

## COVER SHEET FOR GRANT PROPOSALS

State Board of Education

SBOE PROPOSAL NUMBER:  
(to be assigned by SBOE)

AMOUNT REQUESTED: \$74,593

TITLE OF PROPOSED PROJECT: Infrasonud Detector for Localizing Gun Shot

**SPECIFIC PROJECT FOCUS:** This project will develop a low cost mobile infrasonud real-time gunshot detector. This project will expand on a dissertation research, which developed a sensor array to detect infrasonud [Pook 2015]. The research reduced the antenna array size from 20 meters diameter to 2 meters. This project will expand on this earlier work by improving the microphone sensor, implementing real-time detection and signature correlation, and integrating the components into a mobile system using wireless and mobile cell connections. This marketable system will be integrated into existing Emergency Services Dispatch communications.

The project implementation will occur in two phases. The first phase (this proposal) will improve the existing microphone array either using off-the-shelf microphones capable of infrasonud detection or using microphones manufactured by Bruel & Kjaer or G.R.A.S. Sound & Vibration A/S. These microphone manufacturers have offered assistance in selecting and obtaining the correct microphone. The first phase will also focus on adding real-time detection and environmental hardening the infrasonud system. The present system collects data and stores to a secured-digital non-volatile memory card. The data is post processed on a computer.

The second phase of development will focus on developing a mobile system which can be vehicle mounted and integrated into the local emergency services dispatch system. The mobile system will consist of a Smart Phone Apps capable of performing the detection, processing and communication to central system. It is our plan to seek another source of funding to continue Phase II of this project.

PROJECT START DATE: 7/1/17

PROJECT END DATE: 6/30/18

NAME OF INSTITUTION: Boise State University

DEPARTMENT: Office of Sponsored Programs

ADDRESS: 1910 University Dr., Boise, ID 83725-1135

E-MAIL ADDRESS: osp@boisestate.edu

PHONE NUMBER: 208-426-4420

NAME:

TITLE:

SIGNATURE:

PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR

Dr. Sin Ming Loo

Professor

Not required

CO-PRINCIPAL INVESTIGATOR

N/A

NAME OF PARTNERING COMPANY: Preco Electronics

COMPANY REPRESENTATIVE NAME: John Fadgen

NAME:

SIGNATURE:

Authorized Organizational Representative

Karen Henry

**SUMMARY PROPOSAL BUDGET**

Name of Institution: Boise State University

Name of Project Director: Dr. Sin Ming Loo

**A. PERSONNEL COST (Faculty, Staff, Visiting Professors, Post-Doctoral Associates, Graduate/Undergraduate Students, Other)**

Name/ Title	Salary/Rate of Pay	Fringe	Dollar Amount Requested
Dr. Sin Ming Loo, Professor, 1 month.	\$112,197 for 9 mos.	32%	\$16,455
Graduate Research Assistant, responsible for hardware and software development. Request is for academic year stipend (\$18.46/hour for 1300 annual hours).	\$18,000 for 9 mos.	4% academic year, plus \$2332 fee for health insurance	\$21,052
Graduate Research Assistant responsible for hardware and software development. Request is for summer (\$18.46/hour for 1300 annual hours).	\$6,000 for 3 mos.	10% summer, plus \$777 fee for health insurance	\$7,377
Undergraduate Research Assistants (2). Funding for two undergraduate students is requested to help in building hardware, testing, and deployment. Request is for academic year and summer wages for 1300 combined annual hours.	\$11/hour for 12 mos. each	4% academic year & 10% summer	\$15,215

<b>% OF TOTAL BUDGET:</b>	80%	<b>SUBTOTAL:</b>	\$60,099
---------------------------	-----	------------------	----------

**B. EQUIPMENT: (List each item with a cost in excess of \$1000.00.)**

Item/Description	Dollar Amount Requested
<b>SUBTOTAL:</b>	

**C. TRAVEL:**

Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested

<b>SUBTOTAL:</b>	
------------------	--

**D. Participant Support Costs:**

	Dollar Amount Requested
1. Stipends	
2. Other	

<b>SUBTOTAL:</b>	
------------------	--

E. Other Direct Costs:		Dollar Amount Requested
1. Materials and Supplies: sensors, electronic components, printed-circuit fabrication, enclosure fabrication.		\$6,100
2. Publication Costs/Page Charges		
3. Consultant Services (Include Travel Expenses)		
4. Computer Services		
5. Subcontracts		
6. Other (specify nature & breakdown if over \$1000): Academic year 2017-2018 tuition and fees for the graduate student working on the project.		\$8,754
<b>SUBTOTAL:</b>		\$14,854
F.. Total Costs: (Add subtotals, sections A through E)		<b>TOTAL:</b> \$74,953
G.. Amount Requested:		<b>TOTAL:</b> \$74,953
Project Director's Signature: Not required.	Date: Not required.	

<b>INSTITUTIONAL AND OTHER SECTOR SUPPORT</b> (add additional pages as necessary)	
<b>A. INSTITUTIONAL / OTHER SECTOR DOLLARS</b>	
Source / Description	Amount
<b>B. FACULTY / STAFF POSITIONS</b>	
Description	
<b>C. CAPITAL EQUIPMENT</b>	
Description	
<b>D. FACILITIES &amp; INSTRUMENTATION (Description)</b>	

**Project Title:** Infrasound Detector for Localizing Gun Shot

**Institution:** Boise State University

**Faculty:** Sin Ming Loo, PhD, Professor, Department of Electrical and Computer Engineering

**Previous HERC Funding:** None

**Executive Summary:**

This project will develop a low cost mobile infrasound real-time gunshot detector. This project will expand on a dissertation research, which developed a sensor array to detect infrasound [Pook 2015]. The research reduced the antenna array size from 20 meters diameter to 2 meters. This project will expand on this earlier work by improving the microphone sensor, implementing real-time detection and signature correlation, and integrating the components into a mobile system using wireless and mobile cell connections. This marketable system will be integrated into existing Emergency Services Dispatch communications.

The project implementation will occur in two phases. The first phase (*this proposal*) will improve the existing microphone array either using Off-The-Self (OTS) microphones capable of infrasound detection or using microphones manufactured by Bruel & Kjaer (BK) or G.R.A.S. Sound & Vibration A/S (GRAS). These microphone manufacturers have offered assistance in selecting and obtaining the correct microphone. The first phase will also focus on adding real-time detection and environmental hardening the infrasound system. The present system collects data and stores to a secured-digital non-volatile memory card. The data is post processed on a computer.

The second phase of development will focus on developing a mobile system which can be vehicle mounted and integrated into the local emergency services dispatch system.

The mobile system will consist of a Smart Phone Apps capable of performing the detection, processing and communication to central system. It is our plan to seek another source of funding to continue Phase II of this project.

### **Project Objective and Total Amount Requested**

The intent of the project is to design, prototype, test, deploy, and market a low cost, real-time mobile gunshot detector that can be deployed to emergency services and to the public as a mobile device.

“Gap” Project Objectives:

- i. Use Preco Electronics<sup>®</sup> engineering expertise, supply chain, and distribution network to design a marketable product
- ii. Simplify the board design and remove unnecessary components to minimize production costs
- iii. Turn current design into a marketable product in a cost efficient manner
- iv. Select optimal microphone with inputs from BK and GRAS
- v. Design a weather hardening solution to protect the electronics from weather elements
- vi. Evaluate system with local law enforcement agencies

We requested the amount as listed in the following table. The major portion of the fund will be expended on salaries for faculty, and graduate and undergraduate students. This is the most important part of this budget; we need the personnel to carry out the design, implement, and test the prototypes. Materials and supplies funding requested includes printed-circuit board fabrications, electronics components, and enclosure

design/prototypes. The other item on the budget is one-year of fee waiver for one graduate student.

Item	Fund (\$)
Salaries (plus fringe benefits)	60,099
Materials and Supplies for Prototypes	6,100
Fees	8,754
Total Amount Requested:	74,953

**Description of how resource commitments reflect the priorities of the home institution(s)**

This project allows BSU’s Department of Electrical and Computer Engineering to apply its experience in sensor, hardware and firmware technologies to develop a real time gunshot localization detector. This project combines PhD level research at Boise State University with the real world product development, supply chain, manufacturing and distribution network of Preco Electronics® to take this product idea to market. The project gives real world electronics system design experience to students, and to improve the operations of local customers, such as Boise Police Department, Ada County Dispatch, County and State Law Enforcement and others, while greatly increasing public safety and providing a system that can be deployed many Law Enforcement Agencies. The goal is for Boise State University and Preco Electronics® to develop a system that can help protect cities big or small with cost effective systems.

BSU was part of a national, multi-university Federal Aviation Administration National Air Transportation Center of Excellence for Research in the Intermodal Transport Environment. As part of this Center, BSU has developed sensing systems for various applications in the intermodal transport environment. Additional funding by NIH, DOE, and Boeing, has led to sensor system projects in home environment, spent nuclear

monitoring, and coal mine operations. In total, these federal agencies have vested over \$3M in sensor systems works at Boise State University. Another recent project on a Sensor Adaptor for commercial vehicles monitoring has been funded by Idaho Department of Commerce's IGEM. The prototypes are going through vehicle testing. Dr. Loo has been the primary investigator in these projects at BSU, all of which are machine-to-machine (M2M) sensor communications projects, which uniquely qualifies him to lead this project.

### **Specific Plan and Project Budget**

#### *The Market Opportunity*

This project will focus on delivering a real time, low cost, mobile gunshot sensor and localization array based on off-the-shelf components. The primary focus of the gunshot detector and localization market is in the military and public safety sectors. This project is targeting the public safety sector mainly the law enforcement area. ShotSpotter, [www.shotspotter.com](http://www.shotspotter.com), is the main contributor to this market in the US and they have deployed systems through the world, including New York City, Chicago, Birmingham, AL, San Diego, CA, San Antonio, TX, Salinas, CA, Cape Town, South Africa. Safety Dynamics, [www.safetydynamics.net](http://www.safetydynamics.net), provides a gunshot sensor, SENTRI, and has deployed systems in Baltimore, MD, Baton Rouge, LA and LA County, CA.

Multiple large cities and counties have adopted the Shot Spotter and Safety Dynamic systems for public safety concerns. The need for such systems has increased over the years as shown by the deployment of existing systems. Presently, large cities and counties have the budgets for existing systems. The focus of this project is to provide a low cost and mobile system that will provide smaller locales access to this technology.

Cost of current gunshot detection systems are in the range of \$5k to \$6k per sensor node. The actual prices have been difficult to determine. Information we can find is total package cost, for example: Shot Spotter plans to install 45 to 60 sensors in Syracuse, NY at a cost of \$300K. We do not know how much of the quoted price is sensors, installation, and maintenance costs.

The key competitive advantage is to provide low cost, mobile system integrated into existing systems. The low cost aspect will be achieved by focusing on off-the-shelf components. Previous research at BSU has shown that off-the-self microphones were capable of detecting gunshots and the system was able to calculate azimuth and elevation within reasonable accuracy [Pook 2015]. A portable system mounted on cruiser or truck is the entry to this market; currently, such a system does not exist.

#### *Technology and Path to Commercialization*

The most recent prototype is shown in Figure 1. The top-left pictures show the complete system setup with four microphones on edges (bottom-left pictures) and motherboard (top-right pictures). The signals on the bottom-right show the infrasound sound signals detected which are used to determine direction of infrasound.

This is the base system that will be “redesign” into a marketable product with engineering inputs from Preco Electronics®. The work and milestones are described in the following:



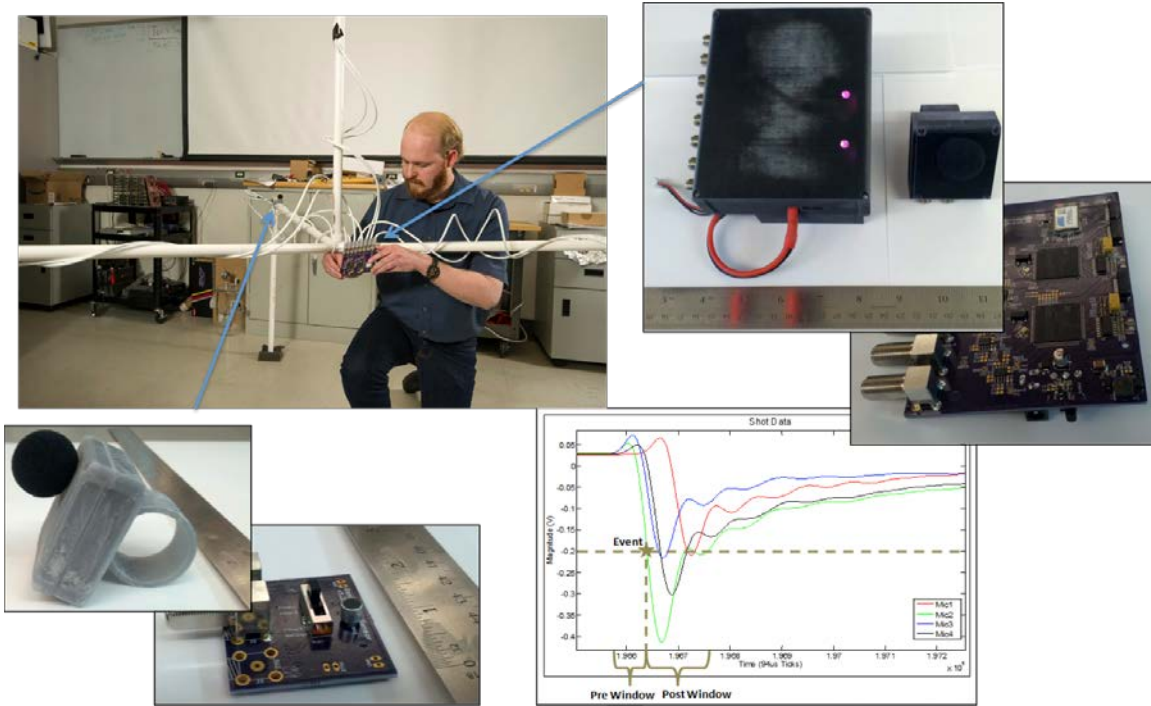


Figure 1: Current working prototype

### **Milestone 1: BSU and Preco Electronics® build sensor integration requirements**

We will work with Preco Electronics®, our industry partner, to design a marketable system. As part of this, Preco Electronics® will work with us in defining sensor integration requirements.

### **Milestone 2: Design, prototype, and test infrasound system in BSU lab**

We will work to simplify the printed-circuit board design and select an optimal microphone. We have an existing method for testing an infrasound detector in the lab; we will evaluate the detector in the lab prior to field tests.

### **Milestone 3: Test infrasound system in outdoor environment**

We will do further testing in the south desert after the prototype functionality has been verified in the lab. We will seek Boise Police or Ada County Sheriff for those tests in town and city environment.

#### *Commercialization Partner*

Preco Electronics® is in the business of heavy-duty safety systems for commercial applications. This project will be new to Preco Electronics®, but will service a similar market. Preco Electronics® currently designs, manufactures and sells object detection systems (radar) to municipalities and is familiar with this market. Preco Electronics® has been in an advisory role for the first few months on this project. The financial investment has been less than \$5K of engineering consultation time. Preco Electronics® will be contributing engineering expertise to this project over the course of the next year. We anticipate that upwards of \$100K of engineering time will be devoted to the project.

#### *Institutional Support*

One of BSU's research pillars is sensor and sensor systems. Dr. Loo has been contributing to this since he joined BSU in 2003. This project takes the sensor systems research and funding managed by Dr. Loo at BSU, directly to market. The working prototype of infrasound detector as shown in Figure 1 was completed the infrasound prototype under his guidance. This project eliminates the need for citizens to call in the event of gunshot. It allows auto detection and informs authorities of the event in real-time.

#### *Budget*

The major portion of the requested budget goes to personnel's salaries. This includes salaries for faculty, and graduate and undergraduate students. Dr. Loo will be paid one month of summer from this project. He will continue to support this project throughout the academic year. Graduate and undergraduate students have also been identified. Mark Laverty, former HP and Micron engineer, has been working in HSIL and this could be a part of his dissertation research. Two undergraduate students (Austin Davis and Grady Anderson) have also been employed in HSIL. Currently, all the students are working on sensor adaptor project funded by Idaho Department of Commerce IGEM program.

**Reference:**

[Pook 2015] Pook, M. 2015. A small acoustic goniometer for general purpose research, PhD Dissertation, Boise State University.

## **Appendix: Facilities and Equipment**

Boise State University: The facilities required for administrating our project include office space and the conventional office equipment associated with a university faculty member.

Boise State University – Hartman System Integration Laboratory will be leveraged to design and development of the sensor system will be performed in the Hartman System integration Laboratory (HSIL) located in the Electrical and Computer Engineering Department at Boise State University. The HSIL is 1,000 square feet and contains with a variety of prototyping equipment related to sensor design and development.

The equipment that is currently available for the design and development of the sensor systems include multiple Formlabs 3D printer, Agilent Mixed Signal Oscilloscopes (model MSO7104A), MDO4000 Mixed Domain Oscilloscope, a two-layer PCB milling machine (LPKF S62), a re-flow oven, a wireless spectrum analyzer (Anritsu MS 2721A), multiple soldering stations and microscopes, four TSI AeroTrak™ 9303 Airborne Particle Counter, three TSI Q-TRAK™ 8552 IAQ Monitor, hood and gases for sensor calibrations, and related computers/software for development and integrations. We have all the necessary computers required to carry out the design work.

---

## SIN MING LOO, PHD

### PROFESSIONAL PREPARATION

---

Inti College, Malaysia	American University Program	1994
University of Alabama, Huntsville	Electrical Engineering	1997, BSc
University of Alabama, Huntsville	Computer Engineering	2000, MSc
University of Alabama, Birmingham/Huntsville	Computer Engineering	2003, PhD

### APPOINTMENTS

---

2012 – Present	Professor of Electrical and Computer Engineering, Boise State University
2011 – 2013	Chair of Electrical and Computer Engineering, Boise State University
2008 – 2011	Associate Professor of Electrical and Computer Engineering, Boise State University
2003 – 2008	Assistant Professor of Electrical and Computer Engineering, Boise State University

### PRODUCTS

---

#### PUBLICATIONS

1. Michael L. Pook, Sin Ming Loo, "A Small Acoustic Goniometer for General Purpose Research," *Sensors* 2016, 16(5), 622; doi:10.3390/s16050622
2. Noah Salzman, Sin Ming Loo, "Connecting Hardware and Software in a Middle School Engineering Outreach Effort," ASEE 123rd Annual Conference & Exposition, June 26-29, 2016, New Orleans, LA, USA.
3. Vikram Patel, Sin Ming Loo, Brian Jaques, Michael Hurley, Darryl Butt, "Monitoring and Predicting Stress Corrosion Cracking of Long Term Spent Nuclear Fuel Storage," CORROSION 2016 Conference & Expo, Vancouver, BC, Canada, March 6-10, 2015.
4. Sin Ming Loo, Jim Hall, "A low-cost wireless portable particulate matter monitoring system," 2014 Indoor Air, Hong Kong, July 12 – 16, 2014.
5. Jim Hall, Michael Pook, Josh Kiepert, Sin Ming Loo, "Monitoring Aircraft Cabin Particulate Matter Using a Wireless Sensor Network," AIAA 43rd International Conference on Environmental Systems, July 14 - July 18, 2013.
6. Jim Hall, Sin Ming Loo, Dale Stephenson, Ross Butler, Michael Pook, Josh Kiepert, Jordan Anderson, Nicholas Terrell, "A Portable Wireless Particulate Sensor System for Continuous Real-Time Environmental Monitoring," AIAA 42nd International Conference on Environmental Systems, July 15 - July 19, 2012.
7. Josh Kiepert, Sin Ming Loo, Derek Klein, Jim Hall, Michael Pook, "Wireless Sensor Network for Aircraft Cabin Environment Sensing," AIAA 41st International Conference on Environmental Systems, July 17 - July 21, 2011

- 
8. Jim Browning, Carl Lee, Don Plumlee, Sonya Shawver, Sin Ming Loo, Mallory Yates, Matt McCrink, Jesse Taff, "A miniature inductively coupled plasma source for ion thrusters," IEEE Transactions on Plasma Science, pp. 3187-3195, Nov. 2011.
  9. Derek Klein, S. M. Loo, Michael Pook, Jim Hall, Josh Kiepert, "Survey of Sensor Technology for Aircraft Cabin Environment Sensing," 41st International Conference on Environmental Systems, Portland, Oregon, USA, July 17-21, 2011.

---

#### SYNERGISTIC ACTIVITIES

---

1. Develop monitoring system for commercial vehicle, funded by Idaho IGEM
2. Conduct Embedded Systems summer camp (Summer 2012 and Summer 2013) for junior high and high school students
3. Research and develop FAA funded portable sensor system for aircraft cabin environment monitoring. This system has been EMI/EMC approved for operating in commercial aircraft.
4. Institution Principal Investigator at Boise State University of FAA Center of Excellence for Intermodal Transport Environment
5. Transfer embedded system design techniques from research laboratory to teaching laboratory. The adaptation of these techniques have been published at ASEE conference and ACM
6. Collaborate with Health Sciences and Geoscience faculty in developing sensors for science applications

---

#### COLLABORATORS & OTHER AFFILIATIONS

---

##### ***Collaborators and Coauthors:***

Jack Spengler (Harvard), Byron Jones (Kansas State Univ.), Tony Overfelt (Auburn Univ.), Cliff Weise (Rutgers University), Dale Stephenson (Boise State University), HP Marshall (Boise State University), Darryl Butt (Boise State University). Total = 7

##### ***Dissertation Advisor and Postgraduate-Scholar Sponsor:***

PhD Theses (all Boise State University):

Josh Kiepert (Spring 2014), Jim Hall (Spring 2014), Michael Pook (Fall 2015), Vikram Patel (Fall 2017), Mark Lavery (Fall 2018)

MS Theses:

David McCarver (Schweitzer Engineering Laboratories), Jon Cole (Preco Electronics), Naovarat Sajjapongse (Micron), Michael Owen (DCI Inc.), Arlen Planting (Boise State University), Joshua Kiepert (Boise State University), Mark Jurenka (Micron), Derek Klein (Marvell), Vikram Patel, Michael Pook, Ross Butler (HP), Jeff Richardson (Micron), Ali Ibrahim (HP), Nick Terrell (Micron), Andy Wolin (Micron), Henry Hoang (On Semi, Fall2018), Tola Ayanwusi (Micron, Fall 2017)

---

#### CURRENT EXTERNAL FUNDING

---

Title: Sensor Adapter for Enhanced M2M Integration

Sponsor: Idaho Department of Commerce

Amount: \$211,098

Project Period: 11/17/15-9/30/17

Current PI commitment: Sin Ming Loo, 1 month for summer 2017

---