Onboard Acoustic Camera Technical White Paper

HZ-FA-36 | Lightweight Acoustic Perception and Autonomous Inspection Integration



Core positioning A lightweight acoustic sensing module for quadruped robots, wheeled inspection robots, pan-tilt heads and autonomous inspection platforms. With a 64-channel MEMS array, acoustic imaging, optical video and open interfaces, it brings sound-source localization and diagnostics to robotic systems.

HERTZINNO | HZ-FA-36 | White Paper V1.0 | November 2026

Executive Summary

Industrial inspection robots commonly carry visible-light cameras, thermal imagers and environmental sensors. Yet many emerging equipment faults first generate audible or ultrasonic signatures, such as pressurized gas leaks, partial discharge, and abnormal friction or impacts in bearings, gearboxes and pumps. The HZ-FA-36 combines a multi-channel microphone array, beamforming, optical imaging and edge-side detection in a compact module, allowing robots to locate and visualize anomalous sound sources without contact.

Using current HZ-FA-36 technical information as the hardware baseline, this white paper explains the integration architecture, detection workflows, parameter selection, inspection sequencing and engineering considerations for autonomous inspection robots. It also draws on HERTZINNO experience with edge analytics, camera-side alarms and field deployment.

Reach waypoint	Stabilize pose	Set band / ROI	Start detection	Localize and analyze	Return result / continue

Lightweight design The source white paper specifies a 350 g device with an 80 × 84 × 40 mm enclosure and around 6 W typical power. Its small footprint is intended for robots with limited payload, endurance and gimbal space.

1. Product Positioning: Giving Robots the Ability to Hear

HZ-FA-36 is a miniature acoustic imaging camera designed for inspection robots and automation platforms. Its 64-channel MEMS microphone array and beamforming algorithms convert ultrasonic gas leakage, partial discharge and abnormal equipment noise into acoustic images overlaid on live optical video. Sound localization, feature extraction, detection and alarm decisions run on the camera itself.

The robot controller does not need to perform acoustic signal processing: it can manage tasks over TCP/IP using HTTP and receive event results, alarms and associated media through a push workflow.

Gas Leak Detection

Pressurized gas escaping through small openings in pipes, valves, flanges, or fittings generates turbulent acoustic emissions, often containing ultrasonic components. HZ-FA-36 uses frequency-selective acoustic imaging and beamforming to identify and localize these emissions, helping inspection robots detect small leaks even in environments with significant background machinery noise.

Partial Discharge Detection

Electrical partial discharge in high-voltage equipment can generate broadband acoustic pulses with ultrasonic components. HZ-FA-36 captures and spatially localizes these signals, enabling inspection robots to identify potential insulation-related abnormalities around switchgear, transformers, insulators, and electrical connections without direct contact.

Abnormal Mechanical Noise Detection

Mechanical defects such as bearing wear, abnormal friction, looseness, and component impacts may produce distinctive acoustic signatures. By combining sound source localization with frequency-domain analysis, HZ-FA-36 helps inspection robots identify abnormal noise sources in motors, pumps, fans, gearboxes, and other rotating machinery, supporting condition monitoring and early fault investigation.

Primary Applications: Partial discharge inspection, pressurized gas leak detection, and abnormal mechanical noise monitoring.

Target Platforms: Quadruped robots, wheeled inspection robots, pan-tilt units, mobile inspection platforms, and fixed robotic inspection nodes.

Operational Value: Extend robot perception beyond visual inspection to acoustic anomaly localization, enabling more comprehensive automated inspections while reducing the need for personnel to approach potentially hazardous equipment.

2. HZ-FA-36 Hardware Baseline

2.1 Acoustics and Imaging

Model	HZ-FA-36
Acoustic	

Microphones	64-channel MEMS microphones
Acoustic image resolution	1920 × 1080
Microphone sensitivity	-26 ± 1 dBFS (at 1 kHz, 1 Pa; source wording)
Minimum imaging sensitivity (1 m)	10 kHz: 5 dB; 20 kHz: -3 dB; 40 kHz: -5 dB; 60 kHz: 6 dB
Leak detection sensitivity	0.05 L/min @ 120 kPa, 6.5 m (source document)
Detection distance	0.3–50 m (application dependent)
Bandwidth	2–100 kHz (source; verify effective usable frequency range)
Sampling rate	200 kHz
Optical camera	5 MP
Optical camera FOV	72° (±3°)
Focal length	3.9 mm
Microphone self-diagnostics	Yes
General	
Video	H.264 / RTSP
Video resolution	1920 × 1080 @ 30 fps
Transmission	Ethernet / HTTP
Power supply	DC 12 V
Typical power	5.6 W
Protection rating	IP65
Dimensions	80 × 84 × 40 mm
Weight	350 g (source white paper; confirm against current website)
Operating temperature	-20 to +55 °C
Storage temperature	-30 to +70 °C
Applications	Partial discharge; gas leak detection; mechanical noise

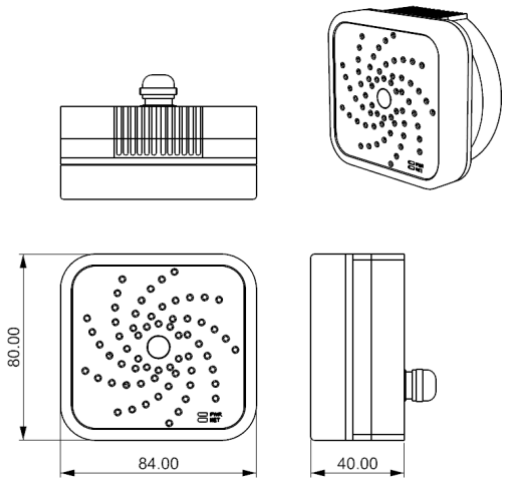
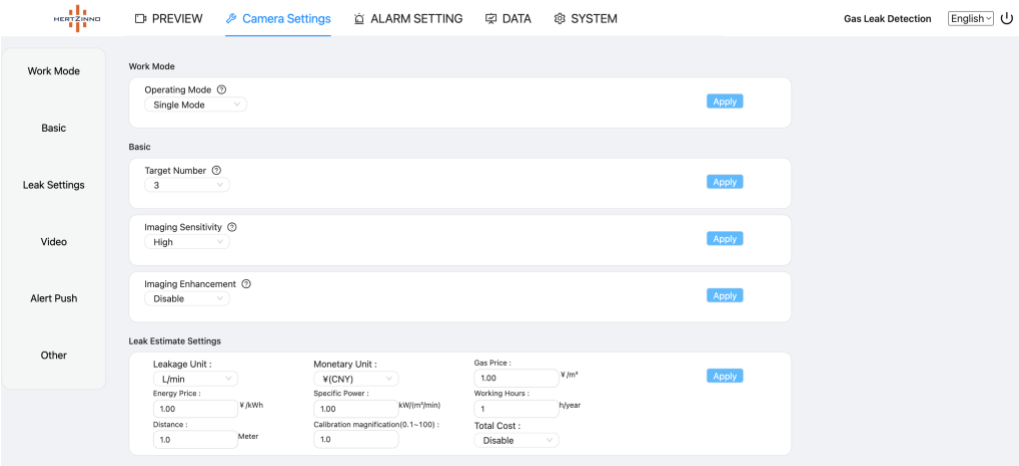


Figure 1. HZ-FA-36 dimensions and mounting interface (product specification reference)



3. Principles of Acoustic Imaging

An acoustic camera collects sound simultaneously using microphones distributed across a known geometry. Because acoustic waves arrive at each microphone with a slightly different travel time and phase, a beamforming algorithm can estimate the direction and relative strength of a sound source. The resulting acoustic map is registered to the optical image, displaying both location and sound intensity.

For robotic inspection, the essential benefit is spatial localization. A single microphone can indicate that sound is present; a microphone array helps determine where it originates. The robot can therefore associate an acoustic anomaly with a particular valve, joint, insulator, bearing or motor.

64-ch synchronized capture	Frequency selection	Beamforming	Source localization	Acoustic overlay	Feature analysis / alarms



3.1 Why Frequency Selection Matters More Than Wideband Scanning

Industrial background noise is often concentrated in specific frequency bands. Robot motion, fans, pumps, motors and other equipment can operate simultaneously. Effective inspection therefore begins with reviewing the spectrum and selecting a band that separates the target signature from background noise. Higher ultrasonic frequencies generally offer finer angular resolution but experience greater propagation loss; lower frequencies can travel farther but are more vulnerable to machinery noise and poor angular resolution in small arrays.

3.2 Signal Filtering and Beamforming

The 64-channel MEMS array measures the same sound source at spatially separated microphone positions. Different propagation paths produce small differences in arrival time. Beamforming uses the array geometry, speed of sound and candidate scan direction to time-align and coherently combine these signals, enhancing the response from a selected direction while suppressing interference from others.

Array geometry and frequency. In the far field, the acoustic wavelength is $\lambda = c / f$, where c is the speed of sound and f is frequency. For an array with fixed effective aperture D, angular mainlobe width generally scales with λ / D: higher frequency or larger aperture tends to produce a narrower beam and better angular discrimination. Microphone spacing and geometry also affect sidelobes, spatial aliasing and false peaks. Channel count alone does not define resolution.

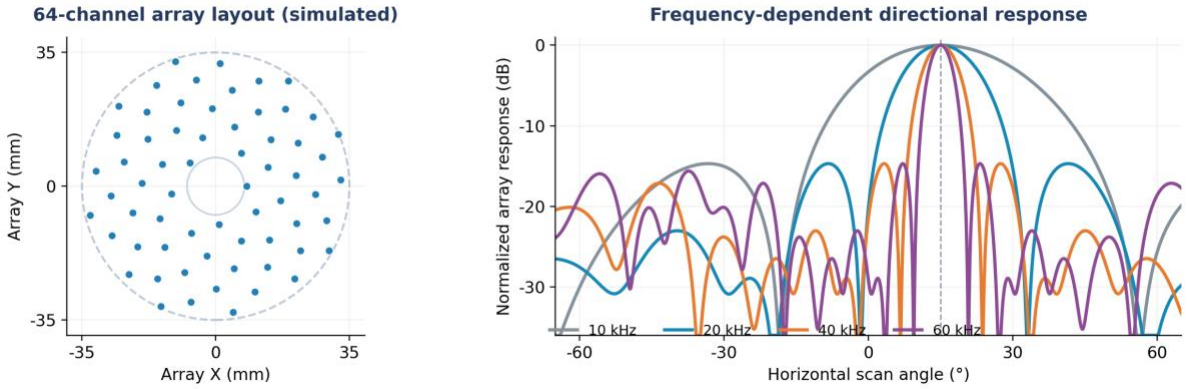


Figure 3. Example 64-element nonuniform array and simulated directional response at different frequencies (Delay-and-Sum)

From frequency filtering to spatial focusing. Spectral filtering and spatial beamforming are complementary but distinct operations. First, a band with useful defect-related energy and reduced environmental interference is selected. Next, the microphone phase and time differences are used to scan directions and coherently combine signals within that band, producing an angular acoustic-energy distribution. Small high-pressure gas leaks can produce ultrasonic turbulence; combining frequency selection with spatial filtering may improve their identification even near pumps, fans and motors.

For a scan direction θ, a conventional time-domain Delay-and-Sum beamformer can be written as $y(t, \theta) = (1 / N) \cdot \Sigma\, x_m(t + \tau_m(\theta))$. Here N is the number of microphones, x_m is the signal from element m, and τ_m is its geometry-based delay compensation. Scanning multiple directions and evaluating output energy yields a beam pattern with a mainlobe, sidelobes and a two-dimensional directional response.

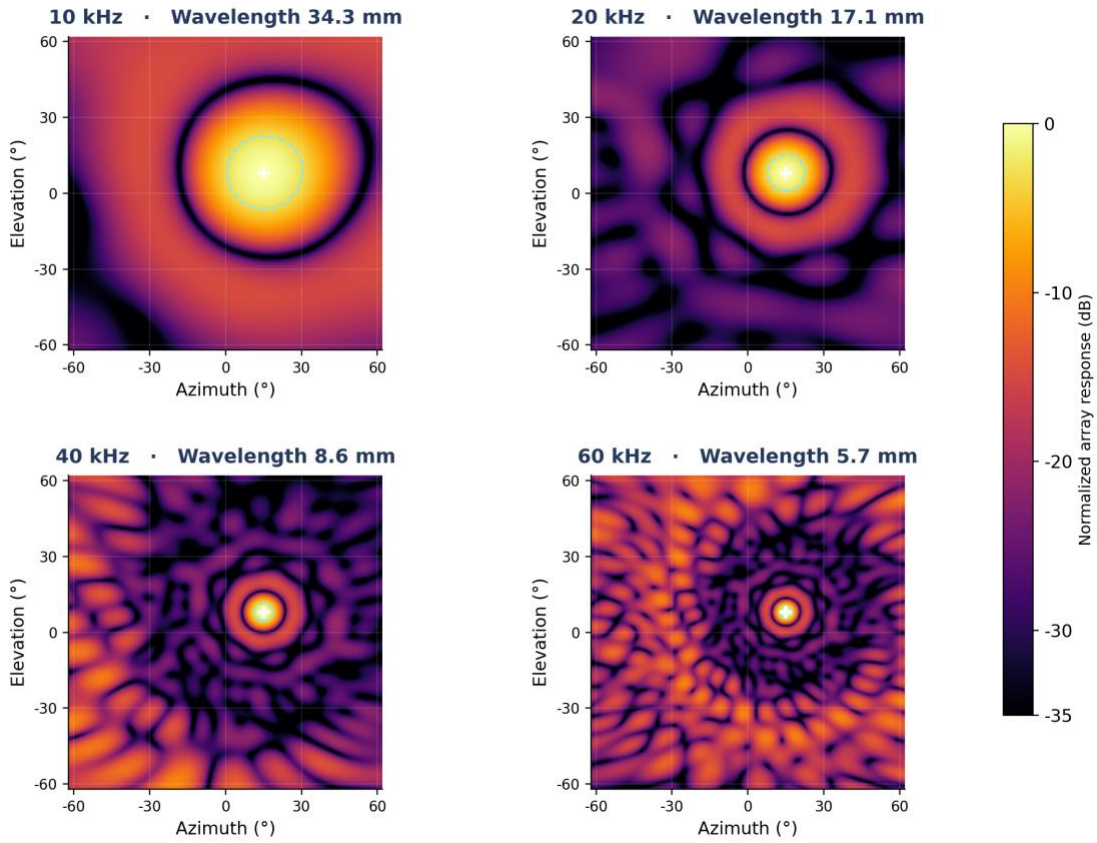


Figure 4. Simulated two-dimensional beam patterns; the cross marks the source direction and the cyan contour marks the −3 dB mainlobe boundary

Engineering interpretation. Figures 3 and 4 show that the same aperture produces broader mainlobes at lower frequencies. Higher frequencies typically narrow the mainlobe but can also reveal more complex sidelobe structures. Long-range detection of small gas leaks requires balancing improved angular discrimination against frequency-dependent air absorption. A practical imaging band should be chosen based on the measured leak spectrum, inspection distance, ambient noise and target geometry rather than automatically using the highest frequency.

Simulation scope. Figures 3–4 are reproducible theoretical simulations, not measured HZ-FA-36 beam patterns. The model assumes a 64-element nonuniform spiral array with a 70 mm effective aperture, sound speed of 343 m/s, far-field plane waves, ideally matched microphones and a conventional Delay-and-Sum beamformer. Source direction: azimuth 15°, elevation 8°. Product-level validation requires the actual microphone coordinates, amplitude/phase calibration and field measurements.

4. Three Core Inspection Tasks

4.1 Partial Discharge Inspection

Partial discharge generates broadband impulses and ultrasonic components. HZ-FA-36 can support non-contact inspections of switchgear, transformers, insulators, cable terminations and overhead electrical equipment. At a planned inspection point, the robot can hold a safe stand-off distance, perform directional acoustic inspection and associate the localized source with the optical scene.

Recommendation	Engineering starting point / principle
Inspection distance	Typically 3–30 m; maintain electrical safety clearance and adequate site SNR
Initial band	20–40 kHz; adjust using field spectrum
Inspection timing	Prefer stationary or low-vibration robot posture
Output	Camera-side localization, PD/leak/mechanical analysis and alarms, with results pushed to robot

4.2 Pressurized Gas Leak Detection

Pressurized gas escaping through small holes, valves, flanges or fittings generates turbulent sound, often including ultrasound beyond human hearing. Acoustic localization depends primarily on the emitted sound, rather than identifying a gas species, and can be applied to screening various pressurized-gas systems. The source specification cites sensitivity of 0.05 L/min at 120 kPa from 6.5 m; actual performance varies with background noise, stand-off distance, pressure differential and installation conditions.

Recommendation	Engineering starting point / principle
Typical distance	1–20 m; prefer shorter ranges for very small leaks
Initial band	25–45 kHz; higher bands may improve close-range spatial separation
Targets	Valves, flanges, pneumatic fittings, compressed-air systems, process pipes
Output	Leak localization; optional leak-rate estimation

4.3 Abnormal Mechanical Noise

Mechanical wear, looseness, friction, impacts and gear faults can produce acoustic features that differ from normal operating conditions. A robot may repeatedly collect data at defined viewpoints near motors, pumps,

fans, gearboxes and compressors, combining sound localization with spectral comparisons to help identify emerging anomalies.

Recommendation	Engineering starting point / principle
Typical distance	1–10 m; maintain clearance from rotating equipment
Frequency band	Start at 2–50 kHz; narrow around relevant fault signatures
Baseline	Record reference spectra under normal operation
Inspection strategy	Repeat with similar distance, angle and operating state

5. Coordinating Inspection Distance and Frequency Band

Acoustic detection distance is not a fixed universal value. Source strength, frequency, temperature, humidity, wind, background noise, occlusion and robot self-noise all affect performance. The starting bands below are deployment guidelines, not guaranteed detection ranges. Adjust them using measurements at the actual inspection site.

Distance	Suggested band	Trade-off	Typical use
0.1–2 m	45–65 kHz	Higher angular resolution but greater attenuation	Small leaks; pinpoint localization
2–20 m	25–45 kHz	Balance between range and angular resolution	Routine leak, PD and mechanical checks
20–100 m	10–30 kHz	Lower attenuation but less spatial separation	Outdoor pipeline and power-line screening

Route planning note Do not define only the robot waypoint coordinates. Associate each waypoint with an asset, stopping pose, intended distance, frequency band, inspection region and detection period. This turns an acoustic camera from a passive video attachment into a repeatable robotic sensing task.

6. Lightweight Onboard Robot Integration

With a compact enclosure and low power demand, HZ-FA-36 is suited to mobile platforms where payload capacity, endurance and mounting space are constrained. Mechanical mounting, acoustic isolation, power and networking must all be considered during integration.

Design area	Recommendation
Mechanical mounting	Maintain an unobstructed view of the microphone array; avoid robot brackets, covers or cables obstructing the sensing aperture.
Vibration isolation	Wheeled-chassis vibration, quadruped footsteps and gimbal motion generate self-noise. For sensitive tasks, use a stop–stabilize–measure routine.
Power	Supply DC 12 V; plan for approximately 6 W typical power and sufficient margin for startup peaks and cable losses.
Network	Connect the camera through Ethernet/TCP/IP. Standard workflow integration uses HTTP; the robot does not need raw acoustic streams. Implement address management, HTTP timeout/retry and result reception.
Optical alignment	The optical field of view is 72°. Align the module with the target viewing direction and avoid extreme pitch that places targets outside useful scan directions.
Environment	IP65 and -20 to +55 °C are the source specification baseline. Confirm any deployment beyond those limits or in a classified hazardous area separately.



Figure 2. HZ-FA-36 compact acoustic camera

7. Open Interfaces and Robotic System Architecture

HZ-FA-36 should be treated as an intelligent edge acoustic node with its own processing and alarm functions, not merely a multi-channel audio sensor. The robot controller handles navigation, mission scheduling and asset context. The camera performs acoustic acquisition, beamforming, sound-source localization, feature analysis, detection strategy execution and alarm evaluation. Standard business integration uses TCP/IP and HTTP; the robot need not consume raw multi-channel audio or reimplement acoustic algorithms.

Interface / Mechanism	Purpose on robot side
HTTP / REST	Standard control: task parameters, mode/ROI/strategy settings, start/stop, status queries and results.
HTTP push	Recommended result delivery: camera sends results, alarms, image/video and file references to the robot or platform service.
On-camera edge analytics	64-channel acquisition, beamforming, localization, feature extraction, PD/leak/mechanical analysis and alarms all execute locally.
Optional lower-level interfaces	WebSocket / RTSP may be used for commissioning, real-time visualization or special integration; not required for standard task integration.

Robot mission / navigation	HTTP request	HZ-FA-36 edge analysis	Camera alarm evaluation	HTTP push	Robot / platform receives

7.1 Recommended API Workflow

Waypoint reached	HTTP configure / trigger	Camera acquisition / analysis	Camera alarm evaluation	Push results / media	Resume robot mission

After reaching an inspection waypoint, the robot can issue or confirm detection mode, frequency band, region of interest and alarm strategy over HTTP, then trigger a one-time measurement or continuous monitoring workflow. The camera acquires and analyzes the data locally. It can subsequently push structured results, alarm information and associated acoustic/optical images or video to the robot or central platform, according to project integration requirements. This reduces host-side software complexity, bandwidth demand and cross-platform integration effort.

8. Single Detection and Smart Patrol

Robot projects commonly progress from commissioning to unattended operation. Single Detection supports initial waypoint modeling and inspection-strategy validation; each trigger generates a record that can be reviewed by an engineer. Smart Patrol is intended for stable production strategies and scheduled autonomous monitoring, saving and pushing events when alarm conditions are met to reduce unnecessary data.

Mode	Use case	Data behavior

Single Detection	Commissioning, field tuning, acceptance testing, waypoint modeling	Each trigger runs complete camera-side analysis and returns a record for verification.
Smart Patrol	Long-term unattended and repeated inspection	Camera executes a periodic strategy and generates/pushes results when alarm conditions are met.

Deployment principle Build normal/abnormal samples and site settings using Single Detection before switching to Smart Patrol. Do not apply default alarm thresholds to unattended operation without a measured baseline.

9. Robot-Side Data and Platform Integration Recommendations

Because acoustic analysis and alarm logic execute on the camera, the robot platform does not need to store or process all raw acoustic streams in real time. Instead, it should manage inspection results and link every measurement to an asset, waypoint and timestamp. Recommended minimum records include:

- Device/asset ID, robot location, inspection waypoint ID, inspection mode, timestamp, robot pose and mission identifier.
- Camera frequency band, region of interest, detection cycle, alarm-strategy ID and camera-reported status.
- Detection decision, alarm severity, source location, acoustic images or result files, optical images or videos, and mode-specific diagnostic output for PD, leaks or mechanical noise.
- Camera software/firmware version and relevant strategy revision for long-term traceability. Raw real-time data should be requested only for commissioning, algorithm validation or specialized projects—not required for standard robot integration.

10. Typical Applications

Industry / Site	Robot inspection task	Acoustic imaging value
Substations / switchgear rooms	Inspect switchgear, bushings, joints and insulation	Locate PD sources at a distance and reduce close approach to HV assets
Oil & gas / chemicals	Inspect valves, flanges, pneumatic lines and process pipes	Locate pressurized gas leaks amid industrial background noise
Manufacturing	Inspect motors, pumps, fans and gearboxes	Associate abnormal noise with physical assets to support early fault discovery

Data centers / infrastructure	Inspect air lines, electrical equipment and rotating machinery	Complement optical/thermal monitoring with acoustic sensing

11. Project Implementation Workflow

Phase	Activity	Recommended deliverable
1. Site survey	Target assets, noise, distance, obstructions, robot parking pose	Waypoints and environment baseline
2. Mechanical integration	Mounting location, view angle, vibration isolation, power and network	Mechanical/electrical integration drawing
3. Parameter setup	Spectrum, band, threshold, ROI and period	Waypoint settings template
4. Sample validation	Normal, abnormal and interference samples	Reference data and alarm conditions
5. API integration	HTTP configuration, triggering, result/alarm/media push, timeouts and retries	Robot HTTP integration interface
6. Pilot operation	Use Single Detection to measure false positives and missed detections	Acceptance-test record
7. Unattended operation	Switch to Smart Patrol and periodically review performance	Long-term inspection strategy

12. Conclusion

HZ-FA-36 is more than a miniature acoustic camera: it is an edge acoustic analysis node capable of independent detection and alarm evaluation on a robotic platform. Its compact 80 × 84 × 40 mm form factor, 64-channel microphone array, acoustic imaging and onboard processing allow robotic systems to obtain usable acoustic inspection results over TCP/IP and HTTP without performing acoustic computation on the robot controller.

This architecture keeps acoustic processing on the sensor and simplifies robot-side operations to arrive at waypoint → trigger or execute → receive result → associate asset → report to platform. With waypoint-specific configuration, site baselines, camera-side alarm policies and HTTP result pushing, robotic deployments can evolve from carrying a camera to performing repeatable autonomous acoustic diagnostic tasks.