TRACING A DECADE OF GROWTH

ACCOLADES such as R&D 100 awards rarely represent a technology's climax, but rather its beginning. DNATrax, which garnered a 2013 R&D 100 Award for Livermore, touted aerosol particle traceability with unparalleled accuracy. (See *S&TR*, October 2013, pp. 4–5.) The technology's subsequent path to commercialization and applications in both agriculture and indoor air quality epitomizes the potential of Laboratory inventions to transcend early scope and function. "I'm a physical chemist and an aerosol expert, not a biologist," says inventor and former Lawrence Livermore scientist George Farquar. "This work might not have come to fruition without an out-of-the-box approach to the challenge of airborne particle tracing."

The technology's novelty is in its DNA—literally. Short for DNA-Tagged Reagents for Aerosol eXperiments, DNATrax utilizes sugar-based microparticles no larger than 10 micrometers in diameter to safely mimic the size and shape of airborne contaminants. Researchers laced these microparticles with a short sequence of non-coding, synthetic DNA (roughly 100 base pairs) that functions like a barcode, only with nucleotide bases in place of digits. The microparticles, manufactured with Food and Drug Administration–approved ingredients, contain a unique identifier allowing researchers to distinguish them from other airborne matter once dispersed. After releasing DNATrax particles, collecting air samples and using a standard polymerase chain reaction technique to amplify DNA nametags to testable volumes allows experts to map airflow patterns inside a building by tracing particles' paths from start to end.

Breaking Out

The first big break for DNATrax came during a biodefense conference. Farquar's well-rehearsed, 30-second elevator pitch convinced a prospective funder of the technology's potential. With funding from the Defense Threat Reduction Agency, Farquar and his team advanced the technology from concept to product through significant research and development efforts. "Our human resources ultimately made this technology possible," says Farquar. "Our researchers, program managers, and administrative team moved the project through testing and a mountain of paperwork, even while facing logistic complications from Hurricane Sandy. I cannot say enough good things about our team."

No longer confined to the walls of Livermore's laboratories, DNATrax was soon deployed in the hallways of the Pentagon and on New York City subway platforms to predict the effects of a hypothetical bioterrorism event. Research teams analyzed large, interconnected structures to pinpoint vulnerable entry locations and stagnant air regions where harmful substances could concentrate and pose significant hazards.

In coordination with the Pentagon Force Protection Agency, researchers released DNATrax microparticles—multiple types of particles with unique DNA barcodes—to reveal air circulation or stagnation resulting from the Pentagon's heating, ventilation, and air conditioning systems.

Originally conceived as a security and defense solution, the researchers—and investors—quickly realized the invention's broader applicability. DNATrax presented a risk-free way to evaluate private, public, and government properties for the dangers of many aerosolized substances, including pathogens, combustive products of wood-burning stoves, tobacco, and potent chemicals including formaldehyde and asbestos. "After the 2013 R&D 100 Award, we received loads of press, including a story in the *New York Times*, and interest in the technology took off from there," says Farquar.

Seeing the growing popularity of DNATrax, Farquar eventually left Lawrence Livermore to establish a company based on the innovation and serve as Chief Technology Officer. He says, "The Laboratory prepared me to be a better entrepreneur by teaching me how to seek funding and approach problems in unique ways. After learning the ins-and-outs of government research operations, I'm unfazed by complex processes concerning regulation, certification, and intellectual property for a product."

Agricultural Use Reaches Fruition

The next step, commercialization, represented a major turning point for the technology. In 2015, the company reincorporated under the name SafeTraces and pivoted to a new mission: ensuring product quality and integrity in the agricultural industry. Ulrike Hodges, Chief Operating Officer and founding member of SafeTraces, understood that global agricultural systems face issues of product adulteration, labor exploitation, and environmental destruction. SafeTraces' particle tracing technology offered a glimpse into the weakest links of food supply chains by applying innocuous amounts of DNA-tagged particles (made primarily of harmless, ingestible sugar) at a harvest or production site. The ability to trace individual grocery items to their source exposed whether the product had been contaminated, swapped, or diluted; whether it was associated with exploitative labor practices; and whether its region of origin was flouting environmental regulations.

Chief Executive Officer Erik Malmstrom joined SafeTraces in late 2018 as the company focused on food production and distribution challenges. He says, "We saw a huge opportunity for product traceability to address vulnerabilities and inefficiencies in preventing, detecting, and responding to pathogens entering food chains as well as issues with counterfeiting and adulteration. We could also meet consumer demand to know how and where food is produced, spotlighting food chains with a history of environmental and labor abuses, such as palm oil. SafeTraces countered earlier, flawed approaches with safe, edible, invisible DNA barcodes applied directly and cost-effectively on food products."

The SafeTraces team presents air quality-related features of the technology at the 2022 International Facilities Management Association conference in Nashville, Tennessee.

Change Is in the Air

Agriculture remained SafeTraces' priority until the COVID-19 pandemic emerged and shelter-in-place orders prevented SafeTraces technicians from performing commercial tracer applications. The company examined the emerging "new normal." The specter of infection spread by airborne particles demanded individuals and businesses avoid crowded indoor spaces, maintain physical separation, and provide contact tracing. Interest grew in indoor air circulation improvements and identifying problematic building layouts and inefficient heating, ventilation, and air conditioning equipment.

Recognizing a sudden, pronounced need for effective indoor air quality mapping, SafeTraces revisited the proprietary technology's original application and elected to focus exclusively on air quality assessment. Malmstrom champions the company's unique, tangible solutions. "I see a great deal of pure software and analytics solutions in the marketplace, but fewer companies are developing applied diagnostics that generate high-quality data to derisk the vulnerability of software- and data-based solutions," he says. "We're a mission-focused company in that we provide these services not just to the best-funded customers, but the spaces that need improved air quality most such as mass transit systems, public schools, prisons, and low-income housing developments. We seek to partner with disproportionately underfunded groups—not just Fortune 100 companies—to make the greatest difference."

In November 2022, SafeTraces received a Phase II Small Business Technology Transfer contract from AFWERX to monitor air quality at U.S. Air Force healthcare sites. Farquar, who has since founded another substance detection company, notes, "Inventing a technology that continues to grow in impact a decade later is nothing short of amazing." Such success signals this year's awardees that scalability and social benefit are within reach.

— Elliot Jaffe

Key Words: aerosol, airflow, air quality, contact tracing, COVID-19, DNATrax, microparticle, R&D 100 Award, SafeTraces.