Dear Michael,
Here is the copy of the Project Pitch with reference number : **00044382** submitted to the **Robotics (R)** on **1/24/2022**.

1. Submitter Name

   Michael

2. Submitter Email

   michael@vivtek.com

3. Submitter Phone

   7872398387

4. Company Name

   ToPRobot CRL

5. Zip Code

   00601

6. Corporate Website

   N/A

7. SBIR/STTR topic that best fits your projects technology area

   Robotics (R)

8. Is this Project Pitch for a technology or project concept that was previously submitted as a full proposal by your company to the NSF SBIR/STTR Phase I Program – and was not awarded ?

   Yes

8a. Please provide the Proposal Number of the previously submitted full NSF SBIR/STTR Phase I proposal ?

   1746794

8b. Have you contacted the associated NSF SBIR/STTR Program Officer, via email or phone, to discuss this prior full proposal submission?

   This pitch is actually for a refinement of one component of the 2017 proposal. We haven't discussed the proposal in detail; just about the time it was declined we started learning roof work after Hurricane Maria.

9. Has your company received a prior NSF SBIR or STTR award?

   No

10. Does your company currently have a full Phase I SBIR or STTR proposal under review at NSF?

   No

11. Briefly Describe the Technology Innovation?

Our overall development focus is to bring low-cost automation to the growing, harvesting, and processing of shadegrown coffee. The holy grail in terms of market fit is harvest, since the labor shortage is most painful during the harvest months. However, the selective harvesting of coffee on mountainous terrain is
a project that will take some time and effort, so we are currently looking at intermediate opportunities to commercialize some of the component technologies that will have to go into any fully automated harvesting system.

One of those technologies is field navigation. Over the course of the past year, as we've cleared one of our fields and harvested coffee from its hundred fifty or so surviving trees, we have realized that a small-scale chassis capable of reaching even a portion of our field would be invaluable in maintaining it – this maintenance could include mowing and the clearing of leaf debris as well as collection of fallen cherries in support of pest control. While we are pursuing a range of tools to be brought to bear for these land tending tasks, the one thing they all have in common is that they need a chassis capable of navigating around at least some part of a coffee field.

We propose a system for navigation using QR code waypoints on terrain that – unlike earlier work in this area – is not flat. Our fields are very rugged and have slopes up to 60 degrees. They are challenging for human access. They are not regular in any dimension, but they are well-defined in scope and, to our thinking, they would be the ideal testbed for navigation solutions in real-world conditions.

Each of our chassis is equipped with a camera (using a Raspberry Pi camera system) and will initially use a QR code waypoint navigation framework. QR codes have to date been used only in level environments, but they are a good fit for our fields, where the individual coffee trees are essentially permanent and fixed in position.

As there is considerable additional sensor data available (including the camera vision input itself, but also a tilt sensor, ultrasonic range sensors to the front and below the chassis, and the compass included in typical inclination sensor packages) we also plan to run a reinforcement learning loop to correlate that data with the waypoint information; the result should effectively be a learned Kalman filter that can be seen as the system “learning” the field independently of the waypoints, making overall navigation more robust.

During the course of this reinforcement learning, we can characterize difficult (and impossible) points within the field in terms of an accessibility map. That can lead us to develop both the field itself and more refined chassis designs to encompass greater agility and access to difficult terrain over a range of difficulty.

This would be foundational work in reliable outdoor navigation, and its ultimate impact would be immense, not only in our own application but in any outdoor mobility situation.

12. Briefly Describe the Technical Objectives and Challenges?

Field navigation based on waypoints (whether using QR codes or other types of marker) is well-represented in the literature, but has not yet been extended to a three-dimensionally rugged ground, so that adaption would be the first objective of the proposed project.

Iterated reinforcement learning on a few different metrics, including repeatability of location, would follow; the goal of this phase would be to establish the reliability of goal-oriented movement within the field and guarantee thorough coverage for land-tending tasks such as cherry collection and fertilizer application. It would be ideal to derive an accessibility map listing the locations of the trees (marked by QR code) and showing the points the chassis can and cannot access around them.

The third phase of the project would then be to enhance navigational reliability by using correlated additional data; this reinforcement loop would then benefit from daily use of a small fleet of land tenders to maintain the field while recording a thorough log of sensory data. The initial benefit of using this additional data would be to have a fallback in case a QR waypoint is damaged or missing, but it may be possible to dispense with the waypoints entirely if the other sensor data is sufficient; evaluating this would be a subsidiary goal of this phase.

The result would then be twofold: not only would land-tending be a valuable service that could be leased, but reliable and robust field navigation and chassis design would support any later application on this terrain, up to and including harvest.

13. Briefly Describe the Market Opportunity?

The market for this project is complex. Puerto Rico's total acreage devoted to coffee farming has plummeted over the past few decades, from 21,564 farms totaling 177,820 acres to just 2,445 farms totaling 13,283 acres in 2018 after Hurricane Maria (of those, just 818 farms with shade-grown coffee remain, 3,804 acres in all). During that same period, America's love of coffee has not abated, and in fact America's preference for high-quality, ethically grown coffee has grown even more rapidly.

There are a variety of reasons for the Puerto Rican coffee exodus, but the one common to the majority of farmers is simply that labor is hard to find for strenuous, skilled work with a sharp upper bound on pay, especially during the harvest-season crunch. One direct route to improving that situation for the individual farmer is to make the work less strenuous.

A toolbox of solutions like the ones we propose could revolutionize coffee tending and harvesting in Puerto Rico, allowing hundreds of thousands of acres that are largely lying fallow today to be put back in productive use for the good of the island's economy. Similarly, the same pain point applies wherever coffee is shade grown in forested terrain and harvested selectively for quality.

Additionally, the components we develop will directly support the later development of further, more advanced automated solutions for coffee, and our general approach should adapt well to use for other crops as well – particularly cacao, another locally grown crop in high demand.

14. Briefly Describe the Company and Team?

We founded ToPRobot CRL in April of 2017 for our first SBIR grant proposal. In August, it was declined. In September, Hurricane Maria blew the roofs off both houses on our coffee farm. Since that time, we have learned roof building, restored our financial situation, experienced an earthquake swarm and a global pandemic, and cleared nearly two acres of forest on our farm to restore it to active coffee production. In 2021, we resumed work on robotics, now armed with more field expertise and, since we now live
on our farm, more contacts in the local agricultural community.

Our core team is our family: Agnes has a background in mechanical engineering and a doctorate in theoretical physics, Michael has a background in software development and has run a technical translation services business for fifteen years, Vivienne has a masters degree in medical physics specializing in imaging, and Orion is in his senior year of a mechnical engineering degree at Iowa State.

Our robotics work in 2021 has been focused on machine learning for vision tasks and on a fleet concept for smaller chassis addressing land-tending needs.

We have a robust network of contacts and friends both among the local farming community here in Adjuntas, Puerto Rico and among technical professionals across the island and the nation, as well as being located on our own coffee farm for daily test runs, with a local machine shop on tap for prototyping and a focused drive to improve the local economy and bring the world's best coffee back to America's attention.

15. How did you first hear about our program?

Other

15a. Please provide any Other Reason on how you have heard about the Program?

Business forum on Reddit

NSF SBIR/STTR Phase I Eligibility Information:

In addition to receiving an invitation to submit a full proposal from the NSF SBIR/STTR Phase I Program based upon the review of their submitted Project Pitch,potential proposers to the program must also qualify as a small business concern to participate in the program (see SBIR/STTR Eligibility Guidefor more information).

The firm must be in compliance with the SBIR/STTR Policy Directive(s) and the Code of Federal Regulations (13 CFR 121).

- Your company must be a small business (fewer than 500 employees) located in the United States. Please note that the size limit of 500 employees includes affiliates.
- At least 50% of your company's equity must be owned by U.S. citizens or permanent residents, and all funded work needs to take place in the United States (including work done by consultants and contractors).
- Primary employment is defined as at least 51 percent employed by the small business. NSF normally considers a full-time work week to be 40 hours and considers employment elsewhere of greater than 19.6 hours per week to be in conflict with this requirement.
- The Principal Investigator needs to commit to at least one month (173 hours) of effort to the funded project, per six months of project duration.

For more detailed information, please refer to the SBIR/STTR Eligibility Guide by using https://www.sbir.gov/sites/default/files/elig_size_compliance_guide.pdf. Please note that these requirements need to be satisfied at the time an SBIR/STTR award is made, and not necessarily when the proposal is submitted.