LABORATORY FOR
Computational
Sensing + Robotics
THE JOHNS HOPKINS UNIVERSITY

JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Automation of Mosquito Dissection for Malaria Vaccine Production

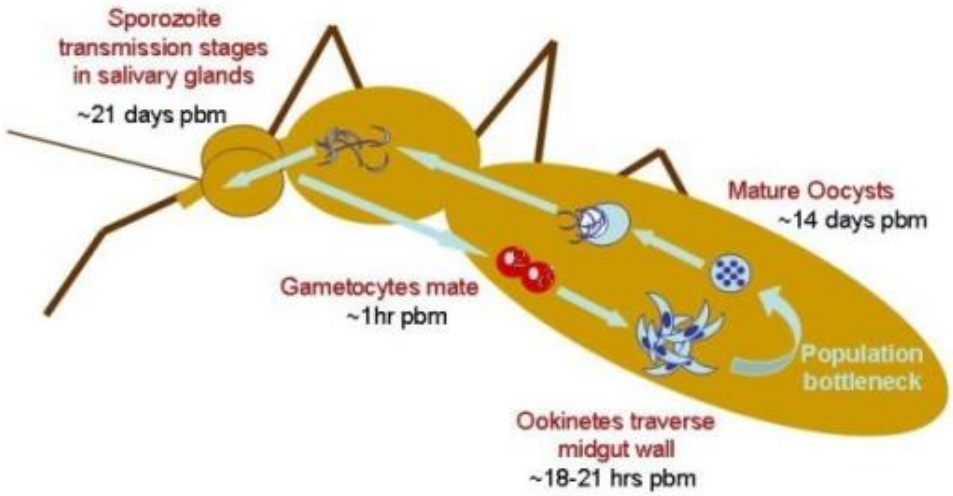
Computer Integrated Surgery II
February 26, 2019

Group 1: Michael Pozin, Henry Phalen, Alexander Cohen

Mentors:
Drs. Russell Taylor, Iulian Iordachita

Background

- Working as part of larger LCSR effort
- Small Business Innovation Research (SBIR) grant from NIH with Sanaria Inc.
- Sanaria has developed a methodology to produce a **malaria vaccine**
- Malaria is spread by a parasite (*Plasmodium falciparum*) that grows in the salivary glands of mosquitoes *(anopheles)*

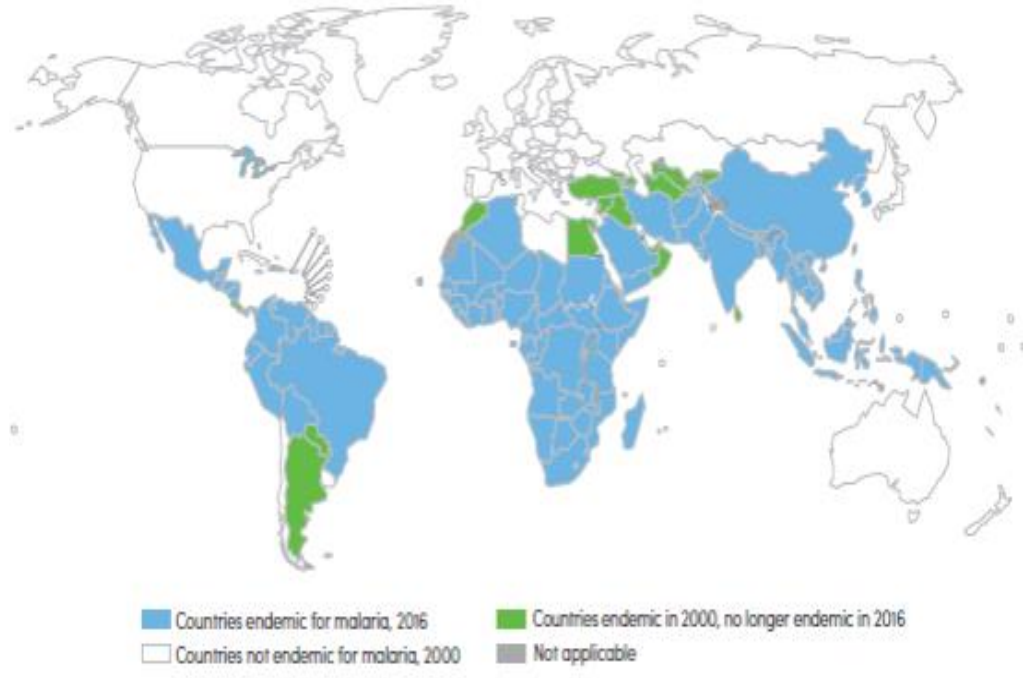


SANARIA

MALARIA ERADICATION THROUGH VACCINATION

Clinical Motivation

- Malaria is a **global** health problem



- Estimated malaria deaths 2015:
  - 438,000[1]
  - 666,000[2]
  - 730,500[3]
  - Estimated clinical cases 2015: 214,000,000[1]
- >$12B GDP loss in Africa alone[1,4]

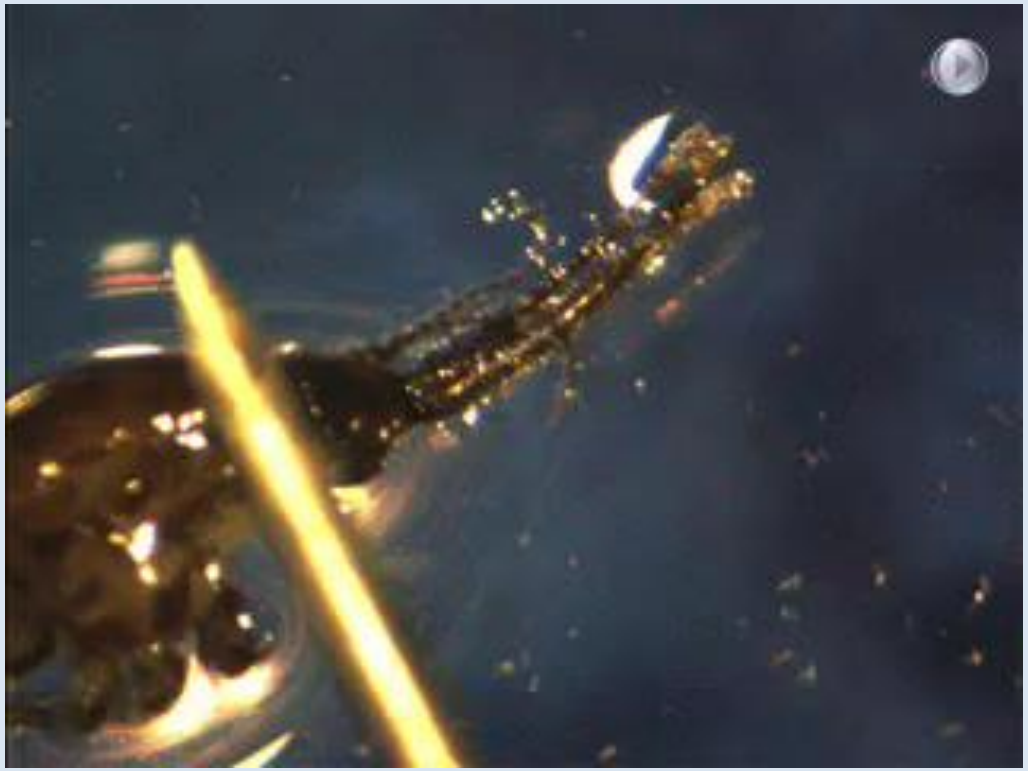
From WHO World Malaria Report 2016

1.World malaria report 2016. Geneva: World Health Organization; 2016.
2. Gething *et al. N Engl J Med* 375: 2435-2445, 2016.
3. GBD 2015 Mortality and Causes of Death Collaborators. *Lancet* 388: 1459-1544, 2016
4. Murray *et al*. *Lancet* 379: 413-431, 2012

The Project

- To develop the vaccine, mosquitoes are bred, infected, dissected, and their salivary glands harvested and purified
- The harvested parasite sporozoites become the vaccine agent

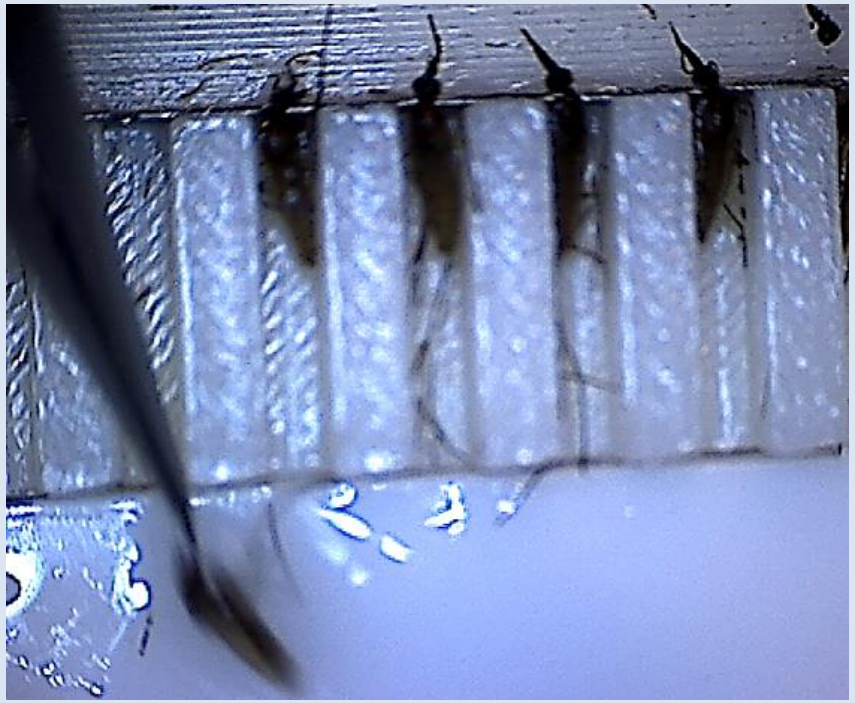
Current Dissection Procedure:



- Major bottleneck to vaccine production:
- 5-6 mosquitoes per minute after **several months of training**

Prior Work

- A team from LCSR created a mechanical system to increase efficiency
- Training time reduced to ~1.5 weeks



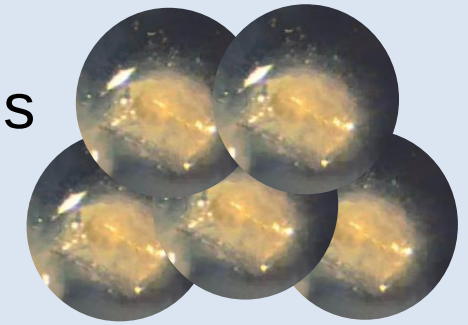
1. Place mosquito neck between a pair of blades

2. Squeeze out the salivary gland (and some “guts”)

An Automated Approach

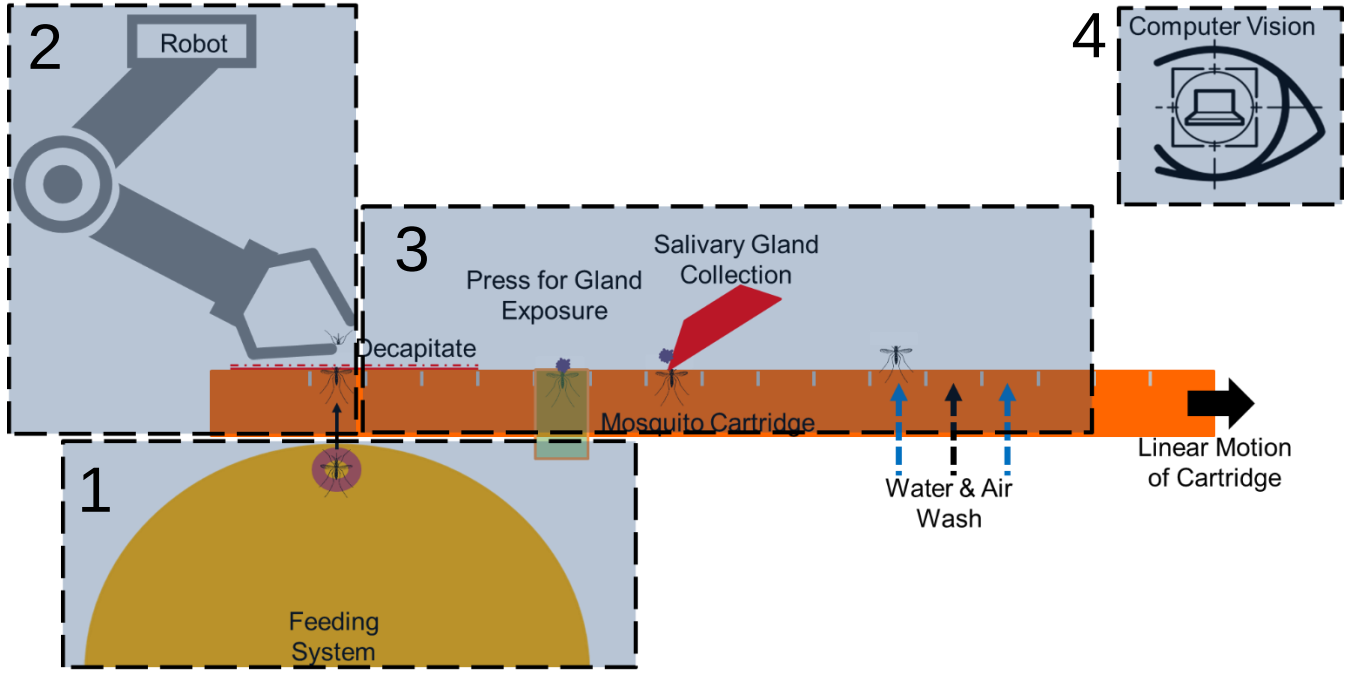
- Our goal is to develop an automated mosquito dissection system

Staged Mosquitoes → Dissection System → Salivary glands



Within a Larger System:

1. Mosquito separation
2. **Mosquito pick-and-place**
3. **Mosquito dissection**
4. Mosquito recognition (throughout)



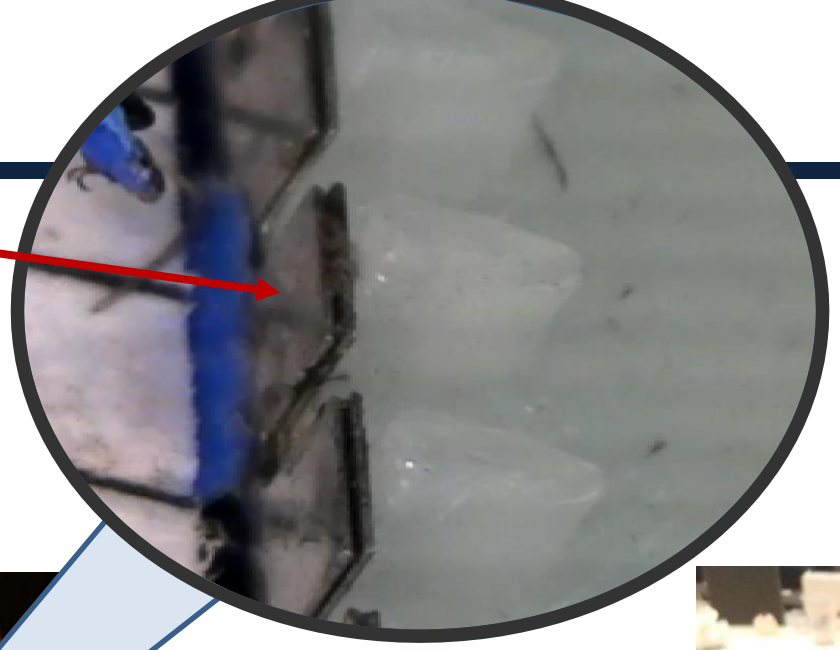
Technical Approach: Outline

1. Minor changes to robotic pick-and-place assembly
    - Mosquito alignment slot geometry
2. Development of current dissection system
    - Redesign of downstream processes
    - Verification testing
3. Multi-component integration
    - Timing & Code
    - Systems out of Control (Vision & Feeding/Staging System)
4. Rotary Stage Design
    - Develop rotating cartridge design for integration with pre-existing and developed modules

Robot Setup

Johns Hopkins University

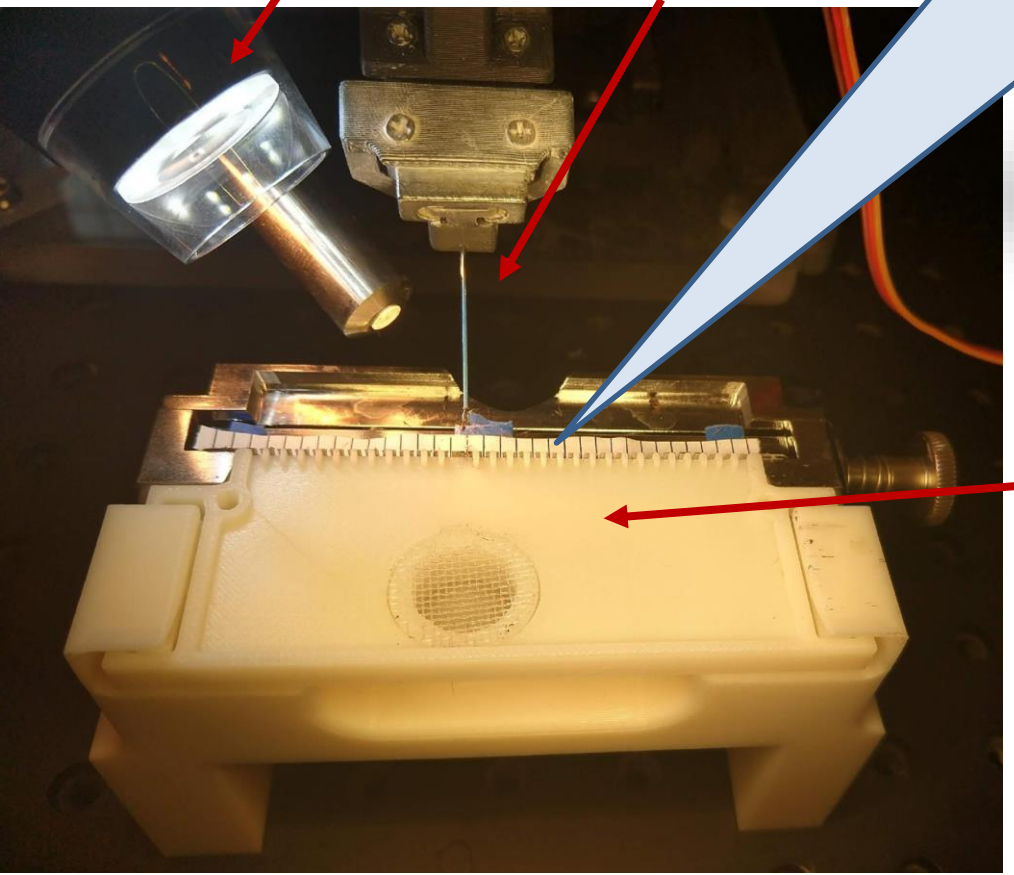
Laboratory for Computational Sensing + Robotics



Decapitation blades

Behind-blade camera

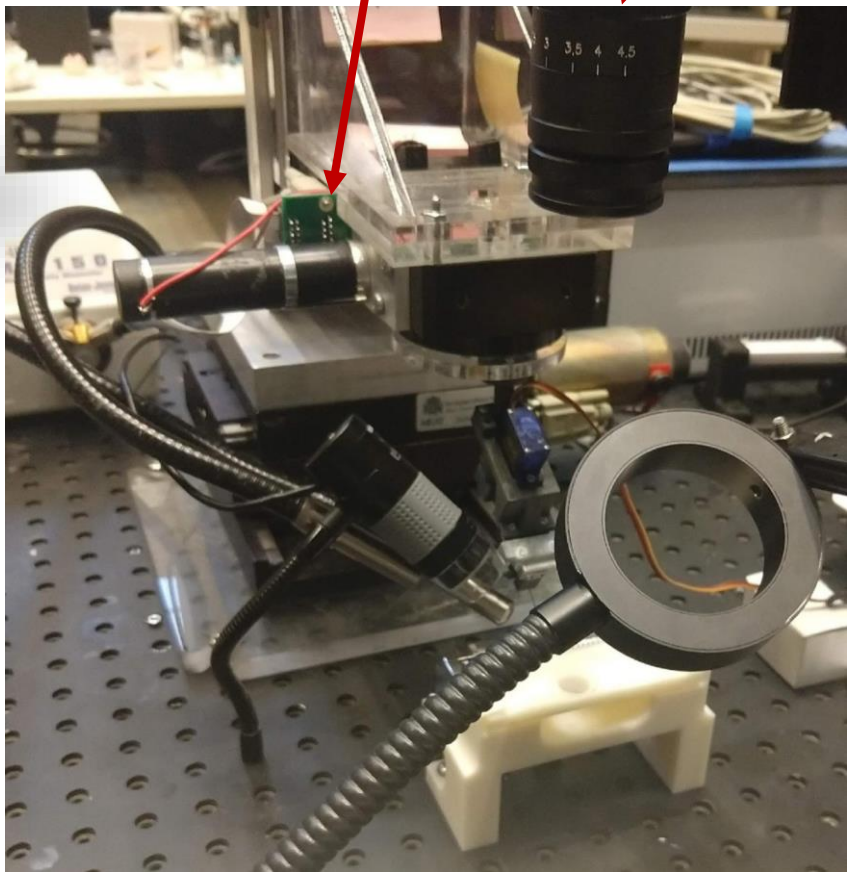
Micro-gripper



Cartridge

Overhead camera

Cartesian stage



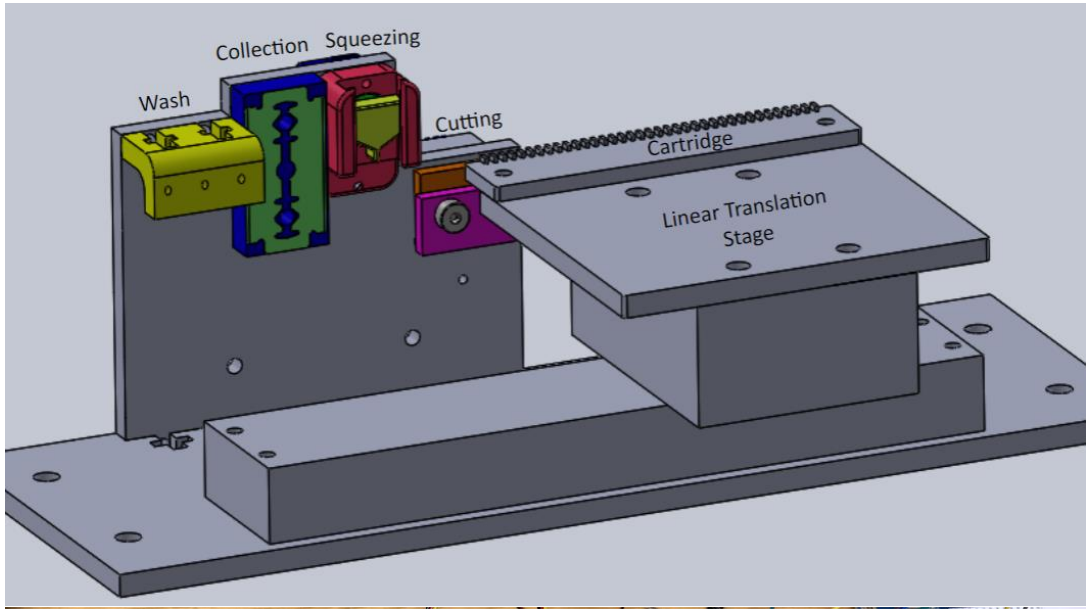
1. Changes to Pick-and-Place System

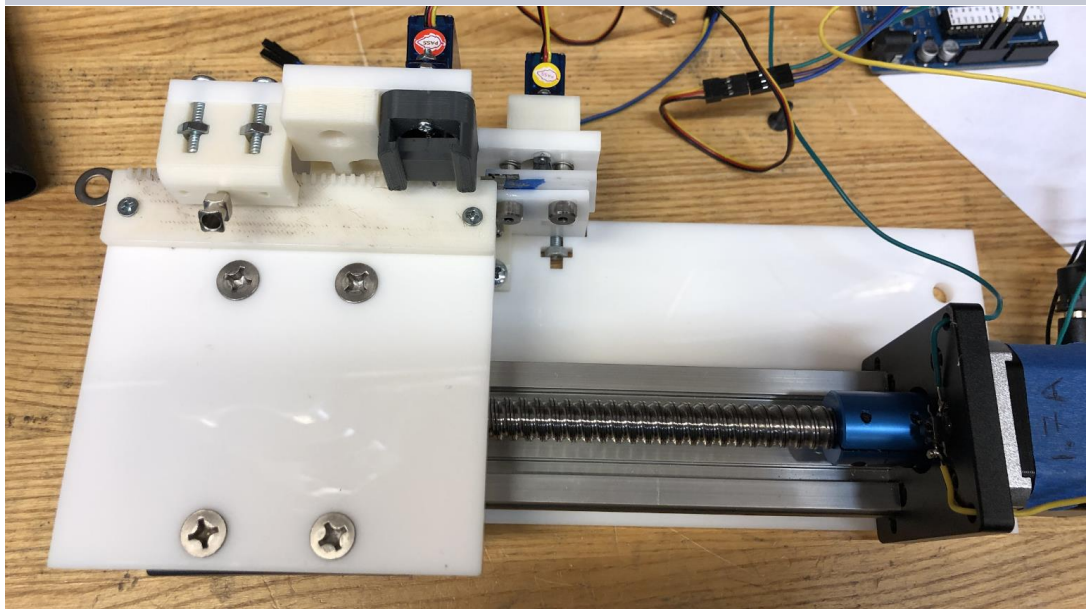
- Robot can take a image location, navigate to the site, grasp a mosquito, position between blades
- Bernstein polynomial calibration
- No downstream processing attempted

- ~85% accuracy - hope to improve this
  - Minor changes to mechanical geometry
  - Better use of information from vision

2. Development of current dissection system

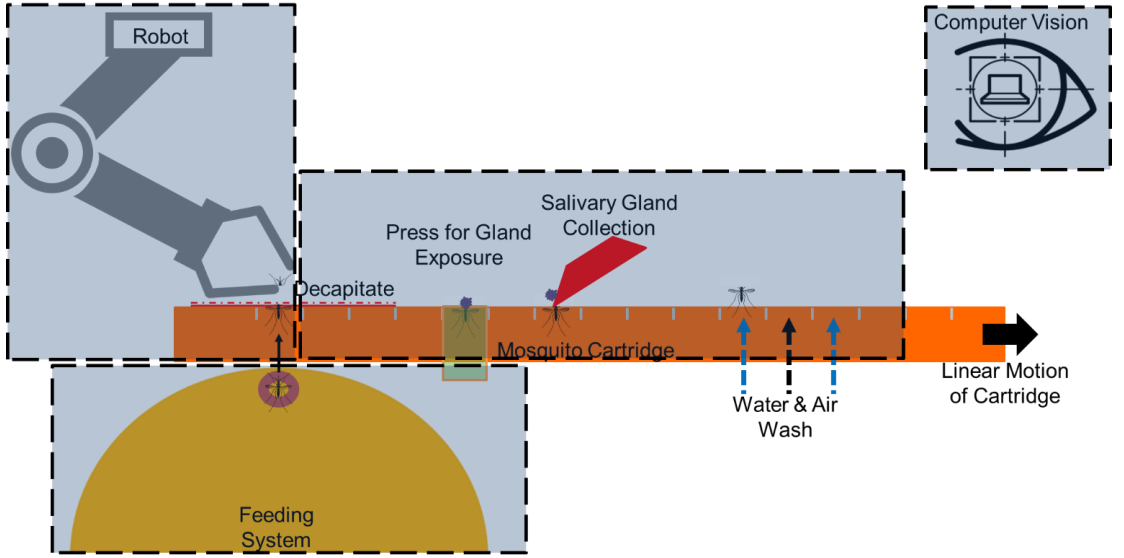
- Redesign and test downstream processes
  1. Cutting
  2. Squeezing
  3. Gland Collection
  4. Wash





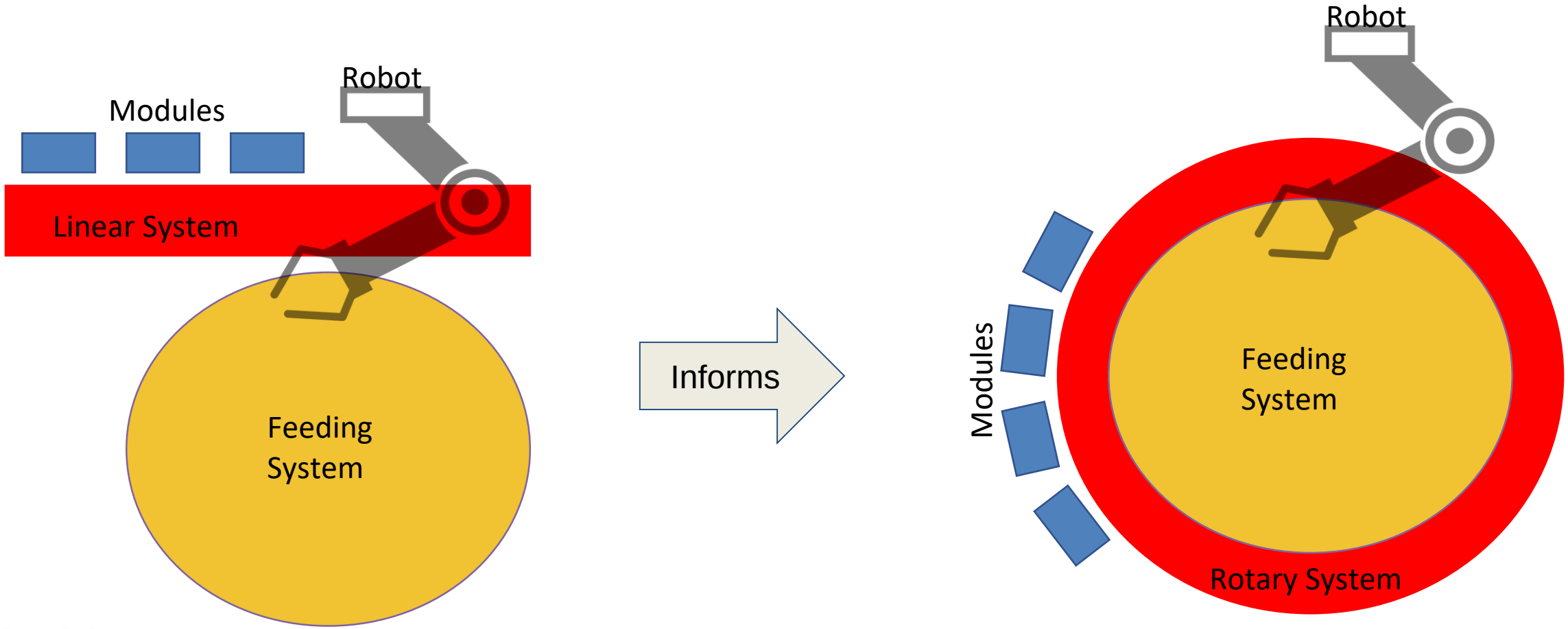
3. Multi-system integration

- Multi-component timing
  - Single time bottleneck (most likely robot motion)
  - Simultaneous actuation at multiple levels of system
- Code
  - High-level system control
  - ROS topics
  - Serial communication with microcontrollers
- Integration with systems out of our control
  - Vision, mosquito feeding/staging



4. Rotary Stage Design

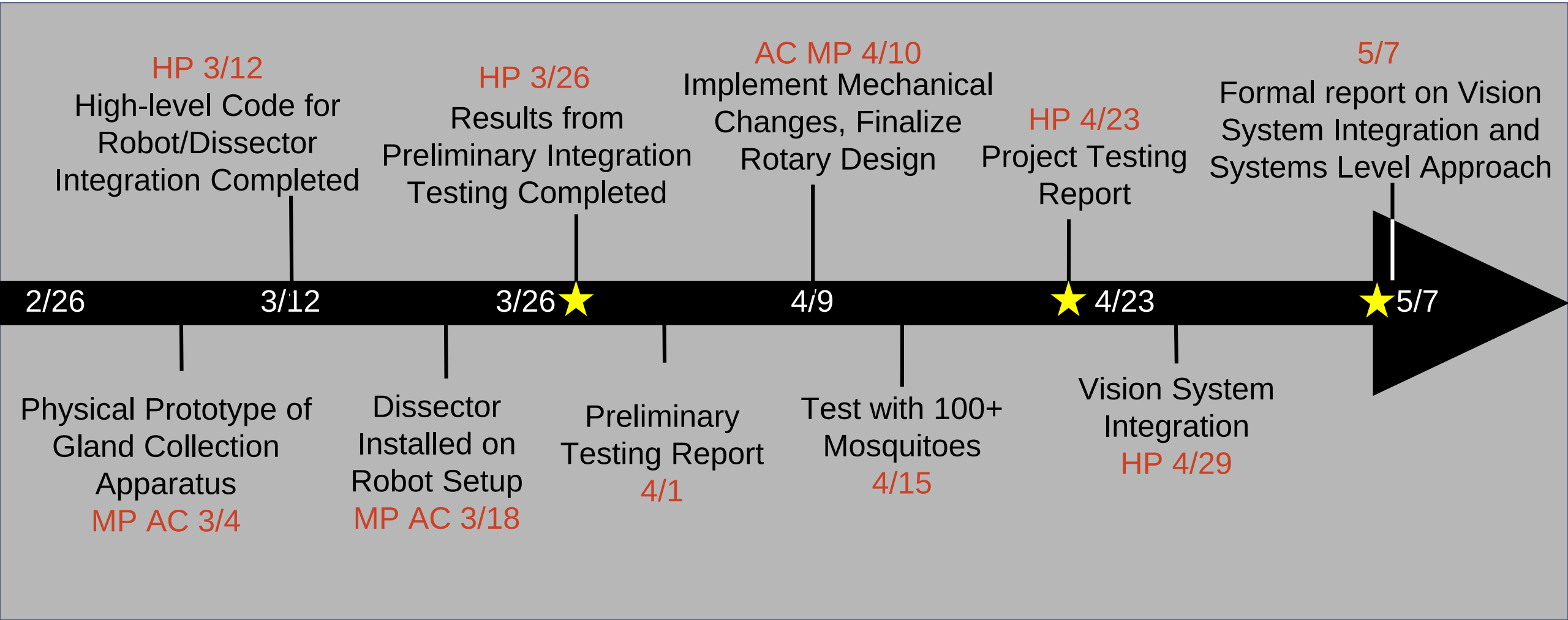
- Linear system will provide proof-of-concept of modules
- Rotary system will be developed to allow for a more streamlined process



Milestones

Responsible Member's Initials

★ Key deliverable



Deliverables

MIN

Video of a mosquito processed from presentation to body disposal, specifically:
Presentation → Pick & Place → Decapitation → Squeeze → Gland Collection → Body Disposal

03/26/19

IDEAL

Written report detailing system integration (no vision), automated dissection of 50+ mosquitoes
Written report of design concept of rotary stage

04/23/19

MAX

Written report on system integration (with vision), automated dissection of 100+
Physical prototype of rotary stage concept

05/07/19

Dependencies

Dependency	Solution	Date Expected	Date Required	Mitigation
Access to shared setup, computer, robot in Robotorium	Coordinate with collaborators	2/26	2/28	Perform testing in off-hours
Access to Lab Pod, JH Box (Alex)	Ask Dr. Taylor for Access	2/28	2/28	N/A
Access to mosquitos (weekly basis)	Email colleagues and Sanaria to coordinate pickup	Weekly	Weekly	No testing that week, or unofficial testing with old mosq's or those in ethanol
Interface with computer vision system	Rely on collaborators to continue development	3/15	4/23	Continue to use manual user-click commands
Upstream mosquito staging system	Rely on collaborators to continue development	4/1	4/23	Dissection system can be demonstrated with human-staged mosquitoes
Money for mechanical development (e.g new stage, fabrication costs, etc).	Ask mentors as needed - grant has funding	As needed	As needed	Use what resources are available
Continued functionality of recently re-designed micro gripper	Rely on collaborators to continue ongoing improvements	2/26	2/28	Complete redesign ourselves, possibly adjust project goals

Management Plan

Project Lead: Henry

Group Meetings: Monday Noon - 1PM, Friday Noon - 3PM

- ➢ Robot control, high-level code, integration: Henry
- ➢ Downstream dissection : Michael & Alex
- ➢ 2nd generation system design: Alex

<u>Organizational Items:</u>

- Weekly meetings with mentors and collaborators (Mondays 9-10AM)
- Any code stored in current project private Git repo
- Communication via Slack (Instant Messaging) and email
- All documentation stored in project JH Box and on course website

Reading List

- “Protection Against Malaria by Intravenous Immunization with a Nonreplicating Sporozoite Vaccine” Robert A. Seder, et al. *Science 2013.*
- “Protection of Humans against Malaria by Immunization with Radiation-Attenuated Plasmodium falciparum Sporozoites.” Stephen L. Hoffman, et al. *Journal of Infectious Diseases 2002.*
- Richie, Thomas L., et al. "Progress with Plasmodium falciparum sporozoite (PfSPZ)-based malaria vaccines." Vaccine 33.52 (2015): 7452-7461.
- “An Efficient Production Process for Extracting Salivary Glands from Mosquitoes” Mariah Schrum, Amanda Canezin, Sumana Chakravarty, Michelle Laskowski, Suat Coemert, Yunuscan Sevimli, Greg Chirikjian, Stephen L. Hoffman, and Russell H. Taylor. *Unpublished.*
- Phase II Mosquito Microdissection SBIR Grant Submission. Greg Chirikjian, Iulian Iordachita, Russell H. Taylor. *Unpublished & Confidential.*
- “Mosquito Staging Apparatus Design for producing PfSPZ-based Malaria Vaccines” Mengdi Xu, Shengnan Lu, Yingtian Xu, Can Kocabalkanli, Jing Jia, Brian Chirikjian, John Chirikjian, Joshua Davis, Jin Seob Kim, Sumana Chakravarty, Iulian Iordachita, Russell Taylor, Gregory Chirikjian. *Unpublished & Confidential.*


Questions?