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Real-time, Autonomous Biosurveillance for Vector-borne Viral Pathogens (SMART Traps)

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UC DAVIS UNIVERSITY OF CALIFORNIA
U.S. DEPARTMENT OF ENERGY
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Project Overview

- Overall goal is to develop and field-test an *autonomous sensor* to detect presence of mosquito-borne viruses (West Nile, etc) with daily reporting capabilities.
- Data from sensors will be integrated into BSVE along with mapping & visualization software and predictive models.
- Partnership between Sandia National Laboratories
  - Systems engineering, assays, statistical modeling
- …and UC Davis Center for Vectorborne Diseases (CVEC)
  - Virology, entomology, and ecology of vectorborne disease
  - Integrated with public health and vector control districts in CA

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Why study arboviruses?

- "Arbovirus" = Arthropod-borne virus
  - Mostly RNA viruses; carried by mosquitoes, ticks, flies, *etc*
- West Nile, Dengue, Chikungunya, and now Zika exemplify how fast these viruses can emerge, re-emerge, or change boundaries.

Dengue viruses
Yellow fever virus
Chikungunya virus
Zika virus

West Nile virus*
St. Louis encephalitis virus*
Japanese encephalitis virus
Rift Valley fever virus
Equine encephalitis viruses
(WEE*, VEE, EEE)

Transmits malaria
(not a virus!)

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Current approaches to arbovirus surveillance

- Low-tech sample collection
- Manual skilled labor (mosquito sorting, etc)
- Sophisticated molecular assays

1-2 week turnaround
>$20/sample

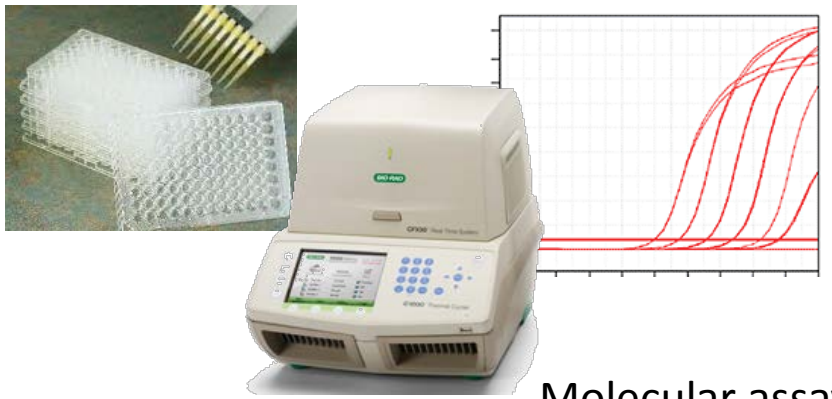
Mosquito collection



Mosquito sorting

Sentinel animals

Laboratory processing



Molecular assays

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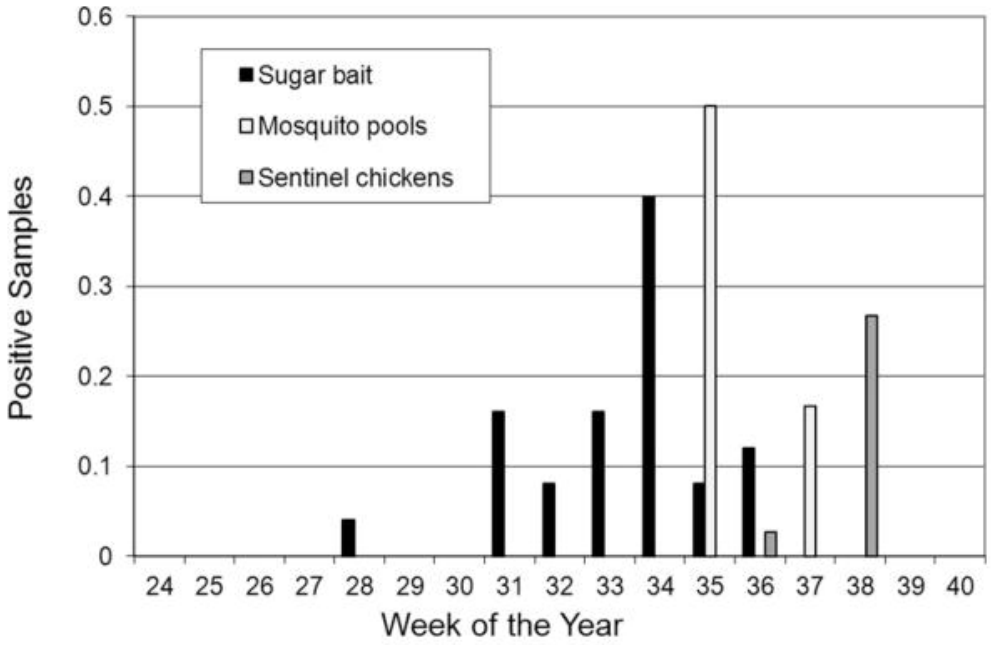
Sugar baiting is a field-tested alternative to mosquito trapping



- A passive sugar bait, made from a cryovial and dental wick with blue-colored syrup and a floral attractant
- tested by UC Davis for WNV surveillance in southern California
- Requires laboratory processing to recover viral RNA for qRT-PCR testing

- Sugar baits were positive for WNV *before* mosquito pools or sentinel chickens
- Research is ongoing by UC Davis to compare passive sugar baits to CO_2 baited traps for WNV surveillance in California.

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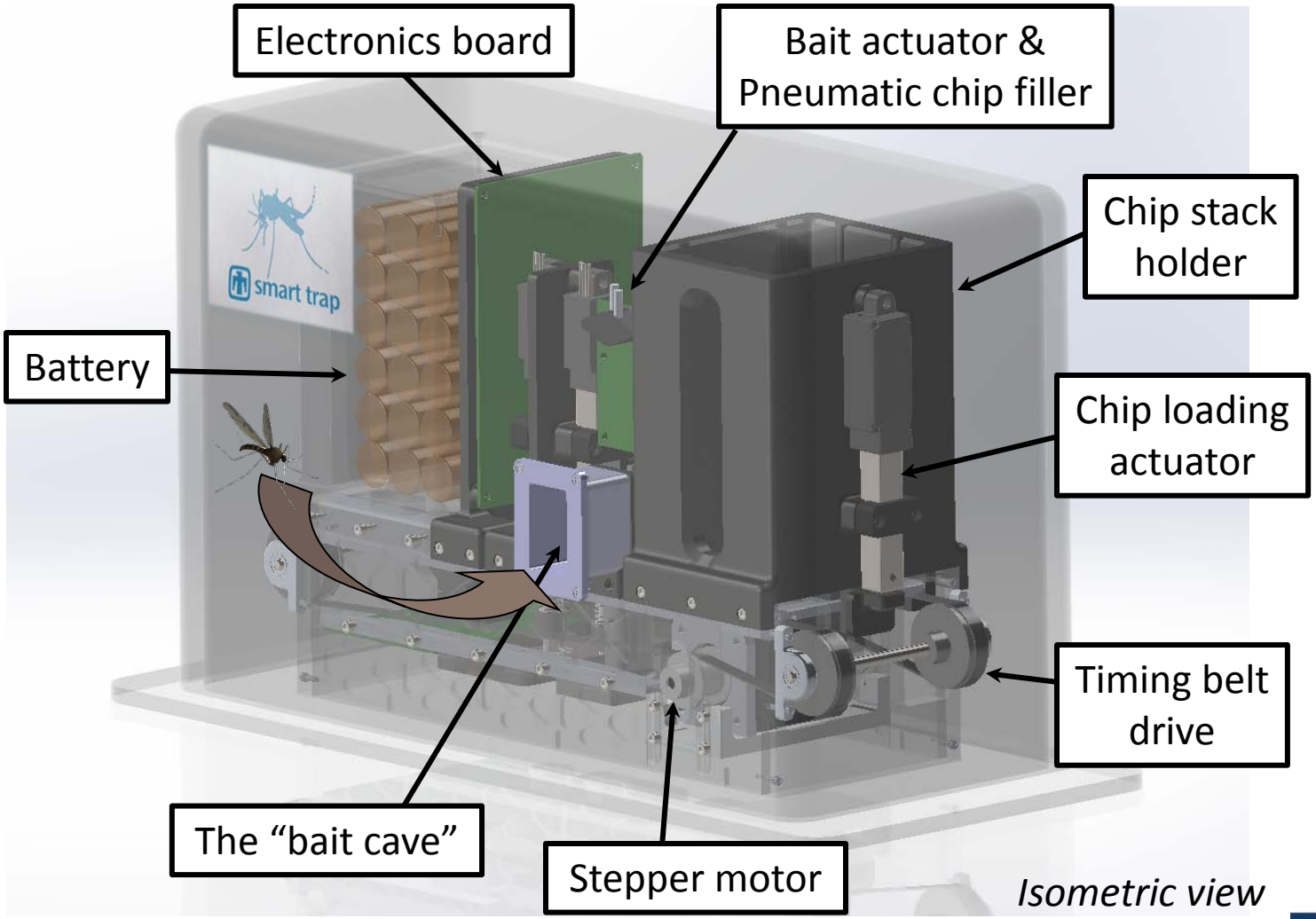
The smart trap automates sugar baiting and molecular assay for viral RNA



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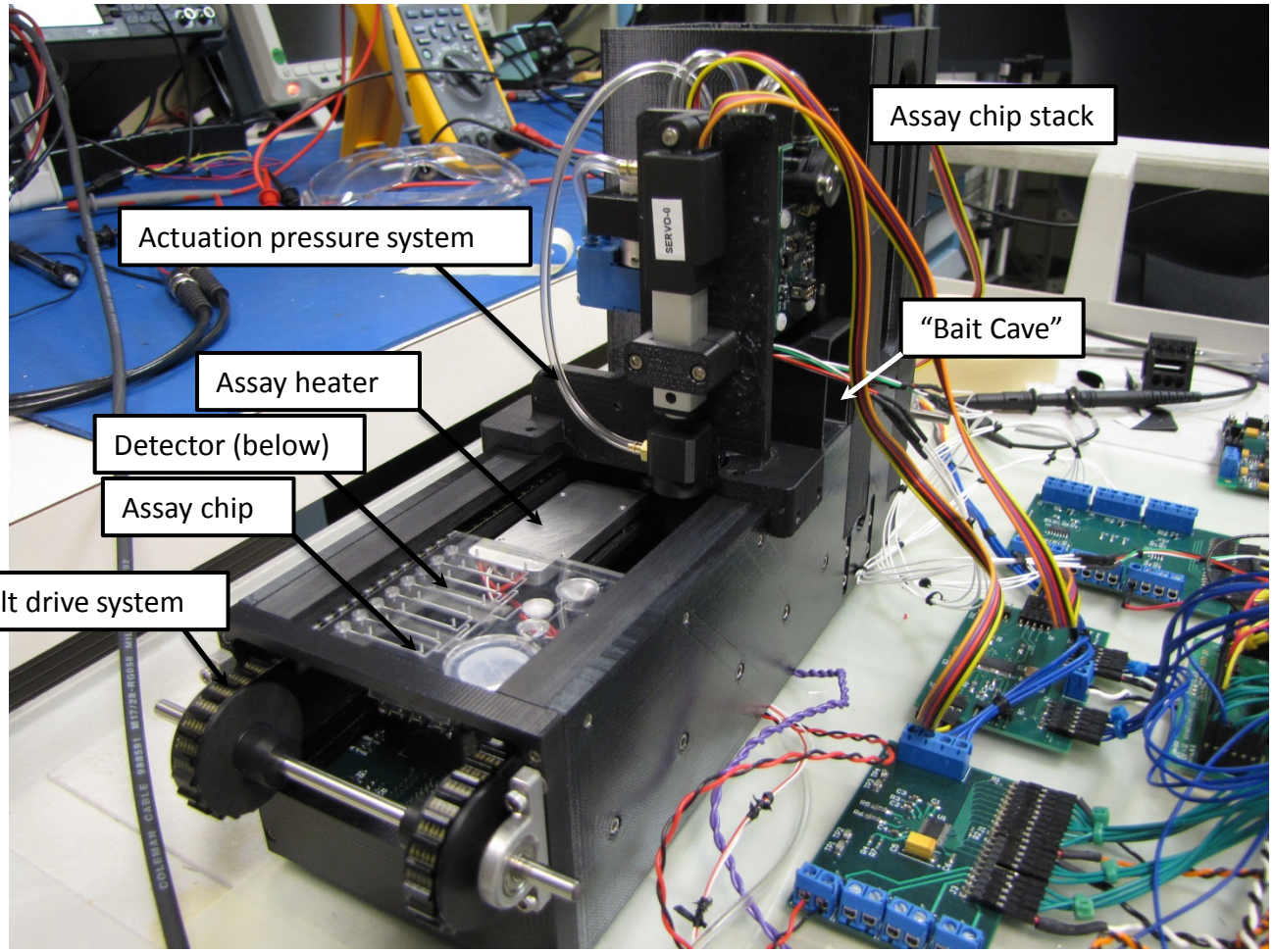
Smart Trap hardware



Electronics – now on a single board, but not shown here to allow better view of components

Not shown: system case and battery pack, normally positioned above where assay chip is situated

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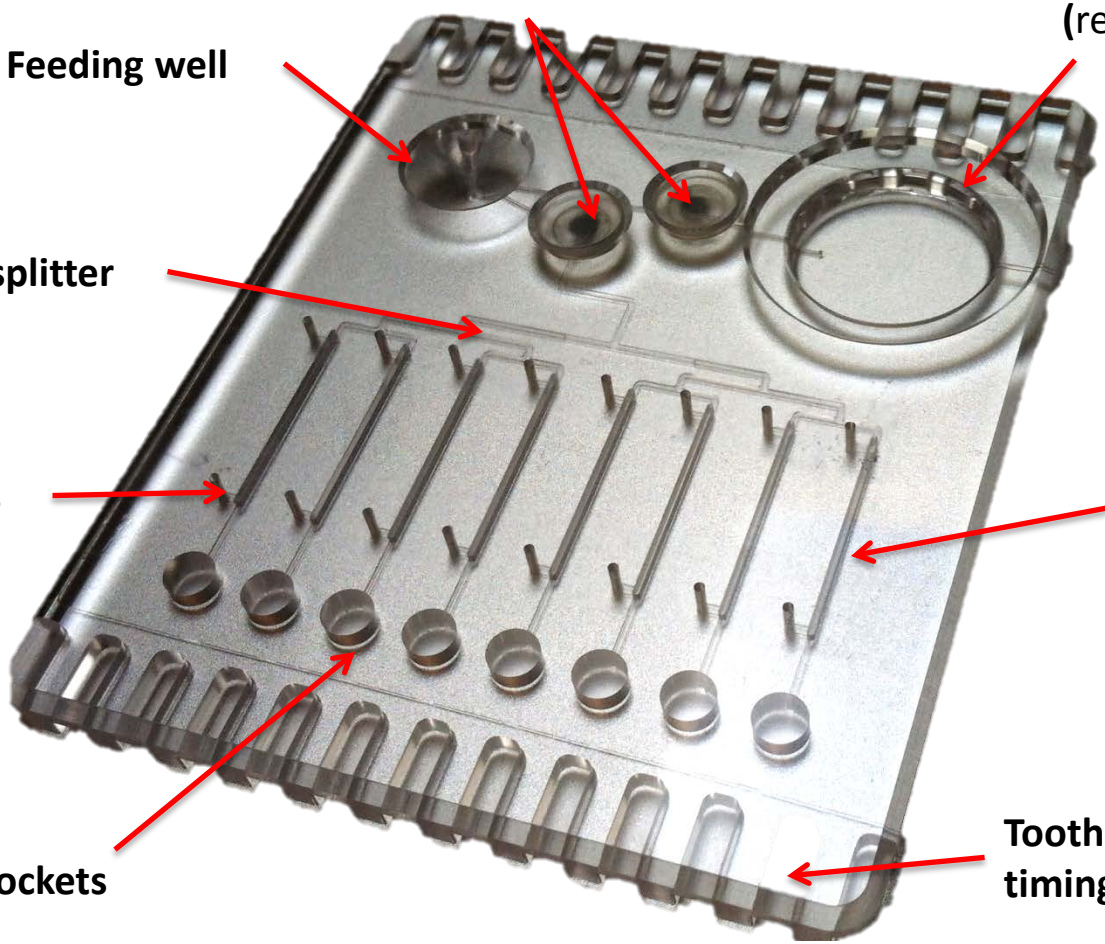
Smart Trap Assay Chip



Check valves

Fluid reservoir (reaction buffer)

Feeding well

Flow splitter

Fill holes

Assay channels for multiple viral targets + controls (stabilized, dried RT-LAMP reagents)

Air pockets

Toothed track to engage timing belt

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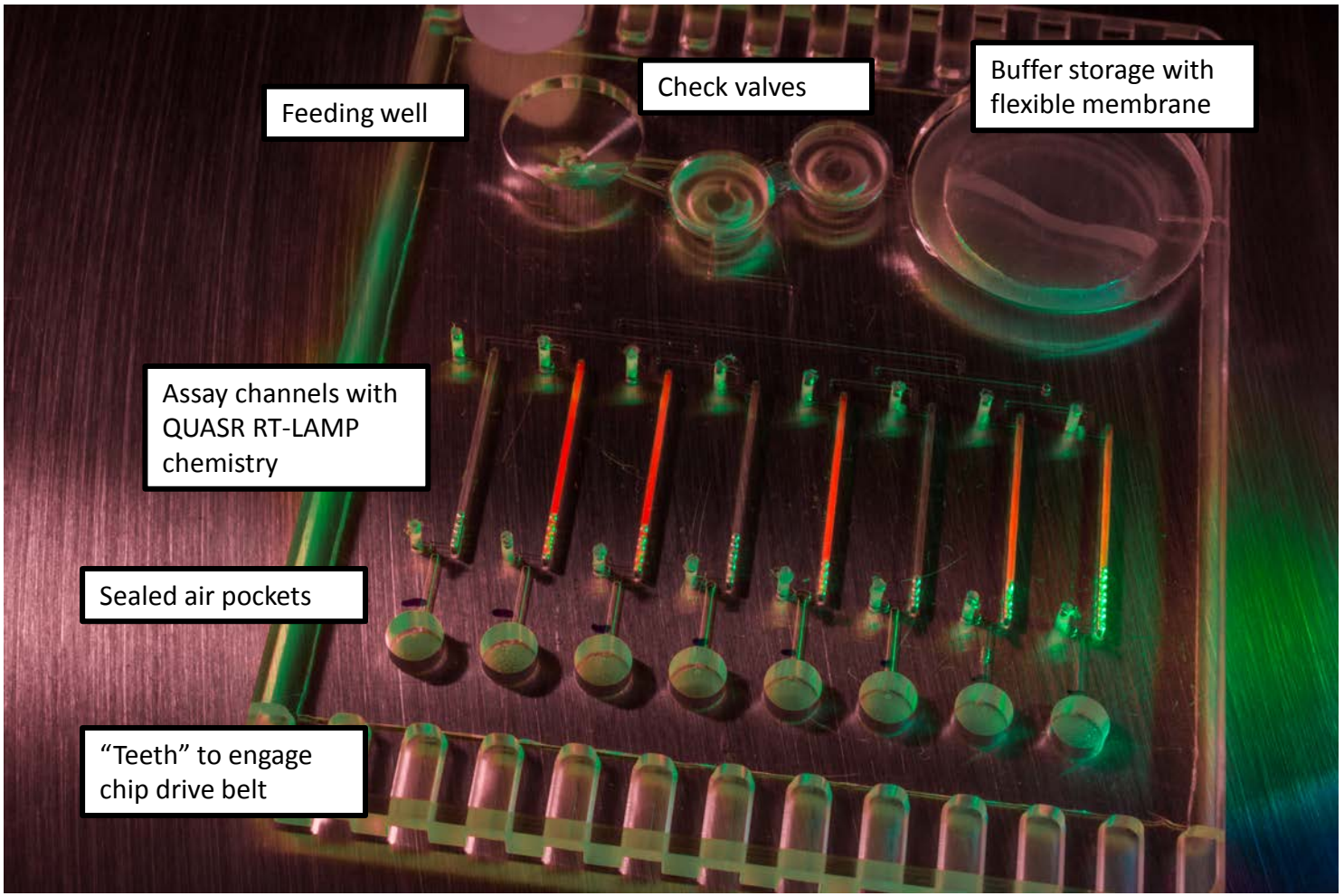
Mosquito sugar feeding assay chip

RT-LAMP amplification is performed dried-down reagents, stabilized with reagent from Biomatrica



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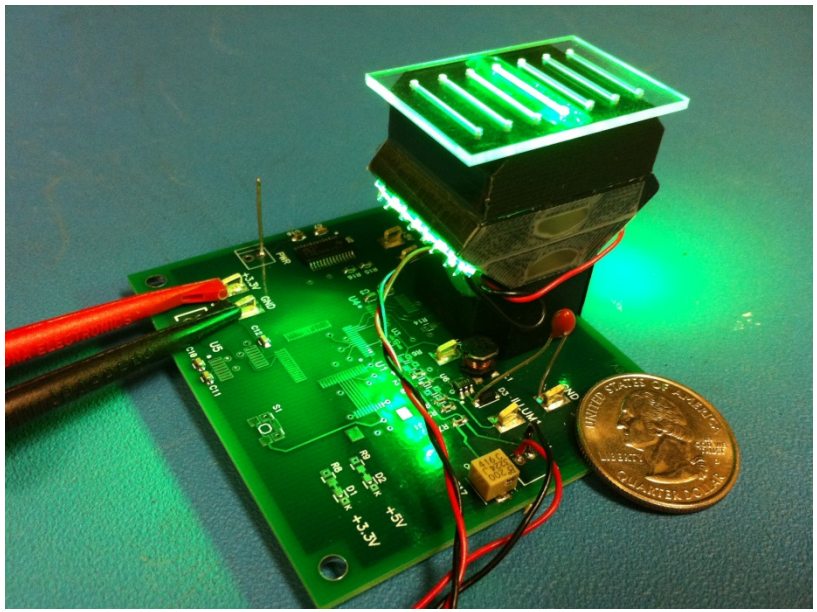
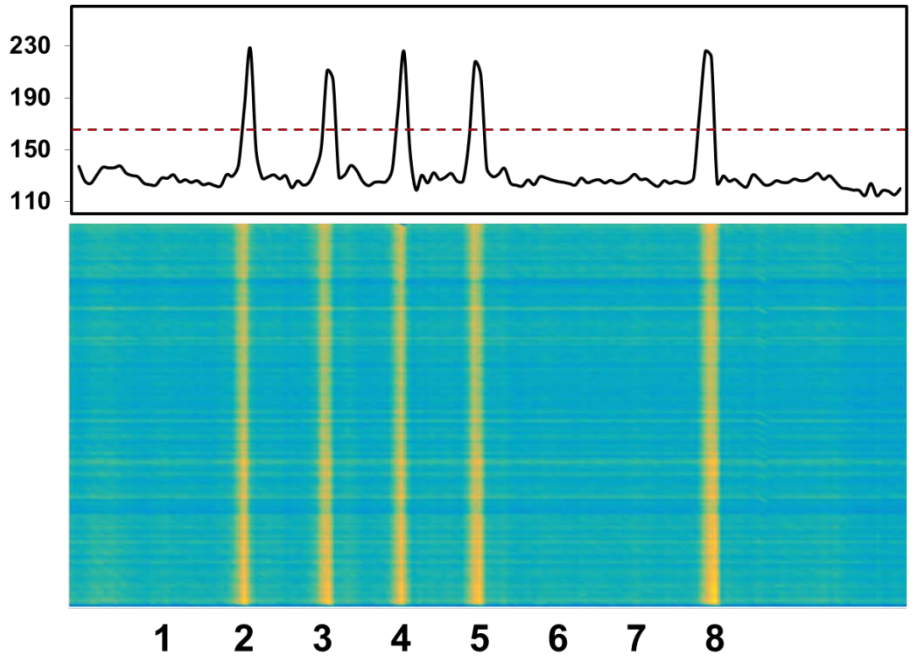
Reading the assay chip



Photodiode detector module, equipped with green LEDs and colored plastic gel filters. Inexpensive optics integrated into 3D printed part.



Detector scan of an 8-channel assay chip, illustrating discrimination between positive and negative channels and comparison to a threshhold (red dashed line).

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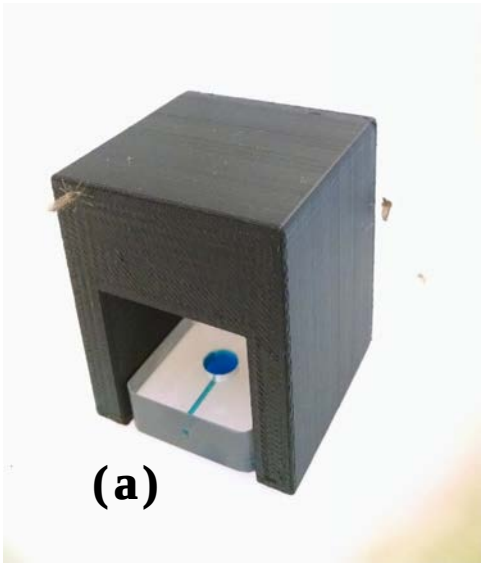
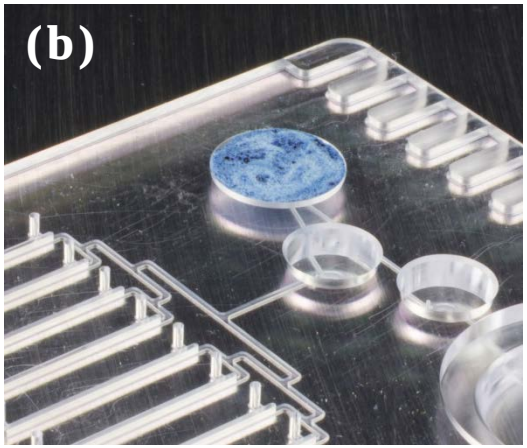
Mosquito feeding from baits

Previous sugar baiting: sugar-soaked cotton balls/wicks (with poor recovery of virus)
Smart Trap achieves total recovery from either (a) liquid-phase baits, or
(b) dried sugar films/spun sugar



"Bait cave" with blue-colored sugar bait

Blue food coloring allows identification of mosquitoes that fed on bait



Scented, polymer-modified spun sugar as a stable attractive bait for mosquitoes

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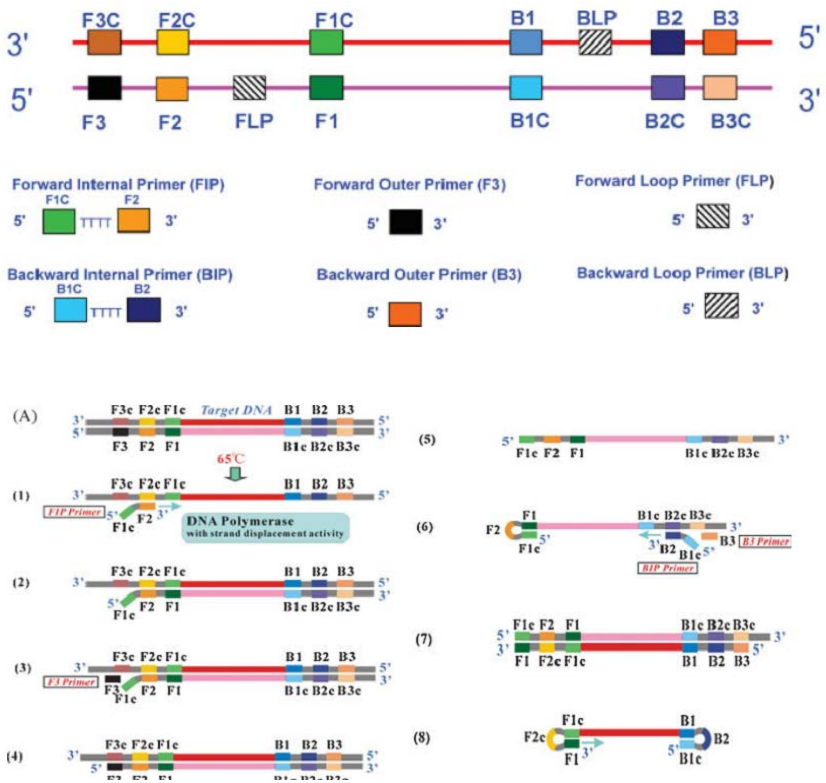
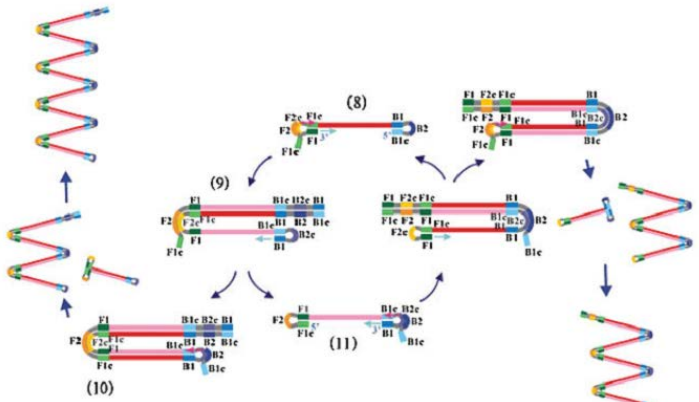
RT-LAMP viral assays



- Isothermal (65 °C) “alternative” to RT-PCR for point-of-care or low-resource settings
- Complex reaction scheme, but high sensitivity (<0.1 PFU virus in 20-30 minutes) and high specificity
- Many RNA viruses including WNV can be detected “directly” by RT-LAMP, without purification, lysis, or RNA extraction.



LAMP reaction scheme proposed by Notomi *et al* (2000).

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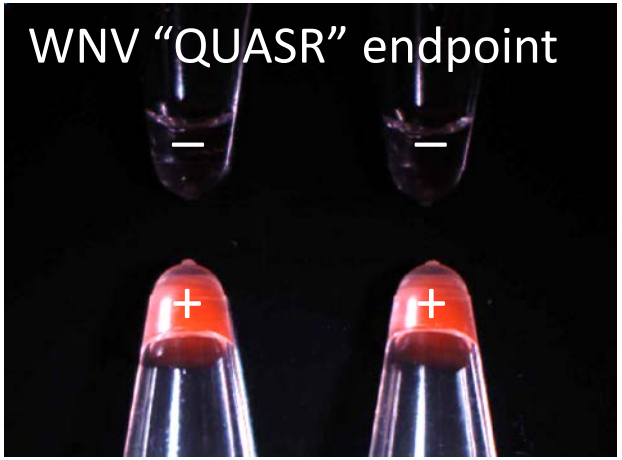
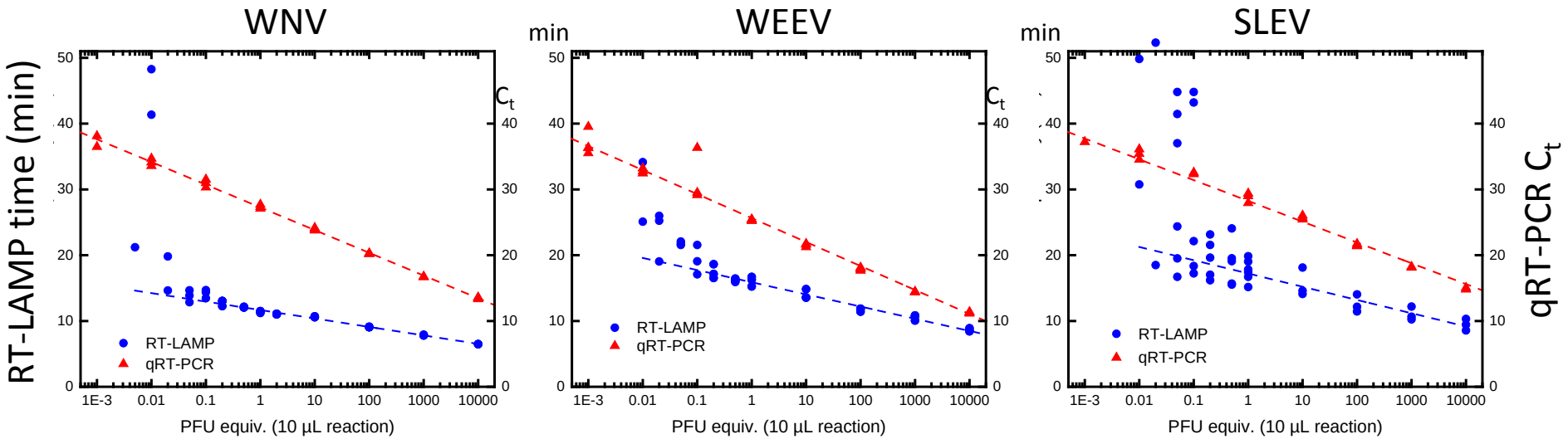
Viral assays by RT-LAMP

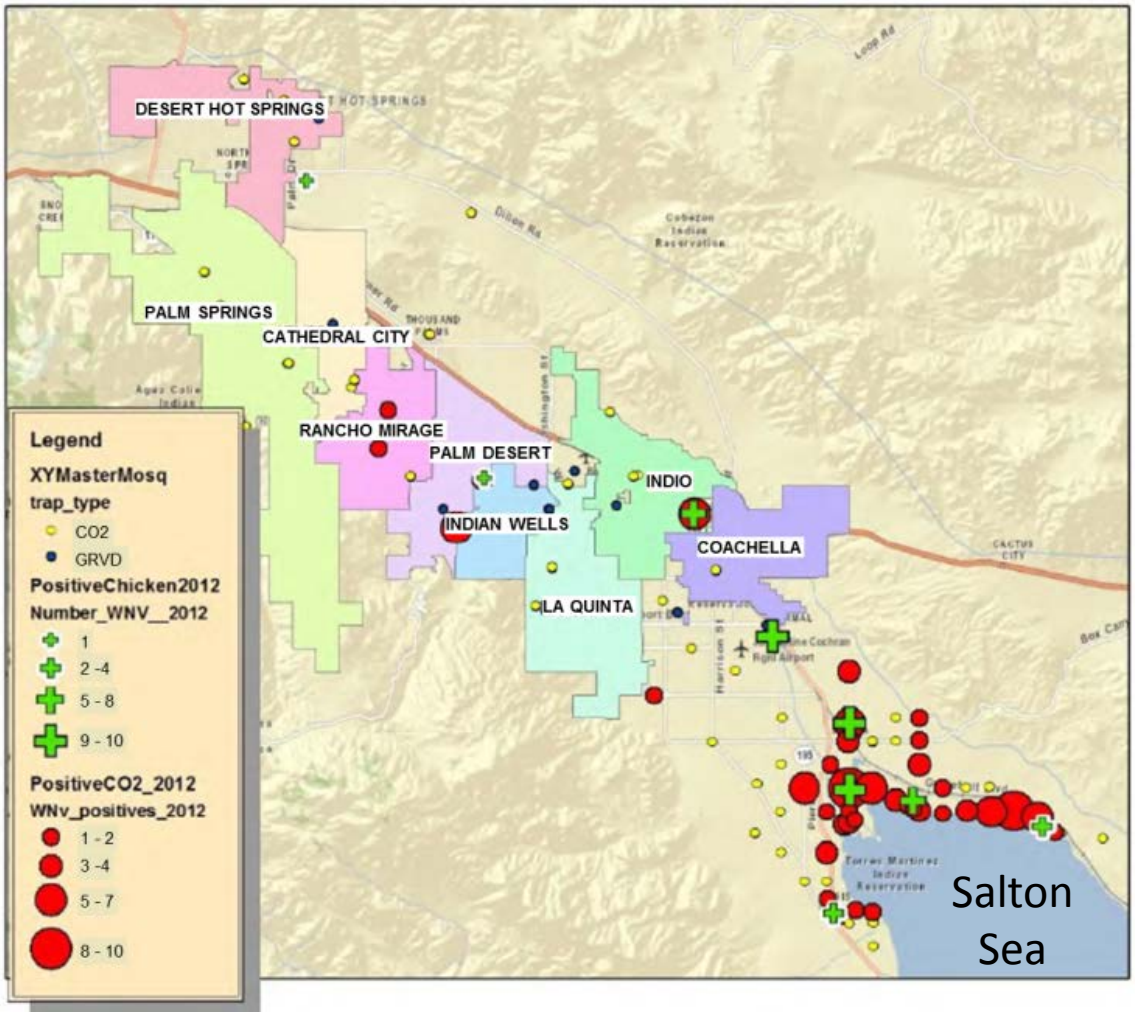
- Novel detection chemistry “QUASR” gives bright and distinctive fluorescence endpoint signal, with multiplexing capability and reduced false positives compared to “traditional” LAMP
- RT-LAMP quantitative precision and sensitivity is usually less than qRT-PCR





Wheeler *et al*, PLOS One 2016

Field test for Smart Trap planned 2016



- We will deploy a network of Smart Trap prototypes near the Salton Sea in southern California.
- Irrigation, warm summers, and abundant birds lead to ideal conditions for West Nile virus
- We will perform a field test of the Smart Trap concurrently with conventional vector surveillance for WNV (traps & sentinel chickens)

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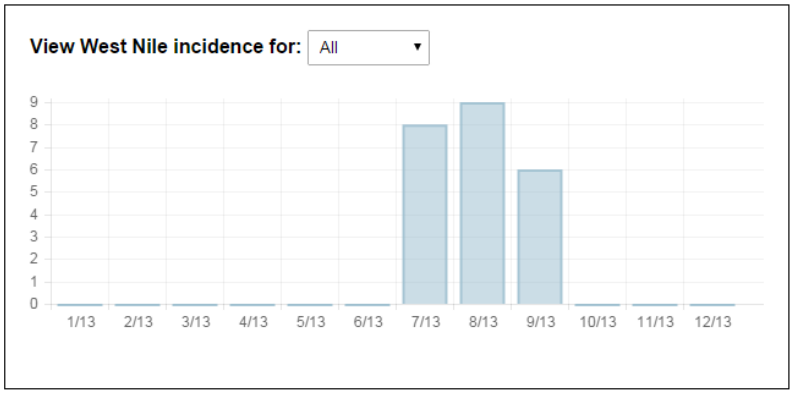
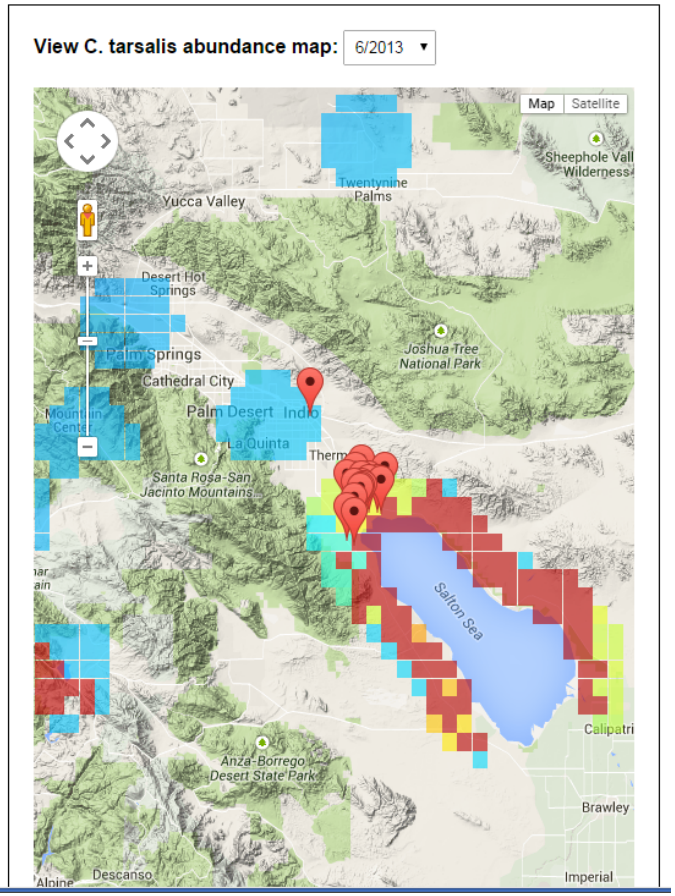
Cloud-based mapping and modeling

- 3rd party app: data stored on Amazon cloud, “private” data (from CA vector control) used to generate model visualizations for BSVE
- Daily viral incidence data, combined with physical data and models of vector abundance lead to prediction of disease transmission risk.





Trap Data

Search:

Time	Site ID	West Nile
1/2013	Site121	Negative
1/2013	Site13	Negative
1/2013	Site17	Negative
1/2013	Site204	Negative
1/2013	Site30	Negative
1/2013	Site33	Negative
1/2013	Site34	Negative
1/2013	Site35	Negative

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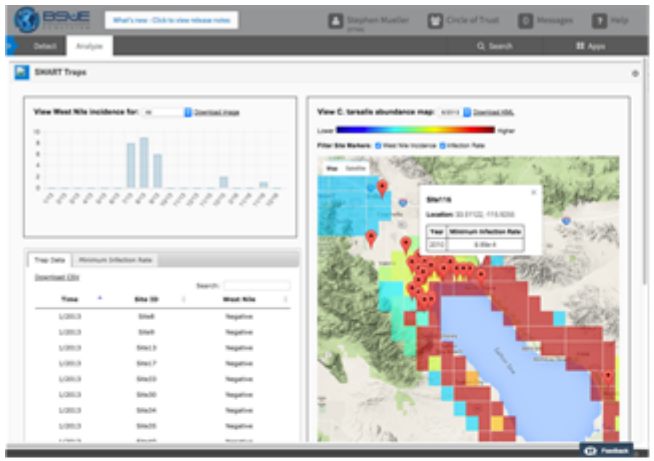
SMART Trap communicatin with BSVE



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

Download data via REST

SMART Traps Web Server and Datastore
Running on Amazon AMI
Spring Framework, Java, R

Upload data via REST

SMART Traps

Receiver

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