Engineers build three new open-source tools for COVID-19

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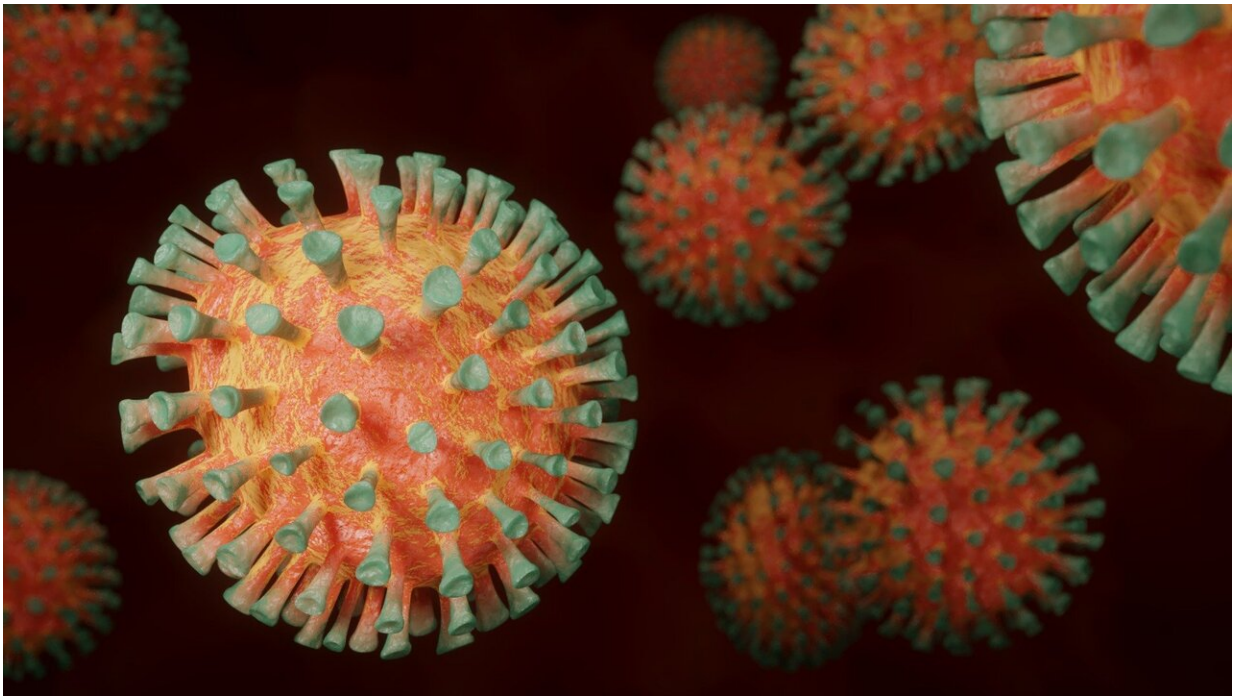

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Michigan Tech's Open Sustainability Technology (MOST) Lab developed three new open-source tools in response to COVID-19: a high-temperature 3-D printer, a firefighter PAPR mask and a printable, emergency-use ventilator.

Today, with the evolution of digital manufacturing technologies such as

3-D printers and circuit milling systems, humanity can share designs with others who can then replicate medical-grade devices for the cost of locally sourced materials. When the team began these studies last spring, personal protection equipment (PPE) was in short supply, most PPE was one-use and disposable, and the demand for hospital equipment was greater than supply. So the MOST Lab focused on a printer that could make reusable face masks, respiratory equipment that could be custom fit for firefighters and an inexpensive design for a 3-D-printed ventilator.

Joshua Pearce leads the MOST Lab and is the Richard Witte Endowed Professor of Materials Science and Engineering and a professor of electrical and computer engineering. His team intentionally made open-source designs, which have been published in a special edition of HardwareX dedicated to COVID-19 technology.

"The nature of these designs is such that desired features are relatively easy to add with the test using protocols and parametric design files provided," Pearce said. "Our hope is that such devices can be built upon by others to achieve full regulatory approval in all countries to ensure humanity is prepared for the next pandemic."

Specs for the high-temp 3-D printer Cerberus:

- three-headed, self-replicating rapid prototyper (RepRap)
- open-source and can be built for less than $1,000
- 200 degree Celsius-capable heated bed
- 500 degree Celsius-capable hot end
- isolated heated chamber with 1 kilowatt space heater core with mains voltage chamber and bed heating for rapid start
- prints polyetherketoneketone (PEKK) and polyetherimide (PEI, ULTEM) with tensile strengths of 77.5 and 80.5 MPa, respectively

Specs for the powered air-purifying particulate respirator (PAPR) for firefighters:

- open-source and can be 3-D-printed and assembled with widely available components for under $150, replacing commercial conversion kits (saving 85%) or proprietary PAPRs (saving over 90%)
- parametric designs allow for adaptation to other core components and can be custom fit specifically to firefighter equipment, including their suspenders
- controllable airflow and its design enables breathing even if the fan is disconnected or if the battery dies
- meets National Institute for Occupational Safety and Health (NIOSH) airflow requirements for four hours, which is 300% over expected regular use

Specs for emergency-use ventilator:

- open-source and can be 3-D-printed for less than $170
- resuscitation system based on open-source Arduino controller and 3-D-printable parametric component-based structure
- controlled breathing mode with tidal volumes from 100 to 800 milliliters, breathing rates from 5 to 40 breaths/minute, and inspiratory-to-expiratory ratio from 1:1 to 1:4
- The system is designed for reliability and scalability of measurement circuits through the use of the serial peripheral interface and has the ability to connect additional hardware due to the object-oriented algorithmic approach.
- Experimental results after testing on an artificial lung for peak inspiratory pressure (PIP), respiratory rate (RR), positive end-expiratory pressure (PEEP), tidal volume, proximal pressure, and lung pressure demonstrate repeatability and accuracy exceeding human capabilities in BVM-based manual ventilation.

More information: Noah G. Skrzypczak et al, Open source high-temperature RepRap for 3-D printing heat-sterilizable PPE and other applications, *HardwareX* (2020). DOI: 10.1016/j.ohx.2020.e00130