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NAVY SBIR TRANSITION PROGRAM

SPOTLIGHT

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Deploying AI to the tactical edge: Tercero Technologies is enabling real-time threat detection for the Marine Corps

By Jennifer Reisch

Carl P. Evans III left his job working for a mid-size DoD contractor in 2019 and started his third business, Tercero Technologies LLC, an edge artificial intelligence (AI) company focused on field programmable gate arrays (FPGAs). A month later, a Marine Corps SBIR topic came out. As the sole employee of the business, Evans replied to the topic. Tercero won the award, and the company's innovations will transition into the Marine Corps' next-generation programs, bringing new real-time AI capabilities to Marines on the ground.

According to Evans, "After I left my job I decided I would focus on FPGAs because I knew they were going to become a more important technology for domain-specific accelerators for machine learning inference. It turns out that FPGAs have really blown up over the past few years, including AMD's 2022 $35B acquisition of Xilinx, the market leader in FPGA technologies. But when the SBIR topic was released, there really wasn't a mention of FPGAs. Instead, the topic hinted toward another technology such as GPUs, which are very popular in machine learning. I took a bit of a risk and wrote my proposal saying that GPUs are great, but FPGAs are the future and the way to go. It was risky, but it worked out. To my surprise, we were the only company selected for Phase I. I didn't know this at the time, but it turned out that the Marine Corps was familiar with FPGA technology."

Evans did all the work for the Phase I. "I was writing FPGA code. I was writing MATLAB code to do simulations. I was doing machine learning model development. I had a contractor helping with a small amount of work, but mostly it was just me. With the volume of work and the scope of development that I proposed for Phase II,

Carl Evans exhibiting Tercero's Acelerado™ FPGA tool and example radio frequency processing applications at the 2023 Modular Open Systems Approach (MOSA) Industry and Government Summit.

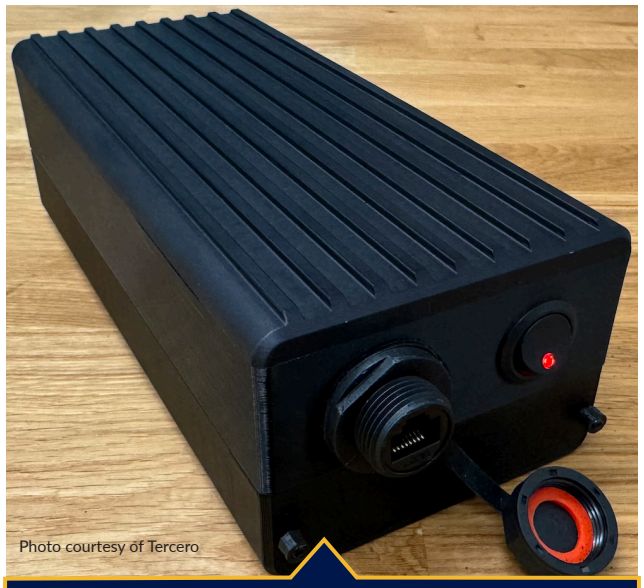
I needed to hire someone to join me and was fortunate to hire my colleague David Finol to lead our machine learning model development efforts. He has been an outstanding addition to the team."

Tercero's SBIR awards from the Marine Corps funded development of a complete FPGA-based AI system specialized for reprogrammable FPGA applications. Tercero developed a novel FPGA-based target tracking system that can be integrated into Marine Corps systems. To implement the tracking system using FPGAs, Tercero also developed a tool that automatically converts machine learning (ML) models to FPGA firmware designs, allowing faster development and deployment of FPGA-based technologies in size, weight, and power (SWaP) constrained applications.

"We are using FPGAs—which are energy efficient and fast—to use artificial intelligence to analyze data at the sensor. Historically it's been very difficult to develop the specialized type of programming for FPGAs. The process

could take days to months, depending on the complexity of the design. What we've done is create software that automates the process of converting certain machine learning models to FPGA designs. And depending on model size we can do that in a matter of minutes to a couple of hours," Evans explained.

"For instance, David has created machine learning models that can ingest data and track targets in complex scenarios. We can run those models on any device. However, when it's time to convert that model to run on small embedded FPGA-based devices, we need something to do the model conversion for FPGAs, allowing us to take advantage of the benefits of the reconfigurable embedded chips. Again, historically, a human would do that by manually writing code to implement the models. Our software is able to take those machine learning models and automatically convert them to a design for the FPGA. This allows us and our customers to get working technology into the hands of Marines or Sailors or any other service much more quickly."



An assembled CELER FPGA and AI-based signal processing payload.

According to one of the technical points of contact (TPOC) for Tercero's project, "Tercero's work is agnostic to many different pieces of hardware and that is a huge value to us and is why it is transitioning. It can go on anything we choose to put it on. It's an additive capability to so much technology that's already out there."

The technology comprises two key innovations: an FPGA-based data preprocessor, and software to automatically convert high-level ML models to FPGA designs.

The Computationally Efficient Deep Learning-Powered EWS Radar (CELER) preprocessor—the name of Tercero's SBIR project—is an FPGA-implemented ML-based system that can track very slow-moving objects and can draw out multiple tracks at once from billions of data points, with a false alarm rate below 5%. The system can provide critically important information on potential threats in the vicinity of Marines on the ground. However, tracking systems generate billions of data points per minute, some of these resulting from clutter in the environment, such as birds and insects, posing challenges to real-time analysis in the field. The CELER system can process those types of data in real-time. In addition, to allow Marines to view the CELER real-time tracking inference results in a way that provides increased situational awareness without information overload, Tercero is also developing an augmented reality interface based on the Microsoft HoloLens. CELER tracking results can also be viewed in Tactical Android apps.

As Tercero moves toward commercializing the technologies developed under this SBIR effort, the company has branded its commercial version of its FPGA tool as the Acelerado™ platform. While there have been other FPGA-related efforts that have matured while Tercero has been developing its technologies, Tercero's approach is designed to be more secure to address requirements for tactical edge devices carried by dismounted Marines. Tercero's approach also uses the state of the art in machine learning model compression in order to minimize FPGA resource utilization. Furthermore, Tercero has implemented Acelerado™ as a software as a service (SaaS) application that can be run locally or in a

secure cloud environment, providing a simple one-click method for converting machine learning models.

"Field programmable means we can reprogram them. The work that Tercero did allows us to program and reprogram systems for the Marine Corps remotely. Once you deploy their capability, modifications can be disseminated via network so it has the ability to rapidly improve or change. The agile framework that Tercero created allows us to modify a capability and quickly deploy it. They were told to build a capability and they went above and beyond that and built a hardware agnostic capability; if your hardware card changes out you can recompile their software and load it on that card and it will work. Having ubiquitous or agnostic hardware is of significant benefit to the Marine Corps and supports our open architecture standards for DoD. Now I can buy the best quality product from any vendor and this software can be integrated on it," the TPOC said.

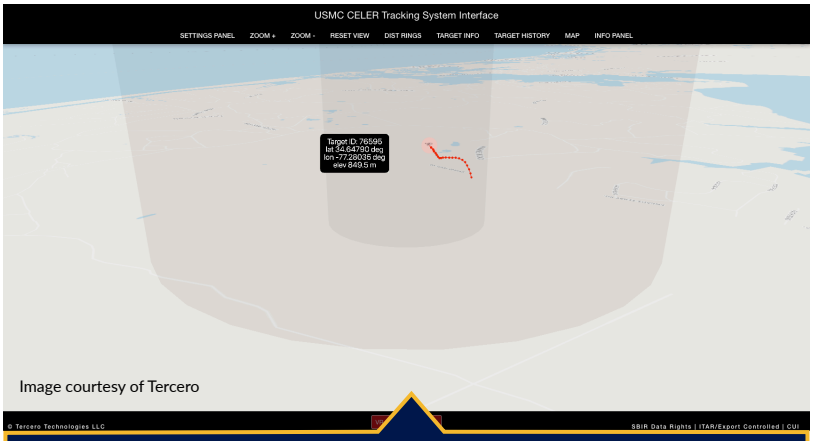


Image courtesy of Tercero

Tercero's user interface for displaying the CELER tracking system inference results.

"FPGAs can only have so much processing, so many gates and so much memory and of course this capability takes up a certain percentage of each of those things on that FPGA. So it has to fit with whatever else we need to run on that FPGA, but they are reprogrammable so we can take this capability on and off as needed based on where we're at," he added.

Evans had experience applying for and winning SBIR awards in previous roles and he brought that to his startup. "The SBIR program is super competitive, so you never know. I've had some really good proposals that were not selected in the past. But I knew the process, how to write a successful application. I think my success with this Marine Corps SBIR award was a combination of a few things. Probably the most important was my vision for the project, thinking about the future of machine learning and edge artificial intelligence, my vision for where I thought things were going to go with these embedded devices. It's been very exciting over the past four and a half years to have been correct and to see exactly where things have gone. I considered what it looked like when we were successful with our past SBIR projects: executing on what we said we were going to do, being open about challenges we were facing, and delivering."

Evans has a graduate degree in engineering, an MBA with a focus on entrepreneurship, and a law degree with a focus on intellectual property (IP) law. His background and degrees gave him skills to develop the technology and then commercialize it while protecting his IP.

"I wrote my first SBIR proposal in the early 2000s when I was working as an unmanned systems engineer at a company called Foster-Miller, Inc. that is now part of QinetiQ US. Other than my job as an attorney, most of the companies I have worked for have been funded by SBIRs. When I first wrote the Marine Corps proposal, I was certainly looking at commercial opportunities. But also, within the DoD, there are many battery-powered systems where size, weight, and power are very important. This technology could be applied to ground vehicles, aerial vehicles, drones, unattended ground sensors, or basically any type of system that's powered by batteries where you want a lot of processing on-device and a long battery

life, which are competing objectives. With current technologies with CPUs and GPUs, it's pretty challenging to do that. But FPGAs have a lot of processing power and are more energy efficient. This will be important for future Marine Corps concepts. To support distributed information sharing, we currently support the Joint Interface Control Document (JICD) 4.2 specification and are working to support the Sensor Open Systems Architecture (SOSA) standard."

According to the TPOC, "The cost for performance for the government was outstanding. We get a huge benefit working with a microbusiness because of lower costs and much more capability with such a small business, but the con is that there's a risk of the company folding if they don't get these projects. These businesses face a hardship in that they may have to go months without pay between fiscal situations and the time to get contracting on board and that makes it even harder for them. It's something I'm concerned about from where I sit in the government because we're paying money for a capability and the last thing you want is to get all the way there but they aren't in business anymore. In this case we'd still get the software developed but then we lose the expertise. We'd be stuck with the product as is, with no improvements.

Photo courtesy of Tercero

Evans' colleague David Finol testing the Microsoft HoloLens outside of Tercero's office in Chicago.

"Tercero was able to rapidly prototype with 3D printing; they built their own boards for a physical hardware-based solution for implementation and for testing and evaluation of their algorithms," the TPOC explained. "There was no way for them to implement without building a physical prototype: There was no available Marine Corps system for the company to prototype on. However, their prototyping hardware is sufficient that it can probably be inserted in any program requiring artificial intelligence/machine learning capabilities. So their box can be used to add AI/ML into existing programs that do not have it as an add on capability. We got additional benefit to the government because they did such a good job. Because of the improvements in additive manufacturing, they were able to produce a representative prototype that can be used elsewhere even though it wasn't required in the program."

Evans said, "It's been great working with the Marine Corps and having access to the Navy SBIR Transition Program. This has been a very exciting project to work on and it's been an absolute pleasure to see the excitement for the work that we're doing on the side of the government. We're looking forward to continuing our work on the project."

Tercero is a Chicago-based startup focused on advanced FPGA-based tactical edge AI software and hardware for commercial and defense intelligent sensor and autonomous vehicle applications, as well as other novel applications of autonomy and ML technologies. Learn more at https://www.tercero.ai.

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