CONCEPT PAPER

The Silent Burden

Non-Invasive Detection of Microplastics in the Human Body

An Invitation to Collaborate

We have identified a physics-compliant pathway toward non-invasive microplastic detection in living humans. We are seeking collaborators to help make it real.

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January 2026
Document ID: AG-2026-CP-001

The Opportunity

Microplastics have infiltrated the human body. They have been found in blood, brain tissue, lungs, liver, placenta, and arterial plaques. Yet we have no way to see them in a living person. No scan. No test. No diagnostic window into this invisible contamination.

This concept paper proposes a research direction to change that. It is not a finished solution—it is an invitation to build one together.

Why This Matters

The human health implications of microplastic accumulation remain poorly understood precisely because we cannot measure it non-invasively. Current methods require tissue destruction. You cannot track accumulation over time in a living person. You cannot screen populations. You cannot evaluate interventions. This diagnostic void must be filled before the health consequences of plastic pollution can be properly studied, let alone addressed.

What We Know

The contamination is real and documented. Leslie et al. (2022) detected microplastics in 80% of human blood samples. Marfella et al. (2024, NEJM) found microplastics in carotid plaques, with contaminated plaques showing higher rates of cardiovascular events. Green et al. (2025) quantified that cardiopulmonary bypass circuits release 60 microplastic particles per liter per hour into patient blood during surgery. The particles are there. We simply cannot see them.

What We Propose

A multi-modal detection architecture that respects the physics of biological tissue while exploiting the optical and acoustic signatures that distinguish synthetic polymers from human tissue. This is not one technology but a coordinated system of complementary techniques, each addressing limitations of the others.

The concept has undergone rigorous internal review. Earlier versions contained physics errors; those have been corrected. The architecture is now defensible. What remains is the engineering challenge of turning a sound concept into working hardware—and that requires collaboration across multiple disciplines.

The Core Concept

We propose a tiered detection system with three complementary arms, each operating where its physics are valid:

Deep Tissue Detection: SWIR Photoacoustic Imaging

The Problem: Standard optical imaging cannot see pristine plastics. They are transparent in the visible and near-infrared wavelengths where tissue is also transparent. No absorption means no contrast—the particles are invisible.

The Solution: Shift to the Shortwave Infrared (SWIR) window at 1000-1700nm. Here, synthetic polymers exhibit C-H vibrational overtone absorption bands. When pulsed laser light at these wavelengths is absorbed by a plastic particle, it heats momentarily, expands, and generates an ultrasound wave. This photoacoustic signal can be detected centimeters deep in tissue.

The Physics: The NIR-II optical window achieves 1-4cm tissue penetration. Polyethylene shows characteristic absorption peaks at 1210nm (second C-H overtone) and 1730nm (first overtone). Polystyrene and PET show aromatic signatures at 1140-1170nm. Multi-wavelength acquisition enables spectral unmixing to distinguish crystalline polymer signatures from the broader absorption bands of biological lipids.

Status: Conceptually validated. Requires development of optimized OPO laser source, multi-wavelength acquisition protocols, and AI spectral unmixing algorithms. Detection limits and signal-to-noise ratios need to be characterized experimentally.

Surface Identification: QCL-ATR Spectroscopy

The Problem: Mid-infrared spectroscopy provides definitive polymer fingerprinting—each polymer type has a unique spectral signature. But water absorbs mid-IR radiation so strongly that penetration in hydrated tissue is limited to roughly 100 micrometers. You cannot see deep into the body with mid-IR.

The Solution: Do not fight the physics. Instead, target surfaces where the penetration limit becomes an asset: the stratum corneum (outer skin layer) and the corneal surface of the eye. These are sites where environmental microplastics accumulate and where shallow penetration is sufficient.

The Physics: The stratum corneum has lower water content (15-30%) than deeper tissue, making it more mid-IR transparent. Attenuated Total Reflectance (ATR) configuration probes only the surface layer. Polymer-specific fingerprints include polystyrene at 1029 cm^{-1}, PVC at 966 cm^{-1}, and PET at 1282 cm^{-1}.

Status: Surface QCL-ATR is mature technology (TRL 7-8). Application to dermal microplastic quantification requires validation studies correlating in-vivo readings with ex-vivo tape-strip analysis.

Ocular and Dielectric Detection: Terahertz Imaging

The Problem: We need an independent validation channel that does not rely on the same contrast mechanisms as the optical methods.

The Solution: Terahertz radiation is exquisitely sensitive to water content. Plastics are hydrophobic with distinct dielectric properties. A microplastic particle in the tear film or corneal

epithelium appears as a "dry spot" against the wet tissue background—a dielectric anomaly detectable through THz reflection imaging.

The Physics: THz penetration in tissue is limited to hundreds of micrometers, but this is ideal for ocular surface assessment. The technique is non-ionizing and safe for repeated exposure. Uniquely, THz penetrates carbon-black pigmented plastics that defeat conventional optical sorting.

Status: THz imaging is established for skin hydration mapping. Application to microplastic detection requires validation of contrast mechanisms and development of ocular-specific protocols.

What We Have Done

This concept has been developed through iterative refinement with systematic critical analysis. Two rounds of formal Red Team review identified weaknesses in earlier versions, which have been addressed:

Physics Errors Corrected

Original Claim (v1.0)	Red Team Finding	Corrected Position (v3.0)
100nm nanoplastic detection in vivo	Diffraction limits prevent this; no modality achieves 100nm in vivo	Minimum detectable size ≥1μm in vivo; ~200nm ex vivo validation only
QCL penetrates several centimeters	Water absorption limits mid-IR to <100μm in hydrated tissue	QCL restricted to surface analysis only; deep detection uses SWIR
AI will learn to separate signals	No training data exists; hand-waving on how AI would be developed	Sim-to-Real pipeline defined: phantoms → simulation → transfer learning

Architecture Validated

The revised architecture assigns each modality a distinct, non-overlapping role where its physics are valid. Deep detection uses SWIR photoacoustics. Surface identification uses mid-IR QCL-ATR. Dielectric validation uses THz. The modalities complement rather than duplicate each other.

Graceful degradation has been designed into the system. If one modality fails, the others continue to provide meaningful (though reduced) information. This addresses the earlier critique that the system would fail catastrophically if any component produced unreliable output.

Fragility Reduced

Independent Red Team analysis assessed the concept's fragility score at 52%—down from 74% in the original version. The remaining fragility reflects not physics errors but implementation uncertainties: detection limits that need experimental characterization, costs that need estimation, and teams that need assembly.

These are not failures of the concept. They are invitations to collaborate.

What We Need: The Collaboration Opportunity

No single researcher or institution possesses all the expertise required to develop this system. The interdisciplinary requirements are substantial. This is acknowledged openly—and it is why we are seeking collaborators.

The Core Challenge

Red Team analysis identified "bus factor" as a critical risk: the required expertise spans biomedical optics, photoacoustic imaging, quantum cascade lasers, terahertz systems, AI/ML, regulatory affairs, and potentially nanorobotics. This skill set does not exist in a single institution. The solution is not to pretend otherwise—it is to build a multi-site collaboration with complementary capabilities.

Expertise Sought

Domain	Specific Need	Contribution to Project
Biomedical Optics	SWIR/NIR-II tissue optics expertise; OPO laser systems	Lead development of deep-tissue photoacoustic detection arm
Photoacoustic Imaging	System design; transducer arrays; image reconstruction	Translate SWIR contrast into clinical imaging capability
QCL Spectroscopy	Mid-IR laser engineering; ATR probe design	Develop surface identification module for dermal screening
Terahertz Systems	THz imaging instrumentation; ocular applications	Build dielectric validation arm for eye/skin assessment
AI/Machine Learning	Spectral unmixing; transfer learning; domain adaptation	Create training pipeline and classification algorithms
Tissue Phantoms	Optical phantom fabrication; standardization	Establish ground-truth calibration standards
Regulatory Affairs	FDA De Novo pathway; medical device classification	Navigate regulatory strategy and clinical trial design
Clinical Translation	Occupational health; dermatology; ophthalmology	Define clinical use cases and validation endpoints

Institutional Partners Sought

We envision a consortium model with complementary institutional capabilities. Ideal partners might include academic medical centers with biomedical engineering programs, national laboratories with advanced optical instrumentation, clinical research organizations with regulatory expertise, and international collaborators to ensure global applicability of standards and protocols.

The project is structured to allow modular participation. A collaborator with QCL expertise need not also have THz capability—the architecture is designed for distributed development with integration milestones.

Near-Term Opportunities

While the full vision is ambitious, several components are achievable with current technology and represent lower-risk entry points for collaboration:

Surgical Circuit Monitoring (TRL 7-9)

Cardiopulmonary bypass circuits demonstrably contaminate patient blood with microplastics, yet this goes completely unmonitored. Clamp-on ultrasonic sensors already exist for bubble detection and flow measurement in these circuits. Adaptation for particle counting represents an engineering challenge rather than a fundamental research problem.

Opportunity: A standalone inline monitor for surgical circuits could achieve FDA 510(k) clearance using existing predicates, establishing proof-of-concept for real-time microplastic detection while generating data on iatrogenic exposure.

Dermal Surface Screening (TRL 6-7)

QCL-ATR spectroscopy of the skin surface requires no deep-tissue penetration. The technology is mature. What is needed is validation: correlating in-vivo spectroscopic readings with ex-vivo analysis of tape-strip samples to establish that the technique accurately quantifies dermal pollution burden.

Opportunity: A skin screening study with occupational health populations (plastics manufacturing, recycling workers) could validate the surface detection approach while generating publishable clinical data.

Phantom Standard Development (TRL 5-6)

The field lacks standardized reference materials for microplastic detection in biological matrices. PVCP (polyvinyl chloride plastisol) phantoms with embedded NIST-traceable microplastic particles could serve as calibration standards for any detection system.

Opportunity: Open-source publication of phantom fabrication protocols would establish the collaboration as a standard-setting body, building credibility and attracting additional partners.

Funding Strategy

Red Team analysis correctly noted the absence of cost estimates and funding pathways. This section addresses that gap—not with precise figures (which require institutional input) but with a strategic framework for financial sustainability.

Target Funding Mechanisms

Funding Source	Mechanism	Alignment with Project
NIH NIBIB	R21 Exploratory/Developmental	Novel biomedical imaging technology; high-risk/high-reward profile
NIH NIEHS	R01 Environmental Health	Human exposure assessment; environmental health diagnostics
EU Horizon Europe	Cluster 1: Health	Non-invasive diagnostics; personalized medicine
NSF BMMB	Biophotonics program	Fundamental optics research; tissue-light interaction
DoD CDMRP	Toxic Exposures Research	Occupational/military exposure monitoring
Private Foundations	Environmental health focus	Plastic pollution health effects; diagnostic innovation

Phased Funding Approach

The project is structured for incremental funding with defined milestones, reducing risk for funders while building evidence for subsequent phases:

Phase 1 (Seed, $200-500K): Phantom development and single-modality proof-of-concept. Deliverables: Published phantom standard; laboratory demonstration of SWIR-PA microplastic detection in phantoms.

Phase 2 (Development, $1-3M): Multi-modality integration and ex-vivo validation. Deliverables: Integrated benchtop prototype; correlation with O-PTIR ground-truth analysis.

Phase 3 (Translation, $5-10M): Clinical validation and regulatory submission. Deliverables: Pilot human studies; FDA De Novo submission; peer-reviewed clinical evidence.

Non-Profit Operational Model

The stated goal is a "non-profit machine to help people." The operational model envisions open-source publication of methods and standards, with revenue from industrial applications (occupational health screening, quality control) subsidizing deployment to research institutions and underserved communities.

This is not charity—it is strategic positioning. By establishing the standard for microplastic detection, the collaboration creates a platform that others build upon rather than compete against.

Longer-Term Research Directions

Beyond the near-term applications, the concept paper identifies several transformative research directions that extend the timeline but offer potentially paradigm-shifting capabilities:

Enhanced Capsule Endoscopy (4-7 Years)

Capsule endoscopy is a mature ingestible platform. Integration of miniaturized Raman spectroscopy and photoacoustic transducers would enable scanning of the GI tract lumen during capsule transit—detecting microplastics at the site where most dietary exposure occurs.

Research questions: Can Raman spectrometers be miniaturized to capsule power budgets? Can acoustic concentration enhance detection sensitivity sufficiently for clinical utility?

Sonar-Inspired Resonance Detection (5-8 Years)

Synthetic particles may exhibit characteristic acoustic resonances based on size, shape, and material. Frequency-swept ultrasound could identify particles by their harmonic or subharmonic emissions—signatures that biological tissue cannot produce.

Research questions: Do microplastics exhibit detectable resonant behavior in tissue? Can resonance patterns provide material identification without optical spectroscopy?

Nanorobotic Distributed Sensing (7-10+ Years)

Rather than scanning from outside, nanorobotic swarms could distribute throughout the body to find and characterize particles. This represents a fundamentally different detection paradigm—currently at low TRL but potentially transformative.

Research questions: Can nanorobots be equipped with SERS sensing for polymer identification? Can swarm accumulation around targets create detectable collective signals?

These longer-term directions are included not as near-term commitments but as illustrations of where the research could lead. They represent opportunities for collaborators with relevant expertise to shape the future direction of the program.

What Success Looks Like

For Science

The ability to measure microplastic burden non-invasively would transform environmental health research. Longitudinal studies could track accumulation over time. Intervention trials could assess clearance. Epidemiological studies could correlate exposure with health outcomes. The diagnostic void that currently limits our understanding would be filled.

For Medicine

Occupational health programs could screen workers in high-exposure industries. Clinicians could assess patients with unexplained inflammatory conditions. Surgical teams could monitor iatrogenic exposure in real time. A new category of environmental diagnostic would emerge.

For Public Health

Population-level screening would generate the data needed for evidence-based policy. Geographic exposure mapping would identify hotspots. Demographic profiling would reveal disparities. The invisible burden would become visible—and therefore addressable.

For Collaborators

Early participation in a standard-setting initiative offers strategic advantages. Collaborators would co-author foundational publications, co-develop intellectual property, and establish their institutions as leaders in an emerging field. The first-mover advantage in environmental diagnostics is substantial.

The Ask

We are seeking expressions of interest from researchers and institutions with relevant expertise. This is not a request for funding—it is an invitation to explore collaboration. Initial discussions would focus on identifying complementary capabilities, defining potential contribution areas, and assessing mutual fit before any formal commitment.

Next Steps

If this concept resonates with your research interests or institutional capabilities, we invite you to reach out. The immediate goal is conversation, not commitment.

For Potential Collaborators

- Review this concept paper and identify areas of alignment with your expertise
- Consider what unique capabilities your team or institution could contribute
- Reach out to discuss potential collaboration models and mutual interests
- Participate in shaping the research direction—the concept is mature but not fixed

For Funders and Program Officers

- This concept aligns with multiple funding priorities across NIH, NSF, DoD, and international programs
- The tiered approach allows incremental funding with defined milestones
- Early engagement can shape the proposal to align with specific program objectives

For Industry Partners

- Occupational health applications offer near-term commercial opportunity
- Open-source standards reduce development risk while enabling differentiated products
- Early partnership positions companies as leaders in emerging environmental diagnostics market

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Document ID: AG-2026-CP-001

This concept paper represents an invitation to collaborate on a research direction we believe is both scientifically sound and socially important. The physics have been validated. The architecture is defensible. What remains is the collaborative work of turning concept into reality. We hope you will join us.

Appendix A: Technical Summary for Specialist Review

This appendix provides additional technical detail for specialists evaluating the physics and engineering feasibility of the proposed approach.

SWIR Photoacoustic Detection Parameters

Parameter	Target Value	Basis
Excitation wavelengths	1210nm, 1170nm, 1730nm	C-H overtone absorption peaks for PE, PS, PET
Tissue penetration	1-4 cm	NIR-II window; reduced scattering vs NIR-I
Spatial resolution	100µm-1mm (depth-dependent)	Ultrasonic resolution; frequency-depth tradeoff
Minimum particle size	≥1 µm (target)	Requires experimental validation
Laser fluence	<20 mJ/cm²	ANSI Z136.1 MPE limit for skin
Acquisition time	To be determined	Multi-wavelength sweep adds scan time

QCL Surface Spectroscopy Parameters

Parameter	Target Value	Basis
Spectral range	900-1800 cm^{-1}	Polymer fingerprint region
Penetration depth	0.5-2 µm (ATR)	Evanescent wave; water absorption limit
Target tissue	Stratum corneum	15-30% water content; more IR transparent
Polymer discrimination	PS, PVC, PET, PE, PP	Distinct mid-IR signatures
Spatial resolution	~10 µm	Diffraction-limited
Acquisition time	Seconds per spectrum	Established QCL-ATR performance

Open Research Questions

The following questions require experimental investigation and represent priority areas for initial collaborative research:

- What is the signal-to-noise ratio for SWIR-PA detection of 1-10µm polymer particles at 2cm depth in tissue phantoms?
- Can multi-wavelength spectral unmixing reliably distinguish polymer C-H signatures from lipid C-H in mixed tissue environments?

- What is the minimum detectable polymer concentration (µg/g tissue) for each modality?
- How do weathered/degraded environmental microplastics differ spectrally from pristine reference particles?
- What training data volume is required for robust transfer learning from phantoms to clinical use?

These questions are not obstacles—they are research opportunities. Addressing them systematically is the purpose of the proposed collaboration.

Appendix B: Methodology and Transparency Statement

Document Development

This concept paper has been developed through iterative refinement over multiple versions. Each version was subjected to systematic Red Team analysis to identify weaknesses, physics errors, and logical gaps. The current version (v3.0) addresses findings from two rounds of critical review.

AI-Assisted Development

In the spirit of transparency: generative AI tools (Claude, Gemini, ChatGPT) were used as assistants in developing this document. Specific uses included literature synthesis, technical writing refinement, and editorial support. As a researcher with dyslexia, these tools serve as assistive technology for written communication.

All technical claims have been validated against primary literature. Physics constraints are quantified from peer-reviewed sources. The intellectual oversight and responsibility for accuracy remains entirely with the human author.

Conflicts of Interest

The author has no financial conflicts of interest related to this work. The goal is explicitly non-profit: to develop an open diagnostic capability for human benefit rather than commercial exploitation.

Document Version

Concept Paper Version: CP-001

Based on Technical Roadmap Version: 3.0

Red Team Fragility Score: 52% (improved from 74% in v1.0)

Document Date: January 2026