Acoustic vector sensors

Here's a **refined, professional, and technically polished version** of your paragraph — ideal for an engineering report, defense technology paper, or project portfolio:

Acoustic Vector Sensors (AVS) – Advanced Battlefield Acoustic Intelligence

Acoustic Vector Sensors (AVS), developed by **Microflown Technologies**, represent a breakthrough in modern military surveillance and situational awareness systems. These sensors are engineered to **detect, classify, and localize** a broad spectrum of acoustic events in **three-dimensional space**, including **small arms fire, rockets, artillery, mortars, ground vehicles, and aircraft**.

Unlike conventional acoustic arrays that rely on triangulation from multiple sensors, the AVS directly measures the **particle velocity of air movement** induced by sound waves. This unique measurement principle enables **highly accurate sound source localization** using a single compact unit.

With a form factor of approximately **1 cm** and a weight of only **100 grams**, the AVS is both **lightweight and energy-efficient**, consuming **less than 1 Watt of power**. These features make it ideal for seamless integration across diverse platforms such as **unattended ground sensors, armored vehicles, UAVs, dismounted soldiers, and rotary-wing aircraft**.

The combination of **miniaturization, precision, and low power consumption** establishes the AVS as a critical component in next-generation **battlefield awareness, threat detection, and acoustic intelligence systems**.

Would you like me to make it sound more **academic (for a report/paper)** or more **project-focused (for inclusion in your robotics/defense portfolio)**? I can tailor the tone accordingly.

Great — here's an expanded, project-ready technical briefing on Microflown Acoustic Vector Sensors (AVS) with practical integration advice, specs, signal-processing guidance, and links to manufacturer resources you can use while building your battlefield-awareness prototype.

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1) Quick summary (what makes Microflown AVS useful for your project)

- Microflown's sensors **measure acoustic particle velocity directly** (not only pressure), giving an immediate vector (direction) estimate from a single compact sensor. This enables single-node direction-of-arrival (DoA) estimation and greatly simplifies localization compared with pressure-only microphones that require arrays/triangulation. Microflown +1

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2) Representative sensor composition & typical specs

AVS = 3 orthogonal particle-velocity probes (Microflown elements) + a sound-pressure microphone (a common AVS assembly). Key performance numbers (from Microflown product literature / datasheets):

- **Frequency range:** ~20 Hz – 10 kHz (±2 dB typical for many Microflown probes).
- **Sensitivity:** ~70 mV/Pa (pressure) and ~17 V/(m/s) (particle velocity) for some probes.
- **Max SPL:** pressure ~112 dB; particle velocity equivalent up to ~130 dB (model dependent).
- **Noise floor (20 Hz–2 kHz):** ~21 dB(A) for pressure; particle velocity higher as reported by Microflown products.
- **Form factor:** MEMS element itself is very small (millimetre scale); packaged probes and AVS modules vary — product lines include compact modules designed for field use. Microflown +1

(If you need exact numbers for procurement or simulation, I can fetch the exact datasheet for the particular AVS model you plan to use.)

3) How the sensor works (concise physics / principles)

- The Microflown transducer uses **two ultra-thin heated wires** (MEMS) whose resistance depends on local temperature. Particle velocity causes asymmetric cooling between the wires, producing a differential signal proportional to particle velocity in that wire pair's axis. Combining three orthogonal elements gives a 3-D particle-velocity vector **u = (u_x, u_y, u_z)**; a colocated microphone gives sound pressure **p**. Using u (and optionally p) you can compute azimuth/elevation directly (no array TDOA required). Microflown +1

4) What you can measure & expected capabilities in a battlefield setting

- **Gunshot detection & localization:** muzzle blast and ballistic shockwave content fall within the AVS bandwidth; AVS gives rapid bearing estimates and can separate overlapping sources better than single microphones.
- **Vehicle / rotorcraft / artillery detection:** useful because particle-velocity signatures contain directional info and energy at low–mid frequencies.
- **Multi-source scenarios:** a single AVS can localize in 3D and, with signal processing, can separate and track multiple concurrent sources (within limits). Field/academic tests show effectiveness for small arms, mortars, aircraft. Microflown +1

5) Data acquisition & interfacing (what you'll need)

- **Front end / preamp / DAQ:** Microflown supplies DAQ front-ends (example: **Scout V2**) — 24-bit USB DAQ aimed at Microflown sensors with synchronized channels and tach/IO. For embedded/wireless deployments you'll need a compact DAQ or custom analog front end with high-resolution ADC (≥24 bit recommended for high dynamic range). Microflown
- **Common interfaces:** USB (for lab/field laptop connection), analog outputs (amplified), IEPE in some product families, and custom digital interfaces depending

on module. For UAV/vehicle integration you may prefer an embedded microcontroller + ADC or an FPGA for pre-processing. Microflown

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6) Practical integration checklist (hardware)

1. **Select model** — pick the Microflown AVS or PU/PU-mini probe that matches your bandwidth and ruggedness needs.
2. **DAQ choice** — Scout V2 for development; for embedded nodes, design a 24-bit ADC front end with synchronized sampling for all channels (u_x, u_y, u_z, p).
3. **Power & weight budget** — sensor element is tiny; packaged AVS modules + DAQ weight and power vary. Validate the exact model's power draw (claim <1 W is possible for small modules but confirm for the chosen product). Microflown +1
4. **Ruggedization & wind/flow protection** — use appropriate windscreen or flow-management booms for outdoor use (windscreens reduce low-freq wind noise but introduce minor directional smoothing).
5. **Mounting & orientation** — ensure orthogonal axes are aligned to your vehicle/body/boom coordinate frame; record exact orientation for correct DoA conversion.
6. **Sync & timestamps** — if you use multiple nodes, synchronize clocks (GPS PPS or PTP) and store accurate timestamps for cross-node fusion.
7. **EMC & thermal** — heated wires are temperature-sensitive; allow for thermal compensation and avoid heat sources near the element. Microflown

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7) Practical integration checklist (software & processing)

- **Preprocessing:** bandpass filtering (set based on target: e.g., 20 Hz–6 kHz for muzzle blasts and vehicles), de-noising (spectral subtraction or wavelet methods), and wind noise suppression (high-pass + adaptive filters).
- **Instantaneous DoA from AVS:** compute azimuth/elevation from the particle velocity vector. Basic formulas:
  - Azimuth (ϕ) = atan2(u_y, u_x)

  - Elevation (θ) = atan2(u_z, sqrt(u_x² + u_y²))
    (use vector averaging over a short window for stability; correct for sensor orientation.)
- **Source classification:** extract features (spectral centroid, bandwidth, kurtosis, rise time, envelope shape, MFCCs for spectral shape) and train a classifier (random forest, SVM, or small CNN) for classes like small arms, rotorcraft, vehicle, artillery.
- **Localization / tracking (single node):** AVS gives bearing; if you need absolute position, fuse multiple spatially separated AVS nodes or combine with GPS/IMU on a single mobile platform as it maneuvers for triangulation (mobile localization).
- **Multi-sensor fusion:** combine AVS bearings with other sensors (radar, EO, seismic) using an Extended Kalman Filter or particle filter for tracking. Microflown

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8) Example pseudocode — compute azimuth/elevation and detect events

python

```python
# inputs: u_x, u_y, u_z (particle velocity channels), p (pressure), fs = sampling rate
# windowed processing
for each time window:
    ux = bandpass_filter(u_x_window)
    uy = bandpass_filter(u_y_window)
    uz = bandpass_filter(u_z_window)
    # vector average in window
    ux_m = mean(ux)
    uy_m = mean(uy)
    uz_m = mean(uz)
    azimuth = atan2(uy_m, ux_m)          # radians
    elevation = atan2(uz_m, sqrt(ux_m**2 + uy_m**2))
    # simple event detection using pressure energy
    if rms(p_window) > threshold:
        mark_event(time, azimuth, elevation, features_extract(ux,uy,uz,p))
```

This is a minimal pipeline — production systems include adaptive thresholds, VAD, multi-frame smoothing, and confidence metrics.

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9) Calibration & validation recommendations

- **Factory calibration:** use Microflown's provided calibration or traceable acoustic calibration services to get sensitivity and axis alignment.
- **On-site checks:** emit known sources at known bearings/distances and check bearing error across frequency bands.
- **Temperature compensation:** log ambient temperature and, if necessary, apply temperature-dependent gain correction (due to heated wire principle). Microflown

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10) Limitations & things to watch for

- **Wind & airflow sensitivity:** particle-velocity sensors can be sensitive to flow; use booms/windscreens and algorithmic filtering.
- **Low SNR / reverberant environments:** near-field multipath and reflections can bias instantaneous DoA — combine temporal smoothing and multi-sensor fusion.
- **Sensor saturation / clipping:** gunshots and explosions produce very high SPLs; ensure DAQ chain has enough dynamic range or use attenuators.
- **Legal / export considerations:** defense/military applications may be subject to export controls — check legal/compliance requirements before procurement or export.

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11) Useful Microflown resources & next steps (I can fetch any of these for you)

- Microflown product pages and catalogs (particle velocity sensors, AVS modules, PU probes). Microflown +1
- Application note: **Battlefield acoustics** (gunshot localization, field tests). Microflown
- Data acquisition: **Scout V2** DAQ product page for development hardware. Microflown
- Technical ebooks/papers on the Microflown principle and AVS theory. Microflown +1

12) Suggested immediate actions for your project

1. Choose 1–2 Microflown probe/AVS models and I'll pull the exact datasheets (sensitivity, power, weight) for procurement and mechanical design.
2. Decide target platforms (UAV / dismounted / vehicle) so we can size power, DAQ, and mounting.
3. If you want, I can generate: a) integration block diagram, b) sample acquisition firmware pseudocode for a microcontroller, or c) a short test plan (calibration + field validation) — tell me which one now and I'll produce it.

References / sources used (for the technical numbers and application notes)

- Microflown product pages and specification sheets (Particle Velocity Sensors, Standard Probes). Microflown +1
- Microflown technical e-book and application note collections (operating principle). Microflown
- Microflown AVISA / AVS technology descriptions and field application papers (battlefield acoustics, AVS on UAVs). Microflown AVISA +1
- Scout V2 data acquisition product page (Microflown). Microflown

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Would you like me to:

- (A) fetch the **exact datasheet(s)** for a specific Microflown model and produce a one-page spec sheet for your design team,
- (B) make a **hardware + DAQ block diagram** sized for a UAV or a dismounted soldier node, or
- (C) produce **sample code** (embedded C or Python) for real-time DoA estimation and event detection?

Pick A, B, or C (or say "all three") and I'll generate it right away.

Sources

Good — I'll act as a researcher and give you a concise, military-grade analysis plus **two** best alternative sensor classes (each with a representative, field-proven product/vendor), recommended use, limitations, and integration notes for your *"Border Surveillance System"* (footsteps / gunshots / covert intrusion). I'll also end with a clear recommendation on how to use them together for a robust system.

Executive summary (one line)

For detecting footsteps and covert intrusions at a border, **buried seismic (geophone) sensors** and **compact ground/perimeter surveillance radars** are the two best non-acoustic alternatives to a pure sound sensor — each excels at different threat types and operating conditions, and together they provide complementary coverage and low false-alarm rates. telonics.com +1

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1) Buried seismic sensors (geophones / smart seismic nodes) — best for footsteps, tunneling, ground movement

Representative vendors / products: RBTEC / *Seismo* buried seismic detector family, SensoGuard SGx smart seismic sensor, Telonics SP-500 buried geophone (examples/properties shown in product literature). RBtec Perimeter... +2

Why this is a top choice for footsteps

- **Direct coupling to ground vibrations:** footsteps produce near-field seismic signatures that are much stronger in buried geophones than airborne sound sensors, so detection ranges for human footsteps (quiet walking) can be tens of meters depending on soil type and installation. fkyxrkyq.eleme... +1
- **Very low signature for wind / weather:** seismic sensors are far less affected by wind or rain than microphones, drastically reducing weather-related false alarms. Geospace
- **Discriminative features:** wavelet/spectral/time-domain features from geophones allow good separation between footsteps, vehicles, animals, and excavation/tunneling with well-trained classifiers. ResearchGate

Typical capabilities & specs (ranges vary with soil/installation)

- **Detection:** footsteps (single person) at tens of metres (site dependent); vehicles at 100s of metres for heavier vehicles.
- **Form factor / deployment:** buried or surface-mounted geophones in strings or grids; low power for battery operation on remote nodes. RBtec Perimeter…
- **False-alarm mitigations:** multi-sensor voting, adaptive thresholds, grouping multiple geophones in short arrays, and classifier models trained on local ground noise. ResearchGate

Limitations / things to watch

- **Soil coupling & geology:** detection range and signature change dramatically with soil type (rocky, sandy, frozen ground reduce range). Field calibration is mandatory.
- **Localized (point) coverage:** to secure a long border you need many buried nodes or strings — logistics/maintenance cost.
- **Vulnerable to intentional masking:** heavy ground clutter, vibrations from construction or heavy vehicles can mask events if not filtered.

Integration notes (practical)

- Bury sensors in protective pods, space nodes based on required detection probability and soil tests, perform on-site calibration using human walk tests, and implement local pre-processing (edge ML) to reduce false alarms before sending alarms over comms. fkyxrkyq.eleme… +1

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2) Compact ground / perimeter surveillance radar (short-range UWB / micro-Doppler radar) — best for moving intruders and cueing EO/IR

Representative vendors / products: SpotterRF / SpotterGlobal compact surveillance radars and Robin Radar (IRIS / C-UAS family) — these companies supply mission-proven compact radars used for perimeter, ground-move, and small-target detection in military/critical-infrastructure deployments. milestonesys.com +1

Why this is a top choice for covert intrusion & stand-alone detection

- **Detects moving human targets at distance** regardless of light or smoke; radars measure motion (Doppler/micro-Doppler) and can reliably detect walking/running people even through foliage (to some extent) and in poor visibility. milestonesys.com +1
- **Very low maintenance & wide area coverage:** A single compact radar covers a wider sector than a single seismic node; suitable for rapid deployment, mobile units, and on-the-move platforms. milestonesys.com
- **Strong cueing capability:** radar tracks can automatically cue EO/IR cameras (PTZ) and higher-resolution sensors for positive ID and verification. Spotter Global

Typical capabilities & specs

- **Detection ranges:** short-range compact radars detect people from a few hundred metres to a few kilometres depending on model and clutter; typical compact perimeter radars are specified for people/vehicle detection in the 100 m–2 km envelope. Spotter Global +1
- **Classification:** modern units use micro-Doppler and ML to discriminate humans vs vehicles vs animals and to reduce false alarms. robinradar.com

Limitations / things to watch

- **Vegetation & terrain clutter:** dense foliage and complex terrain produce multipath and reduce detection range or increase false alarms without advanced processing.
- **Limited for stationary or very slow movement:** footsteps when a person is immobile or extremely slow may be below a radar's motion threshold (radar detects motion).
- **EMC / regulatory:** radar emissions require frequency planning and may be constrained in some regions; radar signatures may be detectable by hostile signals intelligence in contested environments.

Integration notes (practical)

- Use radars to provide wide-area detection and automatic camera cuing, then confirm with a local seismic array or an acoustic/AVS node for localization and classification. Ensure radar placement avoids strong clutter reflectors and use AI classification models tuned to local conditions. milestonesys.com +1

Comparative summary (which to use when)

- **Footsteps / buried approach detection (quiet, stealthy approach): Seismic (geophone)** is superior — directly senses ground vibration, low effect from weather. RBtec Perimeter… +1
- **Wide area moving target detection, fast cueing, low operator load: Compact radar** is superior — large coverage, works day/night, cues cameras and other sensors. milestonesys.com +1
- **Gunshots:** both are *indirect* solutions — gunshots are best detected by acoustic systems or AVS (particle-velocity) for precise shot localization. If acoustic sensors are not permitted, combine radar (to detect moving shooter/vehicle) with seismic (if shooter is stationary and coupled to ground); however, detection and localization accuracy for gunfire will be lower than acoustic methods.

Recommended operational architecture (military-grade, low false alarms)

1. **Primary wide-area sensor = compact radar** (SpotterRF / Robin Radar class) for 360° or sector surveillance and automatic camera cuing. milestonesys.com +1
2. **Local sensor clusters = buried seismic nodes** deployed in strings or grids at choke points and along fence lines for footsteps/tunneling detection and high-sensitivity intrusion detection. RBtec Perimeter…
3. **Sensor fusion & edge processing:** fusion engine (EKF/particle filter and ML classifiers) running at gateway to combine radar tracks + seismic detections + EO cues and apply rule-based alarm logic to drive very low false-alarm alerts. ResearchGate +1

Quick procurement suggestions (where to look first)

- **Seismic / buried nodes:** RBTEC (Seismo family), SensoGuard (SGx), Telonics SP-500, Geospace geophones — evaluate demo units and request site trials on the border soil you expect to operate in. RBtec Perimeter… +2

- **Compact radar:** SpotterRF compact surveillance radars, Robin Radar (IRIS / C-UAS / ELVIRA families), and SpotterGlobal military COTS radars — request trial setups and AI classification performance data in your clutter environment. milestonesys.com +1

Final recommendation (one short actionable step)

If you must pick **only one** to start field trials for *footsteps + covert border intrusions*, **deploy a grid of buried seismic nodes** (Seismo / SGx class) because they directly detect footsteps and have the lowest weather-related false alarms. Then add a **compact radar** in a second phase to provide wide-area cueing and reduce manpower needed for monitoring. RBtec Perimeter… +1

If you want, I can now (pick one):

- (A) pull **detailed datasheets / model pages** and a quick procurement checklist for **one seismic product** and **one compact radar** (two specific SKUs), or
- (B) create a **short field test plan** (how to evaluate seismic nodes + radar in your local soil/terrain) with test procedures and metrics (Pd / Pfa / range), or
- (C) produce a **fusion architecture diagram + software stack** for combining seismic + radar + EO/IR.

Pick A, B, or C (or say “all three”) and I’ll generate it immediately.

Sources