QUANTUM™ TECHNOLOGY SCIENCES

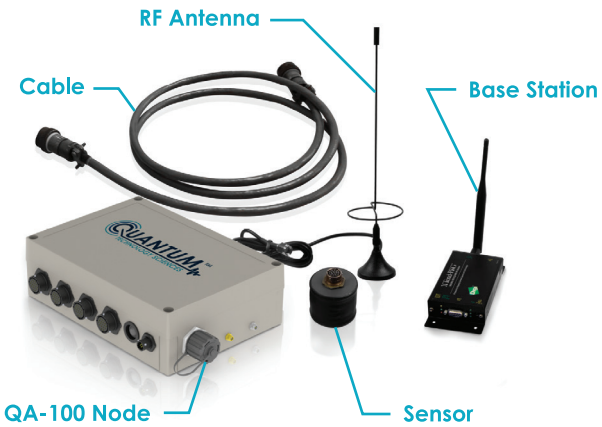
Detecting, Classifying, and Tracking Unmanned Aerial System Aircraft with Quantum's Vector Series QA-100™ Intrusion Detection Solution

A rapidly developing phenomenon of concern to critical infrastructure and corrections interests is that of detecting and alerting to the presence of low cost, high performance Unmanned Aerial Vehicles (UAVs), sometimes known as "drones". Whether in the hands of a novice or experienced pilot – a UAS can pose potential problems regarding aerial trespassing, potential vandalism, delivery of contraband or even the predication of a potential assault. The resulting penetration or surveillance of critical infrastructure assets can evolve into safety issues, potential equipment damage, corporate exposure to liability or poor public relations.

Though UAS aircraft can support effective security operations, in the wrong hands and for malicious intent, they can also be a significant security threat to critical infrastructure facilities.

Drones, when combined with their ground control stations and data links, are referred to collectively as Unmanned Aerial Systems (UASs). Evolved far beyond predecessor systems available to the "Radio Control" hobbyists of the 20th century, modern UASs are inexpensive, readily available, and easy to use. They can carry high quality video cameras and other nefarious payloads.

As a reconnaissance tool, a UAS may help provide security for critical infrastructure facilities, as it can quickly be on-scene to visually verify intrusion threats reported by other sensor systems. However, a UAS can also be a threat to critical infrastructure, depending on how it is used, by whom, with what intent, and on the vulnerabilities of the target facility. A UAS in the wrong hands can smuggle goods, acquire visual intelligence on or deliver a destructive payload to a critical infrastructure facility or to any other valued asset accessible by air. With the increased incidence and audacity of UAS activity, security personnel place critical importance on knowing when an unknown UAS is in the vicinity of any secure site.



Cutting through the Noise – Detecting the UAS Sooner & More Reliably

The Quantum Technology Sciences Vector product line uses seismic-acoustic technology to create a perimeter security awareness zone around high value assets. UASs are among the potential threats the technology detects, tracks, and reports. The detection capability is proving more reliable than the "acoustic" only capabilities of the solutions presently available on the market that depend on continuously uploading new aircraft profiles in order to keep up with the rapidly emerging vehicles and their improving capabilities; or RF-only devices that often mistake the small craft for birds and increase nuisance alarm rates.

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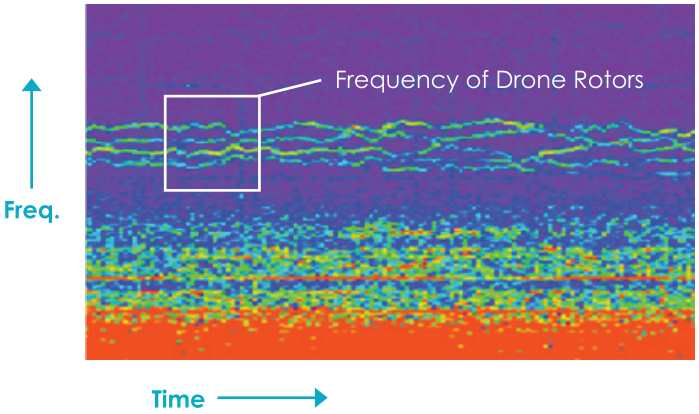
Application for Unmanned Aerial Systems

When a propeller- or rotor-driven drone is in operation, it injects energy into its environment in several ways. In either a gas- or electric-powered drone, the rapidly rotating propellers or rotors interact with surrounding air to force energy into the drone environment. If its engine(s) are combustion-based, rapidly expanding, hot, combusted gases exiting the engine cylinders generate exhaust noise. Both of these energy sources generate acoustic waves, or vibrations, which propagate in all directions, ultimately intersecting the earth and exciting seismic waves. Quantum's Vector seismic-acoustic sensor solution detects and automatically processes these vibrations as they propagate through the ground into Quantum's deployed, invisibly buried sensors. The vibrations generated by drones have attributes known as features and produce characteristic signatures in both time and frequency. These unique drone signature elements enable the presence of a drone and its location to be reported in real-time.



A quadcopter drone spectrogram, showing the energy distribution in the detected signal as a function of frequency and time. Note the signal of each of the four rotors in the higher frequencies. The signals at the lower frequencies are noise and clutter and are ignored by the classification algorithms.

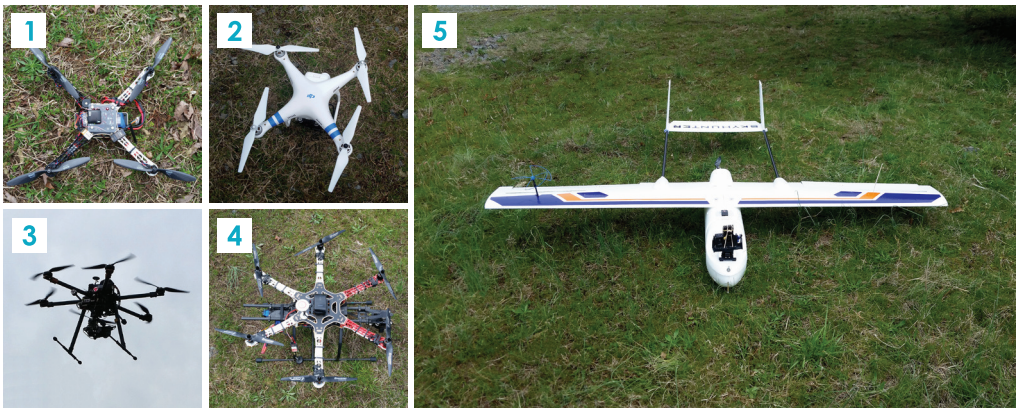
The Quantum QA-100 with SADAR uses a coordinated array of coherent buried sensors to detect the UAS signatures. With the SADAR system, the detected energy from each of the array sensors is phase-combined using sophisticated signal processing to exploit signaturet features in time, frequency, and space. In real time, SADAR can determine the bearing (direction) to the drone, a unique capability for buried ground sensors.

Software algorithms analyze the time, frequency, and spatial features in the detected signal automatically and in real-time to determine if the detected signal represents one of the potential threat types it is seeking, in this case a UAS, and confirms its findings by complex statistical means. Once it classifies a detection as a UAS with sufficient confidence, the system sends an alert to the user interface. The alert contains the threat classification (UAS), the bearing of the UAS location from the sensor array, in degrees, and other information. The data processing is immediate, and alerts are sent directly to Quantum's stand-alone System Monitor or to a 3rd party Security or Supervisory Control And Data Acquisition (SCADA) Center application. Quantum's Vector data packets easily integrate into existing security and surveillance systems to enhance their capabilities. The alerts can directly cue Network Operations Center personnel, provide cues for cameras, customer UAVs, and/or other security system elements to facilitate visual and other verification the presence of the aircraft. They can also initiate deterrence activities to discourage further intrusion.

The Table lists some of the unmanned aircraft types Vector has detected and tracked at distances ranging up to hundreds of meters from working critical utility assets. The UAS types used represent a broad span of capabilities, airspeeds, costs, features, and payloads. All were powered electrically, which generates far less detectable vibrations than does a drone with gasoline or other combustion engines.

NAME	TYPE	# OF ROTORS/PROPELLERS
Quad 450™	Quadcopter	4
DJI Phantom 2™	Quadcopter	4
Tarot 810™	Hexacopter	6
Hex 550™	Hexacopter	6
Skyhunter™	Airplane	1

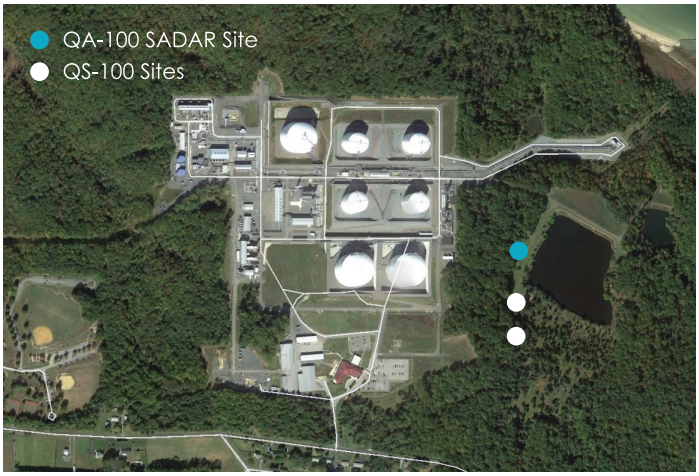
DETECTING & TRACKING DRONES



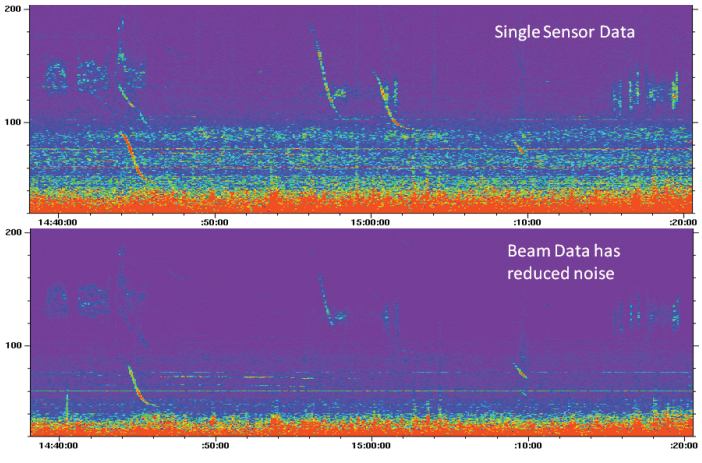
1 *Quad 450™*
2 *DJI Phantom 2™*
3 *Tarot 810™*
4 *Hex 550™*
5 *Skyhunter™*

Testing for this Note was done in the vicinity of an active Liquid Natural Gas (LNG) terminal, with two Quantum Vector series products. The first product, from the Quantum Vector QS-100 Single Channel series, comprises a single, autonomous sensor and an electronic node providing automated signal processing. The other product, from the Quantum Vector QA-100 SADAR series, uses an array of coherent sensors to extend sensing range and to continuously indicate the bearing from the array to the potential threat. The figure illustrates the product deployment locations. Note that the area is heavily wooded, highlighting the importance of non-line-of-sight technology to detect and classify threats.

With the in-ground sensors in place and activated, the drones were flown in straight line courses and meandering patterns at varying altitudes and speeds over the area. The vibrations generated by the drones were detected by both the Vector QS-100 and Vector QA-100 with SADAR systems. The figure shows a comparison of the data spectrograms. Though both products can detect and classify drones, QA-100 with SADAR systems combine the data from the sensors in their sensor arrays early in the data processing. This reduces noise and clutter, and enables the formation of a directional beam. In this case, the UAS threat is isolated by the SADAR system while it ignores competing noise coming from non-threat sources such as the LNG terminal itself.



LNG terminal and sensor deployment locations. The terminal was active and generated significant noise and clutter, but the QA-100 with SADAR analytical algorithms simply ignored the energy coming from the direction of the facility, increasing system sensitivity.



Comparison spectrograms between UAS data acquired by a single sensor and the combined data of the SADAR array. Both detected sufficient data to classify a drone as such, but the SADAR array data has much less noise and clutter, enabling drone detection and classification at significantly enhanced range. The SADAR array data also forms a beam indicating direction from the array to the drone.

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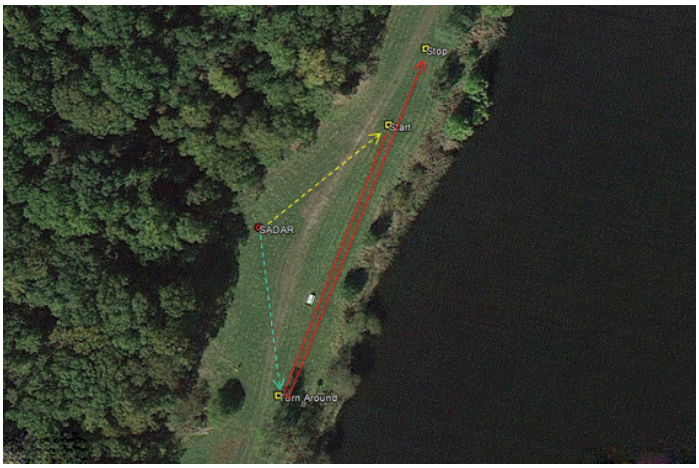
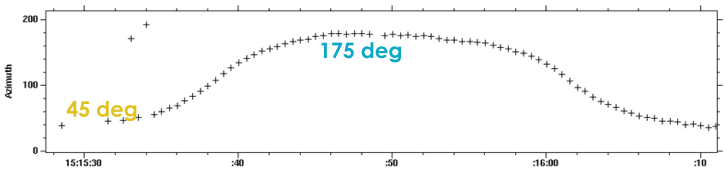
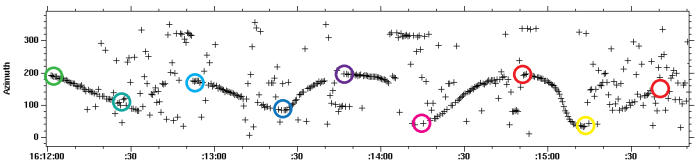
The next figure illustrates the SADAR results for one of the drones, the TAROT 810™, a hexacopter powered by six electric motors. It was flown back and forth along a northeast to southwest line which passed the SADAR array location. The plot is of the drone bearing as a function of time, as viewed from the array location. The bearing to the drone with respect to due north initially increased as the drone approached the sensor array. The drone hovered at its turn-around point, nearly south of the array, then returned to beyond its starting point, until contact with the array was lost at an array-to-drone distance of about 50 meters. In practice, the system generates an aerial view on a graphical user interface screen and tracks the drone with a dynamic, real-time line which points from the array location towards the drone position. Similar detection and bearing results were achieved for the other drones flying similar patterns.

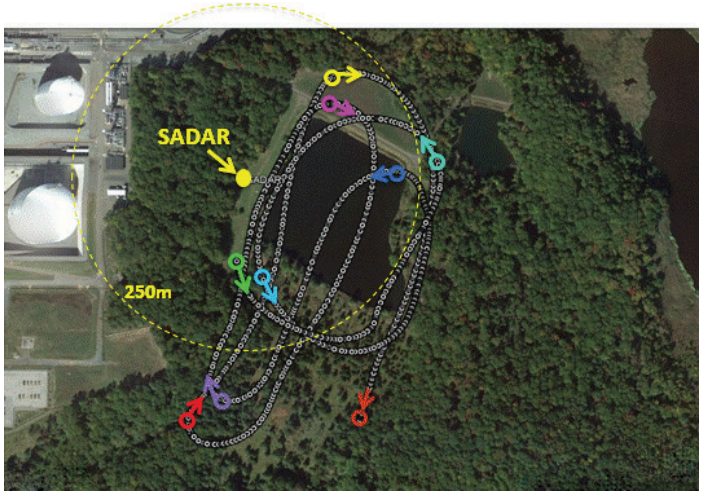




Aerial view indicating flight path of TAROT 810™ drone, first SW at 60 feet altitude, then reversing to the NE. Plot shows azimuth from SADAR array to drone, beginning at 45°, increasing to 175° at turnaround, then decreasing to about 40°, effectively tracking drone movement. Maximum detection range for this drone was t50 meters.



Skyhunter™ drone tracked by SADAR. Aerial view shows path taken by drone. Colored circles link drone position in aerial view to azimuth plot above. Red circles correspond to maximum tracking distance of 350 meters.



For the SkyHunter™ drone meandering flight, see the final figure. It was detected and tracked continuously at distances ranging up to 350 meters, with much of the flight being in non-line-of-sight conditions from the array location. The circles in the figure correlate the GPS position of the drone in the aerial view with its bearing from the SADAR array.

The focus of this Application Note has been on the Quantum Vector QA-100 with SADAR and its ability to detect, classify, track, and alert on the aircraft associated with Unmanned Aerial Systems. The Vector QA-100 can simultaneously detect, classify, track, and alert on many other targets, including footsteps and vehicles. For UAS attacks in which the UAS operator travels to the vicinity of the site to deploy the drone, a Vector QA-100 system will also alert on and track both the ingress and egress of the human threat accompanying the UAS, delivering even more time and space for security force interdiction.

Conclusion

UAS incursions into critical infrastructure facilities may be both dangerous and costly. For example, a UAS attacking a power utility substation has the potential to cause property damage, disrupt power transmission, cause loss of productivity and result in the need for expensive repairs and replacement. Such an incident may even initiate a cascading effect throughout the power grid, resulting in massive power losses that adversely affect public services and safety. It is vital to immediately acquire and report actionable information associated with any potential occurrences of this type. By providing early warning to personnel that a potential aerial threat is approaching a secured facility, this technology supports proactive threat deterrence, either as an autonomous system or integrated into existing or anticipated comprehensive security systems to minimize cost and complexity.

For correctional institutions – protecting the inmates and providing security for the guards – preventing contraband from entering the facility is of the utmost importance. And being able to detect the pilotst from a covered position as they prepare for launch or pilot the craft over the facility gives Security time to intervene, collect the items deposited before they enter the general population, and potentially apprehend the pilots and prosecute them for their acts.

The Quantum solution provides critical infrastructure, high value assets, oil & gas assets and borders with enhanced full area coverage for the potential threats presented by unauthorized footsteps, motor vehicles, digging, gunshots, UASs, and, upon request, other activities identified as associated with potential threatening situations.

About Quantum

A tactical geophysics company firm with a strong background in asset protection, Quantum Technology Sciences provides situational awareness solutions for intrusion detection and movement monitoring. The company's products safeguard high value assets and critical infrastructure facilities within the energy industry.

Learn more by visiting the Quantum Technology Sciences website: **www.QTSI.com**
Or call us at: **321-688-0288** to speak with a business development representative.