### Research Proposal Summary

* 1. **Proposed work plan for internship unit(s) (IU):**

Please summarize the work plan for the project by showing which intern will work when. Each internship unit (IU) corresponds to one 4-6-month internship. This table provides a high-level overview of the proposed research project and information about intern(s). Please refer to the [**Accelerate Guide: Writing your proposal**](https://www.mitacs.ca/sites/default/files/resources/accelerate_guide_to_writing_your_proposal.pdf)for assistance.

*To add additional row, click on any cell in the bottom row of the table and then click on the "+" symbol on the bottom row.*

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|  | | | | | | | **Year 1** | | | | | | | | | | | | | | | | | | | | | | | | **Year 2** | | | | | | | | | | | | | | | | | | | | | | | | **Year 3** | | | | | | | | | | | | | | | | | | **Year 4** | | | | | | | | | | | | **Year 5** | | | | | | | | | | | |
| **Months** | | | | | | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | | 10 | | 11 | | 12 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | | 10 | | 11 | | 12 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Intern Name | | Degree Level | IU | | *Highlight the cells using a shade or colour to indicate the work plan for interns* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MASc1 | Masters | | | 2 | | X | | X | | X | | X | | X | | X | | X | | X | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| **Total internship units:** | **4** |
| **Total project funding:**  The amount entered here should equal the total amount including partner and Mitacs contributions | **$60,000**  *e.g., $30,000* | |

### Description of proposed research

* 1. **Research abstract** (Max. 200 words):

Please include: Research problem to be addressed and its significance, objectives, and proposed methodology. This section will be used to recruit reviewers; it differs from section 7.2. (Public project overview) and must clearly summarize the research proposed.

The overall objective of this research is to advance a foot-based wearable device (ImpactSense) co-developed in previous research agreements to facilitate individual gait and mobility assessments. The proposed research investigates the potential utility of ImpactSense to facilitate gait assessment methods under dual-task conditions (i.e., walking while performing a secondary cognitive task, such as counting backwards by 3) as a marker of mild cognitive impairment (MCI) and/or Alzheimer’s disease and related dementias (ADRD). Specifically, the scope of the proposed project is to develop technology-facilitated methods to characterize gait using assistive devices (i.e., walker, cane) and dual-task gait performance. Normative data will be collected in both healthy, young and older adults to assess feasibility and validate methods development. A case series study (n=3-5) in mild cognitive impairment (MCI) and/or mild-to-moderate ADRD will be conducted to assess clinical feasibility in the target population. The deliverables of the proposed research will advance methods to assess dual-task gait performance in older adults to inform clinical decisions, such as diagnosis or evaluation of treatment effectiveness.

* 1. **Background** and review of relevant prior work (minimum 500 words):

Considering the incidence of Alzheimer's disease and related dementias (ADRD) is projected to double within a generation, and the associated cost of care will increase 10-fold, the need to develop assistive technology to sustain the health and independence of seniors is clear [REF]. While the hallmarks of ADRD are declines in memory and executive functions, the disease also affects coordination and control of body movements. Individuals with ADRD and, to a lesser extent, mild cognitive impairment (MCI) experience deficits in gait and stability affecting the important ability to maintain mobility, engage in physical and social activities, and continue to live independently at home.

Individuals with ADRD have demonstrated reduced stability when performing dual-tasking, operationally defined as walking while undertaking a secondary cognitive task (e.g., conversing with others, counting continuously). Compared to age-matched controls, individuals with mild-to-moderate ADRD demonstrated poorer dual-task performance, indicated by changes in spatiotemporal gait parameters (e.g., step time, length, variability) [REF]. Linked to deficits in attentional capacity, the implications of reduced dual-task gait performance has been suggested as a mechanism contributing to the high incidence of falls in this population [REF].

Current clinical assessment of dual-task gait performance has been conducted largely without technological tools, relying primarily on direct observation of changes in gait speed and/or step variability by an assessor. While visual assessment is sensitive to large changes in performance, such as stopping or stumbling, small changes in performance likely linked to early stages of ADRD progression remains a challenge. There have been numerous research studies employing sensor-based technologies, such as wearable IMUs (combining accelerometer, gyroscope, magnetometer sensors) and/or pressure-sensitive mats [REF] to measure spatiotemporal metrics (e.g., step time, length, variability). However, these tools currently remains resource intensive. Both the high cost of research-grade equipment and need for highly trained personnel and clinician time to set up, operate, and interpret test results constrains widespread adoption. Considering the lack of accessible technologies in the current market, there is a need to advance wearable sensor methods to facilitate dual-task gait assessments for clinical use.

Interpreting dual-task test results remains a major challenge due to the influence of assistive devices (i.e., walker, cane) commonly used in the older adult population [REF]. Despite known impact of assistive devices on single-task gait previously investigated [REF], the interaction between assistive devices under dual-task conditions remains largely under-examined. Another barrier to interpreting dual-task performance results to inform clinical care decisions is heterogeneity in the older adult population. Largely attributable to the accumulation of individual minor conditions (e.g., injuries, chronic conditions) and lifestyle factors (e.g., diet, physical activity) over time, developing normative data to allow direct comparisons remains a significant challenge. Alternatively, a personalized approach where repeated assessments are conducted longitudinally to track performance changes has been proposed.

Prior work co-developed by the academic and industry partners focused on advancing methods to automatically quantify common spatiotemporal gait parameters (e.g., gait speed, cadence, step length) from a pair of low-cost foot-worn wearable sensor called ***ImpactSense***. Recently, the partners have developed novel algorithms to extract advanced gait metrics from ImpactSense signals, including less commonly measured spatial measures including foot roll, toe clearance, and heel clearance. While the evidence remains preliminary, recent laboratory studies using research-grade motion capture equipment indicate these metrics as potential markers of gait deficits related to cognitive impairment [REF].

In summary, the projected population living with ADRD presents a major challenge to our current systems of care. Despite mounting evidence indicating dual-task gait assessments are a valuable indicator of disease progression and risk for falls, there remains a lack of available wearable sensor tools to facilitate clinical assessments. Furthermore, methods of interpreting dual-task performance results to guide clinical decision-making, such as recommending secondary (e.g., early screening) and tertiary prevention measures (e.g., promoting healthy lifestyles), remains underexamined.

* 1. **General objective** of the research project broken down into sub-objectives, activities, themes, or subprojects, as applicable:

The overall objective of this project is to develop dual-task gait assessment technology to facilitate clinical care for individuals with ADRD, or those who are at high risk of developing dementia. Building on recent algorithm developments, the scope of the current proposal aims to advance a rapid clinical test using wearable sensors. The proposed technology will enable automatic measurement of a suite of spatiotemporal gait parameters, including newly developed spatial metrics of the foot (e.g., toe clearance, foot roll). Technical development aims to provide a tool with near zero-effort from clinicians to permit rapid assessment reports. The proposed research comprises of 3 sub-objectives:

1. Methods development and characterization of dual-task gait performance in healthy, young adults (YA)
2. Investigation of influence of assistive devices on dual-task gait performance in healthy, older adults (OA)
3. Case series (n=3-5) study of dual-task performance in mild cognitive impairment (MCI) and/or ADRD
   1. **Details of internships or subprojects:**

**For each intern or subproject, provide the following mandatory information:**

*To duplicate the section below, click within any part of the section and then click on the "+" symbol on the bottom right corner.*

**Intern #**S1 **information**

1. **Name of intern.**

MASC1: Shovon Saha, MASc candidate

PHD1: TBD, to be recruited from Kinesiology or Biomedical Engineering graduate programs at University of Waterloo.

1. **Specific objectives of the internship or subproject**. Clearly state your [sub-] objectives so reviewers can assess if they are achievable.

MASC1 will be primarily responsible for sub-objective S1 aimed at developing protocols and tools towards zero-effort dual-task gait assessment in collaboration with PHD1 (Jan-Mar/24). For sub-objective S2 focusing on characterizing dual-task performance with assistive device use (e.g., walker, cane), both MASC1 and PHD1 will collaborate and share responsibility. PHD1 will be solely responsible for sub-objective S3 aimed at conducting a case series study in 3-5 individuals with MCI or mild-to-moderate ADRD.

Key activities for both interns include developing testing protocols, informing ImpactSense system design towards zero-effort assessments for clinical use, preparing ethics documents, recruiting participants, data acquisition and analysis, and preparation of manuscripts for journal publication.

1. **Methodologies**. Provide enough detail so reviewers can determine if the proposed methodology is appropriate and sufficient to achieve the [sub-] objectives.

S1. Methods development and characterization of dual-task gait performance in healthy, young adults (YA). MASC1 will be responsible for sub-objective S1, with support from PHD1. In this sub-objective, the primary activity is to develop dual-tasking protocols using ImpactSense prototypes and cloud-based analysis interface. The interns will pilot established dual-tasking protocols, such as serial backwards counting (by 1, 3, 7), verbal fluency, memory (e.g., N-back), and selective attention (e.g., Stroop) tasks. In collaboration with MegaIntech technical developers, the intern will inform the design of a novel interface to acquire, analyze, and report metrics extracted from ImpactSense with the aim of minimizing operational overhead towards a zero-effort assessment protocol (i.e., minimal steps needed to conduct assessment). Pilot testing will inform Office of Research Ethics (ORE) applications towards conducting a study to evaluate feasibility and characterize performance in 20 healthy, young adults (YA). Metrics extracted from ImpactSense will be validated against criterion-standard (Vicon) motion capture (i.e., measuring foot roll, toe/heel clearance) and GaitUp/Physilog wearable sensors (i.e., measuring step time, gait speed). Based on analyses focusing on technical feasibility (i.e., minimal burden) and accuracy of ImpactSense outputs compared against criterion-standard equipment, promising protocols will be advanced S2 for further investigation. A technical report documenting procedures, apparatus, and findings in the YA cohort will be generated as the primary deliverable.

Key deliverable(s): Technical report documenting dual-task testing procedures and findings, including analyses of data validity against motion capture and established wearable devices. Recommendations for prototype advancement will be generated and reported in written and verbal communications.

S2. Investigation of influence of assistive devices on dual-task gait performance in healthy, older adults (OA). In this sub-objective, to be conducted by both MASC1 and PHD1, the primary activity is to examine the impact of assistive device use on dual-task performance using ImpactSense prototypes. Based on operational burden and ImpactSense accuracy, 2 promising protocols from S1 will be employed in S2. The interns will pilot dual-task protocols while using 2 common assistive devices (e.g., wheeled walker/rollator, cane). Pilot testing will inform ORE applications towards conducting a study in 20 healthy, older adults (OA) examining interaction effects across task and assistive device conditions (e.g., backwards counting x walker use). OA participants will be recruited through the Waterloo Research in Againg Participant (WRAP) program (<https://uwaterloo.ca/waterloo-research-in-aging-participants/>) and partnerships with Schlegel Research in Aging (RIA, <https://the-ria.ca/>). Study analyses will focus on the influence of assistive device (3 conditions: no device, walker/rollator, cane) and dual-task (3 conditions: single-task, dual-task #1, dual-task #2) conditions via 2-way analysis of variance (ANOVA) methods. Similar to S1, inclusion of assistive device use factors into the system interface design will be conducted in collaboration with MegaIntech technical staff towards minimizing operational burden.

Key deliverable(s): A manuscript for journal publication will be prepared to report findings, focusing on characterizing interactions between assistive device use and dual-tasking conditions. Recommendations for dual-task protocols and ImpactSense system advancement will be generated and reported in written and verbal communications to the partner.

S3. Case series (n=3-5) study of dual-task performance in mild cognitive impairment (MCI) and/or ADRD. To be conducted by PHD1, this sub-objective will focus on testing the developed protocols and prototypes in 3-5 cases of individuals with MCI or ADRD. The focus of the study will be to examine the feasibility and clinical utility of ImpactSense-facilitated dual-task assessments to inform care decisions. Participants will be recruited through partnership with the Schlegel Research in Aging (RIA, <https://the-ria.ca/>). In consultation with RIA staff, cases will be selected based on cognitive impairments associated with MCI or ADRD and physical capacity to perform dual-task assessments. Where possible, cases will be selected to include cases that use assistive device(s) for mobility. Individual cases profiles will be established using standard questionnaires for cognitive status (e.g., MOCA, MMSE), physical activity (e.g., IPAQ), and fall risk (Morse Fall Scale). Performance-based gait assessment, including ImpactSense-mediated dual-tasking protocols, will be conducted as the primary measures under investigation. Analyses will focus on interpreting dual-task performance measures appropriate to the case profile to inform clinical recommendations for fall risk interventions (e.g., device prescription), and promoting appropriate physical activity programs (e.g., cognitive-motor training, BoneFit - <https://bonefit.ca/>).

Key deliverable(s): A manuscript for journal publication will be prepared to report findings, focusing on case profiles, and the role of ImpactSense-mediated dual-task assessments to inform clinical decisions/recommendations. Recommendations for further development of ImpactSense system advancement and clinical use of technology will be generated and reported in written and verbal communications to the partner.

1. **Timeline**. We suggest using a Gantt chart to provide a timeline showing which task will be done when to achieve each objective.

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| Table 1: Proposed project timeline. Black shading indicates MASC1 primary responsibilities; Dark grey indicates collaborative MASC1 and PHD1 responsibilities; Light grey indicates PHD1 primary responsibilities | | | | | | | | | | | | | |
| **Sub-objective** | **Month** | | | | | | | | | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
| S1.1: (Dual-task development) Pilot testing & ImpactSense co- development | X | X |  |  |  |  |  |  |  |  |  |  |
| S1.2: Ethics application preparation and revisions | X | X |  |  |  |  |  |  |  |  |  |  |
| S1.3. Participant recruitment & testing |  | X | X | X |  |  |  |  |  |  |  |  |
| S1.4. Analysis and reporting |  |  |  | X | X |  |  |  |  |  |  |  |
| S2.1: (Assistive device study) Pilot testing & ImpactSense co- development |  |  |  |  | X | X |  |  |  |  |  |  |
| S2.2: Ethics application preparation and revisions |  |  |  |  | X | X |  |  |  |  |  |  |
| S2.3. Participant recruitment & testing |  |  |  |  |  |  | X | X |  |  |  |  |
| S2.4. Analysis and reporting |  |  |  |  |  |  |  | X | X |  |  |  |
| S3.1: (Case series study) Ethics application preparation and revisions |  |  |  |  |  |  | X | X |  |  |  |  |
| S2.2. Participant recruitment & testing |  |  |  |  |  |  |  |  | X | X |  |  |
| S2.3. Analysis and reporting |  |  |  |  |  |  |  |  |  |  | X | X |

1. **Expected deliverables.** Each project requires the submission of a completed Mitacs Final Report and Mitacs survey at the end of the project**.** Please describe the additional expected deliverables of the project i.e., expected outcomes, results, documents (e.g., intern’s thesis, peer-reviewed journal, teaching material, conference presentation, artistic production).

In addition to the identified key deliverables (summarized in Table 2), interns are expected to generate documentation to communicate and discuss progress & results, including slides/presentations, reports, and/or scientific papers.

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| Table 2: Deliverables | |
| **Sub-objective** | **Deliverables** |
| S1: Dual-task development | * Ethics application materials, incl. dual-task protocols * YA test data and analyses * Preliminary technical report including study findings and recommendations for ImpactSense system development |
| S2: Assistive device study | * Ethics application materials, incl. assistive device use protocols * OA test data and analyses * Journal manuscript to disseminate study findings * Revised technical report |
| S3: Case series study | * Ethics application materials, incl. case series study protocols * Case series test data and analyses * Journal manuscript to report study findings * Finalized technical report |

1. **Benefit to the intern.**

The benefits to the interns relate to experience complementary to academic research and coursework required for the interns’ respective graduate programs. The primary benefits of the proposed project are tangible opportunities to:

● work on industry-oriented research and have an impact on people (i.e., users of the product)

● experience industrial R & D and broaden their professional network

● expand their knowledge on gait biomechanics and gait analysis

● acquire skills on sensor fusion and signal processing

1. **Interaction**. Indicate the percentage (%) of time during the project that the intern will spend on-site at the partner organization location and at the academic institution(s). Research should be carried out equally (50%) in the premises of the partner organization and the academic institution(s).
2. Partner interaction:

|  |  |
| --- | --- |
| Interaction % at partner organization location in Canada | % |
| Interaction % at partner organization location abroad | % |
| Interaction % at academic institution in Canada | % |
| Interaction % at academic institution abroad | % |
| TOTAL (must equal 100%) | 100% |

1. If the research is not carried out equally (50%) at the premises of the partner organization and academic institution(s), please include a justification. NOTE: The minimum interaction at either site is 25% with a maximum of 75%.

Under standard (non-COVID social distancing) conditions, interns will be expected to carry out project duties 50% at the partner location (including site visits) and 50% at the University of Waterloo. Variances in time spent at the partner location will depend on respective duties requiring access to instrumentation (e.g., data collection) or computational resources (e.g., Vicon processing, GPU workstation for machine learning).

1. **Partner interaction.**
   * + 1. Provide a detailed description of the activities that will be performed on-site at the partner organization and the expected interaction with and supervision by employees of the partner organization.

For **Accelerate Entrepreneur** applicants, please provide a detailed description of the activities that will be performed on-site at the pre-approved incubator, including the expected interaction with and supervision with incubator staff.

Primary Activities at Partner Organization

Interns will be expected to follow partner development practices, including:

● Use of Git repositories for code development and versioning

● Thorough documentation practices and presenting their work on a bi-weekly basis

● Bi-weekly planning sessions with Agile development practices

● Development tasks managed with Jira

● Strict timelines and commitment to deliverables and deadlines

* + - 1. Describe the setting in which the intern(s) will be supported. Indicate (1) information about facilities available at each location, (2) where these facilitates are located, (3) the resources the partner organization will provide to support the intern’s work at their premises, and (4) who the intern(s) will have direct interaction with at each location.

For **Accelerate Entrepreneur** applicants, please indicate the resources the pre-approved incubator will provide, including information about space, resources, and expertise.

Key partner personnel

The interns will work closely with MEGA InTech’s CTO, Emanuel Ilyayev, towards achieving the primary deliverables. With 20+ years of software development experience, Mr. Ilyayev offers a depth of experience overseeing complex software development projects.

Space

● The partner has office space available at the MEGA InTech headquarters (Concord, ON) for interns. At the time of writing, it is unclear whether in-person activities are permitted due to COVID-19 distancing measures. In-person interactions are subject to Federal, Provincial, and Municipal-level guidelines for distancing. Under ideal circumstances, interns will work at the partner site. If in-person interaction is not possible, "work from home" accommodations will be used.

Resources

● Each participant is expected to supply their own computer (e.g., laptop). Development will be conducted using Open Source software tools as a primary choice. The partner will provide instructions on how to install the development environment and internal tools.

Expertise

● Interns involved in the project will benefit from working directly under the supervision of CEO and President, Kevan Orvitz. With a background in podiatric medicine, Dr. Orvitz has studied all aspects of biomechanics and the human body, specifically the lower body and feet. Following MegaComfort, a highly successful company bringing health solutions to the workplace, Dr. Orvitz founded MegaIntech to become a leading-edge technology company to help decrease employee risks, medical costs, and optimize performance.

* 1. **Relevance to the partner organization and to Canada**:  
     Describe (1) the main activity of the partner organization (2) the partner’s experience and proposed role in the project, (3) how the partner will benefit from this research, and (4) how Canada will benefit from this research.

Overview

MEGA Intech is leading edge provider of wearable technology for the workplace, providing accurate risk assessment and rehabilitation data and analytical key metrics allowing companies to proactively maximize employee engagement, productivity, and reduce risk.

Technology Products

ImpactSense™ is a smart device combining state-of the-art sensors with the for use in an insole or footwear. Through these sensors, ImpactSensegenerates performance data and step-by-step analysis in real-time to empower users to improve their daily walking and running activities.

As a disrupter, ImpactSense is an innovator in risk prediction and mitigation solutions, which will help companies to monitor and analyze employee’s movement at the workplace to avoid potential injuries and encourage individuals to live a healthier lifestyle.

Expected benefits for the Business Partner (MEGA InTech)

1) First to Market

The current market is an open ground for companies to enter into the space. Considering there are no brands in the occupational health and safety industry providing digitally integrated safety and wellness solutions for the lower extremity, projected timely launch of these products is critical to advance the business.

2) Leveraging Existing Market

The CEO of MEGA InTech, Dr. Kevan Orvitz founded MEGAComfort and also acted as President, until its sale to Surewerx in August 2022. MEGAComfort is a leading-edge company in the Occupational Health and Safety Market which offers a complete range of patent pending ergonomic anti-fatigue insoles and orthotics. MEGAComfort Products have been clinically proven to reduce employee muscle fatigue as well as reducing pain and increasing worker comfort and well-being in multiple field tests.

3) Geographical Expansion

The European Markets mirror the same need gap and opportunities as North America. With clothing and footwear segments yielding the highest rate of return across all countries in Europe, with Germany and Netherlands leading the way, the proposed project aims to advance the partner’s European product line as a strong potential market.

4) Talent Acquisition

A core component of any Technology business is the talent. Considering the footwear industry is evolving every single day, the partner is seeking to acquire the right talent. The proposed research will provide opportunities for the partner to recruit highly qualified talent from the University of Waterloo.

5) New Revenue Sources

Technology Integrated products will open new revenue sources for the partner (MEGA InTech), including licensing technology to other non-competing industries and International markets (e.g., Europe).

Expected benefits for the Canada

1) Job creation

The partner has planned an ongoing schedule of development and GoTo Market strategy, including a job creation strategy. Planned roles span functions including R&D, Tech development, Marketing, Sales, Production and Operations. Market expansion is also projected to impact indirect job growth with first- and second-tier suppliers.

2) New product development

The partner is committed to conducting end-to-end product development of Tech products in Canada, including Research, Mechanical, Electrical & Firmware Design / Development, Manufacturing, and Packaging Development activities.

3) Exports

Considering the opportunities and need gaps in other markets (e.g., Europe), the proposed project to advance the partner’s tech products is expected to drive exports.

* 1. **Indigenous community involvement or impact (if applicable):**

Internships that involve or impact Indigenous communities must comply with the [Mitacs Indigenous Research Policy](https://www.mitacs.ca/en/indigenous-research-policy). Please provide information on i) Indigenous community support for the project, and their role in shaping its objectives & approach, ii) plans for Indigenous community access, use, and governance of resulting knowledge / data, and iii) the team’s background in Indigenous research, including any planned training / mentorship the intern(s) will receive to address deficits in experience.

You may also submit 1-2 letter(s) of support from Indigenous Elders who are members of the partner community / communities and possess the authority to speak on community interests.

Click or tap here to enter text.

* 1. **Relationship (if any) to past/other Mitacs projects:**   
     Describe whether or not the current project is related AND provide specifics about the relationship (e.g., not related because it refers to a different research area OR if related: provide information about what has been achieved in past projects and how the current application complements other submissions). Please include the project IT# for the previous or current project, which can be found on your Award Letter.

This project is a continuation (Year 2) of a previous project under the same title (“Insole-based sensor fusion for ambulatory gait analysis for occupational health & safety”), IT27071, conducted with the same academic and industry partners. Briefly, the results of the first collaborative project were excellent with all deliverables completed, primarily test datasets and signal processing/fusion algorithms. However, hardware issues with first generation prototypes prevented a full translation of knowledge. This proposal seeks to further funding to continue the project to Year 2, with objectives related to 2nd generation hardware prototypes and field studies. A key outcome of Year 1 was the development of a strong academic-industry partnership, resulting in continuous exchange of resources and knowledge.

* 1. **References:**

Please cite academic references listed in this proposal.

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