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Detect to Protect

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The editors of *ACS Sensors* have monthly video conference calls to discuss various issues associated with the journal. As is typical of many conference calls these days, the conversation in our most recent call quickly turned to the coronavirus pandemic. My fellow Associate Editor, Shana Kelley, captured a frustration shared by many of us: "So much work has been done to provide rapid, sensitive, and specific sensors and diagnostics, but we still do not have the tools we need to combat this type of pandemic."

Beginning in the cold war era, a sizable portion of the sensor community focused their research on just that problem. Whether it was defending military personnel against attacks involving manufactured chemical or biological warfare (CBW) agents, or civilians against naturally occurring health hazards such as bacteria and viruses, the challenges of rapid identification of a threat with a minimal false alarm rate were identified and codified. Two paradigms that emerged from that early military-related research were "detect-to-warn" and "detect-to-treat".[1] The folks working on detect-to-warn systems faced the huge problem of building a sensor, or system of sensors, that could positively identify an incoming chemical or biological agent in sufficient time for a warfighter to don protective gear, or to initiate an evacuation. This translated to achieving positive detection within 1 or 2 min, usually at a fairly large distance of separation between the agent and the personnel, and at very low agent concentrations. While some excellent solutions for a limited number and type of agents emerged, this need went largely unmet for many decades, and it is still with us today. Indeed, it naturally provided the motivation for the second half of the paradigm, detect-to-treat. Here, we gave up on the notion that we would be able to detect the agent with any reliability in time to warn, but maybe we could identify it in order to give the proper antidote or treatment to the casualties—to minimize bodily damage, or to save their lives. As we see in today's pandemic, the best systems we have been able to develop through all these years are still lacking. The detect-to-treat systems are too slow, inaccurate, costly, or unavailable, and the detect-to-warn systems are basically nonexistent for a coronavirus-type of threat.[2]

With the increased focus on detection of terrorist weapons in the aftermath of the 9/11 terrorist attacks of 2001 came a recognition of the inadequacies of our technologies for such an extremely difficult challenge as identifying a CBW threat in messy real-world environments. A third paradigm then appeared, "detect-to-protect".[3,4] This paradigm was a response to the failure of detect-to-warn technologies; in particular, the issue of false alarms that is all too common with CBW sensors. As a military researcher once told me, referring to the warfighter's interaction with detect-to-warn systems: "after the third false alarm they'll just turn it off." The rationale here is that perhaps a low-fidelity sensor, even if it lacks the specificity to positively identify a threat agent, might still be useful in triggering a response that can serve to minimize potential casualties. For example, a sensor that can detect volatile organic compounds as a broad class, but that has no selectivity for specific organic toxins, might trigger a building ventilation system to increase the air turnover rate, or to switch to activated charcoal filtering.[3] These air handling modes would be too expensive to run continuously, but the cost would be acceptable if they were activated only when triggered by a small number of possibly hazardous events. In the event of a release of any organic compound—be it fumes from a spilled can of paint or a bolus of sarin nerve agent—a detect-to-protect system would offer some degree of enhanced protection to the occupants. It was an imperfect alternative to the inadequate detect-to-warn technologies. The point is: if you cannot avoid the event, then minimize the damage.

The current coronavirus outbreak provides a few examples of detect-to-protect technologies that have helped minimize damage. The pulse oximeter—a device worn on the finger that measures blood oxygenation in patients—has been promoted[5] as a vital early warning tool in dealing with the puzzling problem of "happy hypoxics", coronavirus-infected patients who feel and appear fine, but have critically low levels of oxygen in their blood.[6] Other examples include the airborne particle counters that come with many home HEPA air purifiers (my wife calls it a dog detector because it flips on high every time our furry dog walks into the bedroom), the infrared cameras used to measure body temperature of passengers walking through airport terminals, and kits containing nontoxic fluorescent dyes and ultraviolet flashlights being sold as a visual aid to teach people better handwashing protocols (see glogerm.com).

There are scientific and commercial challenges facing emerging detect-to-protect technologies: the science side involves identifying the sensing problem and its best solutions, while the commercial side involves identifying the paths to translating the most promising concepts into the real world. Some technologies might be excellent detect-to-protect

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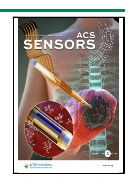

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solutions for problems that are far removed from what their inventors had in mind. Yet others will remain of dubious value forever. This challenge is made more difficult by the lack of a "killer application" for translation of many low-fidelity detect-to-protect sensing systems. Even very high-fidelity detect-to-treat sensing systems face this challenge when the small problem they solve just does not have a sufficiently broad market. The current pandemic underscores this issue in a stark and painful way. Our Chief Editor, Justin Gooding, pointed out that "perhaps this crisis will get the world to start manufacturing some sensors that have been developed for the public good, rather than for the commercial imperative." Or, as my fellow Associate Editor, Heather Clark, put it: "COVID-19 highlights the need for funding mechanisms for academics to take great technology to the next stage, rather than relying on commercial entities to bridge the rather large gap between published work and commercial devices."

So, why do we lack the sensor tools we need to combat this pandemic? Whether the "great technology" be a detect-to-warn, detect-to-treat, or detect-to-protect system, when a small problem suddenly becomes a big problem, neither the great technology nor the commercial world are prepared for it. A better path needs to be made to connect these two.

Michael J. Sailor, Associate Editor orcid.org/0000-0002-4809-9826

AUTHOR INFORMATION

Complete contact information is available at:
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Notes

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