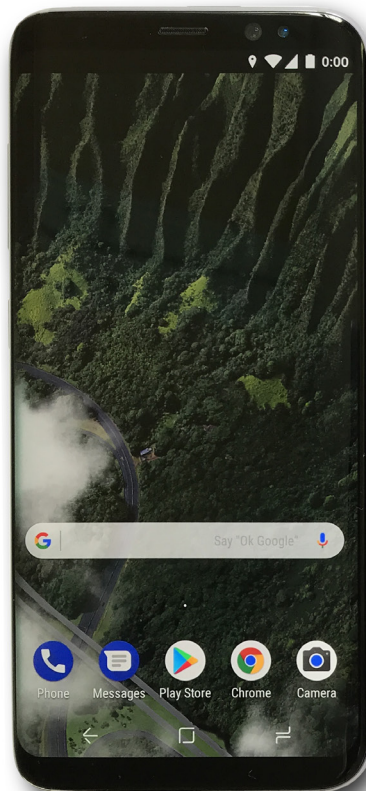


# POWERING the SMARTPHONE REVOLUTION

A DARPA CONTRACT HELPED DEVELOP THE INTEGRATED NETWORKING CHIPS THAT STILL DRIVE TODAY'S WIRELESS TECHNOLOGY.

Innovations supported by a DARPA Small Business Innovation Research (SBIR) topic have vastly increased the capabilities of the ubiquitous smartphone. A single, inexpensive chip in our phones now connects via WiFi, Bluetooth, and GPS, allowing users to browse the Internet, provide driving directions, and beam music to wireless headphones.

“Before, [these technologies] were not in all phones because they added more space and cost,” said inventor Ahmadreza “Reza” Rofougaran. “The integrated chip allowed a cost, size, and power advantage.” A small business contract funded by the Defense Advanced Research Projects Agency (DARPA) helped commercial-



ize Rofougaran’s inventions.

Rofougaran was working on his PhD at UCLA when he became involved in efforts to convert the complex and costly frequency-hopping hardware found in military radios to a single-layer silicon chip. This transformation reduced cost, physical size, and power consumption. It also opened the door for potential consumer applications.

“We converted a very expensive solution to a tiny, inexpensive chip,” Rofougaran said.

Rofougaran’s prior academic advisor, Dr. Henry Samuelli, went on to co-found Broadcom, which had until then focused on wired networking solutions. Rofougaran continued his research, consulting as part of a company



called Physical Research, Inc. He had his eye on the potential commercialization of wireless technology in small, low-cost, integrated chips made using complementary metal oxide semiconductor (CMOS) technology.

In 1998, as a post-doctoral student, Rofougaran took on a DARPA SBIR topic. The research facilitated by the contract introduced a new wrinkle: adding GPS (Global Positioning System) functionality to a single-layer silicon chip. For Rofougaran, the SBIR contract highlighted the potential value of using the same kind of radio connectivity to communicate with nearby devices. “GPS talks to satellites, but all [wireless communication] has to do a lot of handshaking and frequency hopping,” Rofougaran said. “I realized the real application is in short-range communication. The world without wires is going to be huge. I knew if I started this, it would lead to product after product.”

Following the DARPA award, Rofougaran and his sister, Maryam, formed their own company, Innovent Systems, which developed a proof-of-concept RF CMOS chip that could wirelessly transmit data to nearby devices. Encouraged by his former advisor, Innovent merged with Broadcom in 2000.

After releasing Broadcom’s first single-chip networking technology in 2002, Rofougaran led continued developments in integrated chips which accelerated the explosion of the wireless networking and mobile phone markets during the first decade of the century. Broadcom’s initial integrated chips captured most of the pre-smartphone mobile market, while the company’s WiFi technology became nearly universal in laptop computers. The introduction of Apple’s iPhone in 2007 ushered in the consumer smartphone era. Within a few years, integrated chips



that included WiFi, Bluetooth, FM, and ultimately GPS, made the technology inexpensive enough for smartphones to become nearly universal.


“Basically they have revolutionized the whole field by completely integrating [these technologies] onto a single system on a chip,” Frank Chang, chairman of

the UCLA electrical engineering department, told the *Orange County Register* in 2012.

Today, technology developed by Rofougaran and supported by the SBIR program is found in virtually all smartphones and computers, and Broadcom’s annual revenues now exceed \$18 billion, of which wireless technology is a significant amount. Samueli has called Rofougaran’s contributions “immeasurable.”

In 2018, for his work in RF-CMOS and the industrialization of the technology, Rofougaran was awarded the IEEE Circuits and Systems Society Industrial Pioneer Award, which recognizes groundbreaking innovations in circuitry engineering and related disciplines. The 2018 UCLA Engineering Alumnus of the Year award and recognition as both a Broadcom and IEEE fellow are among the many other awards Rofougaran has received for this work.

Noting the complexity and cost of developing new hardware-based technologies, Rofougaran credits the SBIR process with helping support him even while developing technology that would ultimately transform an entire industry.

“I came here [to America] for an education. And I wanted to make something big out of my life,” Rofougaran said. “DARPA helped me with my education, and the experiences I needed to build up all of these things and bring them to consumer electronics.” 



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#### Physical Research, Inc.

Modernization Priorities: 5G, Microelectronics

Torrance, CA • SBIR contract: DAAH01-98-C-R142 • Agency: DARPA • Topic: SB971-038, Design of GPS Receiver Module on a Single Silicon Chip

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