low-wind speed tests, the UAS platform performed exceptionally well when compared to the RMY, with no clear bias." Their tests showed that in moderate-wind comparisons that there was an overall positive bias of ~0.5 ms-1 in the UAS-measured wind speeds, compared to the RMY tower-mounted measurements. Clements was quick to clarify that this bias is not constant, with periods when UAS wind speeds were 1 ms-1 less than tower wind speeds. Their research demonstrated that when the anemometers were mounted next to each other, the TriSonica Mini sonic anemometer had a low bias compared to the RMY and can accurately measure temperature compared to the RMY.

When asked about the TriSonica Mini, Dr. Clements emphasized, "It's really inexpensive. Not poorly made, but well priced, accurate and easy to integrate into a UAS or tower platform. And really once I learned that Steve Osborn (Chief Technology Officer for Anemoment) was the designer of my favorite sonic anemometer at ATI (Applied Technology, Inc.), which I still use and I'm buying two more SX probes, I was like, 'Oh, cool.' The science behind the TriSonica Mini is the same as with all the ATI sonics, that I just think are the best sonics out there. That was important for me as well."

Sensor Placement is Critical

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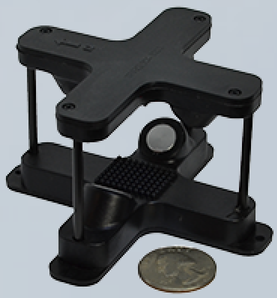
OPTIMIZING SWaP
Size, Weight, and Power

The TriSonica™ Mini Wind & Weather Sensor is the world's smallest and lightest 3-dimensional ultrasonic anemometer.



Small enough to fit in the palm of your hand, the TriSonica Mini is a highly accurate, powerful tool for anyone involved in atmospheric monitoring, weather reporting, turbulence calculations, and ecosystem research.

Even with its small size it provides wind speed, direction, temperature, humidity, pressure, tilt, and compass data. The TriSonica Mini can also provide measurements of all three dimensions of air flow.

The open path provides the least possible distortion of the wind field. Four measurement paths provide a redundant measurement. The path with the most distortion is removed from the calculations to provide accurate wind measurements. Further, data output can be customized to user requirements.

Available with a pipe-mount base accommodating any 1/2" DN15 Schedule 10 pipe. To further protect components and streamline your installation, wiring runs through the interior of the pipe when using this configuration.

> " For me, size and weight are key attributes. The TriSonica™ Mini is small, easy to put on the UAV and it doesn't take much power. I can always add more instruments to my payload, especially if they all weigh nothing and they don't take up any space.
>
> ***Alex Clark***
> *Senior Engineer, AEgis Technology Group*

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