AeroSense Bio

Business Plan

A Bio-Integrated Biomimetic Olfactory Sensing Platform —
Giving Machines Biological-Grade Smell

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iGEM 2026

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1. Executive Summary and Positioning

MISSION	FOCUS (Phase 1)	STAGE
Give machines biological-grade smell — turning odor into a measurable data dimension	Early VOC detection of disease in Taiwan's banana export supply chain (tea as follow-on markets) — validating the business model in a single beachhead market first	Cell-level proof of concept complete; edge-hardware prototype board fabricated; industry interviews completed; exporter validation and device pilot still ahead

Starting Point of This Revision: Per our mentor's advice, this document does not open with what technology we have, but first answers where the industry's real pain lies and why current solutions fall short, before explaining whether — and to what extent — AeroSense's technical advantages address that pain. This October 2026 version additionally synchronizes the plan with the team's latest evidence: the banana-export beachhead, the field and industry interviews completed since August, the 14 October patent-attorney consultation, and the updated financial workbook (version 0924).

Smell is the most underrated data source in the world. Crop disease, food spoilage, environmental pollution, and even lung cancer all release specific volatile organic compounds (VOCs) before symptoms become visible. Yet today's electronic noses remain constrained by three core bottlenecks — insufficient sensitivity, poor selectivity, and long-term baseline drift — which can be further broken down into six specific pain points shared across industries (see Chapter 3).

AeroSense Bio engineers Drosophila (fruit fly) olfactory receptors for expression in human cells, reads odor binding in real time via calcium fluorescence, and identifies odors using a neuromorphic algorithm modeled on the fly brain — all packaged into a field-deployable edge device. Our sensing element is alive: the cells continuously renew their receptors, which in principle avoids the aging and drift of static chemical films (to be verified in long-term testing), and the receptors can in principle be swapped to target other odors of interest, making the platform programmable. Commercially, we build recurring revenue on a "device + replaceable live-cell cartridge" model, entering through banana-export disease detection — a low-regulatory-burden category — and, once this beachhead validates a repeatable business model, extending to mango and tea, then food safety and environmental monitoring, with early medical screening evaluated only as a long-term direction (see Chapter 8, Focus Strategy).

Positioning: Fast · On-site · Low operator dependence. Interviews with an analytical-instrumentation professional and an electronic-nose CSO showed that the barrier to on-site testing is not instrument price but trained personnel and lab infrastructure. AeroSense is therefore positioned as a rapid on-site screening layer that flags suspicious samples for laboratory confirmation — not a replacement for the lab, and not a food-safety or diagnostic verdict (a mold-VOC signal is not the same claim as a safety verdict).

Validation Status: What Is Done and What Is Still Open. Completed: field interviews at the Taoyuan District Agricultural Improvement Station's Plant Protection Lab, local farmers' associations and facility farms; an interview with a pest-and-disease specialist at the Taiwan Banana Research Institute (September 2026); interviews with the CSO of an established domestic electronic-nose company, with Challenge Bio, and with an analytical-instrumentation professional; a patent-attorney consultation (14 October 2026); and a public survey (n=300, directional). Still open: demand validation among exporters and packing houses — several were contacted and the one company that replied said the problem does not occur routinely in its process — and hardware validation data (first board built; only main power verified so far). See Chapter 4 and Appendix B. This BP discloses validation progress honestly: what evidence we have, and how we plan to close the remaining gaps.

2. Key Achievements and Validation

Biological olfaction is already an international frontier race; AeroSense shows clear validation signals in technical originality and research foundation:

Achievement / Validation	Description	Validation Status
Original Technology Integration	Integrates Drosophila olfactory receptors and neuromorphic AI in a self-renewing cell + edge-device sensing system; to our knowledge no commercial platform combines these elements (a formal prior-art search has not yet been run)	Concept complete; prior-art search pending
Leading Research Foundation	Core computation layer builds on mushroom-body olfactory coding research from the Institute of Systems Neuroscience (published in Science Advances, 2025; the team has direct research lineage)	Published, independently verifiable
Cell-Level Proof of Concept	Cell-level proof of concept complete: receptor activation produces a measurable fluorescence transient (ΔF/F)	Complete
Edge Hardware (DLIA)	In-house digital lock-in amplifier (DLIA) readout architecture; first PCB fabricated and reviewed with iST Group's engineers — main power supply verified; light-detection and signal-conversion tests await test firmware; staged validation protocol (Stage A–E) finalized	Prototype built; quantitative data pending test firmware
Ecosystem Validation	Originated from the international synthetic biology competition (iGEM); incubated at NTHU Garage+ (18th cohort); selected into FITI; presented at SynBioBeta 2026	Complete
Field and Industry Interviews	Completed: Taoyuan station Plant Protection Lab, farmers' associations, facility farms, Taiwan Banana Research Institute, e-nose CSO, Challenge Bio, analytical-instrumentation professional, patent attorney (see Appendix B)	Complete; exporter / packing-house validation still open

3. Problem and Market Pain Points

3.1 Argument Logic: Starting from Pain Points

Our mentor advised us to "first identify the market's pain, then check whether we actually have an advantage in solving it." This chapter is therefore structured in two layers: the first layer covers **six technical pain points common across industries** (3.2), and the second layer covers **the specific symptoms and quantitative data for each of four application scenarios** (3.3). Chapter 5's solution responds to each of these six shared pain points in turn, so that technical specifications and market pain points don't talk past each other.

3.2 Six Cross-Industry Pain Points

Traditional odor/VOC sensing approaches — whether metal-oxide electronic noses, gas chromatography–mass spectrometry (GC-MS), or manual sensory inspection/spot checks — repeatedly exhibit six types of problems. This is also where our mentor specifically asked us to show, point by point, how our solution performs:

Pain Point	Specific Symptom	Industry Impact
Blind (Insufficient Sensitivity)	Signal-to-noise ratio is inadequate for low-concentration VOCs; most metal-oxide sensors need ppm-level concentrations for reliable detection, while signals released in the early stages of disease/spoilage are typically at the ppb level — effectively "unable to smell it."	The early-warning window is missed; by the time symptoms are visible to the eye, the golden window for intervention has already passed.
Biased (Poor Selectivity / Prone to Misclassification)	Weak discrimination between cross-reactive odors, since the same sensor responds to overlapping sets of VOCs; published literature shows electronic-nose sensitivity/specificity for lung-cancer breath screening swinging widely between 71%–100% depending on the study method.	High misclassification rates make it difficult to establish a reading standard trusted in clinical or production settings.
Fragile (Baseline Drift / Short Lifespan)	Chemical sensing membranes oxidize, get poisoned, and age with use, requiring frequent recalibration; precision instruments like GC-MS are also sensitive to environmental vibration and temperature.	Accuracy degrades quickly after field deployment, requiring frequent maintenance or return to the manufacturer for recalibration.
Fixed Scope (Targets Cannot Be Expanded)	Once a sensor is manufactured, its target odor is fixed; adding a new detection target often requires redesigning the sensing membrane or retraining the entire system.	Unable to quickly iterate for new diseases, new regulations, or new customer needs; scaling up is costly.
High Power Consumption	GC-MS requires continuous heating for sample preparation and a vacuum pump; most precision instruments are not viable on battery power.	Difficult to deploy in greenhouses, outdoor controlled-environment agriculture, or sites without stable power.
Failures Are Hard to Detect	Most sensing systems lack built-in self-diagnostics; membrane poisoning or drift is often only discovered once results become obviously abnormal — for example, readings keep showing "normal" while a crop has already suffered widespread disease.	False negatives accumulate over time unnoticed, eroding user trust.

3.3 Specific Pain Points and Quantitative Data Across Four Application Scenarios

Early Disease Detection in the Banana Export Chain (Beachhead)

Taiwan's banana export sector is our beachhead. We estimate potential fungal-disease-related loss at roughly NT$3.51 billion per year — about 33.6% of the sector's NT$10.445 billion annual output value (team estimate, to be refined with exporter data). For context, the UN Food and Agriculture Organization (FAO) estimates that pests and disease cause crop yield losses of up to 40% globally each year. Disease often releases volatile organic compounds before visible lesions appear, yet field and packing-house practice still rely mainly on visual inspection. A researcher at the Taoyuan District Agricultural Improvement Station's Plant Protection Lab confirmed the gap from the grower's side: there is currently no monitoring method beyond looking at the crop, so no data are collected.

A pest-and-disease specialist at the Taiwan Banana Research Institute (September 2026) added where odor-based screening would help most: the strongest odors come from belowground and basal tissue — corm and pseudostem weevils, bacterial soft rot, crown rot and Fusarium wilt (Panama disease) — while fruit-side

problems such as finger-tip rot and cigar-end rot are not strongly scented. The odor of Fusarium wilt is most obvious late, when the plant is already rotting; he said a faint signal exists earlier, usually noticeable only in the middle to late stage, and that detecting it is largely a matter of sensor sensitivity. He also cautioned that a heavy pseudostem smell often just reflects a dirty orchard. **These are an expert's qualitative judgments, not our measurements; we treat them as hypotheses to test — how many days earlier the faint signal appears, and whether it can be separated from background orchard odor.**

Food Freshness and Safety (Secondary, Longer-Term)

Based on the team's 2026 "Food Preservation and Mold Risk — Public Habits and Needs Survey" (n=300, bilingual online questionnaire, self-selected respondents, directional reference only), we observed patterns that shape our product design:

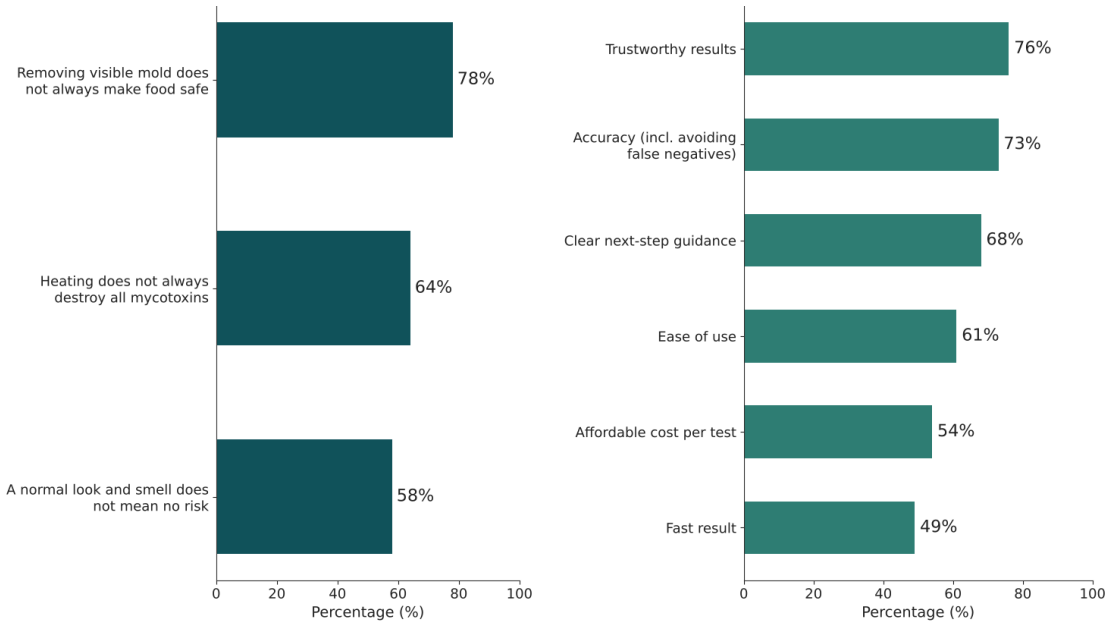

Figure 1 Key Findings from the Public Survey (Source: AeroSense team survey, 2026, n=300; self-selected sample, directional)

- Respondents understood the risk they can see better than the risks they cannot: 78% understood that removing visible mold does not always make food safe, 64% that heating does not always destroy all mycotoxins, and only 58% that a normal look and smell does not mean no risk (27% unsure, 15% held the misconception). **Knowing does not automatically become doing**: respondents with higher knowledge (n=180) were more likely to record the opening date than those with lower or uncertain knowledge (n=120) — 42% against 25% — yet most of them still did not.
- Respondents want a trustworthy, actionable result, not just a number: trustworthiness of results (76%), accuracy including avoiding false negatives (73%) and clear next-step guidance (68%) ranked ahead of ease of use (61%), affordable cost per test (54%) and a fast result (49%). This supports an output that reports a **risk tier with a confidence signal and a recommended next step**, rather than a binary "safe/unsafe" verdict.
- These consumer responses are peripheral to the agricultural B2B beachhead. They are included because they shape product design — risk tiers, and saying plainly what the tool does not certify — not because households are our buyer. Interviews with the analytical-instrumentation professional and the banana research institute both pointed to institutions (associations, cooperatives, research institutes, exporters) rather than individual farmers or households as the realistic paying customers (see Chapter 4).

Environmental Odor / Industrial Safety Gas Monitoring

Industrial fugitive emissions, odor pollution, and low-concentration hazardous gases in indoor air all require precise identification against high background noise — exactly where traditional electronic noses' two weaknesses, poor selectivity and susceptibility to environmental interference, are most exposed. This application is still at the concept stage (see Chapter 10, Application Pipeline) and awaits more complete field and regulatory research.

Non-Invasive Early Medical Screening

Published literature shows that the accuracy of breath VOC analysis for early lung cancer detection varies widely depending on the technique and study design: GC-MS sensitivity ranges from 85%–97%, while electronic-nose approaches swing between 71%–100% (Machado et al. 2005; Gasparri et al. 2016; Di Natale et al. 2003; among others). Current low-dose CT (LDCT) screening also commonly suffers from a high false-positive rate requiring invasive biopsy confirmation. This application faces the highest regulatory bar (medical device classification, see Chapter 15) and is a long-term direction, not a priority for resource investment in the next one to two years.

4. Customer Insights and Untested Hypotheses

Mentor Comments 3 and 4 explicitly state that market pain points and needs must be validated through **field interviews and observation**, not assumed unilaterally by the team; they also require us to confirm whether existing solutions already satisfy the need, to avoid investing resources in a problem for which no strong switching motivation actually exists. This chapter honestly distinguishes between validation work that is "completed" and "planned but not yet completed," and explains the impact on our business judgment.

4.1 Validation Completed to Date

Validation Item	Method / Sample	Key Findings	Judgment Supported
Public Survey (food preservation and mold risk)	Bilingual online survey, n=300, self-selected respondents	Risks that cannot be seen are the least understood (58% understood that a normal look and smell does not mean no risk); knowing does not reliably become doing; users value trust and next-step guidance (see Section 3.3)	Supports a risk-tier output design; peripheral to the B2B beachhead and not evidence of purchase intent
Field Interviews: Taoyuan Station Plant Protection Lab, Farmers' Associations, Facility Farms	Interviews and site visit (discovery, not device pilots)	No monitoring beyond looking at the crop, so no data are collected. The station researcher asked what a device would look like in a field, how many sampling points a plot needs and what the returned data mean, and noted that purchase depends on crop and target — "detects a smell" and "works in a field" are different claims	Confirms the gap from the grower's side; field-use questions remain open

Validation Item	Method / Sample	Key Findings	Judgment Supported
Banana Research Institute: Pest-and-Disease Specialist	Interview (September 2026) and review of the institute's growth-stage guide to banana pests and diseases	Strongest odors come from belowground and basal tissue; Fusarium wilt smells strongest late, with a faint earlier signal; a heavy pseudostem smell may just reflect a dirty orchard; an institute like his is more willing to pay than individual farmers and could serve as a pilot entry point	Qualitative expert judgment; points to institutional buyers and raises field-level detection as a possible second line
Electronic-Nose Industry: CSO Interview	Interview with the Chief Science Officer of an established domestic electronic-nose company	Four properties decide usefulness — selectivity, sensitivity, reliability and lifetime, reproducibility; almost no commercial electronic nose has genuinely high selectivity; "sensors just aren't good enough — the hardware and the algorithms are the easy part"	Supports betting on the sensing element itself; sets the bar our sensing layer must clear (see Section 7.1)
Challenge Bio: Food-Safety Biotechnology Professionals	Interview and technical follow-up	"Start from the technology, not the application"; mold VOCs do not necessarily represent food safety because processing can kill fungi while a toxin such as aflatoxin remains	Adopted the target-selection framework Detectability × Consequence × Unmet Need × Willingness to Pay; the tool is described as rapid risk screening, not a safety verdict
Analytical-Instrumentation Industry Professional	Interview with a professional with hands-on GC-MS/LC-MS testing-service experience	Instrument cost is not the barrier (interviewee's figures: roughly NT$5–10M amortized over about 15 years plus NT$200,000–300,000 per year maintenance); trained personnel and lab infrastructure are; individual farmers may have low willingness to pay and may resist having their own product flagged. All figures are the interviewee's own and not independently verified	Repositioned to Fast · On-site · Low operator dependence; buyer shifted toward associations, agencies, cooperatives and certification bodies
Patent Attorney Consultation	Consultation, 14 October 2026	Route differs by what is protected (invention patent vs utility model); our own early disclosures can later count as prior art; file first, publish afterwards (see Chapter 15)	Plan to file through the university first and to delay public disclosure of technical detail
Technical Literature and Scientific Foundation Review	Peer-reviewed literature trace-back (see Chapter 6)	The core algorithm and receptor engineering have clear, independently verifiable scientific sources	Supports technical credibility, but is not market validation
Electronic-Nose Market Review	Public data and market research reports	The global electronic-nose instrument market is approximately US$164M in 2026, growing to approximately US$293M by 2031 (CAGR 12.26%) (see Chapter 8)	A cross-check that the instrument category exists and is growing; not our addressable market and not proof of product-market fit

4.2 Still Open: Customer-Side Validation Gaps

The grower-side, expert and industry interviews above are complete. What remains open — and is the single largest source of uncertainty in this venture's business case — is demand inside our own supply chain (exporters and packing houses), institutional willingness to pay, and hardware evidence. Desk research cannot substitute for these.

Untested Hypothesis	Validation Method	Key Questions	Expected Timeline
Exporters and packing houses — the customers inside the beachhead chain — feel the pain we assumed and would pay to address it	Short follow-up conversations about how they inspect and grade today (rather than requests for loss data); on-site observation where permitted	Several exporters and packing houses were contacted. The one company that replied said the problem does not occur routinely in its process, that occasional incidents are within its control, and that it could not supply large amounts of data. This is a single data point: it could mean losses are genuinely low, or that a company is reluctant to share loss data with an unfamiliar student team. How are lots inspected and graded today? How large is loss per shipment? Would they pay NT$120,000 per device plus NT$4,000 per month, or would an institution pay?	Q4 2026 – Q1 2027 (outreach under way)
Institutional buyers (research institutes, associations, cooperatives, improvement stations) would host a pilot and pay	Pilot discussions, starting with the institute's Pingtung site	Would they host a pilot? Who pays? What decision does a detection signal enable — and does detection alone reduce loss, or is it not yet a full solution? Is there a subsidy or regulatory route that supports adoption?	Q1 2027 (planned)
The faint early odor signal exists early enough to matter, and can be separated from background orchard odor	Controlled sampling of infected versus healthy material with the team's device, with a laboratory method as reference	How many days earlier does the signal appear? How does field hygiene change the reading? Is post-harvest, field-level, or both the better entry point?	Depends on hardware validation; 2027
Existing solutions (visual inspection, spot checks, GC-MS) are already "good enough," so there is no real motivation to switch	In every conversation above, ask "why haven't you switched yet?" rather than only "would you like to?"	Is there a case of knowing the problem exists but lacking motivation to switch? What are the threshold conditions (price / accuracy / regulation / subsidy)?	In parallel with the interviews above

Appendix B records the interviews completed to date and the open outreach. **Until exporter, packing-house and institutional-buyer evidence is in, this BP's demand argument for the banana beachhead should be treated as a hypothesis supported by grower-side interviews, expert judgment and international literature — not as a validated conclusion**. This is why Chapter 8 commits Phase 1 to a single beachhead: completing a fast build–measure–learn cycle in one scenario first. Medical early screening is a long-term direction; interviews with laboratory physicians are deferred until it becomes a resourced project.

5. Solution and Core Technology

Rather than building a better chemical sensor, we "domesticate" an olfactory system already validated by evolution, and digitize it with AI. The platform consists of three interlocking subsystem layers: the live sensing layer, the neuromorphic computation layer, and the edge hardware layer.

- **Live Sensing Layer**: Human HEK293T cells co-express Drosophila olfactory receptors (OR/Orco) and the GCaMP6 calcium fluorescence indicator. Odor binding triggers calcium influx, producing a real-time fluorescence transient (ΔF/F). The cells continuously renew their receptors, which in principle avoids the aging drift of a static chemical film; month-scale stability still has to be verified.
- **Neuromorphic Computation Layer**: An engineered version of the Drosophila olfactory circuit (AL→MB) — lateral inhibition improves the signal-to-noise ratio, and locality-sensitive hashing (LSH) sparse coding separates overlapping odors; low power, edge-deployable.
- **Edge Hardware Layer**: An in-house optical readout system — photodiode array + optical frequency-division multiplexing (FDM) + digital lock-in amplification (DLIA) — designed to reject ambient light and slow drift. Excitation light that leaks onto the detector at the modulation frequency still survives lock-in, so emission filtering, blank wells and per-well calibration remain necessary.

5.1 How the Solution Addresses the Six Cross-Industry Pain Points

Responding to Mentor Comment 5: the following explains, point by point, exactly how our technology addresses each of the six shared pain points and what level of evidence currently supports it, avoiding vague claims of being "better."

Industry Pain Point	AeroSense's Technical Response	Evidence Level
Blind (Insufficient Sensitivity)	The live-cell receptor binding signal is amplified via GCaMP6 calcium fluorescence, and DLIA digital lock-in extracts weak signals from noise; in principle this compresses the effective detection bandwidth into a narrow-band filter, greatly improving the signal-to-noise ratio	Cell-level ΔF/F validated; DLIA lock-in validation (Stage B) not yet complete — first board built, only main power verified
Biased (Poor Selectivity)	A single receptor has evolutionarily derived high specificity for its target ligand, and lateral inhibition combined with LSH sparse coding can separate overlapping odor patterns across a multi-receptor array	Cell-level validation complete; cross-selectivity of the multi-receptor array awaits systematic testing once the receptor library is expanded
Fragile (Baseline Drift)	The sensing element consists of continuously dividing, self-renewing live cells, which in principle do not suffer the oxidative poisoning and physical aging problems of chemical sensing membranes	Stable receptor expression has been validated at the cell-culture level; long-term (month-scale) field stability awaits validation in the field pilot

Industry Pain Point	AeroSense's Technical Response	Evidence Level
Fixed Scope (Targets Cannot Be Expanded)	Receptors can be "reprogrammed" via molecular biology methods, and structure-prediction tools such as AlphaFold can accelerate the screening and affinity optimization of new receptors	The technical principle has a clear literature basis (see Chapter 6); the actual turnaround time for bringing a new receptor online awaits validation on the first non-original target odor
High Power Consumption	The neuromorphic computation layer replaces dense matrix operations with sparse coding (LSH), and digital lock-in can be implemented on an ESP32-class MCU; in principle, power consumption is far lower than approaches like GC-MS that require continuous heating and vacuum pumping	Architectural design target; the under-1 W figure for the classifier on a Raspberry Pi was tested by another team in our group and its conditions are still to be documented; full-device power data to follow hardware Stage D testing
Failures Are Hard to Detect	DLIA outputs a noise floor and dynamic reserve value with every measurement, which can serve as a self-monitoring indicator of system health; the receptor layer additionally incorporates redundant candidate sequences and AI-based pre-screening of abnormal receptors (see Chapter 14, Risks and Mitigation)	Design has been incorporated into the architecture; no failure-detection cases yet exist from long-term field operation

6. Scientific Evidence and Technical Provenance

Our mentor advised that we "should supplement the scientific evidence currently available." This chapter formally incorporates the "Technical Source Supporting Documentation," originally a separate attachment, into the body of the BP, tracing each module back to peer-reviewed literature to demonstrate that the platform is not conceptual speculation.

6.1 Core Technical Source: Flagship Peer-Reviewed Paper

Cheng, L.-S., Charng, C.-C., Chen, R.-H., Feng, K.-L., Chiang, A.-S., Lo, C.-C., & Lee, T.-K. (2025). Hybrid neural networks in the mushroom body drive olfactory preference in Drosophila. **Science Advances**, 11(22), eadq9893. DOI: 10.1126/sciadv.adq9893.

Author affiliations: Institute of Systems Neuroscience and Department of Life Science, Brain Research Center, and Department of Physics at National Tsing Hua University (as well as UC San Diego and Academia Sinica's Institute of Physics, among others). This paper is open access (CC BY 4.0); the analysis code is publicly available on Dryad, and the data is stored on Zenodo, so it can be independently verified. The study found that the projection-neuron (PN) to Kenyon-cell (KC) connections in the Drosophila mushroom body (MB) are not entirely random, but instead form a spatially organized "hybrid network" — a structure that achieves a computational advantage between "food-odor detection" and "odor discrimination." This is precisely the first-hand, experimentally validated scientific foundation for the core algorithm of AeroSense's neuromorphic computation layer (the AL→MB→MBON circuit).

6.2 Direct Lineage Between the Team and the Research

- **Co-author Ching-Che Charng**, advisor to our team (China Medical University): provides direct research continuity from this paper to AeroSense's computation layer.
- **Co-author and faculty advisor Chung-Chuan Lo**: Associate Dean of the College of Life Science and Director of the Institute of Systems Neuroscience at National Tsing Hua University, whose main research areas are computational neuroscience and NeuroAI.

Therefore, AeroSense's "fruit-fly brain algorithm" is an engineering extension of the team's own published, verifiable research — not an application of secondhand literature. This is one of the most defensible pieces of evidence in this venture's deep-tech due diligence.

6.3 Technology Module × Scientific Source Mapping

Technology Module	Corresponding Subproject	Peer-Reviewed Scientific Source
Neuromorphic Computation Layer (AL→MB, PN–KC–MBON, LSH Sparse Coding)	Subproject 2: Biomimetic Computing / SNN	Cheng, Charng et al. 2025, Science Advances (flagship, team's own); Dasgupta et al. 2017, Science (Drosophila olfactory LSH algorithm)
Live Sensing Layer (Drosophila OR/Orco + GCaMP6 in HEK293T; OBP; Plasmid Construction)	Subproject 1: Odor Cell Detection Array	Zboray et al. 2023, Sci. Rep.; Butterwick et al. 2018, Nature (Orco cryo-EM structure); Pacalon et al. 2023, Nat. Commun. (OR co-receptor structure)
Programmable Receptor Design (AI Structure Prediction + Site-Directed Mutagenesis for Affinity)	Subproject 1, Objective 1	Jumper et al. 2021, Nature (AlphaFold structure prediction)
Edge Hardware Layer (Optical Readout / FDM / DLIA)	Subproject 3: Integrated Hardware	Standard signal-processing techniques (lock-in detection principles, Stanford SRS App Note #3; Zurich Instruments technical documentation) + the team's own independent engineering development

Verifiability statement: the flagship paper is open access under CC BY 4.0 (full text available via DOI 10.1126/sciadv.adq9893); the connectome analysis code is public on Dryad, and related data is stored on Zenodo, so the computational results are reproducible. All literature cited in this chapter is peer-reviewed and independently verifiable.

7. Benchmark Cases and Competitive Positioning

Biological olfaction already has benchmark companies across the consumer, industrial, and biomedical directions, validating both market demand and technical feasibility:

- **Consumer**: Aryballe (France; peptide + silicon photonics + ML; investors include Hyundai, Samsung, and IFF), Osmo (USA; AI-driven scent design).
- **Industrial / Security**: Koniku (living-neuron detection, partnered with Airbus), and traditional electronic noses (Alpha MOS and others).
- **Biomedical**: Owlstone Medical (UK; breath analysis for early disease screening), Aromyx (human olfactory-receptor cell-based biosensing).

7.1 Benchmarking Against Shih-Chuang Biotech and the Electronic-Nose Industry

Our mentor recommended that the team learn from Shih-Chuang Biotech's nearly decade-long development since its founding in 2017 (ROC year 106), and assess the scope for collaboration or integration between the two teams — particularly since our respective faculty advisors have collaborated before. The team has since completed an **interview with the Chief Science Officer of an established domestic electronic-nose company** (name withheld at the interviewee's request); its findings are summarized below. Below that, the desk research on Shih-Chuang is retained as background. **Any collaboration or integration discussion between the two teams has not yet begun.**

Item	Publicly Available Information We Have Gathered
Founding and Origins	Formally founded in 2017 (ROC year 106), spun out of a National Tsing Hua University electronic-nose research team that had already accumulated over a decade of R&D capability before founding; founded by young NTHU students, and backed by NTHU incubation support and angel investment
Core Technology	Electronic nose (digital olfaction platform) integrating artificial intelligence, machine learning algorithms, nanomaterials science, and system-on-chip technology
Validated Application Results	Rapid breath screening achieved over 90% recognition accuracy for pneumonia and four of its bacterial strains (17th National Innovation Award judges' comments, 2020)
Application Portfolio	Medical (rapid breath screening, lung cancer diagnosis, monitoring and treatment-effect assessment for diseases such as NTM), industrial (toxic gas detection in specialized settings), and agriculture (agricultural process monitoring, tea-processing quality control)
Observations on Its Development Over the Past Decade	From a campus research team to an incorporated company, raising an angel round and winning a national-level innovation award, it followed the path of "first achieve high recognition accuracy in a single scenario (rapid respiratory-infection screening), then expand horizontally into industrial and agricultural applications." AeroSense has adopted the same logic: one beachhead (banana export chain) first, extension afterwards (see Section 8.3).

What the CSO Interview Told Us

Selectivity: the sensor must respond strongly and specifically to the target gas, not broadly to many gases at once. The CSO was direct: almost no commercially available electronic nose today has genuinely high selectivity.

Sensitivity: how low a concentration (down to ppm level) the sensor can still detect with a signal-to-noise ratio that survives outside a quiet lab — the single most common failure mode, since sensors that perform well on the bench become unusably noisy in a real field or warehouse.

Reliability and lifetime: how long a sensor can be used before its response degrades. Replacing a sensor daily, as some current products effectively require, is not workable for continuous monitoring.

Reproducibility, including batch-to-batch consistency: does the same measurement repeated give the same answer, and do 100 units of the same sensor behave alike? This is a manufacturing-and-QA problem as much as a chemistry problem, and one the CSO said the industry has not solved well.

The most consequential insight: "Right now, sensors just aren't good enough — the hardware and the algorithms are the easy part." This is external support for our core technical bet — a living, self-renewing receptor as the sensing element — but it is a rationale, not proof: we must still show selectivity and stability with our own data. It also does not tell us what to sell; it tells us the bar our sensing layer must clear.

7.2 Specification Comparison

Criterion (Corresponding Pain Point)	Traditional Electronic Nose	Aromyx	Koniku	Aryballe	AeroSense
Sensitivity (Not Blind)	Medium	High	High	Medium-High	High*
Selectivity (Not Biased)	Low	High	Medium-High	Medium	High*
Long-Term Stability / Not Fragile (No Drift)	Poor	Single-use	Monthly replacement	Good	Good (self-renewing)*
Ability to Add New Targets (Not Fixed Scope)	Difficult	Slower	Slower	Fixed	Programmable*
Power Consumption	Medium-High (precision instruments need heating/pumps)	Medium-High (lab equipment)	Medium-High	Medium	Low (design target)*
Self-Diagnosable Failures	None	None	None	None	In design: DLIA dynamic-reserve self-monitoring*
Field / Real-Time Deployment	Yes	Lab-oriented	Yes	Yes	Yes (edge)
Reusability	Yes	Single-use	Needs replacement	Yes	Cartridge refill
Unit / Operating Cost	Low	High	High	Medium	Medium (amortized)

* AeroSense entries are design targets and in-principle expectations based on the sensing architecture, not measured results; competitor entries are qualitative assessments from public information and interviews. Measured comparisons will follow hardware validation.

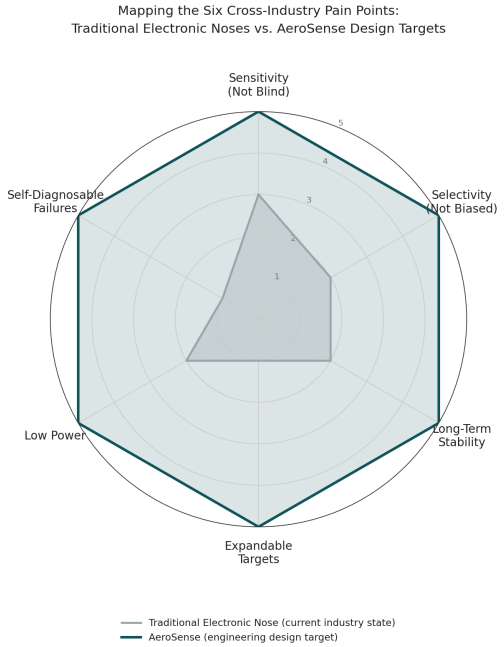

Figure 2 Mapping the Six Cross-Industry Pain Points: Traditional Electronic Noses vs. AeroSense Design Targets

AeroSense's combination of fly receptors, self-renewing cells, neuromorphic edge computing and a programmable receptor library is designed to address competitors' weaknesses — aging, needing replacement, difficulty adding targets, high cost, and lab-bound operation — and to occupy the position of "field-deployable, real-time, scalable, and evolvable"; this remains to be demonstrated with data. Shih-Chuang Biotech, by contrast, has achieved commercially validated high recognition rates in respiratory-infection rapid screening via a chip + nanomaterial approach. How complementary the two technical paths are is worth clarifying in a follow-up conversation.

8. Market Opportunity and Focus Strategy

8.1 Market Size

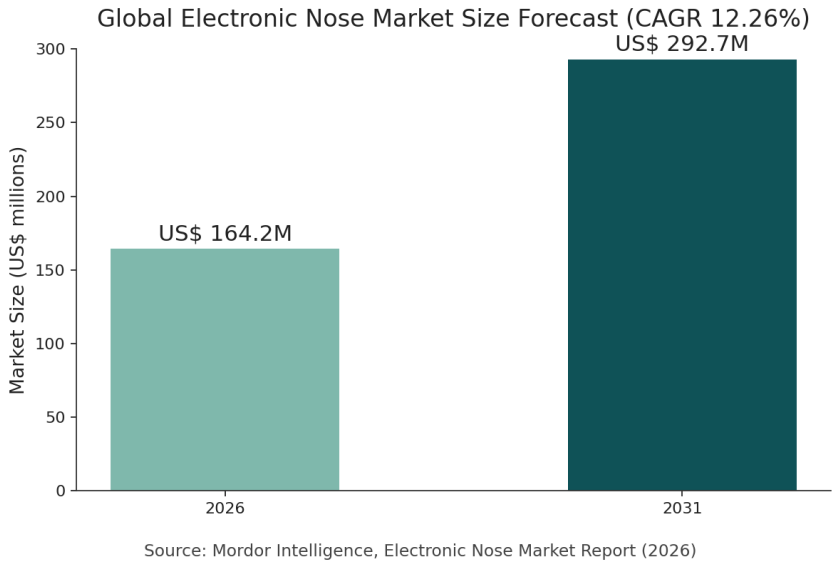

Figure 3 Global Electronic Nose (Instrument) Market Size Forecast — Cross-Check Only, Not Our Addressable Market (Source: Mordor Intelligence, Electronic Nose Market Report, 2026)

According to Mordor Intelligence, the global electronic-nose instrument market was approximately US$164 million in 2026 and is projected to grow to approximately US$293 million by 2031, a CAGR of 12.26%, with food and beverage the largest application and Asia-Pacific the fastest-growing region. This is a specialized-device market, not our customer base, and other market research firms define the category differently and reach substantially different estimates. **We therefore size the opportunity bottom-up from agricultural loss and treat the instrument market only as a cross-check** (responding to Mentor Comment 6).

Tier	Scope	Description
TAM	Global Gas / VOC Sensing Market (agriculture, food safety, industrial monitoring)	Approximately NT$113.6 billion per year (team bottom-up estimate)
SAM	Asia-Pacific Agriculture and Food-Safety Segment addressable by an AI-enabled VOC platform	Approximately NT$15–18 billion per year (team estimate)
SOM	Taiwan's Banana / Mango Export Chain — Crop-Disease-Detection Beachhead	Approximately NT$20 million per year (team estimate). Anchor: the banana sector's estimated fungal-disease-related loss of NT$3.51 billion per year (33.6% of NT$10.445 billion output value)

8.2 Value Chain Positioning

Position	Content
Upstream	Receptor genes and cell engineering, GCaMP fluorescent indicators, electronic components, AI structure-prediction tools
Midstream (This Team)	Receptor engineering and live-cell sensing cartridges, neuromorphic recognition models, edge device integration
Downstream	Banana / mango exporters and packing houses (beachhead); farmers' associations, cooperatives, improvement stations and research institutes (pilot partners and likely institutional buyers); later: tea processors, cold chain and food safety, environmental monitoring, and (long-term) medical and health-screening channels

8.3 Focus Strategy

Why Focus — and Where to Focus

Our mentor explicitly pointed out that this venture's potential scope of applicability is large (agriculture, food safety, environment, medical), but that development should be focused early on so resources are not spread too thin. The team has adopted this advice: in Phase 1 (the next 12–18 months), personnel and funding are committed only to the single beachhead of **early disease detection in Taiwan's banana export supply chain**, with mango (data still pending) and premium tea processing as explicit follow-on markets, not parallel ones — for the following reasons:

(1) A specific customer group with a quantifiable, expensive problem — the banana sector's estimated fungal-disease-related loss of NT$3.51 billion per year, about 33.6% of NT$10.445 billion annual output value.

(2) Lowest regulatory barrier — classified as a general sensing instrument, not a medical device, allowing the fastest path to a field pilot and revenue (see the regulatory phase table in Chapter 15).

(3) Our existing evidence is closest to this scenario: cell-level validation from Subprojects 1 and 2, plus grower-side input from the Taoyuan station, farmers' associations, facility farms and the Taiwan Banana Research Institute.

(4) The three-year P&L and cash-burn models in the financial plan (Chapter 13) are built on the installation and cartridge cadence of this single scenario, keeping resource allocation consistent with the narrative.

The positioning is a **B2B Agricultural VOC Intelligence Platform**, not a general-purpose electronic nose. Food safety, environmental monitoring and early medical screening (see Chapter 10) retain technical extensibility but will not be allocated dedicated resources until the beachhead validates a repeatable build–measure–learn business model; tea is a second-phase market.

9. Business Model and Economic Logic

9.1 Product Definition (Physical Specifications)

The Phase 1 physical product is a gas-tight, desktop detection device, with the internal structure as follows:

- **Gas-Tight Lid**: features gas in/out ports for introducing the sample gas into the sensing chamber.
- **Four-Well Optical Sensing Module**: integrates an LED excitation light source and an optical readout window, enabling simultaneous four-channel detection (FDM optical frequency-division multiplexing).
- **Custom PCB**: an ESP32-based control circuit handling LED driving and digital lock-in computation.
- **Raspberry Pi–Class Single-Board Computer**: handles data aggregation, display/network output, and cloud data upload.

- **Replaceable Live-Cell Cartridge** (consumable): contains engineered cells expressing Drosophila olfactory receptors; the core of recurring revenue, replaced periodically according to cartridge lifespan.

9.2 Three-Tier Business Model and Pricing

The business model builds recurring revenue on three tiers — "device sales + replaceable live-cell cartridge subscription + software/data services (including custom receptor work)" — and leads with B2B. Pricing below is taken from the team's financial workbook (assumed scenario, to be calibrated against actual pilot quotes; purchase intent at these prices has not yet been tested with customers):

Revenue Tier	Pricing Assumption	Business Logic
Hardware Sales (the Razor)	Unit price of NT$120,000 per device, falling to approximately NT$110,000 per device once in mass production	One-time revenue that quickly expands the installed base, building the customer base for cartridge subscriptions
Cartridge Subscription (the Blade)	NT$4,000 per unit per month, rising to approximately NT$4,500 per unit per month once at scale	Periodically replaced live-cell cartridges, contributing predictable recurring revenue (MRR)
Software / Data Services	Recognition-model and dashboard subscriptions, plus custom receptor development services (NRE)	Contributing from Year 2 onward, estimated at approximately NT$1.2M by Year 3

Under these assumptions the financial workbook projects: Year 1, 3 units sold (3 cumulative installs); Year 2, 12 units sold (15 cumulative); Year 3, 35 units sold (50 cumulative). Revenue is NT$0.50 million, NT$2.46 million and NT$7.75 million respectively (device NT$0.36M / 1.44M / 3.85M; cartridge subscription NT$0.144M / 0.72M / 2.70M; software and services NT$0 / 0.30M / 1.20M), with gross margin rising from 45% to 60% as scale and receptor-library reuse increase (see Chapter 13). The cartridge line is computed as cumulative installs × monthly fee × 12, which assumes every install pays for a full year; installs would in practice arrive through the year, so Year-1 cartridge revenue is likely overstated. Reader cost of goods, cartridge bill of materials and cost per measurement are not yet known. We lead with B2B because our interviews point to institutional buyers — associations, cooperatives, research institutes and exporters — as the realistic payers, while individual farmers may have low willingness to pay; evaluation reviewers also asked directly whether farmers will buy at NT$120,000 plus NT$4,000 per month, which is why Chapter 4 lists price acceptance as an open question. Field data flowing back accelerates model optimization and strengthens our moat.

9.3 Data Flywheel

Hardware sales drive growth in the installed base → cartridges and subscriptions contribute recurring revenue (LTV) → field data continuously flows back → the model and receptor library get more accurate the more they're used, forming a competitive moat that becomes harder to catch up with over time. This flywheel logic reinforces the pricing structure in Section 9.2: the device is priced low (the "razor") to win installed base, while the cartridge and software subscriptions (the "blade") are the primary long-term source of gross margin and moat.

10. Application Pipeline and Roadmap

The platform is agnostic to the target odor and can expand horizontally into multiple vertical applications. However, per the focus strategy in Chapter 8, only banana-export disease detection is a formally resourced project at this stage; the other applications retain technical extensibility but are not currently allocated dedicated personnel or funding. Markers show the current stage:

Application Area	Concept	POC	Pilot	Scale-Up	Resourcing Status
Early Disease Detection — Banana Export Chain		●			The only formally resourced item in Phase 1; cell-level proof of concept done, device pilot planned
Mango and Tea (follow-on markets)	●				Mango data pending; tea is a second-phase market; no dedicated resources yet
Food Freshness and Safety	●				Technically extensible, not currently allocated dedicated resources; a VOC signal is not a safety verdict
Environmental Odor / Industrial Safety Gas	●				Technically extensible, not currently allocated dedicated resources
Security / Trace Substance Detection	●				Under observation, not a near-term investment

Roadmap 2026–2031. The table below shows planning windows, not externally committed milestones. Year-level phases follow the pitch deck; quarter-level timing is a planning interpretation.

Phase / Window	Focus and Exit Gate	Status
1 · Validate (Q4 2026 – H1 2027)	Complete hardware validation (Stage A–E), a controlled end-to-end demo and a workflow SOP; publish hardware acceptance criteria; 90-day R&D sprint on receptor validation and the real-time classification loop; iGEM Grand Jamboree (Paris); close the NT$3.0M starting-capital round	Interviews done; device validation pending
2 · Pilot (2027)	Pilots with exporters, packing houses and institutional partners (deck target: up to 10 sites); exit gate is repeat use and a documented willingness to pay or a letter of intent; first hardware accuracy target for the multi-receptor array to be set after Phase 1 data	Planned; no exporter evidence yet
3 · Scale (2028–2029)	Multi-site banana deployment, then mango and tea; unit economics validated against real invoices; possible next funding round and, if supported by pilots, extension to food safety and cold chain	Planned
Long-term option (2030–2031)	Evaluate a diagnostics pathway (TFDA / FDA) and hospital pilots only if the regulatory and clinical route is clear; not a commitment and not resourced	Option only

11. Technical Proof of Concept and Beachhead Use Case

- **Proof of Principle**: co-expressing Drosophila receptors and Orco in cells alongside GCaMP6, we used the Orco agonist VUAA1 to induce a measurable calcium fluorescence transient (ΔF/F), validating the sensing principle of "odor binding → fluorescence signal."
- **Beachhead Scenario (Banana Export Chain)**: deploying the device at a pilot site — an export packing house or an institutional partner such as the Pingtung research institute — to screen banana lots; when a disease-related VOC pattern appears, the output is a risk tier with a confidence signal and a recommendation to send suspect samples for laboratory confirmation. Because the field specialist told us the strongest odors come from belowground and basal tissue, field-level rot detection is a possible second line alongside our original post-harvest focus; the team has not yet decided whether to adopt it.

The commercial validation logic for this beachhead needs to be cross-checked against Chapter 4: the technical path of "flagging a disease VOC pattern" is supported by cell-level and literature evidence and by grower-side interviews, but the business hypothesis that "exporters, packing houses or institutions will pay for this, and that it beats current inspection practice" remains open until the exporter and institutional-buyer work in Chapter 4.2 is done.

Hardware status (October 2026). Our first readout used a blue LED and a camera and failed outside the lab, because ambient light and sensor noise swamped the faint cell signal; we replaced it with a lock-in design that reads only the signal modulated at a known frequency. A first prototype board has been fabricated with design review from iST Group's engineers. Testing the finished board showed the first amplification stage had too much gain, saturating its output whatever the light level; the engineers advised trying feedback components of different values until the gain matches the photocurrent we actually produce. Only the main power supply has been verified so far: light detection and signal conversion cannot be tested until the test firmware and a matching test setup are ready.

12. Team

AeroSense is a deep-tech team spanning biology, AI and hardware. At this stage it consists of four core members, mainly lab students, covering the following functions:

Member	Role	Responsibilities
Pin-Che Huang	CEO, Hardware	Overall operations, business strategy, and external fundraising; optoelectronic readout hardware, electromechanical integration, and device design
Yi-Chia Fang	COO, Systems Integration	Operations management, business development, and cross-disciplinary coordination; fluidics control, signal processing, and device assembly
Chun-Ting Chou	CTO, Dry lab / Machine Learning	Neuromorphic models and odor-recognition algorithms
Yi-Jung Chen	CTO, Wet Lab / Parts Collection	Drosophila receptor engineering, cell transfection, and fluorescence functional validation

Faculty Advisor: Prof. Chung-Chuan Lo (Associate Dean, College of Life Science, and Director, Institute of Systems Neuroscience, National Tsing Hua University). Co-advisor: Prof. Ching-Che Charng (China Medical University). The team has a complete research chain from neuroscience principles to engineering implementation, and its core computational technology has direct lineage to the Drosophila mushroom-body research published in Science Advances (2025).

13. Financial Plan

As an early-stage deep-tech team, we prioritize technical milestones and field validation at this stage, with revenue ramping up only after the beachhead pilot. The charts and tables below are drawn from the team's financial workbook (version 0924): the Year-1 Expense Forecast, the 18-month Burn Rate Forecast, the 3-Year P&L (base case) and the Equity Plan. All figures are modeled assumptions to be calibrated against pilot quotes, not contracts.

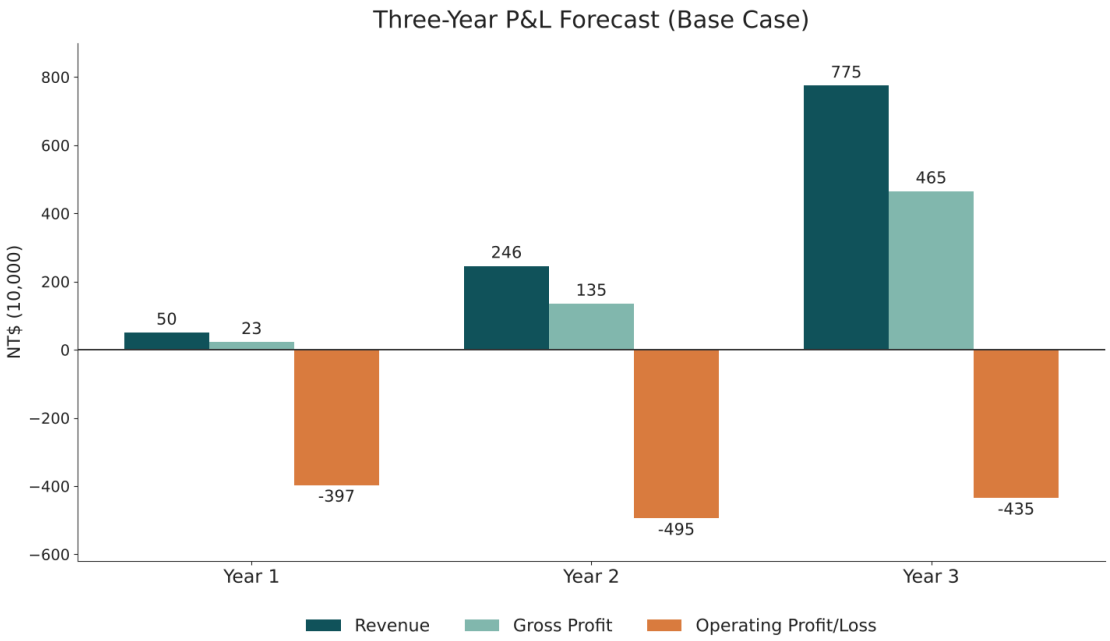

Figure 4 Three-Year P&L Forecast (Base Case): Revenue Grows from NT$0.50M to NT$7.75M, but the Business Still Posts an Operating Loss of NT$4.35M in Year 3 — Underscoring the Need for Further Fundraising

Base-case P&L summary (NT$; workbook sheet "3-Year P&L")

Item	Year 1	Year 2	Year 3
Devices sold (units) / cumulative installs	3 / 3	12 / 15	35 / 50
Total operating revenue	504,000	2,460,000	7,750,000
Gross margin (assumption)	45%	55%	60%
Gross profit	226,800	1,353,000	4,650,000
Total operating expenses	4,200,000	6,300,000	9,000,000
Operating profit / (loss)	(3,973,200)	(4,947,000)	(4,350,000)

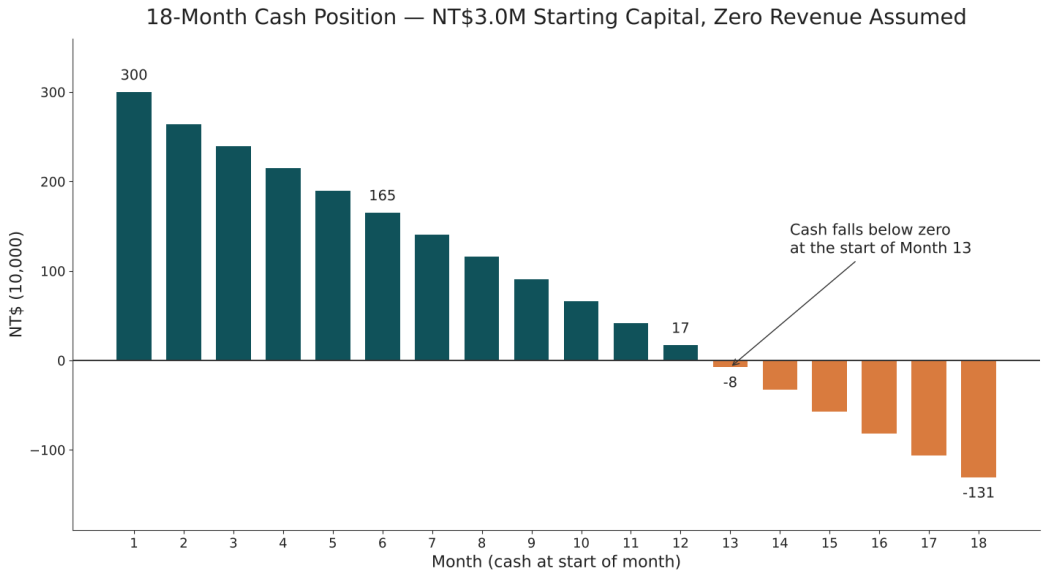

Figure 5 18-Month Cash Position: With NT$3.0M Starting Capital and No Revenue, Cash Falls Below Zero at the Start of Month 13 (Expense-Forecast Basis)

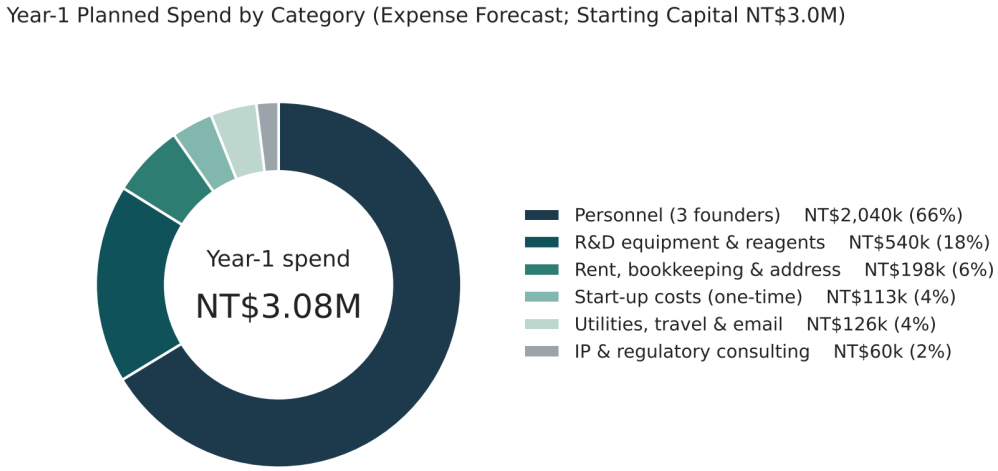

Figure 6 Year-1 Planned Spend by Category (Expense Forecast, NT$3.08M Total, Excluding Share Capital; Starting Capital NT$3.0M)

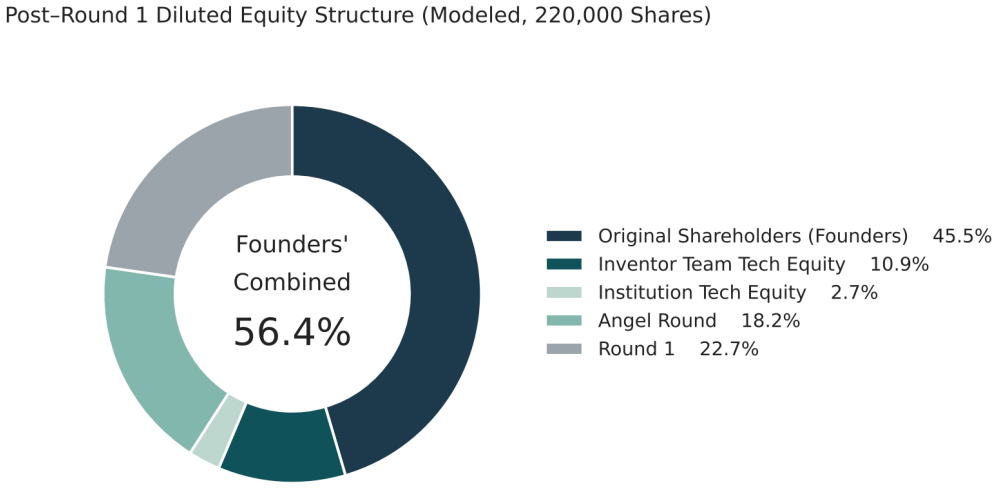

Figure 7 Post–Round 1 Diluted Equity Structure (Modeled): Founders Retain a Combined 56.4% Stake

- **Fundraising**: the NT$3.0M starting capital is the founders' NT$1.0M paid-in capital plus a NT$2.0M angel round (40,000 shares at NT$50); a NT$6.0M Round 1 (50,000 shares at NT$120) is modeled after that. These are modeled rounds, not priced or committed transactions. A seed round is in progress in parallel with competitions and government grants, to fund the critical stage from proof of concept to a commercializable pilot.
- **Key Metrics and Runway**: on the Expense-Forecast basis monthly gross burn is NT$246,958 (NT$359,958 in Month 1, which includes NT$113,000 of one-time start-up costs); cash at the start of Month 12 is NT$170,458 and turns negative at the start of Month 13, so runway is about 12 months against the 12–18-month target. We also track gross margin, LTV/CAC and the breakeven number of installed units.
- **Consistency note on the workbook**: the Expense Forecast (Year-1 spend NT$3.08M, which drives Figures 5 and 6) and the P&L base case (Year-1 operating expenses NT$4.2M, operating loss NT$3.97M) have different scopes. The former is a lean cost base for three salaried founders; the latter assumes team expansion (personnel NT$2.4M, R&D NT$1.2M, other NT$0.6M) and includes Year-1 revenue of NT$0.50M that the burn forecast sets to zero. On the P&L basis the Year-1 loss exceeds the NT$3.0M starting capital, giving a runway of about 9 months rather than 12. We therefore quote runway as **about 9–12 months**, and harmonizing the two sheets is an open modeling task.
- **Funding gap**: the three-year cumulative operating loss is about NT$13.27M, against NT$9.0M of cash in the modeled rounds (founders NT$1.0M, angel NT$2.0M, Round 1 NT$6.0M). The roughly NT$4.3M difference would have to come from grants, faster revenue, tighter costs or a further round; the timing of rounds is not modeled, and operating loss is not the same as cash flow (working capital and capex are not included).

The Equity Plan models 100,000 founder shares at NT$10, a 30,000-share technology pool at NT$10 (issued as non-cash, in-kind technology valuation; the institution's share is assumed to be 20%, i.e. 6,000 shares), a 40,000-share angel round at NT$50 and a 50,000-share Round 1 at NT$120, giving valuations of NT$1.0M, NT$1.3M, NT$8.5M and NT$26.4M after each step and cumulative paid-in (including the in-kind valuation) of NT$1.0M, NT$1.3M, NT$3.3M and NT$9.3M. The three founders each hold about 18.8% after Round 1. The institutional share of technology equity involves university IP ownership and must be finalized with the technology transfer office, which has not yet been formally engaged (see Chapter 15).

Equity plan summary (workbook sheet "Equity Plan")

Stage	Total shares	Founders' combined stake*	Valuation (NT$)	Cumulative paid-in (NT$)
Founding capital	100,000	100.0%	1,000,000	1,000,000
Technology shares	130,000	95.4%	1,300,000	1,300,000
Angel round	170,000	72.9%	8,500,000	3,300,000
Round 1	220,000	56.4%	26,400,000	9,300,000

* Founders' original shares plus the inventor team's technology shares (124,000 shares). Technology shares are non-cash; cash raised is NT$1.0M founders' capital + NT$2.0M angel + NT$6.0M Round 1.

14. Risks and Mitigation

Risk	Mitigation Strategy
Insufficient Receptor/Cell Signal-to-Noise Ratio	Adopt higher-signal GCaMP variants, redundant multi-receptor design, and enhanced imaging algorithms
Loss of Function in Mutated Receptors	Design multiple candidate sequences per target, pre-screen localization with fluorescent tags, and pre-screen with AI
Hardware Mass Production and Cost	Modular design, spreading hardware cost across cartridge consumables, and progressive process optimization. The first PCB is built and has had an engineering review from iST Group, but a manufacturing partner for the board and cartridge has not yet been identified
Lengthy Medical Market Regulation	Monetize first through agriculture/food safety/environment, treating medical as a long-term, high-value option with early groundwork
GCaMP Licensing and Risk of Being Copied	Address GCaMP commercial licensing early, or design around it; build multiple moats through a receptor database, integration know-how, data network effects and patents. An evaluation reviewer asked specifically whether GCaMP6 can be used commercially; this is unresolved
Funding and Operational Runway	NT$3.0M starting capital lasts about 12 months on the Expense-Forecast basis and about 9 months on the P&L base case (Year-1 loss NT$3.97M); the three-year cumulative operating loss of about NT$13.3M also exceeds the NT$9.0M of modeled cash raises. Begin the next raise or grant applications well before Month 6, tie spending to validation milestones, and reconcile the two workbook sheets
Market Demand Not Yet Validated on the Buyer Side	Grower-side interviews are complete, but exporters and packing houses — the customers inside the beachhead chain — are not yet validated: the one company that replied said the problem is not routine in its process and incidents are within its control, and we have no letter of intent or signed pilot. Mitigation: follow-up conversations about how they inspect and grade, an institutional pilot partner, and Phase 1 resources concentrated on a single scenario (see Chapter 4)
Existing Solutions May Already Be "Good Enough," Switching Motivation Unclear	Explicitly probe the threshold conditions for switching during interviews (see Appendix B), to avoid investing resources in solving a problem the customer isn't actually in a hurry to solve
Detection Alone May Not Reduce Loss; Price Resistance in Taiwan's Agriculture	Evaluation reviewers asked whether a detection signal is a full solution and whether farmers will pay NT$120,000 plus NT$4,000 per month. Pair each risk tier with a defined action (segregate, confirm in the lab), quantify avoided loss per shipment, target institutional buyers, and study subsidy and regulatory routes
Early Odor Signal Too Faint or Confounded by Orchard Conditions	A field specialist said the early signal is faint and usually obvious only mid-to-late stage, and that a heavy smell can reflect a dirty orchard. Treat as a hypothesis: measure days gained and interference in controlled sampling, and report readings against field hygiene
Over-Trusted Automated Risk Score (False Negatives)	Report a risk tier with a confidence signal and recommend laboratory confirmation for high-risk samples; never a silent "safe"; state plainly that a mold-VOC signal is not a food-safety verdict
Early Public Disclosure Weakening Patent Novelty	Our own disclosures can later count as prior art. File through the university first, delay public release of technical detail, and confirm with the attorney which earlier presentations count as disclosure (see Chapter 15)

15. Regulatory and IP Strategy

Key Risks That Must Be Addressed Early

(1) Calcium fluorescence indicator licensing: the GCaMP family is patented by HHMI Janelia; the publicly distributed material is for non-profit research use only, and commercial use requires a license or design-around with an alternative indicator.

(2) University IP ownership: the core receptor technology originates from the Institute of Systems Neuroscience and is classified as a work-for-hire invention; before commercialization, a license/assignment agreement must be signed with NTHU's technology transfer office and the technology-equity ratio clarified. Outreach to the office and to an NTHU technology-law faculty member has begun, but no formal discussion has taken place.

(3) Disclosure timing: public disclosure before filing can destroy novelty (see Section 15.2).

15.1 Regulatory Milestones by Phase

Phase	Regulatory Focus
Phase 1: Agriculture / Food Safety	The device is classified as a general sensing instrument, not a medical device — the lightest regulatory bar; compliant with electrical safety/EMC (BSMI, CE). Our materials call it a rapid VOC risk-screening tool, not a definitive safety or diagnostic verdict
Biosafety	Uses genetically modified (GMO) cells and must comply with biosafety level (BSL) requirements; deployed devices require assessment of GMO-related regulations and waste disposal
Phase 3: Medical	Use for diagnosis classifies it as a medical device; in Taiwan it is classified by TFDA under the Medical Device Act, requiring ISO 13485 and clinical validation; in the US it would go through FDA 510(k)/De Novo/PMA

We have not yet interviewed anyone from a regulatory body, so our device-classification reading rests on desk research. The sensing cartridges use a genetically modified cell line; formal biosafety committee sign-off is planned but not yet complete.

15.2 Current IP Position and Plan (Updated After the 14 October Patent-Attorney Consultation)

Currently in Place

- The scientific basis for the core algorithm derives from a published paper the team participated in (Science Advances, 2025), with a clear research timeline and personnel lineage that can serve as the technical disclosure foundation for future patent applications.
- The plasmid construction and cell lines for receptor engineering have completed proof of concept, providing basic feasibility data for a patent application. No patent application has been filed yet, and the attorney advised running a prior-art search before designing any strengthening experiments.

Planned Applications (in Priority Order)

1. **Engineered receptor variants and new uses**: engineered protein variants fit an invention patent, which receives full examination with a prior-art search and lasts 20 years. The attorney noted that a new use of a technology that others have not described can itself be patentable, and that results not yet made public are the strongest position for novelty.
2. **The complete device or system**: a utility model is examined for form only and lasts 10 years; from a start-up's point of view, the attorney said, a utility model for the whole system (including the readout architecture and the cartridge interface) may be the better fit. Whether to patent or keep something as a trade secret is our decision, not his. He was not sure how infringement consequences differ between the two types, so we treat that as unanswered.

3. **Programmable receptor screening workflow**: the combination of AlphaFold structure prediction with site-directed mutagenesis will be evaluated after the prior-art search, together with item 1.
4. **Edge implementation of the neuromorphic decoding algorithm**: pending clarification of the novelty boundary relative to existing literature (Dasgupta et al. 2017, the LSH algorithm), we will assess the patentable scope, to avoid overlapping with public algorithms in a way that would preclude patentability.

Timing and disclosure. Our own disclosures can later count as prior art. Taiwan allows a one-year grace period for the applicant's own disclosures, but China and Europe are stricter, so the attorney advised filing first and publishing afterwards; the grace period does not protect against someone else who sees our work and files first. A provisional filing in the United States can secure an early filing date. When a university is a development partner the university is usually the applicant, with students and advisors as inventors, so we plan to begin with NTHU's route and settle target countries before publishing technical detail. Accordingly, public materials describe what the system does and why but not design parameters, receptor identities or the screening workflow, and this document contains unpublished technical detail and should be treated as confidential. Still to confirm with the attorney: which of our earlier public presentations count as disclosure, and the earliest date.

Freedom-to-Operate and Licensing Gaps

- Commercial licensing of GCaMP6 (see the risk box above) must have negotiations completed, or an alternative solution evaluated, before the beachhead market pilot scales up. This is one of the critical-path items for cash flow and production timing, not simply a legal matter.
- University IP ownership and technology-transfer terms (the institutional share of technology equity) need to be confirmed early with NTHU's technology transfer office, which we have not yet formally engaged, to avoid affecting equity and IP due diligence during future fundraising.

16. Vision and Impact

AeroSense's ultimate goal is to make "smell" a data dimension anyone can use and measure anywhere. In the short term, we aim to help banana exporters and growers intervene before disease spreads, reducing loss and unnecessary pesticide use, and later help the food industry protect freshness and safety. In the medium term, we aim to make environmental odors and hazardous gases harder to hide. In the long term, if the regulatory and clinical path proves viable, a single breath might sound an early warning for disease. Once machines have biological-grade smell, many problems that today are discovered "too late" could be seen ahead of time.

What this revision aims to emphasize is that the path to this vision begins, per our mentor's advice, by validating a real pain point and a repeatable business model in a single beachhead market — the banana export chain — rather than declaring equal-weight commitments across all application areas at once.

Appendix A: Mentor Feedback and Revision Comparison Table

The table maps the 11-point business-plan review (August 2026) to where and how this version responds, with an honest status for each point.

Mentor Comment	Response in This BP	Status
1. Find the market's pain first, then check whether our strengths fit	Chapters 3–4 restructured around pain points; banana-sector loss estimate (NT$3.51B/year) as the economic anchor	Done
2. Visit the domestic e-nose company and learn from its decade of history	Section 7.1: CSO interview completed; desk research retained; collaboration discussion not yet begun	Interview done; collaboration open
3. Interview and observe real customers (farmers' associations; lab physicians)	Chapter 4, Appendix B: station, associations, facility farms and a banana institute interviewed; exporters pending; physicians deferred because medical screening is long-term	Partly done
4. Confirm the need is genuinely unmet rather than already served	Chapter 4.2 and Chapter 14: station says no monitoring beyond looking; the one exporter reply was cautious; still open	Open
5. Show how each pain point (blind, biased, fragile, fixed scope, power, hidden failure) is improved	Sections 3.2, 5.1, 7.2, with evidence level stated per point	Done; evidence mostly design-level
6. Use quantitative data for the problem and our results	Banana loss estimate; survey n=300; bottom-up TAM/SAM/SOM (Chapter 8); updated financials (Chapter 13); instrument market kept only as a cross-check	Done
7. Stay focused early	Section 8.3: banana export chain as the single Phase-1 beachhead; mango and tea follow-on	Done
8. Add the available scientific evidence	Chapter 6	Done
9. Map the competitive analysis onto the same industry problems	Section 7.2 (six pain points); AeroSense entries flagged as design targets	Done
10. Clarify current and planned IP positioning	Section 15.2, updated after the 14 October attorney consultation; no filing and no prior-art search yet	Partly done
11. Define what is actually sold and estimate a business model	Sections 9.1–9.2 and Chapter 13; price acceptance and unit economics not yet validated	Done; pricing untested

Appendix B: Field and Industry Interviews — Completed Record and Open Outreach

Interviewee names are withheld unless the interviewee has agreed to be named. Figures quoted from interviewees are their own and have not been independently verified.

Interview	Status	Key finding and what it changed
Taoyuan District Agricultural Improvement Station — Plant Protection Lab	Completed	No monitoring beyond looking at the crop; practical field questions (sampling points, data meaning) became validation criteria
Local farmers' associations and facility farms	Completed	Grower-side view of inspection practice; confirmed the visual-inspection gap
Taiwan Banana Research Institute (pest-and-disease specialist)	Completed, September 2026	Odors strongest belowground; early Fusarium signal faint; institutions more willing to pay; Pingtung site considered as pilot
Electronic-nose company CSO	Completed	Selectivity, sensitivity, reliability, reproducibility; the sensing element is the bottleneck
Challenge Bio (food-safety biotechnology)	Completed	Start from the technology; mold VOC is not a safety verdict; new target-selection framework
Analytical-instrumentation professional	Completed	Personnel and infrastructure, not instrument cost, are the barrier; Fast · On-site · Low operator dependence
Patent attorney	Completed, 14 October 2026	Invention patent vs utility model; file before publishing; start through the university
iST Group engineers and a senior student with circuit-design experience	Completed (design review)	Gain tuning, detector selection, power and grounding became next-board goals