Sample Application for Small Business Funding

Through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, NIA aims to help small businesses develop effective treatments and interventions for healthy aging. NIH small business funding is competitive, and resubmissions are a common and important part of the award process.

Copyright Notice: The awardee allows you to use the material (e.g. data, writing, graphics) in their application only for nonprofit educational purposes, provided the material remains unchanged and the principal investigator, awardee organization, and NIH NIA are credited.

Find more NIA sample applications and information about SBIR/STTR funding: https://www.nia.nih.gov/research/sbir/nia-small-business-sample-applications
APPLICATION FOR FEDERAL ASSISTANCE
SF 424 (R&R)

1. TYPE OF SUBMISSION*
❍ Pre-application
❍ Application
● Changed/Corrected Application

2. DATE SUBMITTED
2016-09-06

3. DATE RECEIVED BY STATE
blank

4.a. Federal Identifier
AR064111
b. Agency Routing Number
blank
c. Previous Grants.gov Tracking Number
GRANT12241763

5. APPLICANT INFORMATION
Organizational DUNS*:
Legal Name*:
Crossroads Consulting, LLC

Department:
Division:
Street1*:
Street2:
City*:
County:
State*:
Province:
Country*:
ZIP / Postal Code*:

6. EMPLOYER IDENTIFICATION NUMBER (EIN) or (TIN)*

7. TYPE OF APPLICANT*
R: Small Business
Other (Specify):
Small Business Organization Type
● Women Owned
❍ Socially and Economically Disadvantaged

8. TYPE OF APPLICATION*
❍ New
❍ Resubmission
● Renewal
❍ Continuation
❍ Revision
If Revision, mark appropriate box(es).
❍ A. Increase Award
❍ B. Decrease Award
❍ C. Increase Duration
D. Decrease Duration
❍ E. Other (specify):

Is this application being submitted to other agencies?*
❍ Yes
● No
What other Agencies?

9. NAME OF FEDERAL AGENCY*
National Institutes of Health

10. CATALOG OF FEDERAL DOMESTIC ASSISTANCE NUMBER
TITLE:

11. DESCRIPTIVE TITLE OF APPLICANT'S PROJECT*
Portable Slip-Testing Device for Measuring Shoe-Floor Coefficient of Friction

12. PROPOSED PROJECT
Start Date*
05/01/2017
Ending Date*
04/30/2019

13. CONGRESSIONAL DISTRICTS OF APPLICANT

14. PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR CONTACT INFORMATION

Prefix: Dr.
First Name*: Brian
Middle Name: Evan
Last Name*: Moyer
Suffix: 
Position/Title: Technical Director
Organization Name*: Crossroads Consulting LLC
Department: 
Division: 
Street1*: 
Street2: 
City*: 
County: 
State*: USA
Province: 
Country*: USA
ZIP / Postal Code*:  
Phone Number*: Fax Number: Email*: 

15. ESTIMATED PROJECT FUNDING

a. Total Federal Funds Requested* 

b. Total Non-Federal Funds* 

c. Total Federal & Non-Federal Funds* 

d. Estimated Program Income* 

16. IS APPLICATION SUBJECT TO REVIEW BY STATE EXECUTIVE ORDER 12372 PROCESS?*

a. YES ✐

b. NO ●

17. By signing this application, I certify (1) to the statements contained in the list of certifications* and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances * and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)

* The list of certifications and assurances, or an Internet site where you may obtain this list, is contained in the announcement or agency specific instructions.

18. SFLLL or OTHER EXPLANATORY DOCUMENTATION

File Name: 
Mime Type: 

19. AUTHORIZED REPRESENTATIVE

Prefix:  First Name*:  Middle Name:  Last Name*:  Suffix: 
Position/Title*: Managing Director
Organization Name*: Crossroads Consulting LLC
Department: 
Division: 
Street1*: 
Street2: 
City*: 
County: 
State*: USA
Province: 
Country*: USA
ZIP / Postal Code*: 
Phone Number*: Fax Number: Email*: 

Signature of Authorized Representative* 
Date Signed: 

20. PRE-APPLICATION

File Name: 
Mime Type: 

21. COVER LETTER ATTACHMENT

File Name:1244-Cover_Letter.pdf 
Mime Type: application/pdf

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### 1. Human Subjects Section

***Clinical Trial?***

- Yes
- No

***Agency-Defined Phase III Clinical Trial?***

- Yes
- No

### 2. Vertebrate Animals Section

- Are vertebrate animals euthanized?***

- Yes
- No

If "Yes" to euthanasia:

- Is the method consistent with American Veterinary Medical Association (AVMA) guidelines?***

- Yes
- No

If "No" to AVMA guidelines, describe method and provide scientific justification.

### 3. Program Income Section

- *Is program income anticipated during the periods for which the grant support is requested?***

- Yes
- No

If you checked "yes" above (indicating that program income is anticipated), then use the format below to reflect the amount and source(s). Otherwise, leave this section blank.

<table>
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<th>Anticipated Amount ($)</th>
<th>Source(s)</th>
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#178(#00)
### 4. Human Embryonic Stem Cells Section

*Does the proposed project involve human embryonic stem cells?* **Yes** **No**

If the proposed project involves human embryonic stem cells, list below the registration number of the specific cell line(s) from the following list: [http://grants.nih.gov/stem_cells/registry/current.htm](http://grants.nih.gov/stem_cells/registry/current.htm). Or, if a specific stem cell line cannot be referenced at this time, please check the box indicating that one from the registry will be used:

- **Specific stem cell line cannot be referenced at this time. One from the registry will be used.**

<table>
<thead>
<tr>
<th>Cell Line(s) (Example: 0004):</th>
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<tbody>
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</table>

### 5. Inventions and Patents Section (RENEWAL)

*Inventions and Patents:* **Yes** **No**

If the answer is "Yes" then please answer the following:

*Previously Reported:* **Yes** **No**

### 6. Change of Investigator / Change of Institution Section

#### Change of Project Director / Principal Investigator

- **Name of former Project Director / Principal Investigator**
  - Prefix:
  - *First Name:*
  - *Middle Name:*
  - *Last Name:*
  - Suffix:

#### Change of Grantee Institution

- **Name of former institution:**
  - ❍ ●
  - ❍ ●
  - ❍ ❍
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Slip and fall accidents are a major and growing source of occupational injuries. Increasing the available coefficient of friction (ACOF) between the shoe and floor surface is an effective method for reducing slipping risk. A significant need exists for portable, cost-effective shoe-floor ACOF testing equipment that is valid for predicting slip risk. Filling this need is likely to increase the use of rigorous slip-testing in the field, customizing footwear programs to a specific workplace, and selecting the most effective footwear or flooring intervention.

The overall objective of this SBIR Phase II (R44) research study is to develop a portable ACOF testing device that predicts whether a person is likely to slip with sensitivity and specificity. The feasibility of this approach is supported by preliminary development of a biofidelic slip-testing device. The potential for our approach to improve the validity of slip-testing is supported by preliminary data that found that current testing methods do not reflect the kinematics of slipping and that the under-shoe testing condition are critical to the tester's ability to predict slips. The proposed research will be accomplished with four aims:

Aim 1: Identify a set of testing conditions (force, sliding speed and shoe-floor angle profiles) that best predict slip events;

Aim 2: Develop a slip-tester that is portable, inexpensive and biofidelic;

Aim 3: Quantify reproducibility and repeatability of the device using an interlaboratory study; and

Aim 4: Validate the ability of the portable testing device to predict slipping events.

Aim 1 will use previously-collected human slipping data and the biofidelic slip-tester to identify testing kinematics and kinetics that best predict slips. Aim 2 will create a portable device that uses kinematic linkage systems to achieve the testing conditions identified in Aim 1 using stepper motors and calculates ACOF based on forces measured with a load cell. Aim 2 will also include a hypothesis (H2.1) that the developed device will yield ACOF values that are well correlated with the biofidelic slip-testing device developed in Phase 1.

Aim 3 will perform a multiple site interlaboratory study to quantify repeatability of the device and reproducibility across operators and devices. Aim 3 will include a hypothesis (H3.1) that differences in ACOF values will not be observed across operators and devices.

Aim 4 will quantify the validity of the device for prospectively predicting human slip propensity based on ACOF data collected with the device. Aim 4 includes a hypothesis (H4.1) that the device will predict slipping risk.

This proposed research is expected to lead to a state-of-the-art device that will promote interventions that reduce accidental injuries due to slipping. Commercializing this innovation will position Crossroads Consulting, LLC to reach new markets for both laboratory and field slip-testing, targeting safety and occupational health consultants, smaller shoe and flooring manufacturers, as well as the research community. As a result, Crossroads Consulting, LLC is anticipated to grow in size and revenues through product sales and service agreements.
Slip and fall accidents are a significant source of injuries and fatalities for all age groups. Valid measurements of ACOF between shoes and flooring surfaces is essential to identify circumstances in need of intervention and identifying the optimal intervention. The purpose of this research is to develop a portable, valid and cost-effective design for measuring shoe-floor ACOF.
The research team has access to the following equipment and software relevant to the proposed project:

• Biofidelic slip-tester
• Motion capture cameras: Vicon motion capture system (Vicon Motion Systems, Oxford, UK) with fourteen T40S infrared cameras
• Three Bertec forceplates (4060A, Bertec Inc., Columbus, OH)
• Solo-Step ceiling mounted harness system (Solo-Step Inc., Sioux Falls, SD)
• A2D converter/data acquisition device; 16 channels (NI USB-6229, National Instruments, Inc., Austin, TX)
• Anthropometry Measurement Kit
• Pin-on-disk tribometer (Contraves)
• Whole-shoe slip and wear - tester
• Variable incidence tribometer (English XL)
• 2D Stylus Profilometer (Taylor-Hobson Surtronic S100)
• Viscometer (Brookfield LVDVE 115)
• 3D scanner (FaroArm® Platinum)
• Material testing system (ATS 900 Series)
• Digital still and high-speed video cameras
• 3D Printer (Lulzbot TAZ)
• Several desktop and laptop computers; server for data backup
• Microsoft Office 2013 Suite
• EndNote®
• LabView (National Instruments, Inc.; Austin, TX)
• Statistical Software (SAS v9.1, SPSS (17), Minitab)
• Matlab (The MathWorks, Natick, MA)
• Ansys
• Geomagic Studio
• LS-Dyna
## RESEARCH & RELATED BUDGET - SECTION A & B, Budget Period 1

### ORGANIZATIONAL DUNS:

**Crossroads Consulting, LLC**

### Budget Type:
- [ ] Project
- [X] Subaward/Consortium

### Start Date:
05-01-2017

### End Date:
04-30-2018

### Budget Period:
1

### A. Senior/Key Person

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<th>#</th>
<th>Prefix</th>
<th>First Name*</th>
<th>Middle Name</th>
<th>Last Name*</th>
<th>Project Role*</th>
<th>Base Salary ($)</th>
<th>Calendar Months</th>
<th>Academic Months</th>
<th>Summer Months</th>
<th>Requested Salary ($)*</th>
<th>Fringe Benefits ($)*</th>
<th>Funds Requested ($)*</th>
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<tr>
<td>1</td>
<td>Dr.</td>
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**Total Funds Requested for all Senior Key Persons in the attached file**

### B. Other Personnel

<table>
<thead>
<tr>
<th>Number of Personnel*</th>
<th>Project Role*</th>
<th>Calendar Months</th>
<th>Academic Months</th>
<th>Summer Months</th>
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<td>1</td>
<td>Project Engineer</td>
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</table>

**Total Number Other Personnel**

**Total Other Personnel**

**Total Salary, Wages and Fringe Benefits (A+B)**

**RESEARCH & RELATED Budget {A-B} (Funds Requested)**
RESEARCH & RELATED BUDGET - SECTION C, D, & E, Budget Period 1

**Budget Type**: Project, Subaward/Consortium

**Organization**: Crossroads Consulting, LLC

**Start Date**: 05-01-2017

**End Date**: 04-30-2018

**Budget Period**: 1

---

**C. Equipment Description**

List items and dollar amount for each item exceeding $5,000

**Equipment Item Funds Requested ($)**

**Total funds requested for all equipment listed in the attached file**

---

**D. Travel Funds Requested ($)**

1. **Domestic Travel Costs (Incl. Canada, Mexico, and U.S. Possessions)**

2. **Foreign Travel Costs**

**Total Travel Cost**

---

**E. Participant/Trainee Support Costs Funds Requested ($)**

1. **Tuition/Fees/Health Insurance**

2. **Stipends**

3. **Travel**

4. **Subsistence**

5. **Other:**

**Number of Participants/Trainees**

**Total Participant Trainee Support Costs**

---

**RESEARCH & RELATED Budget {C-E} (Funds Requested)**


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<th>Section</th>
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<td>Materials and Supplies</td>
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<td>2</td>
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<td>3</td>
<td>Consultant Services</td>
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<td>4</td>
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<td>Equipment or Facility Rental/User Fees</td>
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<td>Machine Shop Time</td>
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**Total Other Direct Costs:**

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<th>Section</th>
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**Indirect Costs:**

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**Total Indirect Costs:**

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**Total Direct and Indirect Costs:**

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**Fee Funds Requested:**

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**Budget Justification:**

*Attached File Name: 1234-Budget Justification.pdf*
### RESEARCH & RELATED BUDGET - SECTION A & B, Budget Period 2

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<tr>
<td>Project</td>
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<td>End Date*</td>
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#### A. Senior/Key Person

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<th>Prefix</th>
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<th>Suffix</th>
<th>Project Role*</th>
<th>Base Salary ($)</th>
<th>Calendar Months</th>
<th>Academic Months</th>
<th>Summer Months</th>
<th>Requested Salary ($)*</th>
<th>Fringe Benefits ($)*</th>
<th>Funds Requested ($)*</th>
</tr>
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</table>

Total Funds Requested for all Senior Key Persons in the attached file

#### B. Other Personnel

<table>
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<tr>
<th>Number of Personnel*</th>
<th>Project Role*</th>
<th>Calendar Months</th>
<th>Academic Months</th>
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<tbody>
<tr>
<td>Post Doctoral Associates</td>
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Total Other Personnel

Total Salary, Wages and Fringe Benefits (A+B)

RESEARCH & RELATED Budget (A-B) (Funds Requested)
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<thead>
<tr>
<th>Equipment Description</th>
<th>List items and dollar amount for each item exceeding $</th>
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<tbody>
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<td><strong>Total funds requested for all equipment listed in the attached file</strong></td>
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<td><strong>Tuition/Fees/Health Insurance</strong></td>
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<td><strong>Travel</strong></td>
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<td><strong>Subsistence</strong></td>
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**Total Other Direct Costs**

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**H. Indirect Costs**

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Specific slips validity, significant measure Phase I is establish targeting those will be used to determine the optimal set of testing conditions that were identified. Objective Specific will be observed. Necessary flooring developed and the testing condition that was identified.

Hypothesis 4.1: Specific growth, license), a complete build kit commercially available between a walkway and footwear. However, a slip-tester; development to achieve desired force, error and reproducibility will be quantified. Using existing methodology, we can establish the sensitivity and specificity of the ACOF measurements to predict slipping events. This will be prospectively validated using crossroads consulting, services and software.

Objective 1.1: Hypothesis 2.1: Objective 3.1: Hypothesis 4.1: Objective 4.1:
known to under-shoe angling biomechanical companies. A sample biomechanical region of have been shown to influence ACOF.

Floor A. Significance Research Strategy ACOF. While significant ratios shortly studied, the range of insufficient population, Taylor, the number of floor faults and slip and fall injuries sustained growing, the probability of floor falls is $0.18$ and $0.22$ on ACOF. In addition, the mean RCOF across the range of 2006 and 2013 is $0.14$. Clearly, the dynamic flooring hardness tends to reduce falling accidents. Therefore, larger RCOF measures are typical of fluids and materials that experience in the environments.

Furthermore, the dynamic flooring reduces falling rates too expensive ($25,000$). Currently, these devices are portable in order to simulate the shoe-floor-contaminant interactions during walking. However, these studies do not provide fluid and materials parameters. The fidelity that shoe-floor-contaminant testing simulate the real gait conditions, which is important to accommodate shoe-floor-contaminant interactions during walking.

The only floor parameter that is known to differentiate shoe-floor-contaminant interactions is the under-shoe testing parameters. These testing parameters are also known to influence ACOF. Where slipping events occur, the slip can be reduced by applying shoe-floor-contaminant interactions. The mean RCOF of the entire sample is $0.14$. Among these studies, there are several standardized footwear geometries that are typical of fluids and materials that experience in the environments. While some portable devices are commercially available, this device is not commercially available. The floor friction between the shoe and the floor is insufficient in most of these environments. The only floor parameter that is known to differentiate shoe-floor-contaminant interactions is the under-shoe testing parameters.

Furthermore, the flooring is insufficient in most of these environments. The only floor parameter that is known to differentiate shoe-floor-contaminant interactions is the under-shoe testing parameters. These testing parameters are also known to influence ACOF. Where slipping events occur, the slip can be reduced by applying shoe-floor-contaminant interactions. The mean RCOF of the entire sample is $0.14$. Among these studies, there are several standardized footwear geometries that are typical of fluids and materials that experience in the environments. While some portable devices are commercially available, this device is not commercially available. The floor friction between the shoe and the floor is insufficient in most of these environments. The only floor parameter that is known to differentiate shoe-floor-contaminant interactions is the under-shoe testing parameters. These testing parameters are also known to influence ACOF. Where slipping events occur, the slip can be reduced by applying shoe-floor-contaminant interactions.
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### References

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### Deviation Reduction

The entire shoe deviates from the existing options by being portable (Table 1).

Furthermore, the design is more portable and cost-effective. We expect the device to be dramatically over-designed in this context.

The purpose of this research is to develop a device that can be used to couple vertical rail custom-machined tracks.

We have performed testing, validation analyses, testing, and features that allow the slip-tester to be accomplished in the future.

The device will accommodate an approach for creating a cost-effective and low-weight portable whole-shoe testing. The device has been shown to be cost-effective and has performed. It can be demonstrated in several ways, including testing, validation, and features that allow the slip-tester to be accomplished in the future.

The purpose of this research is to develop a device that can be used to couple vertical rails without the need for custom-machined tracks. The device has been shown to be cost-effective and has performed. It can be demonstrated in several ways, including testing, validation, and features that allow the slip-tester to be accomplished in the future.
or mimicking the biomechanics of a slip horizontal motion so that only a single actively controlled degree of freedom is controlled. This approach is innovative since current whole shoe devices control motion in each direction with a separate motor. Human slipping data will be used to select the most predictive set of testing conditions. This innovation goes beyond previous development efforts, which only considered mimicking the under-shoe dynamic conditions of other existing devices. Thus, we expect that the proposed ST EPS device will achieve a high level of innovation relative to existing slip-testers that are currently on the market.

C. Approach

The proposed research utilizes four aims that will lead to a valid, portable, and precise device. The project will identify optimal testing conditions for predicting slips (Aim 1); develop and mechanically validate a portable slip-tester (Aim 2); assess the precision (i.e., repeatability and reproducibility) in the developed device (Aim 3); and prospectively quantify the ability of the device to predict slips (Aim 4). Aim 1 will be accomplished by systematically modifying test conditions using the biofidelic slip-tester that was developed in Phase I of the grant and determining the best set of testing conditions for predicting slips based on existing human slip data. Aim 2 will create a new device that minimizes weight and cost while ensuring it is capable of applying the optimal testing conditions that were identified in Aim 1. Aim 3 will utilize an interlaboratory study to quantify the repeatability and reproducibility of the portable device. Lastly, Aim 4 will collect human slipping data in order to prospectively quantify the sensitivity and specificity of the device to predict the occurrence of slip events.

C.1. Progress Made during Phase I

Fig. 1: Biofidelic slip-tester including the mechanical robotic device (A), the device controller (B) and the software interface (C). This device, which was developed in Phase I, serves as proof-of-concept of our approach.
C.1. Slip-tester development

The developed software converts inputs of testing conditions, allowing for three dimensions of control over the testing process:

1. The shoe's position compresses the vertical motor.
2. The shoe's angle changes the horizontal motors.
3. The shoe's rotation modifies the vertical angle.

These test designs were exposed to water, glycerol, and a liquid contaminant.

C.1.2. Identification of appropriate slip-testing conditions

We have performed analyses of the predictive capabilities of the software system, determined based on human unexpected slipping data.

The vertical force of the horizontal motors exceeded 30% of the shoe-floor contaminant resistance.

During walking, the shoe angle exceeded 30°.

The slipping outcome (slip duration) was 0.3 ms, and the force was 0.5 m/s.

Phase I study: We determined that the shoe at an ACOF cutoff of 0.08 was capable of predicting slips more than 7°. We believe that the software is capable of predicting slips better than the logistic regression curve, which the Phase II testing conditions were used to determine.

Despite the limitations of the software, we have made optimal use of it. A subsequent project will be successful if we make the best use of it.
Differences versus standard conditions. We have collected preliminary knowledge that the normal force, which translates from current research, has been demonstrated that more forces, too.

Utilizing a set of testing conditions, we aim to achieve ACOF relevant to the moment of slipping. The RMS error has been calculated.

C.2.1. Rationale and Preliminary Data:

- **A**: A ROC curve fit with Youden's J statistic. The gray circle marks the point where the ROC curve intersects the slope=1 reference line (gray).
- **B**: The RMS Error for different testing conditions.
- **C**: The test data for slip-testing devices were able to rank the portable device. The portable device was the best among six.

Data:

- **D**: The ACOF and slip outcomes of each set of testing conditions. The results suggest that, for our slip-tester, ACOF and slip outcomes can be systematically predicted using the portable device.

Our research has been demonstrated that ACOF is considered in this study, whereas the normal force, force, and slip rates have been calculated using the portable device.

Previous research has suggested that ACOF is an optimal device for predicting slip events. Logistic regression curves have been fit to achieve ACOF relevant to the moment of slipping. The RMS error has been calculated for different testing conditions.

Utilizing a set of testing conditions, we aim to achieve ACOF relevant to the moment of slipping. The RMS error has been calculated for different testing conditions.
C.2.2. Experimental Procedures

The experimental procedures involved the use of portable slip-testing technology (Portable slip-tester) developed to evaluate the effectiveness of footwear in various environments. The primary motivation for developing portable slip-testing technology was to utilize large slip-testers in the field and improve the relevance of testing conditions to real-world environments.

The testing setup utilized for the experiments was a standardized flooring surface, which was used in various conditions such as laboratory and real-world environments. Each of the shoe-floor-contaminant conditions was tested using the slip-tester with good ACOF (average coefficient of friction) on the outsole of the shoe.

Objective 1.1: To identify optimal ACOF of flooring in the field was achieved by utilizing portable devices that allow for more precise estimates of ACOF compared to previous methods.

Aim 1: The ACOF of different footwear types, particularly utilizing large slip-testers in the field, was found to be typically different from that measured in laboratories, indicating the need for portable, biofidelic tools.

Objective 2: To measure the risk of slipping in different footwear interventions typically used in laboratories and environments, the following conditions were tested:

- 

1. Different walking speeds and shoe-floor-contaminant conditions, ranging from 0.5 to 0.7 m/s, resulting in RMS error of 0.1 increment.

2. A set of four trials per ACOF condition for each shoe-floor-contaminant condition.

The selected model was found to be significant (p<0.001) with a regression equation for each sliding direction, anterior (anterior) and medial (medial), allowing for the performance of critical analysis using the statistic.

Data analysis indicated that the optimal ACOF value is 1.0, with RMS error of 0.1 increment, and these data will be utilized to determine the testing condition for each shoe-floor-contaminant condition.

C.3.1. Rationale and Preliminary Design

The rationale behind the preliminary design of the slip-testing technology was to develop methods that would allow for the testing of different shoe-floor-contaminant conditions and five different walking speeds, with an emphasis on real-world environments.

The design methods used in this study were divided into two categories: experimental and analytical, with a focus on biofidelity. The experimental methods were found to be typically different from previous methods used in laboratories, indicating the need for portable, biofidelic tools.

The preliminary design of the slip-testing technology was developed to perform ACOF tests, substituting previous methods with portable and biofidelic tools.

The ACOF tests were performed using a portable slip-tester developed to measure the risk of slipping in different footwear interventions in both laboratory and real-world environments.
appropriate mitigation measures and estimate return on investment. Creating a business case for slip and fall prevention programs, particularly one that is customized to a business owner's specific conditions, is expected to overcome a significant barrier in encouraging slip-prevention interventions.

Our research team has to date developed five different slip-testers and a test method for measuring shoe-floor ACOF. These slip-testers include a slip-tester developed from a six degree of freedom (DOF) high payload robot [14], the Programmable Slip Resistance Tester II [72], a pin-on-disk tribometer [34, 37, 73], a two DOF slip-tester [19, 30, 74] and a three DOF slip-tester (Fig. 1). During the development and use of these various slip-testers, we have identified several design strategies that will inform the development of the portable STEPS slip-tester. We have determined that normal force tends to be a function of the vertical displacement of the shoe. Thus, vertical force can be controlled through vertical displacement and force loading rate can be controlled using the vertical velocity. Another key design feature is the strength of the horizontal motor, which must be strong enough to achieve the desired velocity profile, overcome friction within the slip-tester and overcome the shoe-floor friction at the shoe-floor interface. Thus, we have determined that the horizontal motor(s) should be able to produce shear forces approximately 100% of the desired normal force.

C.3.2. Design Approach

The proposed STEPS design will utilize kinematic linkage system concepts such that affordable off-the-shelf stepper motors can be used to achieve the needed forces and kinematics (Figure 3A). Specifically a toothed belt and pulley design will be used to convert rotary motion of the motor to linear motion of the slip-tester (Figure 3B). A slider-rocker system will be used to raise and lower the shoe in order to couple the loading and unloading of the shoe with the horizontal motion (Figures 3C and 4). Finally, the shoe height will be manually adjustable by turning an adjustment under the load cell, which will raise or lower the shoe in order to adjust the normal force. Thus, the proposed design will only require two moderate strength motors, which will allow STEPS to become more affordable and portable.

The proposed design will be capable of overcoming 400 N of shear force, applying up to 600 N of vertical force and moving at 0.5 m/s (depending on the results of Aim 1). A pulley with a diameter of 0.033 m will be used with a toothed belt to achieve a gear ratio of 30 (1/m) (Fig. 3C). This system will allow for the desired shear force using two synchronized stepper motors capable of generating 10 Nm of torque each at a speed of 14 rad/s (Potential motor: MST430C213-X1AA9.0, JVL, Birekerod, Denmark). The total shear force achieved by these two horizontal motors is 600 N (100% of normal force), which will be capable of overcoming 420N of friction force assuming an efficiency of 70% in the drive train system. The STEPS device will be powered using
either a power supply to connect with alternating current (80 V, 9 A Potential power supply: W80LT900, Acopi an Technical Company, Easton, PA) or an 80 V battery system (Potential battery: GBA80200, GreenWorks, Ltd., Charlotte, NC). Water-fillable weights will be attached to either side of the device so that STEPS weighs enough to apply the required normal force without lifting off of the ground during testing.

This design will allow for testing using standard and ISO 13287 of shoe-floor surfaces for shoes with a AC OF of up to 0.84. Given that slips are exceedingly rare when ACOF values exceed 0.5 [25, 63], STEPS will C.3.2.1. Sensors:

A 6 DOF load cell will be specified and selected in order to achieve the desired forces. Such a sensor will be capable of measuring normal forces of at least 600 N, shear forces of at least 400 N as well as the moment generated by the shear force (approximately 100 Nm) and have a factor of safety of 2 before any damage to the sensor occurs. We will identify a sensor that best balances low weight and cost, while achieving the needed specifications.

C.3.2.2. Computer control and data acquisition:

STEPS will utilize open-loop control to drive the motors via a low-cost open source microcontroller (Arduino). Because stepper motors are capable of achieving precise angular motion and do not accumulate error during rotation (within normal operating parameters), our device will not require feedback control. End switches will be placed to ensure that the device completed the motion without motor slipping. In the case that the device does not complete the motion, the user will be given feedback that the test was invalid. Furthermore, normal force will be adjusted during each testing setup by having the operator adjust the height of the shoe. The device will be lowered to increase shoe deformation (and subsequently force) or raised to decrease the force. Load cell data will provide feedback to the operator until the desired force is reached. We have determined that using vertical position control results in repeatable normal force levels [14, 30]. Through a connected LCD display, the system will guide the user through setup to set the desired normal force targets. During the data collection phase, the microcontroller will drive the motors to achieve the desired sliding speed while forces are measured from the load cell. During the data processing phase, the microcontroller will provide the ACOF value and advise the operator regarding height adjustments.
C.3.3. Mechanical validation

Objective 2.1 will be assessed once a final prototype is achieved. The ACOF is a bill for the mechanical validation (Hypothesis 2.1 will be confirmed). The final design will allow operators to perform for five of the three laboratories and two floor conditions. Specifically, the slip-tester's variability will be compared across different sources of data. Note that the ACOF values can be substituted with lower mass weights (i.e., 10 kg, 20 kg, 30 kg). Furthermore, we propose to use a round-robin design of five different sites. These tests are commonly performed for windows-based software communicating to additional features. The expected results for the mechatronic devices are expected to be achieved the desired normal force. Note that the cost of the mechanical validation is $20,000. If the objective cost is exceeded, the mechanical validation will be reevaluated. We propose to use a round-robin design of five different sites.

C.3.4. Assessment of Objective 2.1

We will recruited five of the three laboratories and two floor conditions. Specifically, the slip-tester's variability will be compared across different sources of data. Note that the ACOF values can be substituted with lower mass weights (i.e., 10 kg, 20 kg, 30 kg). Furthermore, we propose to use a round-robin design of five different sites. These tests are commonly performed for windows-based software communicating to additional features. The expected results for the mechatronic devices are expected to be achieved the desired normal force. Note that the cost of the mechanical validation is $20,000. If the objective cost is exceeded, the mechanical validation will be reevaluated. We propose to use a round-robin design of five different sites.
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\[ \sum_{i=1}^{A} \sum_{j=1}^{B} \sum_{k=1}^{C} S(X, Y, Z)^2 \]

\[ \text{MSE}_{\text{Repeatability}} = \sqrt{\frac{\sum_{i=1}^{A} \sum_{j=1}^{B} \sum_{k=1}^{C} S(X, Y, Z)^2}{36}} \]

Reproducibility(Z) = standard deviation(M(1,2,3,4 \ 1,2,3 \ Z) \ T$
C.5.1. Rationale and preliminary data:

An unexpected slip-testing paradigm will be used by the tester to assess the ability of the footwear to predict slip events. One of the tests consists of a subject walking on a force plate with their left foot, while the right shoe is contaminated with glycerol. The resultant slip distance will be measured as the distance between the foot of the subject and the floor. The data will be collected using ACOF data, and the accuracy of the predictions will be assessed using logistic regression. The number of subjects and the time of the experiment will be recorded in the database. The results will be compared to the results from a previous study to ensure that the data is comparable.

C.5.2. Subjects:

One of the subjects will be a male with a height of 175 cm and a weight of 70 kg. He will be assigned to the control group and will be exposed to a non-slippery surface. The other subject will be a female with a height of 160 cm and a weight of 55 kg. She will be assigned to the experimental group and will be exposed to a slippery surface.

C.5.3. Procedure:

Six subjects will be recruited to participate in a single testing session where they will be asked to walk on a force plate with their left shoe contaminated with glycerol. The resultant slip distance will be measured and the accuracy of the predictions will be assessed using logistic regression. The power analysis will be provided in the power section.

C.5.4. Data analysis:

The data will be analyzed using logistic regression, with the number of subjects and the time of the experiment being recorded in the database. The results will be compared to the results from a previous study to ensure that the data is comparable.

\[ \text{MSE}_\text{Reproducibility} = \frac{1}{3} \sum_{Z=4}^3 \text{Reproducibility}(Z)^2 \]
C.5.5. Power analysis:

70% of the subjects will be able to respond accurately. The findings are expected to be publicly available in the next 12 months. The research will be conducted in collaboration with the PI's team. The expected outcomes are as follows:

- **Aim 1**: Collect data on the slip occurrence and impact on the subjects.
- **Aim 2**: Perform analyses on the collected data.
- **Aim 3**: Gather additional information on the subjects' perceived impact of the data.
- **Aim 4**: Develop a portable device for testing purposes.

Expected outcomes include the ability to achieve wide use of the device and influence testing standards. The findings will be peer-reviewed and validated for publication.

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Inclusion of Women and Minorities

This research includes women and minorities. In the Human Movement and Balance Lab, half of the primary faculty are women and the breakdown of students and staff working in the lab is approximately 50% men and 50% women. We will continue our active recruitment of underrepresented students through academic advising of students in the department of Bioengineering and through the University of Pittsburgh student organizations including the Society of Women Engineers (SWE) and the National Society of Black Engineering (NSBE).

Study participants will be recruited according to the Pittsburgh demographic distribution (50% women and 50% men; 67% white, 27% African American, and 3% Asian; 1.3% Hispanic). Subjects will be recruited from the general community through flyers posted throughout the Pittsburgh area and through collaboration with Nabors Industries. Women will be actively recruited through organizations such as the Women's Resource Center (YWCA). Minorities will be actively recruited through the Pittsburgh Metropolitan Area Hispanic Chamber of Commerce, African American Chamber of Commerce for Western Pennsylvania, Urban League of Pittsburgh and Urban League of Young Professionals of Pittsburgh.

The results of the proposed research will be disseminated to the public via the Human Movement and Balance Laboratory website, university courses, journal publications, conference presentations, seminars, and the education/training programs which will also be offered online to broaden participation. Journal articles will also be made readily available on the Centers' website.
We do not anticipate children participating in this study. We believe that a separate study for children is warranted given that children's bodies are growing and that the gait patterns of children are transient as a result.

In the state of Pennsylvania, the legal age of majority is 18 years. This procedure is consistent with requirements from the University of Pittsburgh Institutional Review Board.
Risks

Protection of

A. the compensated.

Approximately certain body will movement years, severe chosen to subjects.

All criteria.

A. potential subjects will be assigned a personal ID.

Recruitment Subjects

A. The exclusion criteria are:

- History of previous injury to the Human Movement

Recruitment Subjects

B. The inclusion criteria are:

- Healthy, non-elderly adults with 20/20 vision-corrected vision.

Recruitment Subjects

C. Potential Risks

A. The potential risks include:

- Musculoskeletal
- Neurological
- Other neurological

Recruitment Subjects

D. The personal data collected and de-identified data from the developed slip-testing device will be used to validate the ability to recover.

Recruitment Subjects

E. The biomechanical data will be used to minimize risk of injury during testing at the Human Movement Lab.

Recruitment Subjects

F. Informed Consent

A. All subjects will be informed of the risk and will be encouraged to ask questions.

Recruitment Subjects

G. The team will ensure that subjects meet the inclusion criteria and will not be recruited.

Recruitment Subjects

H. The informed consent form will be randomly assigned to wear shoes.

Recruitment Subjects

I. The informed consent form will be randomly assigned to wear shoes.

Recruitment Subjects

J. The informed consent form will be randomly assigned to wear shoes.

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Z. The informed consent form will be randomly assigned to wear shoes.

Recruitment Subjects
identifying data and by restricting access to identifiers to only the PI's of the study. No vulnerable populations will be included in this study. All of these procedures have been reviewed and approved in previous protocols approved by the University of Pittsburgh Internal Review Board [20, 64, 66, 84, 85].

3.0 Potential Benefits of the Proposed Research to Human Subjects and Other

No benefits are known from participation in the study. However, the knowledge gained from the study is expected to benefit other persons by providing a device that will better guide slip-prevention interventions. Given that the participants will be exposed to minimal risk, we anticipate the benefits to others to justify the risk of the study participants.

4.0 Importance of the Knowledge to be Gained

Slip and fall accidents account for a large portion of occupational injuries and often result in severe injuries. Currently, a need exists for technology that can measure shoe-floor friction in the field. The proposed research will fill this gap. Given the minimal risk and potential benefit provided to the subjects, the knowledge gained is expected to greatly exceed the risk to participants.

5.0 Data and Safety Monitoring Plan

No data and safety monitoring plan is required since the proposed research does not involve a clinical trial.

6.0 ClinicalTrials.gov Requirements

No clinical trial will be conducted so no registration is needed in ClinicalTrials.gov.
In Phase order logging, of user portability, clinical testing this conditions. Delivering Slip primary for Phase rapidly, researchers, measuring coefficient accidents in reproducible friction values, step. Including hardware/software and devices are relevant to human slips and quantification of friction is a critical factor to reliably predicting slipping accidents. An open source microcontroller, providing the reproducibility of this device suitable for measuring friction accurately and cost-effectively, will improve slip and fall incidents. A turnkey technology will enable researchers and safety consultants, shoe and floor, to better verify and document the reproducibility of friction coefficient, improving the portability of this technology and cost-effectively. Most slip-testers are not easy to use and provide reliable data. Some devices can fall short of meeting the optimal conditions for testing. The majority of slips occur during work hours, affecting workers and businesses. Because of these factors, improving accuracy and efficiency in measuring friction is a complex phenomenon that requires innovative and commercially available portable testing devices. The project focuses on developing a standard for reproducible friction values, contributing to the availability and long-term opportunities for researchers and businesses. Unfortunately, the latest science and commercially available devices are not realistic. Developing new devices should be easy to use and provide reliable information, ensuring the reproducibility of friction coefficient. This project will improve the portability of this technology and cost-effectively.

Proposed Project and Key Technology Objectives
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3KDVH, 6%,5 SURMHFHYL6DFWHG2XWFRPHVDQPSDFW

Addressed Need and Limitations of Current Methods
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In the US, there are currently no mandatory standards or friction requirements that must be met in order to classify a sole as "slip resistant," only general guidelines. Many slip-resistant shoe manufacturers use a tester (Figure 1) to measure their products using the Standard Test Method for Measuring the Coefficient of Friction for Evaluation of Slip Performance of Footwear and Test Surfaces/Flooring Using a Whole Shoe Tester, or ISO 13287-2012, Personal Protective Equipment-Footwear-Test Method for Slip Resistance, if they sell shoes in Europe. Others use a tester in which ACOF is determined by the maximum collision angle whereby the shoe material sticks to the floor and does not slip.
Commercial Application and Innovation

Societal & Scientific Impact
As industries and fall-related injuries have historically been augmented by poor indoor environments, a robust industry, marketing, and development mechanism is needed. Crossroads has established Crossroads LLC in 2006 to conduct in-depth evaluations and demonstrations of anti-slip products. It was founded with the mission of promoting a viable commercial product that achieves slip and fall prevention.

Crossroads has a track record of making meaningful contributions to the science and technology of ergonomic footwear and has a robust portfolio of successful projects spanning the last 10 years. The company's achievement includes securing a significant number of SBIR grants to develop innovations in the field of ergonomic footwear. In 2007, the company ramped up the sales and production of ergonomic footwear, and in 2008, the company successfully sold ergonomic footwear to workers and manufacturers, including those in the manufacturing/production, medical, and footwear sectors.

Crossroads has a successful business model that includes selling ergonomic footwear to workers and manufacturers, as well as offering ergonomic footwear as a service to businesses such as manufacturers and retailers.

Crossroads is a small, independent, non-profit company that was established in 2006 to develop and commercialize ergonomic footwear. The company has a dedicated team of engineers, scientists, and educators, and has a proven track record of securing funding through SBIR grants and other sources.

Crossroads' technical and commercial efforts have been focused on developing ergonomic footwear for slip and fall prevention. The company has a strong background in ergonomic footwear and has a proven track record of developing ergonomic footwear for slip and fall prevention.

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In support of numerous biomedical/medical device and clinical applications, Crossroads has developed software, graphical user interfaces, and algorithms for systems used to assess cardiovascular health, evaluate and diagnose pulmonary health, deliver chiropractic diagnosis and treatment, and provide vestibular clinical diagnoses. Many of these efforts involved advanced techniques for data acquisition, signal processing, and process control using electroencephalogram (EEG), eye motion tracking, human motion capture, or other physiological signals. Crossroads also established a private motion capture laboratory to support regional animation, performance evaluation, and entertainment projects. This was used to develop a motion capture-based system for golf swing analysis, enhance rider performance through optimized bike-rider fit, and track human actors in support of the development of a college lacrosse video game.

Representative custom software development examples for industrial applications include assembly line monitoring and data analysis for disposable thermocouple manufacturing, remote data logging and mobile communications for oil and gas well monitoring, and process automation for nanotechnology manufacturing.

Direct federal funding is limited to the Phase I SBIR project performed from 2012 to 2015. Historically, the majority of Crossroads’ client base has been affiliated with the University of Pittsburgh, including various research laboratories within the Swanson School of Engineering as well as the Medical Center. In addition, Crossroads has numerous private sector clients, primarily in the mid-Atlantic region.

Future Vision
As Crossroads evolves from a specialized technology research and consulting company to developing STEPS as a commercial product offering, new management and technical staff will support long-term sustainability. Ms. Heather Moyer joined Crossroads Consulting, LLC in September 2016 as co-owner and Managing Director, assuming full responsibility for day-to-day business operations and giving Crossroads a supply chain advantage as a small woman-owned business. Ms. Moyer is a Chemical Engineering graduate of Carnegie Mellon University with more than two decades of experience managing federal government projects and programs and corporate technology development initiatives. Dr. Moyer maintains a high degree of involvement in Crossroads as the Technical Director and co-owner.

Crossroads will hire a full-time junior engineer to support Phase II development efforts and on-going commercialization objectives. Crossroads also anticipates hiring a full-time sales manager to support marketing, coordinate scheduling and delivery, and manage client relationships as product and service demands increase.

Market Overview and Customer Profile
Targeted clients include safety and ergonomic research labs, occupational and forensic consultants, and manufacturers of anti-slip footwear, flooring, and coating products. Figure 3 shows the relative distribution of market potential based on the following initial market research and client profile assumptions.
Research and development (R&D) laboratories focused on biomechanics, ergonomics, and workforce industry research institutions were identified through the, a research forum promoting interactive discussion on scientific matters related to slips, safety and health are anticipated to be early adopters. More than 60 academic, government, and trips, and falls accidents. Approximately 100 safety and forensic consulting firms were also identified. It is anticipated that the R&D and consulting community will be greatly interested in the biofidelity improvements offered by the STEPS slip-tester as well as the predictive nature of the results for establishing ergonomic guidelines. The portability of STEPS will also be attractive to those conducting on-site assessments and field studies. With a work/occupational/safety footwear market greater than (NPD Group 2014) and the US hard surface flooring market forecasted to reach by 2019 (Freedonia 2015), footwear and flooring manufacturers as well as other niche anti-slip product manufacturers are also a target market. Manufacturers use slip-testers to validate product designs and formulations as well as to provide standards-based test data to market their products. Many smaller manufacturers who cannot afford to invest in current commercially available slip-testing devices, will find STEPS affordable. Given the demand in high-risk industrial (construction and manufacturing) and service (healthcare, food service, retail) sectors, footwear manufacturers are focused on the development of low-cost, comfortable, lightweight, durable, and slip-resistant safety shoes. In a review of more than 150 footwear manufacturers listed in the Thomas Register (ThomasNet.com), approximately half are focused on safety footwear and/or work boots and shoes in North America. Of these, approximately 60% are smaller manufacturers with less than 100 employees – a target market for a lower cost slip-testing device. In addition to shoe manufacturers, there are more than 180 anti-slip flooring manufacturers and anti-slip coating/treatment suppliers in North America (ThomasNet.com). Many of these are also smaller manufacturers who might find STEPS attractive from a cost and portability standpoint. Our preliminary market research shows that the addressable market (North America) for STEPS Technology is in the $Millions, providing Crossroads with ample business opportunity given even modest market penetration (Table 1).

Table 1: Estimated Addressable Market (North America) for STEPS Technology

Discriminators and Strategic Advantages
As a fundamentally new slip-testing technology, STEPS offers the following unique capabilities and attributes:

• Portable: target weight is less than 24 kg
• Affordable: target cost is less than
• Improved Biofidelity: use of predictive slip-testing conditions based on biomechanical analysis of human slipping data better represents the tribological phenomenon at the shoe-floor interface
• Reliable and Repeatable: as validated through an interlaboratory study using four different operators; three different devices; and four different locations
• Predictive: as validated through a laboratory study to quantify the sensitivity and specificity of the portable device to predict slips
The primary objective is to develop a portable slip-tester. As a result, the proposed portable slip-tester has been designed and manufactured, with a focus on reducing weight and cost. This table summarizes the key features of the proposed device:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Not significantly increased compared to current devices.</td>
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<tr>
<td>Cost</td>
<td>Affordable to develop and own compared to other market devices.</td>
</tr>
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</table>

These advantages enable STEPS to compete with existing devices in the market.

## Competition and Market Challenges

The primary competition comes from well-established established industries. The modern slip-tester was introduced in 1919 in North America, and many products have attempted to reproduce its under-floor testing. The portable slip-tester that has been developed, using an electromagnetic motor, meets the maximum collision angle requirement for all shoe materials. The portable device can run on its own and does not require the user to be driven, thereby eliminating the cost of labor. Furthermore, it allows the user to test any shoe manufacturer, thus opening the market to a wide variety of products. The portable slip-tester is currently being worked with the European and North American research sectors, and small and medium businesses are competing for the market.

These portability and cost advantages have enabled STEPS to establish the ACOF Committee for Slip-Resistance Testers and the ACOF Slip-Resistance Test-stand. Though it is not very experienced, the committee had the well-established industry standards that determined the maximum slip. These standards are utilized to guide product development and cost.

The primary challenge that we have encountered so far is the necessity of tremendous effort to develop and manufacture the device to the floor and the ability to measure its effectiveness. Therefore, we have attempted to reproduce the under-floor testing, and we have not achieved the ideal results. Currently, the portable slip-tester that has been developed is not affordable to many users. As a result, STEPS has provided for the push of the portable slip-tester, and the market will be well served.

The portable slip-tester is driven and the devices are not portable due to their size and weight. The modern slip-tester as described in Table 2, with ISO 13287, is applied in Europe, and the US and Canada, while the well-established industry standard is not applied in those sectors. These portable devices do not provide ACOF members with comparative assessments of the devices, and do not allow the user to measure the effectiveness of the slip during testing. These portable devices are pneumatically driven and the devices are gravity driven. Two other devices have attempted to reproduce the under-floor testing, and these devices are utilized in the EN 13287, which is the standard for slip testing. However, these devices are not affordable to many users.

As a result, the proposed portable slip-tester has been designed and manufactured, with a focus on reducing weight and cost. This table summarizes the key features of the proposed device:

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## Challenges

The major challenge we have encountered so far is the necessity of tremendous effort to develop and manufacture the device to the floor and the ability to measure its effectiveness. Therefore, we have attempted to reproduce the under-floor testing, and we have not achieved the ideal results. Currently, the portable slip-tester that has been developed is not affordable to many users. As a result, STEPS has provided for the push of the portable slip-tester, and the market will be well served.

The portable slip-tester is driven and the devices are not portable due to their size and weight. The modern slip-tester as described in Table 2, with ISO 13287, is applied in Europe, and the US and Canada, while the well-established industry standard is not applied in those sectors. These portable devices do not provide ACOF members with comparative assessments of the devices, and do not allow the user to measure the effectiveness of the slip during testing. These portable devices are pneumatically driven and the devices are gravity driven. Two other devices have attempted to reproduce the under-floor testing, and these devices are utilized in the EN 13287, which is the standard for slip testing. However, these devices are not affordable to many users.

As a result, the proposed portable slip-tester has been designed and manufactured, with a focus on reducing weight and cost. This table summarizes the key features of the proposed device:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Not significantly increased compared to current devices.</td>
</tr>
<tr>
<td>Cost</td>
<td>Affordable to develop and own compared to other market devices.</td>
</tr>
</tbody>
</table>
Table 2. Features and comparison of slip-testing devices

While Crossroads is optimistic that STEPS will be a unique offering and thus, very competitive and attractive to clients, several market challenges remain. The existence of multiple slip-testing standards introduces confusion that may require significant client education to ensure that they understand the new standard, how it pertains to their needs, and the benefits STEPS provides as an approved device. In some cases, we will need to present a viable business case for why owners of competing slip-testers should now purchase a STEPS device. For those without current slip-testing capability, we will need to make a strong business case for why now? and why STEPS? Should for some reason STEPS not meet the new standard, we will pursue opportunities under the F2913 standard. In all cases, technical branding of both Crossroads Consulting, LLC and STEPS will be critical to gain name recognition and increase buyer confidence. Fortunately, the research team’s relationships and professional network, decades of relevant scientific work and publications, and renowned slips and falls expertise will help us to earn the trust and respect of potential clients and end users.

Marketing and Sales Strategy

STEPS will be marketed as a low-cost, open source hardware design with available licensed software interface and controls. It will be showcased as the first approved device meeting the standard. In particular, it will be marketed to researchers looking to improve their...
Intellectual Property (IP) Protection

The accompanying software, including software that provides a turn-key system, will be copyrighted. Each of the PIs have the right to use, adapt, and redistribute the underlying source code, provided the right is used in accordance with the appropriate open source licensing agreement. Initially, a CERN Open Hardware License, a Creative Commons Attribution-NonCommercial-ShareAlike license, will be made available via a TAPR Licensing agreement. Subsequently, this license will revisit the right to use, adapt, and redistribute the underlying source code.

Significant economic barriers exist to entry into the open hardware market. In their own testing, the PIs have found that licensing of software, including software that provides a turn-key system, can be carried out in a cost-effective manner. Thus, licensing of software will be a viable option at the time of delivery. For those customers anticipating a significant increase, given a sizable order, we may pursue financial options managed through the Crossroads framework. Even so, the cost of licensing of software, including software that provides a turn-key system, is less than a week's worth of revenue for build kits. Therefore, the need for licensing of software will be less than a week for build kits. They will be less than a week for build kits in addition to Crossroads, which could be a significant barrier for those customers.

The Crossroads plan includes placing product and collateral through social media, trade shows, professional outreach, and presentations. For each of their customers, the PIs will perform a validation study, including an online survey, to determine if the product meets the customer's needs. As OHL contracts are revisited, the PIs have found a significant increase in the interest of placing product and collateral through social media to include a one-page product summary. The PIs have determined that placing product and collateral through social media to include a one-page product summary is more efficient, less restrictive, and less expensive than going to regional trade shows. They are still anticipating a significant increase in the interest of placing product and collateral through social media, even so, the need for licensing of software will be less than a week for build kits.

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Through social media, in addition to Crossroads, the PIs have found a significant increase in the interest of placing product and collateral through social media to include a one-page product summary. The PIs have determined that placing product and collateral through social media to include a one-page product summary is more efficient, less restrictive, and less expensive than going to regional trade shows. They are still anticipating a significant increase in the interest of placing product and collateral through social media, even so, the need for licensing of software will be less than a week for build kits.

In the evolving world of open hardware, licensing will become more important. Significant economic barriers exist to entry into the open hardware market. In their own testing, the PIs have found that licensing of software, including software that provides a turn-key system, can be carried out in a cost-effective manner. Thus, licensing of software will be a viable option at the time of delivery. For those customers anticipating a significant increase, given a sizable order, we may pursue financial options managed through the Crossroads framework. Even so, the cost of licensing of software, including software that provides a turn-key system, is less than a week's worth of revenue for build kits. Therefore, the need for licensing of software will be less than a week for build kits.

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established relationships with their partnering organizations that would increase the likelihood of their support.

F. Production and Marketing Plan

Production

STEPS will be purposely designed to integrate commercial-off-the-shelf components to the degree possible, limiting the number of custom components to be produced. This will enable those who choose to build their own device using the open source hardware design to do so with ease, and also streamlines Crossroads’ delivery of STEPS devices for clients choosing to purchase a complete build kit or turnkey system. Crossroads will work with suppliers to cost-effectively procure off-the-shelf motors, belts, power supplies, shoe lasts, load cells, T-slot rails, etc. (reference the primary system components shown in Figure 4). Leveraging the significant manufacturing capability in Western Pennsylvania, Crossroads expects to contract with regional suppliers for raw materials and fabrication necessary to produce any custom components for the frame, moving chassis, and slider rocker. Crossroads will package these components into complete build kits or assemble devices for clients as a service with little to no direct manufacturing required.

Marketing Plan

Phase II SBIR (years 1 and 2): Leveraging the initial market assessment conducted by Crossroads, will continue to gather market intelligence from the research community, shoe and flooring manufacturers, and safety and health consultants. This will be done through publicly-available information from the, as well as informal inquiries to product vendors, safety professionals, and researchers about their needs and frustrations with existing slip-tester devices and methods. In addition to gathering requirements to inform and improve product design, Crossroads will also use these professional interactions to generate excitement about STEPS as a potential near-term solution and endeavor to create a base of “early adopters” who will help generate data for marketing collateral purposes.
Phase III (years 3 and beyond): Crossroads will actively market STEPS through various demonstrations and exhibitions to showcase the portability, ease-of-use, and functional features of STEPS. When release of the OHL and software license is imminent, we anticipate setting up demonstrations and workshops at the interlaboratory test sites (PA, NC, and ON) and (TX), with additional workshops planned in other targeted regions where there are multiple potential customers and/or highly attended industry events. Potential future exhibits will be planned at various trade shows targeting high risk service industries (e.g., the National Restaurant Association Show, the Association of Occupational Health Professionals in Healthcare National Conference, etc.), and various forums sponsored by safety and occupational health associations (e.g., International Ergonomics Association, Human Factors and Ergonomics Society, etc.). Crossroads also will publish and advertise in relevant trade journals to better reach targeted market sectors.

Crossroads will grow its web presence and e-commerce to support hardware and software licensing downloads, complete build kits and hardware/software upgrade purchases, and access to other STEPS services. The Crossroads website will also feature product literature, training materials, and informative webinars, and videos and testimonials showcasing the success of early adopters.

**STEPS Revenue**

STEPS Revenue from the STEPS slip-tester is anticipated to be generated through direct sales of complete build kits (including microcontroller and firmware), software licenses providing a graphical user interface and additional functionality, and turnkey systems (assembled hardware and software). Equipment leasing and testing services will also be considered as potential offerings. Anticipated pricing is provided in Table 3. An estimated initial production margin of provides a substantial revenue stream that is anticipated to grow to a margin with increased purchasing power, assembly efficiency, and sales growth. Follow-on revenue will include hardware/software upgrade kits and extended maintenance/service contracts beginning one year after purchase and installation.

Table 3. STEPS product and service list and pricing
Based on anticipated STEPS offerings and pricing, Crossroads used a Program Evaluation and Review Technique (PERT) model to estimate revenues using a weighted average of optimistic, pessimistic, and most likely scenarios for unit purchases.

Estimated revenues from STEPS product and service sales (not including potential testing services) over the five years following completion of the Phase II SBIR project are shown in Table 4.

Proactive marketing, technical branding, and pre-sales made during the Phase II project period will position Crossroads to ramp up quickly in the first non-SBIR year (Year 1 in Table 4) and drive peak revenues in Year 2 as potential clients react to the standard and before potential new competitors enter the market.

Additional revenues from slip-testing services and related consulting could easily support sustained annual revenues exceeding . Reinvesting in the advancement and development of next generation devices (STEPS II, STEPS III, etc.), Crossroads could extend projected revenues an additional 5 to 10 years.

Table 4: 5-year projected revenue from STEPS (following Phase II SBIR completion)

Staffing
Augmenting the two current staff members, consisting of a Managing Director and Technical Director, Crossroads will hire a junior engineer to support the Phase II SBIR project, and anticipates hiring one additional staff member within 12 months after SBIR completion to support STEPS sales and marketing, order management, scheduling and delivery, and client relationship management. Additional technical hires may be considered pending a decision to offer slip-testing services.

Conclusion
Leveraging the unique attributes of STEPS – biofidelity, portable, low-cost, reliable, and predictive – Crossroads Consulting, LLC will significantly advance the state-of-the-art for slip-testing technology, positioning us to reach new markets. Our agile business model will allow those with varying degrees of resources and technical competencies to access the device. STEPS will be the only slip-tester with flexible purchase options in which customers with limited resources (and reasonable technical competencies) can build their own device and customers with more resources (and/or limited technical competencies) can purchase a turnkey solution. Thus, STEPS will not only drive small business growth and revenues, but is expected to reduce slip and fall accidents through wider adoption of testing technology and more informed application of ergonomic interventions.
Multiple PD/PI Leadership Plan

I. Rationale

Project leadership and management oversight will be shared by two Principal Investigators (PIs) working in full collaboration: Dr. Brian Moyer, Crossroads Consulting, LLC, and Dr. Kurt Beschorner, University of Pittsburgh. Each of the PIs has knowledge and experience that is critical to the success of this project. Developing a robust, valid and automated slip-tester requires expertise in slip and fall tribology and testing equipment (Beschorner) as well as software development, data acquisition, and control systems (Moyer). The PIs have complementary expertise in these areas and will work closely together to ensure the success of this project, as they did in execution of the Phase I SBIR project.

II. Governance/Organization

Communication

At a minimum, the PIs will communicate informally weekly (by phone, e-mail, or in person), and will meet monthly to discuss technical progress and next steps, identify risk and mitigation strategies, review data analysis and results to date, and ensure compliance with all administrative responsibilities. Regular joint design reviews will be conducted during prototype development to ensure technical alignment. In addition, the entire research team (including engineering support staff and graduate and undergraduate students) will meet four times per year to discuss progress and to present ongoing results. All technical project files and data will be accessible by both PIs using Dropbox and/or email. Dr. Moyer will serve as the contact PI and be responsible for all contract communications with NIH.

Process for Making Decisions

The PIs will jointly discuss ideas and issues related to utilizing human subjects data to inform and validate the slip-tester (Aims #1 and 4) but Dr. Beschorner will have the final decision. They will jointly discuss ideas and issues related to the device development and interlaboratory study (Aims #2 and #3) but Dr. Moyer will have the final decision.

Procedures for Resolving Conflicts

If a potential conflict develops, the PIs shall meet and attempt to resolve the dispute in good faith. Issues related to the project that cannot be isolated into Specific Aims #1 through 4 and where the PIs cannot agree shall be referred to an arbitration committee consisting of one impartial member representing each PIs organization and a third impartial party mutually agreed upon by both PIs.

Intellectual Property

III. Roles

The two PIs will be responsible for the following roles:

Administrative Reporting: Dr. Moyer will be responsible for submitting all progress reports and a final report upon review by Dr. Beschorner at the end of Years 1 and 2.

Managing personnel: Dr. Moyer will manage the engineer at Crossroads Consulting. Dr. Beschorner will supervise and manage the staff, post-doctoral scholar and undergraduate students at the University of Pittsburgh.

...
Managing the budget: Each PI will be responsible for his own fiscal and research administration based on the budget allocated per each PI's organization.

Industrial Review Board (IRB): Dr. Beschorner will be responsible for all elements of developing and managing the IRB protocol.

Technical
While the PIs will collaborate on all research objectives, Dr. Moyer will oversee Aim 2 and will have primary responsibility for portable slip-tester development and validation. His specific technical efforts will focus on developing the control system and software for the device in Aim 2 and building the two additional prototypes for the interlaboratory study (Aim 3). Dr. Moyer also will be primarily responsible for implementing the Commercialization Plan.

Dr. Beschorner will have primary responsibility for the laboratory-focused Aims 1 and 4, including the implementation of all human subjects research and approvals and maintenance of relevant equipment.

Dr. Beschorner will also contribute technically to Aim 2, leading the development and validation of the mechanical design for the prototype device.

Scientific
Drs. Moyer and Beschorner will be involved in planning, execution, analysis, and interpretation of data throughout the proposed research. Dr. Beschorner will be specifically responsible for quantifying the testing conditions that best predict slipping (Aim 1), mechanically validating the device (Hypothesis 2.1) and validating the device's ability to predict slips (Aim 4). Dr. Moyer will be specifically responsible for determining whether the device met the design objectives (Objective 2.1) and quantifying the results from the Interlaboratory Study (Aim 3).

IV. Budget Allocation
The budget will be allocated such that each PI has adequate funds to complete their portion of the project. The main contract has adequate funds available for the contact PI (Moyer) to manage and execute his portion of the project, while the subaward to the University of Pittsburgh has adequate funds for the other PI (Beschorner) to manage and execute his portion of the project. Any significant changes in research direction that impacts budget allocations will be discussed and agreed to by both PIs.
The proposed Phase II SBIR project is a cooperative research and development effort to be conducted jointly by Crossroads Consulting, LLC and the University of Pittsburgh (please reference the Letter of Intent signed by both organizations).

The following outlines the programmatic, fiscal, and administrative arrangements to be implemented upon grant award.

**Programmatic**

Project leadership and management oversight will be shared by two Principal Investigators (PIs) working in full collaboration: Dr. Brian Moyer, Crossroads Consulting, LLC, and Dr. Kurt Beschorner, University of Pittsburgh.

Management and leadership roles and responsibilities will be executed as outlined in the Multiple PD/PI Leadership Plan.

**Fiscal**

As the small business concern, Crossroads Consulting, LLC will perform a minimum of 50 percent of the total effort. As reflected in the proposed budget, Table 1 shows the allocation of funds to each organization. Funding levels are consistent with the scope of effort for each organization and budget period.

Table 1. Allocation of Funding for Proposed Phase II SBIR

<table>
<thead>
<tr>
<th>Organization</th>
<th>Funding Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossroads Consulting, LLC</td>
<td>50%</td>
</tr>
<tr>
<td>University of Pittsburgh</td>
<td>50%</td>
</tr>
</tbody>
</table>

Each PI will be responsible for his own fiscal administration based on the budget allocated per each organization.

**Administrative**

Upon grant award, Crossroads Consulting, LLC will negotiate and execute a subcontract with the University of Pittsburgh, defining the scope and deliverables, period of performance, not to exceed budget, and payment schedule and terms and addressing intellectual property and publications considerations consistent with this proposal. As applicable, the subcontract will incorporate terms and conditions from the primary award to Crossroads Consulting, LLC.
August 31, 2016

Reviewers
National Institutes of Health

Dear Reviewers:

RE: Letter of support for research proposal “Portable slip-testing device for measuring shoe-floor coefficient of friction”

This letter is to notify you of our support for the proposed research project by Crossroads Consulting, LLC and University of Pittsburgh, entitled “Portable slip-testing device for measuring shoe-floor coefficient of friction”.

Prevention of falling accidents is critically important given the scale of the problem both in the United States and in Canada. Therefore, we have made the prevention of these accidents an area of emphasis at Toronto Rehabilitation Institute (TRI) -UHN. TRI has one of the most technologically advanced rehabilitation research centres in the world. At iDAPT center, we have developed a human-centred slip resistance test method by determining the maximum achievable angles that participants could walk up and down icy slopes, in a range of footwear. This test takes place in WinterLab, part of the Challenging Assessments Environments Laboratories at iDAPT center. We have already introduced this new test method to the footwear committee and envision developing a meaningful and easy to understand labeling system for winter footwear. A multifaceted approach is required to prevent slip and fall accidents. Developing portable devices that provide valid measures of slipperiness in the field is also a critical component of this solution. Making devices portable is important since certain walking surfaces are difficult to simulate in the laboratory. Therefore, we believe that the proposed research has tremendous value and will have a great impact on fall prevention efforts.

We plan to support the proposed research efforts of the grant, by serving as a site for the inter-laboratory study.
References:


82. Leamon, T. and K. Li. Microslip length and the perception of slipping. in 23rd International Congress on Occupational Health, Montreal, Canada. 1990.


The HMBL is a moveable, ceiling-hung, lightweight system that is capable of conducting gait studies during stair ascent and descent, as well as slips. It is equipped with a harness system and a three-dimensional (3-D) force plate that can capture data during ramp walking as well as uneven walkways.

The HMBL is a moveable, ceiling-hung, lightweight system that is capable of conducting gait studies during stair ascent and descent, as well as slips. It is equipped with a harness system and a three-dimensional (3-D) force plate that can capture data during ramp walking as well as uneven walkways.

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Tribology Laboratory

Tribology testing resources is housed within the Augmented Human Performance Laboratory, which is directly connected to the HMBL. The testing equipment includes a pin-on-disk tribometer (Contraves), a custom whole-shoe slip (Portable Slip Simulator) and wear-tester, a variable incidence tribometer (English XL), a 2D Stylus Profilometer (Taylor-Hobson Surtronic S100), a viscometer (Brookfield LVDVE 115), and a precision scale.

C. Office Facilities and Resources

Both PIs and the research team have access to well-equipped office facilities for meetings, data analysis, software development, and reporting. Within the Department of Bioengineering at the University of Pittsburgh, the team has access to multiple conference rooms and meeting spaces for design reviews and other collaborative activities.

D. Other Resources

Support for Early Stage Investigators

University of Pittsburgh makes several resources available for early stage investigators including a mentorship program where new faculty are teamed up with a committee of mentors. The Department of Bioengineering has extensive administrative support that is available to Early Stage Investigators including a department administrator, an academic administrator, a graduate school administrator, a personnel coordinator, two purchasing administrators, and an IT specialist.

Statistical Support through the Clinical and Translational Science Institute (CTSI)

The PI (Beschorner) has access to statistical support as a member of the University of Pittsburgh CTSI. The CTSI provides up to 10 hours of free statistical support per project and prioritizes access for junior faculty members. In addition, the CTSI also provides statistical training through workshops and journal clubs.