SANDIA BIOSCIENCE

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REAL-TIME AUTONOMOUS SURVEILLANCE FOR VECTOR-BORNE PATHOGENS

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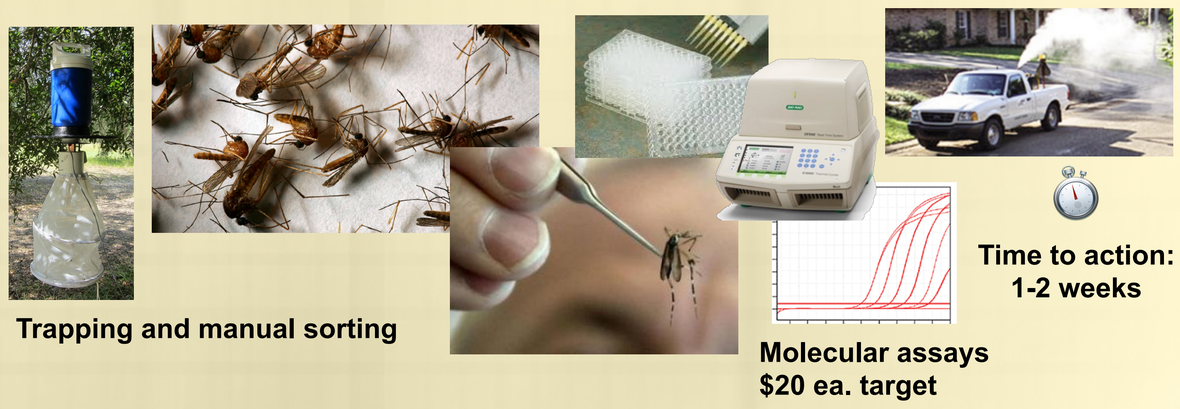
Motivation—Current biosurveillance tools are insufficient

Mosquito-borne pathogens are a menace worldwide. Malaria and dengue significantly burden both civilian and military populations in the tropics, and emerging arboviruses pose health and security risks across the continental U.S., e.g., West Nile virus, chikungunya virus, and now Zika virus. While the risks posed by arboviruses are well known, surveillance for vector-borne diseases is constrained by limited budgets, and a reliance on labor-intensive techniques for sample collection and analysis.



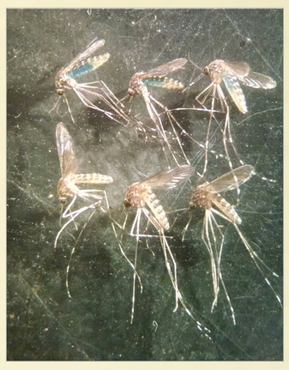
Trapping and manual sorting

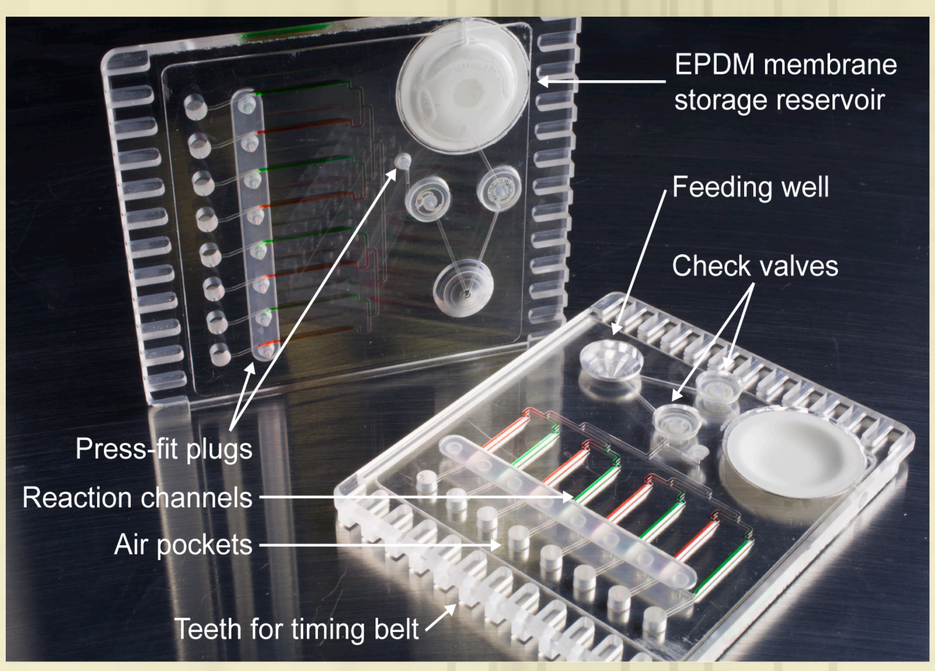
Molecular assays $20 ea. target

Time to action: 1-2 weeks

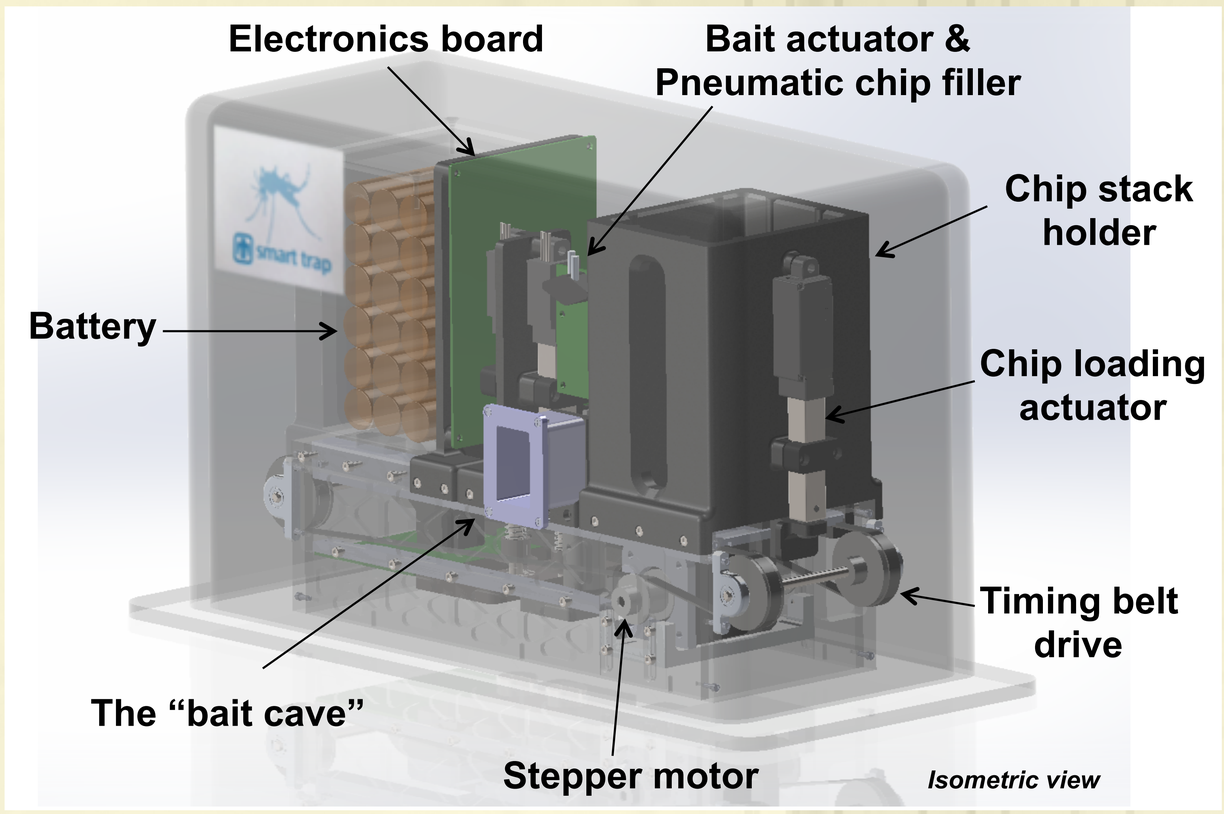
The smart trap

In collaboration with UC Davis, we have developed a device that automates a novel approach to detecting arboviruses in a field setting, based upon the sugar feeding behavior of mosquitoes. Mosquitoes (host-seeking or not) feed upon plant-based sugar on a daily basis for energy. Infected mosquitoes can deposit anywhere from 1-10,000 plaque-forming units of virus on a sugar bait, which we detect by RT-LAMP in 30 min with an autonomous shoe-box sized microfluidic instrument.



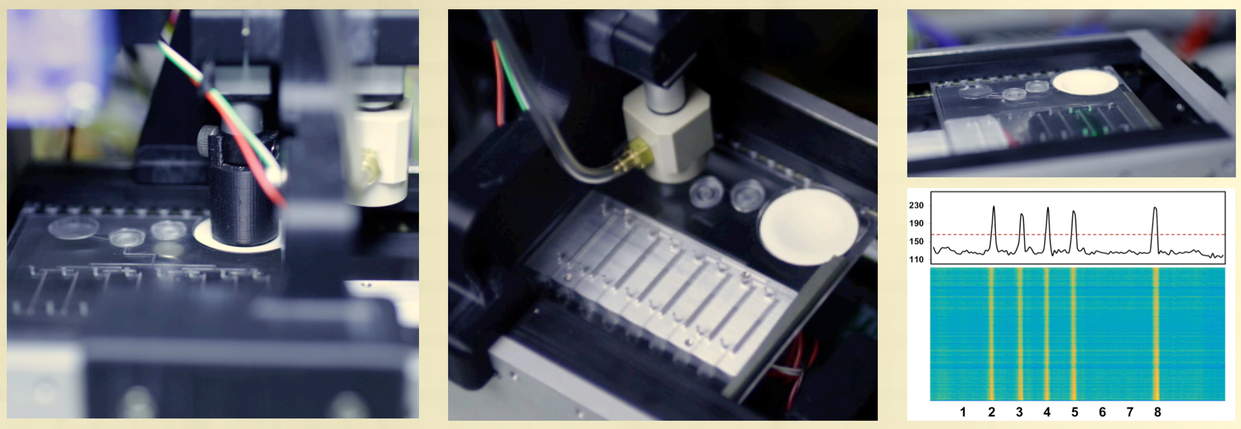


Left: Spun sugar bait and fed mosquitos (blue). **Right:** Plastic (PMMA) analysis chip with dried reagents for up to six virus-specific RT-LAMP assays, plus controls.



Above: The SMART Trap device automatically runs 30 assays, one per day. Simple actuators are used to dispense onboard fluid and fill sealed reaction chambers. Chips are heated for RT-LAMP to 65°C for 30 minutes, then interrogated by an LED and photodiode array detector. Positive reactions fluoresce at room temperature.

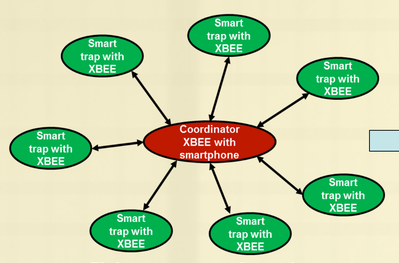
Automated processes



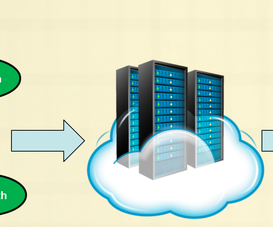
Left to Right: Dispensing onboard fluid with a linear servo; pneumatically filling channels with a servo-mounted pressurized headspace; moving chips off the heater for endpoint detection.

The trap presents microfluidic chips to mosquitoes and automatically handles all microfluidic chip manipulations, including onboard buffer dispensing, pneumatic chip filling, heating, and fluorescence endpoint detection.

Networked biosurveillance

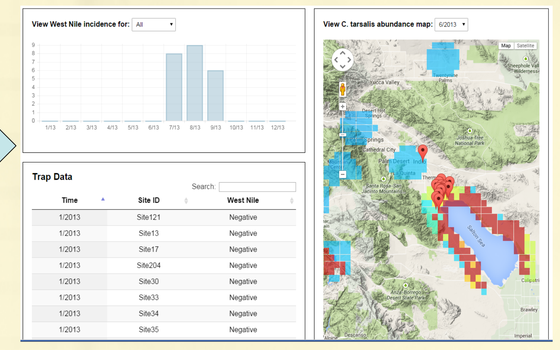


Zigbee star network topology



SMART traps web server and data store running on Amazon AMI

Spring Framework, Java, R



SMART Traps App
Running with BSVE as 3rd Party App
HTML5, Javascript, Google Maps API

Traps are intended to be inexpensive enough ($500 each, upon scale up) to deploy in a mesh network, allowing daily reports at multiple locations within a region of interest. We built an app to provide access to trap data sorted by date or location, as well as map visualizations. Mapping incorporates a statistical model that predicts vector abundance based upon environmental factors. The app is available to analysts within the U.S. Defense Threat Reduction Agency's biosurveillance ecosystem (BSVE).

Conclusions and future work

- Trap detects <1 PFU of a 6 virus panel from sugar feeding mosquitos with low false-positive rate in 30 min.
- Trap is designed for mass manufacture at low cost ($500 per trap, $10 per chip).
- Trap can be reconfigured to target other pathogens.

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