IDIL 2013 RFA – COVER SHEET

INSTRUCTIONS:
1. Please respond to ALL the questions below using the tables provided.
2. This Cover Sheet should be included with your Research Narrative, as a single Word or PDF document.

Project Name (4 words)	**mSpray, IRS Mobile Technology**		
Focus Location	*Enter the country or countries and region(s) targeted* Limpopo Province, South Africa		
Principal Investigator (PI)	Brenda Eskenazi, Ph.D		
PI Email Address	eskenazi@berkeley.edu		
Summary	This project aims to: scale-up an existing mobile phone app to collect geocoded malaria control spray data, develop a new app to collect geocoded data on malaria cases, and integrate data from these sources with the goal of achieving better-targeted malaria control interventions.		
Total Direct Costs (USD)	$ 161,608		
Total Costs (USD)	$ 199,983	Total Indirect Costs (USD)	$ 38,375
Project Start Date	January 30, 2014		
Institution Receiving Award*	University of California, Berkeley and University of Pretoria	Project End Date	August 31, 2015

Project team:

***Letters of support are provided for Dr. Bornman and Mr. Kruger. Additional letters are available to DIL upon request for Drs. De Jager, Seto and Moonasar.**

Name	Title/Position	Institution	Country	Field/Discipline	Gender (opt)
Edmund Seto	Assoc Professor	PH, U Washington	USA	Computer Sci/PH	M
Lesliam Quiros	Post Doc Fellow	PH, UC Berkeley	USA	Exposure Sciences	F
Philip Kruger**	Director	Malaria Control, Limpopo Dept of Health	South Africa	Public Health Officer	M
Riana Bornman**	Professor	PH and School of Medicine, U of Pretoria	South Africa	Physician	F
Christiaan deJager	Professor, Deputy Dean of Research; Director Centre for Sustainable Malaria Control	PH, U of Pretoria	South Africa	Public Health, Toxicology	M
L. Daniel Wu	Student	UC Berkeley	USA	Computer Science	M
Jonah Lipsitt	Consultant	UC Berkeley	USA	Geo Info Syst (GIS)	M

Stakeholders: Please list the stakeholders for this project, including communities, government agencies, USAID operating units or programs, multi- and bi-lateral institutions, foundations, NGOs, businesses, academic researchers, etc. Do not list a stakeholder without an identified point of contact (i.e. Name and Title/Position); these should be individuals or organizations with existing links to your project.

Organization	Contact	Nature of partnership
Malaria Control, National Department of Health for South Africa	Patrick Moonasar Director	National Malaria Program Manager, South Africa. The proposed program will improve and strengthen program monitoring and evaluation, in line with the South African National Malaria Elimination policy. Dr. Moonasar has and will continue to provide important feedback to guarantee the sustainability of the proposed program in South Africa. In addition, because South Africa is seen as the leader in Indoor Residual Spraying in Africa, providing leadership throughout sub-Saharan Africa, the success of this proposed program will have immense impact on malaria control throughout this region.

Outside Resources: If your project directly builds on or incorporates existing infrastructure, equipment, funding or other resources, please list these below. For grant or contract funding, provide the project title, PI, and funding agency. You may include any other non-Federal resources (e.g. private grants, unrestricted funds) or third party contributions that are directly utilized by the project. Only include contributions with estimated dollar values, and describe how the resource supports your project.

Award or Other Resource	Estimated Value (USD)	Description (for award, include dates)
In-kind support	$ 5, 000	Computer equipment, software such as ArG GIS 10.0, Stata, printer, photocopier in Berkeley and Venda and other supplies
In-kind support	Cannot be determined	The proposed program builds directly on the existing malaria control program; therefore, there is considerable in-kind contribution from the Limpopo Province (eg. personnel capturing data, supervisory support to the project, training and data analysis)
In-kind support	$100,000+	Drs. Eskenazi, Seto, Bornman and Mr. Kruger were all involved in the initial development of mSpray and its pilot study last year. They and Dr. de Jager will offer their time in-kind to continue to advise the project. In addition, Dr. Quiros and Mr. Lipsitt and Wu, who were also involved in the development of mSpray, will receive only a partial subsidy under this grant.

USAID Resources: None

DIL 2013 RFA – RESEARCH NARRATIVE

1. PROJECT NAME AND TRACK: mSpray, IRS Mobile Technology; BOTH TRACKS

2. SUMMARY: This project aims to: scale-up an existing mobile phone app to collect geocoded malaria control spray data, develop a new app to collect geocoded data on malaria cases, and integrate data from these sources with the goal of achieving better-targeted malaria control interventions.

3. DEVELOPMENT CHALLENGE:

***We will address the challenge of eliminating malaria, a disease with high impact, affecting masses worldwide, especially those living in poverty*:** Every year approximately 250 million people are infected with malaria, resulting in 880,000 deaths primarily to African children.[1] Malaria is responsible for 3.3% of all disability adjusted life years (DALYs) globally.[2] Malaria primarily affects residents in poor rural areas, where deficient housing poses little barrier against mosquitoes and poor access to healthcare delays treatment. In South Africa, malaria outbreaks have burdened the economy of affected areas through lost productivity, reduced tourism, and increased health care costs, slowing economic growth and perpetuating the cycle of poverty.[3] In the last decade, between 1384 and 6065 malaria cases have been reported in Limpopo, South Africa alone (personal communication, P Kruger). Although South Africa is pursuing a target date of 2018 to eliminate malaria, factors such as climate change, vector and parasite resistance, and deficient regional malaria control programs may hinder progress.

In an effort to eliminate malaria, most countries have taken an integrated approach that includes: rapid case identification, indoor residual spraying (IRS) and long-lasting insecticide treated nets, and therapy treatment.[3] IRS involves the application of residual insecticides to the internal walls and ceilings of dwellings where mosquito vectors alight.[4] IRS coverage in 2011 alone included 4.7 million structures across 13 African countries.5 Although the benefits of IRS are clear, chemical exposure to residents and workers may also pose health risks.[6-7] In addition, IRS programs are costly and inappropriate use of insecticides can lead to vector resistance. Stratified malaria vector control – targeting insecticides for the type of mosquitoes in an area, and prioritizing geographic areas where there are confirmed cases – would ensure more efficient use of resources.

***We aim to improve upon the current IRS and malaria case recording systems*:** IRS recording systems in Africa are currently paper-based. In Limpopo Province, spray workers keep a daily paper-and-pencil-based tally of rooms/structures sprayed and insecticides used (type and quantity). Team leaders compile the tally sheets weekly, summarize them on another form, and submit forms to the central Limpopo Malaria Control Programme (MCP) for data-entry, resulting in a 1–4 week delay before data are available electronically. Information on tally sheets is only available at the village level; i.e., there is no way to accurately identify exact homesteads sprayed within a village because many homesteads do not have addresses and Geographic Positioning System (GPS) coordinates of sprayed homes are not recorded. Improved data flow would strengthen program monitoring and performance, as supervision in remote areas is often limited. Additionally, monitoring of spray coverage could be improved by collecting data at the homestead- rather than at the current village-only level.

To ensure that vector control operations target communities most affected by malaria, data about the probable site of each malaria infection is essential. Currently, MCP staff visit the homes of each reported case within 7 days to conduct an epidemiological investigation. Case Investigators document the physical address (difficult to define, particularly in rural areas) and obtain GPS coordinates; gather data on house construction, points of mosquito entry, and potential larvae breeding sites; and ask about travel outside the area. Investigators also attempt to establish the homestead spray status, including date sprayed and insecticide used, though residents are rarely able to provide this information. All data are recorded on paper and select information is entered on a computer, sometimes with considerable

delay (>1 month). Though the computerized MCP malaria case database includes addresses, GPS coordinates remain only recorded on paper.

Application of mobile technology to improve current recording systems: Mobile telephony subscription in South Africa has increased fivefold over the past decade and dramatically surpasses that of fixed landlines; in 2012, there were 138.4 cell phones per 100 habitants.[8] As mobile phone use increases, cell phone technology is emerging as a valuable tool in a variety of public health contexts.9-10 However, to our knowledge, cell phones have not been used to monitor spray operations or to interface these data with malaria outbreaks. We at the University of California-Berkeley, the Limpopo MCP, and the University of Pretoria have harnessed this growing technology to increase the utility of data gathered by spray workers for malaria control purposes. During the 2012-13 spray season, we piloted an innovative, low-cost cell-phone application, "mSpray," to record real-time, geocoded data on sprayings.

4. APPROACH.

The solution: Our solution is to scale up our mSpray app; to develop a companion app, "mCase," to collect data on malaria cases; and to design a web-based information system merging data from these apps to allow the overlay in time and space of IRS and malaria case data. We aim to provide 45 mSpray-equipped cell phones to spray workers in the North-East region of Limpopo, covering the Mutale Municipality in the Vhembe district. This area has an estimated population of 108,217 habitants and is at the highest risk for local (i.e., not imported) malaria cases in all of South Africa. In 2007-2008 alone, 1748 malaria cases were reported in Mutale (personal communication, MCP). To pilot test mCase, we will provide mCase-equipped cell phones to the 5 MCP Case Investigators and have them record case data and GPS coordinates electronically at the homes of infected residents. Finally, we will develop a web-based information system to facilitate real-time access to integrated spray and case data by MCP authorities. **We anticipate that this timely and integrated data management strategy will increase the effectiveness and efficiency of malaria control operations.**

Preliminary/pilot results: We designed mSpray on an Android-based smartphone *(Samsung Y GT-S5360*) based on its affordability and global availability, the ease with which new apps could be programmed and installed, and its ability to obtain GPS coordinates. The mSpray app, comprised of 24 simple data entry screens and a summary screen (Fig 1), was installed on 10 data-enabled cell phones. Screens prompted users to enter the name of the IRS supervisor (foreman) and the worker(s) conducting the spraying, the number of rooms and shelters sprayed/unsprayed on a homestead, the insecticide(s) used, and to capture the homesteads' GPS coordinates. A date/time stamp was automatically applied to each entry. Once submitted, encrypted data were stored on the phone's memory card and automatically transferred via Internet to a Google Drive Spreadsheet (http://developers.google.com) where data could be viewed in real time. The phone's GPS accuracy was validated and found to be comparable to that of a high-quality GPS unit.

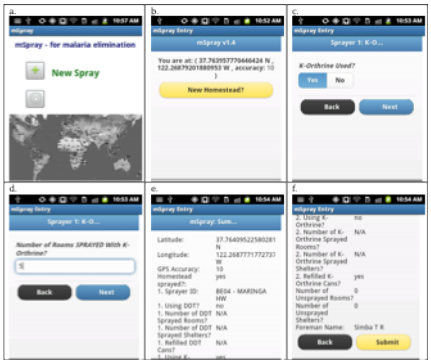

Figure 1. Select screen shots from the mSpray app.

Thirteen MCP staff were assigned to record all sprayings in a low malaria risk area in Thulamela (Vhembe district). Pilot testing began in November 2012 and sprayings were documented until the spray season ended in March 2013. A total of 2,865 spray events were recorded in real time, at the cost of US$28 per phone for the season. We evaluated mSpray by overlaying GPS coordinates of spray events upon high-resolution satellite imagery (Spot 5 2009) using ArcGIS. Resulting maps confirmed that sprays were recorded at visually-identifiable village and homestead locations (Fig 2). We also collected feedback from users via surveys and group discussions. Their insights have already spawned improvements to the mSpray app, and informed protocol revisions proposed herein. For instance, in this new deployment, we will set up phone charging ports within MCP field vehicles to charge all phones

on a nightly basis, and will distribute cell phones directly to spray workers (not foremen) to increase efficiency.

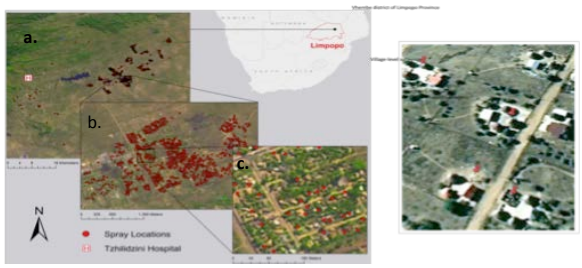

Figure 2. Maps of IRS sprayings in Limpopo, South Africa as documented with mSpray. a.Vhembe district of Limpopo Province; b.Village-level sprayings c. Close-up of sprayings on a section of the village (satellite multi-spectrum imagery).

Our approach will improve health outcomes for the poor: Malaria is a disease of poverty and improved malaria control will allow for populations to develop more rapidly. It is for this reason that elimination of malaria is one of the United Nation's Millennium Development Goals to end global poverty. In South Africa alone, despite great strides to achieve malaria elimination, over 2 million people (108,217 in Mutale) remain at risk for acquiring malaria, and the continued resources needed to protect these individuals hampers development. We anticipate that the use of mSpray in the highly-endemic Mutale municipality will result in more accurate and timely record keeping of IRS coverage. By correlating these records with historical and new malaria case records, local malaria control authorities will be able to better prioritize and plan their resources for improved malaria control. mSpray can beget a more efficient path to malaria elimination by helping target insecticides in homesteads where local transmission is confirmed, e.g., by assuring that nearby homesteads are sprayed and if they have been, by respraying with a different pesticide. In so doing, the haphazard overuse of insecticides that can lead to pesticide resistance can be minimized, and limited public health dollars can be judiciously spent.

5. INNOVATION.

The use of low-cost mobile technology and Internet cloud services to gather and integrate IRS spray and malaria case data will dramatically improve public health officials' access to the specific information they need to make timely data-driven IRS decisions. This represents a critical innovation in a field where malaria control decisions must currently be made with often long delayed access to meaningful, site-specific, spatially- and temporally resolved linkable data on IRS activity and malaria outbreaks. Our use of a mutually-accessible cloud-based data management system will facilitate interactions between our U.S.- and South African-based research teams as we track and map incoming case and spray data. **This solution, because it makes use of low-cost, readily-available cell phone and internet cloud data management technologies, can also be readily customized for use in other malaria-endemic countries.**

6. OUTCOMES. The outcomes we will measure include the following and methods were selected based on prior experience in our pilot study:

mSpray app:

- Accuracy: We will enumerate the homesteads sprayed in Mutale, as recorded by mSpray over the course of the 2014-15 spray season, and compare these numbers to the paper-based records to determine accuracy of mSpray data.
- Acceptability and usability: We will use qualitative and quantitative information collected in focus groups with spray teams and management to assess the acceptability and usability of the app. Information collected will also be used to identify logistical and technical challenges encountered during usage in the field to implement app improvements as needed.

mCase app:

- Accuracy: We will compare information collected on the app with that recorded on paper-forms to determine accuracy of mCase data.
- Acceptability and usability: We will use qualitative and quantitative information collected via surveys and focus groups with Case Investigators to assess the acceptability and usability of the app. Information collected will also be used to identify logistical and technical challenges encountered while using mCase to implement improvements as needed.

Web-based information system interface:

- Performance: We will assess the ability of the web-based interface system to merge information from both apps and produce maps that overlay, in time and space, IRS and malaria case data. Technical problems will be addressed during the development phase.
- Acceptability and usability: We will use qualitative and quantitative information collected via surveys and/or focus groups with MCP authorities to assess the acceptability and usability of the interface system. Information collected will also be used to identify logistical and technical challenges encountered when using the interface to implement improvements as needed.

Future Sustainability: We will engage in discussions with the Limpopo MCP team and the South African National Government to assess their willingness to continue, expand, and fund implementation of the apps for malaria control efforts in future years; decisions made in these discussions will be documented.

7. VISION FOR SUCCESS.

Our vision for success is that the apps: succeed in providing complete and accurate, timely, and detailed geocoded information on IRS and malaria cases; are accepted by all end users; and reduce malaria cases by improving local malaria control efforts without generating large new costs. Ideally, we envision the South African government, recognizing the value of our apps, will fund their future use and attract the interest of other African governments.

8. RELEVANCE.

Findings from this project are most relevant for developing countries where malaria is highly endemic. Our proposed applications have a number of advantages over widely-used paper-based documentation systems, the most important of which being the accurate and timely monitoring of spray and case events at the homestead level (GPS coordinates) and the potential to overlay maps of malaria cases, IRS use, and even entomological data, thereby facilitating more targeted vector control. Integrated data made immediately available to decision makers has the potential to increase efficiency of malaria control efforts, targeting limited resources to where they are most needed and limiting gratuitous use of costly and potentially hazardous insecticides. Furthermore, it can be a powerful tool in managing vector resistance, informing the use of different insecticides at the local level.

Lessons learned from our scale-up may also have relevance to those studying other major diseases (e.g., TB, HIV) in the global south. From a process standpoint, teaming U.S. and foreign partners through the use of technology, including collaborations between malaria and pesticide experts, environmental health scientists, computer scientists, professors, and students, as well as end users (i.e., field workers, managers, and policy makers) assures the likely success and sustainability of the project.

9. PROJECT PLAN.

a) Key activities. The key study activities will be as follows:

1. **Focus groups with spray workers and MCP management.** We will conduct an initial focus group with MCP district managers for the Mutale municipality, and a second focus group with 6-10 local spray workers to demonstrate and receive their final feedback on the latest version of mSpray. For the first year, we will ask spray workers to complete required paper-based logs in addition to mSpray entries. Incentives will be provided for the additional work. We will determine appropriate incentives based on feedback received in focus groups.

2. **Update mSpray in line with field requirements.** Based on the focus groups, our experience from the previous pilot study, and ongoing discussions with MCP and Limpopo Health Department officials, we will finalize the new version of mSpray**.**

3. **Install final version of mSpray on 45 android phones and train spray workers**. The Field Coordinator will install the updated mSpray app on the phones and will lead sessions to train spray workers and their supervisors on how to use mSpray. Training will consist of a slide show presentation and a step-by-step demonstration with the phone. A quick reference manual will be provided to

workers, and they will have the option to call the Field Coordinator (a free function on the phones) if problems arise.

4. **Develop a second app, mCase, for identification and location of malaria cases.** We will use an iterative development practice to design mCase. We will prototype an initial version based upon the current paper form. We will then conduct focus groups with MCP officials and Case Investigators to demonstrate the app and determine what revisions are needed to optimize acceptance and usability.

5. **Develop a web-based information system that integrates data from both apps to address the MCP reporting requirements**. During initial mSpray development, we at Berkeley were responsible for downloading data from the Google server and processing it using statistical and mapping software. Under this grant, we would streamline this process by developing a simple web-based information system so that MCP personnel can directly query data from mSpray and mCase Google Spreadsheets and automatically generate summary reports. The reports that they could generate would include maps of the exact geographic location of cases and spray operations (including chemical used), graphs, and summary records for the selected time period and location of interest. This will be run within a web browser, using Google Javascript-based API calls to access the Google Spreadsheets for data, and common Google APIs for mapping and data visualization. The APIs are free for the level of usage that we anticipate from MCP. We will train Limpopo and National MCP staff on how to use this system.

6. **Collect spray information for the Mutale municipality (Vhembe district) for the 2014-15 spray season**. We will supply 45 spray workers with a phone and will have them collect spray event information on mSpray. As reported above, the spray workers will record number of rooms/shelters sprayed, insecticide used, time/date, and GPS coordinates. All information will be immediately uploaded onto a Google server and accessible in real time by UC Berkeley researchers and MCP officials.

7. **Case Investigators will be supplied phones equipped with the new app, mCase, during the malaria season** to document specific data on identified malaria cases such as: homestead GPS coordinates; residential address (if available), locality and municipality where the case was visited by the Investigator; spray status of the homestead for the malaria case; whether the case was local/imported; and other case information required in the paper-based forms. Information will be immediately uploaded onto a Google server and accessible in real time by UC Berkeley researchers and MCP officials.

8. **Evaluate acceptability and quality control**. Evaluation of mSpray will occur at three levels at season end: (1) we will overlay GPS coordinates of mSpray events upon high-resolution satellite imagery (Spot 5 2009), using ArcGIS Version 10.0 and verify that sprays were recorded at visually-identifiable village and homestead locations. We will overlay residences of malaria cases (captured on mCase) on the same map; (2) we will compare mSpray data with paper records to quantify the percentage of homestead spray events and identify discrepancies; and (3) we will collect feedback regarding app acceptability/usability and needed improvements via questionnaires completed by mSpray and mCase users. These will be followed by focus group discussions aimed at necessary steps to bring mSpray and mCase to full deployment throughout South Africa.

9. **We will generate reports, graphs and maps** to demonstrate the efficacy of this enhanced program and submit these to Dr. Moonasar, National Malaria Program Manager in South Africa. These reports will be followed with discussion with South African malaria control authorities on next steps and future sustainability of these apps for future malaria control efforts.

10. **Finalize mSpray for future use in South Africa and elsewhere**. This effort will include the development of an instruction manual including protocols, information on problem solving and answers to frequently asked questions. The app and manual will be accessible on the Center for Environmental Research and Children's Health website.

11. **Publish the results of the scale-up in the peer-reviewed scientific literature.**

b) Timeline

	2014											2015							
Tasks	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**
Refine mSpray app																			
Develop 2nd app, mCase																			
Develop/test web-based information system																			
Conduct focus groups (pre-deployment)																			
Install apps and train workers and MCP staff																			
Deploy apps in the field, refine as needed																			
Administer questionnaire and conduct focus groups																			
Generate reports, graphs and/or maps																			
Meet with MCP/national government officials (next steps/future sustainability)																			
Finalize app/protocols/manuals																			
Publish findings																			

c) Deliverables

- A final project report/manuscript describing our findings will be produced at the end of our project.
- Regular progress reports will be provided to the DIL program upon request.
- Provision of two apps (mSpray and mCase) with accompanying protocols and manuals.

d) Milestones

- Finish revision of the mSpray IRS app (July 31, 2014)
- Finish prototype for the mCase malaria case tracking app (August 31, 2014)
- Develop web-based interface system (September 30, 2014)
- Complete deployment of the mSpray/mCase apps in the field (March 31, 2015)
- Final evaluation of the mSpray/mCase apps (July 31, 2015)
- Final documentation (protocols/manuals) for mSpray and mCase (August 31, 2015)
- Publish findings (August 31, 2015)

10. REFERENCES.

1. WHO. (World Health Organization). World Malaria Report 2008. Geneva, Switzerland.2008.
2. Murray CJ, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet.* Dec 15 2012;380(9859):2197-2223.
3. Maharaj R, Morris N, Seocharan I, et al. The feasibility of malaria elimination in South Africa. *Malaria journal.* 2012;11:423.
4. WHO. (World Health Organization). WHO gives indoor use of DDT a clean bill of health for controlling malaria. Available at: http://www.who.int/mediacentre/news/releases/2006/pr50/en/. 2006.
5. PMI. President's Malaria Initiative. Indoor residual spraying (IRS) for Malaria Control. Task Order I-Final Report Available at: http://pmi.gov/technical/irs/irs_taskorder1_finalreport.pdf. Accessed: June 6, 2013. 2013.
7. Eskenazi B, Chevrier J, Rosas LG, et al. The Pine River statement: human health consequences of DDT use. *Environ Health Perspect.* Sep 2009;117(9):1359-1367.
8. Horton MK, Rundle A, Camann DE, Boyd Barr D, Rauh VA, Whyatt RM. Impact of prenatal exposure to piperonyl butoxide and permethrin on 36-month neurodevelopment. *Pediatrics.* Mar 2011; 2011;127(3):e699-706.
9. ITU World Telecommunication (2013) Mobile cellular subscriptions (2000-2012). Available at: http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx.
10. Freifeld CC, Chunara R, Mekaru SR, et al. Participatory epidemiology: use of mobile phones for community-based health reporting. *PLoS medicine.* 2010;7(12):e1000376.