Ukrainian Air defense forces engage attacking drones. (Photo Getty Images)

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Mobility Matters: Innovating for Area Air Defense

By COL Jeremey M. Davis

Over a field east of Poltava, the sound of a 4-cylinder piston engine rumbles through the quiet of the night. A small electronic box attached to a cell tower records the sound, identifying the audio profile of a Geran-2 loitering munition, and transmits the data for processing. Responding to an alert, two soldiers fire up the engine on their Nissan pickup truck and go speeding down the road to the grid coordinates provided. In position, they scan the horizon in the direction of the attack. They have only a narrow window of opportunity. Tracers arc into the sky from their old but reliable DShK, their efforts rewarded as the drone disappears in a fireball.

Under constant missile bombardment by the Russians and with Ground Based Air Defense (GBAD) assets in short supply, the Ukrainian Army received aid from an unexpected direction: a voice spoofing company in the tech sector. Zvook is the word for "sound" in Ukrainian, and it's the original name of a project started by i3 Engineering CEO Pavlo Tsiupka and the co-founder of Respeecher, Dmytro Believtsov. Together, they developed a system to address the threat of low-flying cruise missiles and unmanned aerial vehicles (UAVs).

Renamed "Sky Fortress," the system comprises thousands of audio sensors networked to distributed processing nodes running machine-learning algorithms to identify air threats. Systems like Patriot are highly effective at tracking and engaging high-altitude threats at a distance, forcing threats to evade by flying low. Ground-based radars struggle to identify low-altitude targets at extended ranges due to a combination of terrain masking and the curvature of the Earth. However, flying low puts cruise missiles at an altitude where ground-based audio sensors can detect their unique audio signatures.

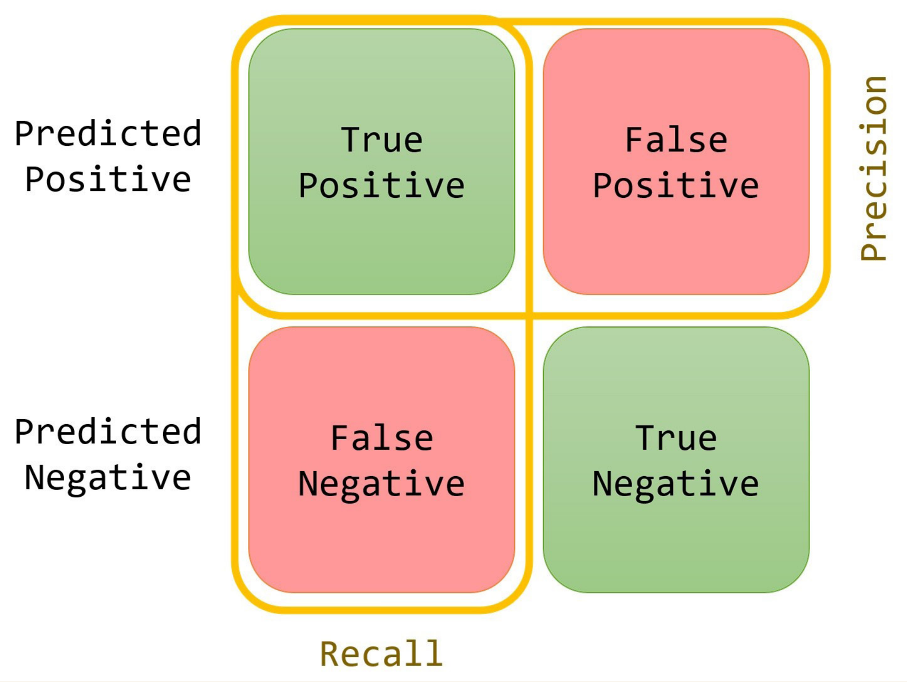
The sensors themselves are a vital part of the Sky Fortress system. Parabolic mirrors focus the audio energy to enhance the fidelity of the microphones. The use of parabolic mirrors in an air defense role has historical precedence in World Wars I and II. However, since Sky Fortress relies on digital microphones instead of human ears, the parabolic mirrors can be much smaller—roughly the size of a TV satellite dish.

A Zvook Audio Sensor
(Photo by Khrystyna Parubiy)

Each sensor's primary housing unit is roughly 12" x 12" x 2" and contains an off-the-shelf Android phone and a backup battery in the event of power loss. Lastly, the sensors are mounted on elevated structures, such as cell towers, which are conveniently located at regular intervals and easily accessible for maintenance. Each sensor costs just over $500 to manufacture, making them cost-effective to deploy in volume.

Another major system component is the machine learning algorithm, which determines whether the sound originates from an aerial threat. Machine learning describes the method by which a computer applies an algorithm to adapt to new information in a way that mimics human learning. In this case, the developers used supervised learning, where humans labeled a vast database of sounds and fed them into the system as the training set. Initially, the model could only correctly identify a hostile target 50% of the time. However, after several iterations, the model can now boast a zero percent false positive rate.

Machine Learning Confusion Matrix



The adaptability and resilience of a machine learning approach were evident when Russian forces attempted to modify their munitions to change their acoustic profile. Because machine learning algorithms are based on pattern recognition rather than relying on an exact match, the modifications only resulted in a 3% degradation in the system's accuracy. Once the new acoustic profile was detected a few times, the developers were able to retrain the model and restore the system to its previous performance.

Detection and tracking of aerial threats provide early warning, but mobile air defense groups are necessary for an active defense. These mobile firing groups (MFGs) must be prepositioned in a ready posture for when a hostile track is identified. Then, operators in an air battle management operations center (ABMOC) direct multiple MFGs to the anticipated engagement area along the low-altitude air avenue of approach (AAA). Once in position and alerted to the attack vector, the MFGs work together to engage and destroy the target.

The systems used by the Ukrainian air defenders vary significantly in equipment and capability to detect and engage targets. Using a radar air picture displayed on commercial tablets, crews use various methods to target incoming munitions, which often fly under cover of darkness. These methods include using high-powered laser pointers to identify and dazzle drones, as well as employing spotlights or even military-grade thermal sights. These air defenders are armed with an assortment of machine guns, including venerable Maxims dating back to WWI, as well as DShKs or Soviet-era weapons. Crews have rigged mounts for MANPADS launchers in some cases, creating makeshift missile turrets. A willingness to use all available equipment has allowed the Ukrainian military to rapidly form an effective mobile air defense force.

A review of current Army manuals reveals the differences between current doctrine and observations on the battlefield. While acknowledging the role of Short-Range Air Defense (SHORAD) in countering low-altitude threats, doctrine primarily focuses on the danger posed to maneuver forces. Regarding employment, doctrine either advises positioning SHORAD units along air avenues of approach or accompanying maneuver forces on the move. FM 3-01.44 comprehensively assesses the role of SHORAD in protecting against low-altitude threats and identifies the risks of low-altitude cruise missiles and UAVs to command and control (C2) centers, assembly areas and logistical support areas, but still characterizes protecting maneuver units as the primary mission. Considering modern low-altitude threats to rear support areas, the Army should develop how SHORAD can best provide mobile rear area defense.

SPC Christopher Bazan, Florida National Guard 3rd Battalion, 265 Air Defense Artillery Regiment, inside an Avenger's turret. (U.S. Air Force photo/Samuel King)

From a technical standpoint, the AN/TWQ-1 Avenger possesses several of the capabilities required to function in a mobile area defense role. The Crew Chief Air Situation Display (CCASD) receives, processes, and displays data from a Single Channel Ground and Airborne Radio System (SINCGARS) or Enhanced Position Location Reporting System (EPLRS) connection. It allows the Team Chief to monitor the airspace, and in an A2 configuration, it commands the Slew-to-Cue (STC) function. The Avenger also has an integral Forward

Looking Infrared Receiver (FLIR) for day and night operation. Furthermore, the Avenger Fire Control Computer (AFCC) is crucial to the Firing Unit. It provides Symbology to the FLIR Monitor for the gunner, allows for automatic tracking capabilities with the FLIR, and enables azimuth and elevation corrections to engage targets. Significantly, the Avenger brings the firepower of eight FIM-92 Stingers. While Ukrainian soldiers have creatively improvised to fill a need on the battlefield, the Avenger is quite capable in its own right.

A significant requirement for a mobile area defense is sufficient decision space to get MFGs into position. Gaining this space requires early target acquisition and tracking throughout the approach, as UAVs and cruise missiles can maneuver in flight. While airborne radar craft operating near the Forward Line of Troops (FLOT) could provide early warning and tracking, employing a high-value aircraft in this manner exposes it to enemy fire. Acquiring and tracking incoming munitions over friendly-held territory is more feasible. Therefore, a mobile air defense is more practical for defending assets in the rear area. Another planning consideration would be identifying roads that traverse the area to facilitate rapid movement between air avenues of approach. Furthermore, as soft-skinned targets, static air defense units are vulnerable to artillery Suppression of Enemy Air Defense (SEAD) missions. Despite the limitations, SHORAD units, given a mission of mobile area defense, could protect more assets and be more survivable than traditional static employment.

The Army can address the doctrinal, organizational, and material gap presented by the Ukraine scenario in three ways. First, update doctrine to highlight that rear areas also require low-altitude air defense and that air defense may need a mobile response area rather than just static positions. Second, SHORAD forces should be trained to respond to short-notice missions and arrive at a particular grid location ready to scan and fire. Third, organize and equip to deploy crewed or autonomous passive sensors throughout the battlefield. In a highly contested environment, passive sensors, in general, and audio sensors, in particular, offer a survivable low-cost supplement to radar sensors.

The war in Ukraine has presented numerous examples of combining old and new technology and adapting tactics, techniques, and procedures (TTPs) to address evolving threats. As low-cost drones supplement high-cost cruise missiles, getting ahead of the cost curve in defensive systems is increasingly important. Using expensive interceptors to shoot down inexpensive drones is unsustainable and will eventually overwhelm the military-industrial complex. Using low-cost sensors to direct a machine gun engagement conserves missile stockpiles, taking pressure off of the supply chain. Among numerous lessons gained from Ukraine, Army doctrine should be updated to include mobile area defense as a tactical mission for SHORAD employment.

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