Automation of Mosquito Dissection for Malaria Vaccine Production

Design Concept of Rotary Stage

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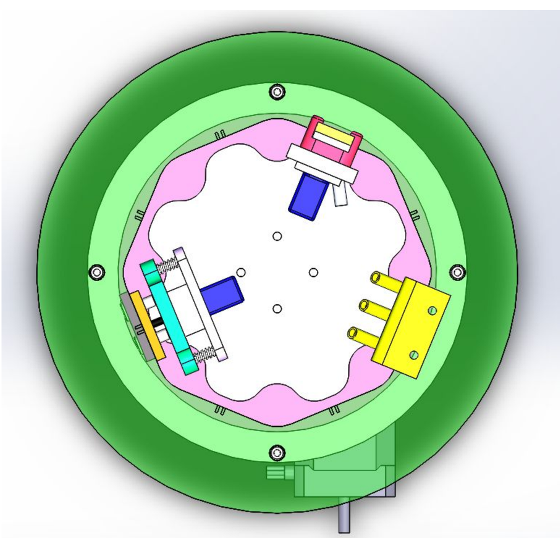
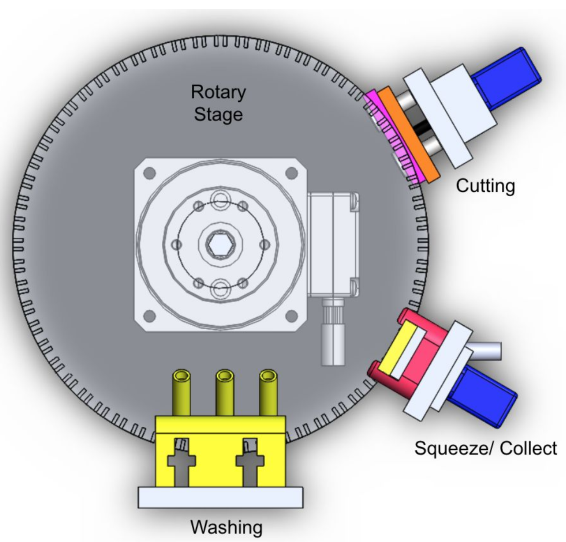
Mentors: Dr. Iulian Iordachita, Dr. Russell Taylor





LABORATORY FOR Computational Sensing + Robotics THE JOHNS HOPKINS UNIVERSITY

JOHNS HOPKINS WHITING SCHOOL of ENGINEERING

The overall goal of our project is to automate the dissection of glands from mosquitoes to streamline the processing of a malaria vaccine for Sanaria. The reason we decided to design a rotary stage when we already have a linear stage is to further optimize our solution. Currently we have a linear stage with three subsystems (cutting, squeezing / gland collection, and washing).

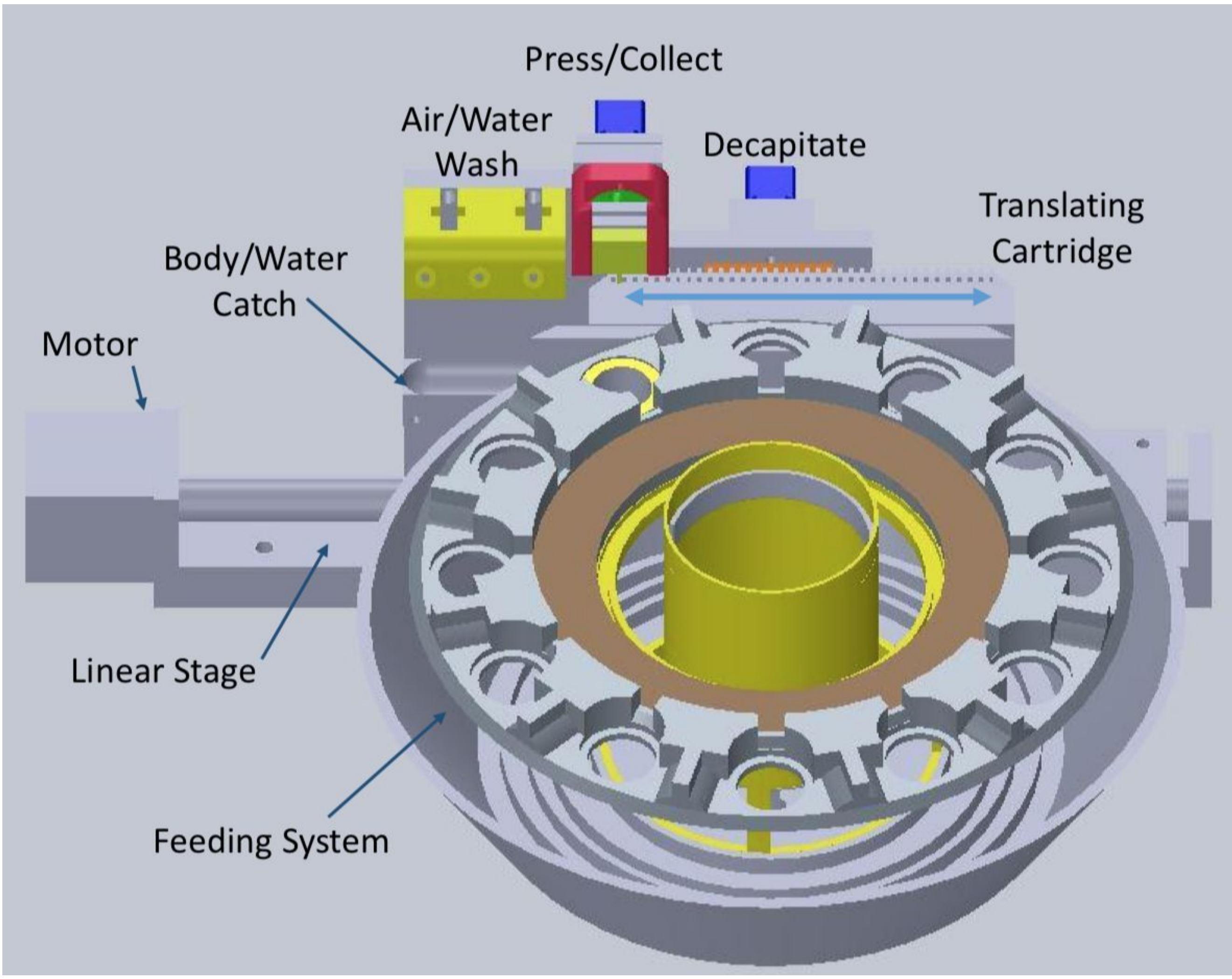


Figure 1. *The Linear stage design currently being used to process mosquitoes with its subsystems and the feeding system used to present mosquitoes to the robot to place on the cartridge.*

The issue with this system is that it is not continuous, once the cartridge holding the mosquitoes reaches the end of the linear stage it has to return to its home position wasting valuable time not processing mosquitoes. The obvious solution is to take the existing subsystems which are developed on the linear stage model and transplant them seamlessly onto a continuous rotary design. This allows for continued testing of our subsystems and the downstream dissection process without major design changes to the existing setup. Which allows for tuning of the subsystems without needing to integrate the rotary stage which will likely take weeks to construct and test.

There were two obvious design avenues for the rotary stage approach; the **Concentric Rotary Stage**, and the **Tangential Rotary Stage** (see Figure 2). The concentric design, which is designed to exist as the concrentic outer ring of the system with mosquito feeder at the interior. This design was terminated early do to the scope of the project, with the issue that the concentric system was so dependant on other teams design choices. Given the time to do this project and the number of different components being designed for the system it did not seem reasonable to try to design around a constantly changing feeding system and its associated subsystems. However in the future the concentric design does offer benefits over the tangential design, in that it can be more compact and could possibly have two processing systems for a single feeder (Figure 3).

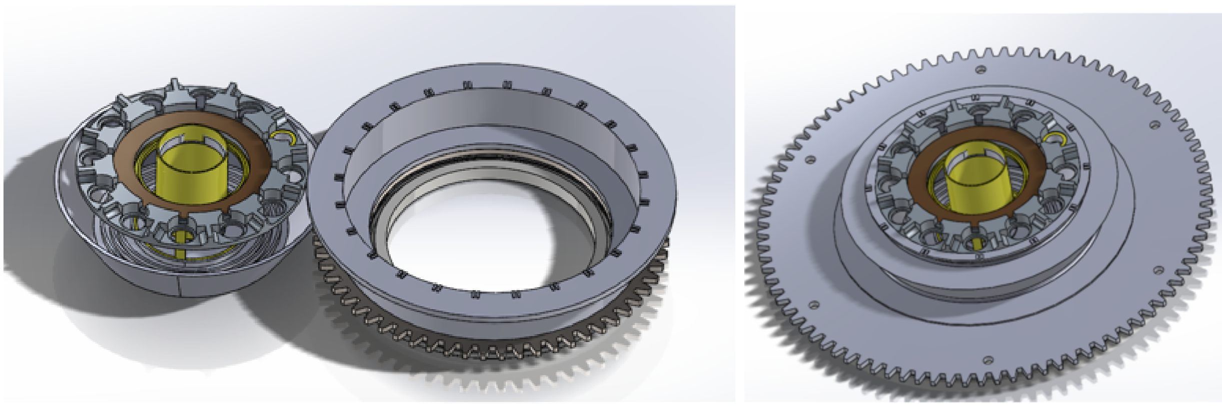


Figure 2. *Initial concept designs for tangential (left) and concentric (right) rotary stages. These where conceptual designs that lead to a decision of pursuing the tangential design in favor of concentric.*

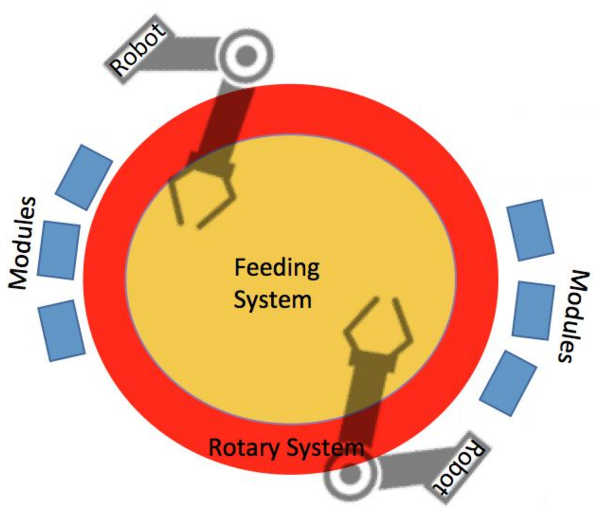


Figure 3. *Rough idea of how the concrete design could utilize multiple robots for a single feeder and process multiple mosquitoes simultaneously.*

The Tangential Rotary Stage design is what we currently have a more complete design review of. The current design utilizes the same subsystem currently being developed with the linear stage design (see Figure 4). This again is to streamline the process of integrating the new new design in the future when we have thoroughly developed method of extracting the processing the mosquitoes.

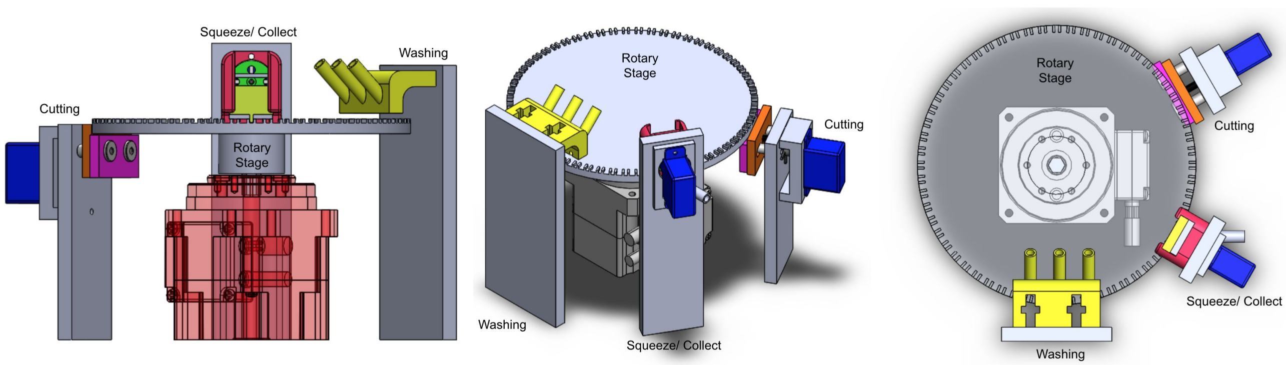


Figure 4. *Rough design of the three subsystem around the tangential rotary stage. Front view (left), Isometric view (middle), and top view (right). Rotation of stage is clockwise as viewed from the top view.*

A significant reason the design was chosen was do to how it can be integrated with the existing feeder system. Since the design is tangential it interacts in the same way the linear stage currently does with the feeder system. The linear system is something the other designers are familiar with and have already designed components with it in mind. The design is simple and has a relatively small footprint it easily integrates the existing subsystems since the stage is basically the same as the linear cartridge but wrapped into a circle (Figure 5). Since we want a high degree of precision in this system a harmonic drive is being used. This may not strictly be necessary but it is believed to only have added benefits. The diving motor is a simple stepper motor with a absolute encoder that should be easy to integrate with our existing setup since our linear design also uses a stepper motor, however a 24V power supply will be needed for this new motor. The harmonic gearbox will make our system a zero backlash system and having a homing mechanism design into the system will make a extremely robust and accurate system for locating the slots directly under the cutting and squeezing/gland collection subsystems. The stage is connected to the driver via a hex shaft which mates the two rigidly. For this design the current robot setup will not work. This design only works for a inverted robot design mounted above the work space. The robot will need to overhang the two systems and perform its pick and place operation from above. This requires a new robot to be designed but both the concentric and tangential systems have this same problem.

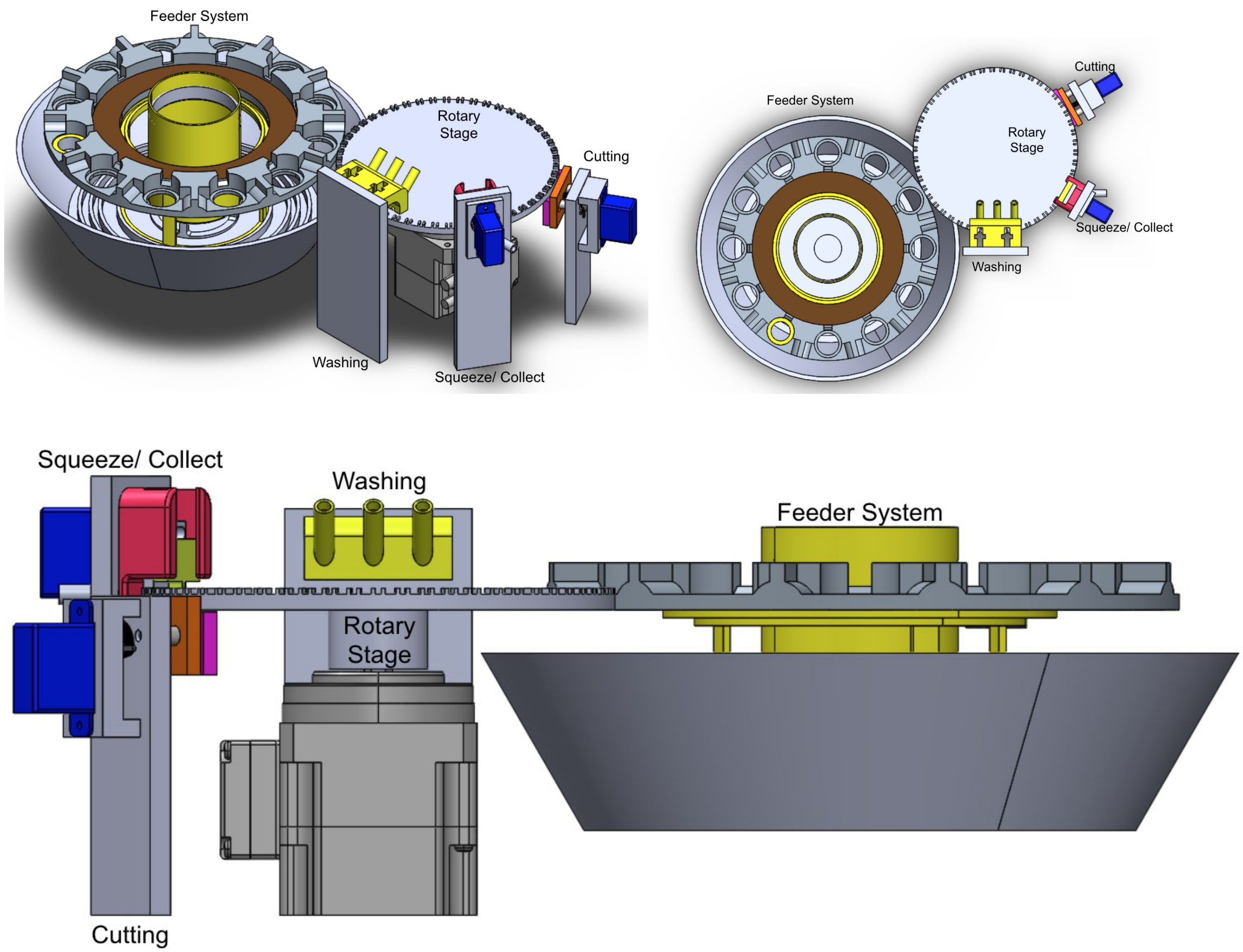


Figure 5. *Possible mating of tangential rotary stage with existing feeder stage. This is just a suggested setup with the idea that the overhanging robot would not need to rotate after picking up the mosquito to place it but other configuration are possible where the cups are closer to the cutting mechanism. Isometric view (top right), top view (top left) and side view (bottom). Looking at the side view the feeder will need to be on a elevated stand but this is not seen as a significant problem which is simple to solve.*

UPDATE 04/26/2019:

After meeting with mentor a small change was made to the design tin increased stability of system in key ways.

The stage in the system above was not sufficiently supported for a proper rotary stage design so a simple support system with bearing surfaces was designed. There is a three legged table like design with a standard roller-ball bearing for axial alignment and a thrust bearing for smoothly supporting the rotary stage on the table also it should be noted that the feeder was moved closer to the cutter to minimize the travel distance of the mosquito (see Figure 6).

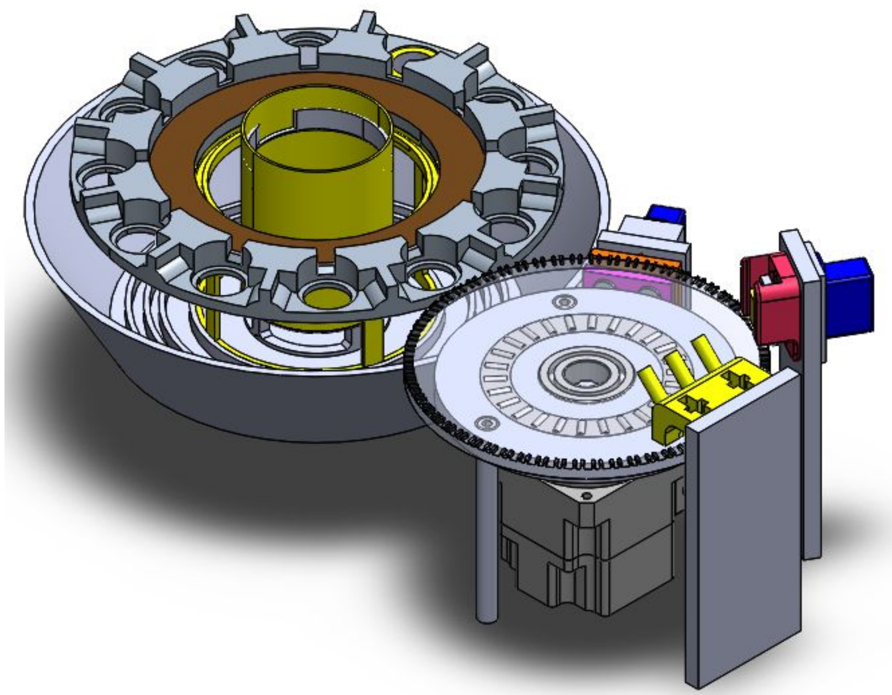


Figure 6. *Isometric view of the new stage design with support structure.*

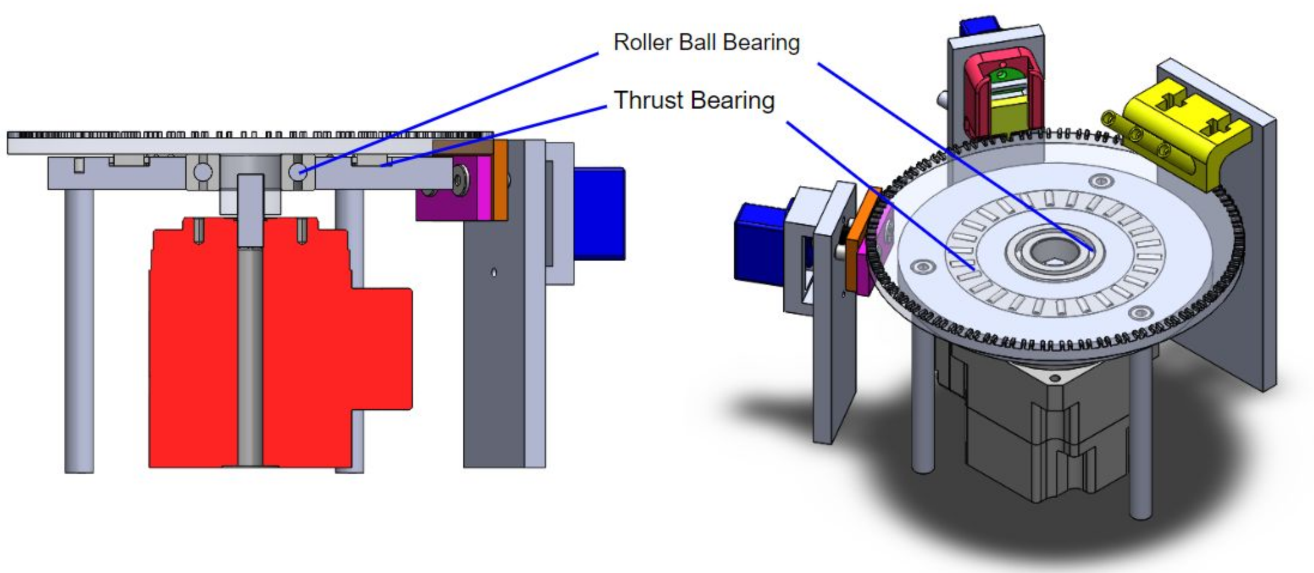


Figure 7. *Front section (left) and isometric view (right) of design additions to the rotary stage.*

UPDATE 05/04/2019:

After meeting again with our mentor some design constraints where reevaluated and a new rotary stage design needed to be designed to satisfy them. The main issue with the last design was that the mosquito needed to be dragged either quite a long distance or rotated which is not practical nor efficient. To remedy this a new design was suggested where the stage was inverted such that the subsystems are interior of the circular stage with and octagonal cut out (see Figure 8). This edit keeps some of the design lessons from the last design in mind. We have replaced the custom rotary stage and the harmonic drive with a precision rotary stage which can be commercially sourced and added our mosquito stage directly on top of it. This replacement of teh drive mechanism will remove the need to design out our rotary stage constraints. The stage consists of two plates. The first is a base plate that mates to the rotary stage directly (shown in white) it is designed to mount the stand offs and pusher cam guide (show in pink), which will be discussed later. The second plate (shown in green) sits on the stand offs and is where the mosquitoes will be dragged into the slots to be processed. This plate is designed with 8 cartridge slots for placing the mosquitoes to accommodate the cutting mechanism with minal design changes from the current linear stage design each slot exists on a flat of an octagonal cut out. Each of the subsystems is designed to be overhanging as before but now are placed in the interior of the octagonal cut out as mentioned earlier. The cutter subsystem is the only one that posed a design challenge.

The design of the cleaning unit and the squeezing & collecting unit have not changed other then the manner in which they will be mounted. The cutter unit is now mounted via spring loaded guides so when the system rotates the cutter will move out of the way of the stage and not stall the system. Originally an additional actuator was going to be used to move the cutting mechanism but some members were wary of introducing another action unit to the design. To remedy this a cam design was implemented (show in pink), though currently this is only a rough design concept in need of several changes it is believed to be a design headed in the correct direction. The cutter carriage has a peg that interfaces with a circular cam (seen in pink) which is designed to push the cutter away from the cartridge plate as the system rotates. This design choice may also prove to be better than the original idea since now the timing of the movement is dictated by a mechanical feature instead of in software.

We plan to interface with the feeder system in a similar way and the original design (see figure 9). The robots orientation will be the same as suggested for the prior design as well (see Figure 10). The current setup will need to reoriented 90 degrees. Currently we have the gripper move forward (away from the robot base) and backward (toward the robot base) we need it to be oriented so that the gipper movement is left to right of the base.

This design is far from a finalized version and requires some significant modifications but overall it serves as a strong starting point. It includes most if not all the needed components and how they interact with the stage and feeder system. What is not included is a detailed method of fixturing each of the overhanging subsystems but this is something that is relatively easy to design as a more concrete design is developed. The cam mechanism is crude at best and is missing crucial elements it simply serves as a general concept of what type of mechanism we are envisioning. The design though incomplete is close to something that we think can be quickly prototyped and iterated for future development of this system.

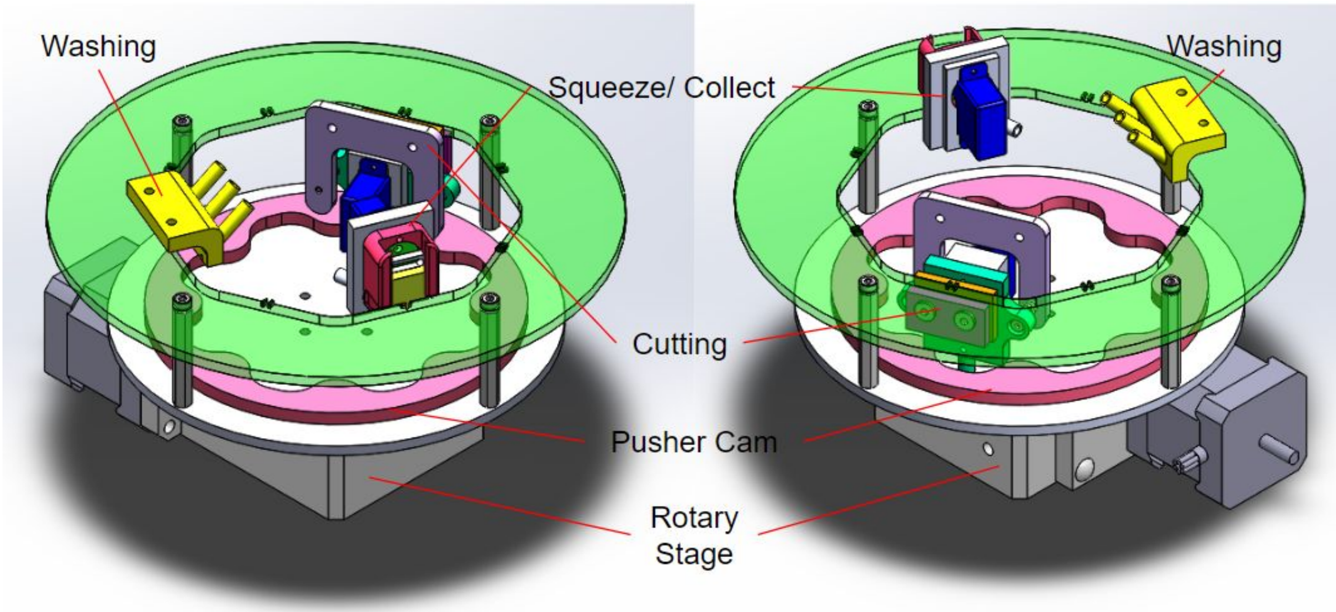


Figure 8. Two isometric views of the inverted rotary stage design

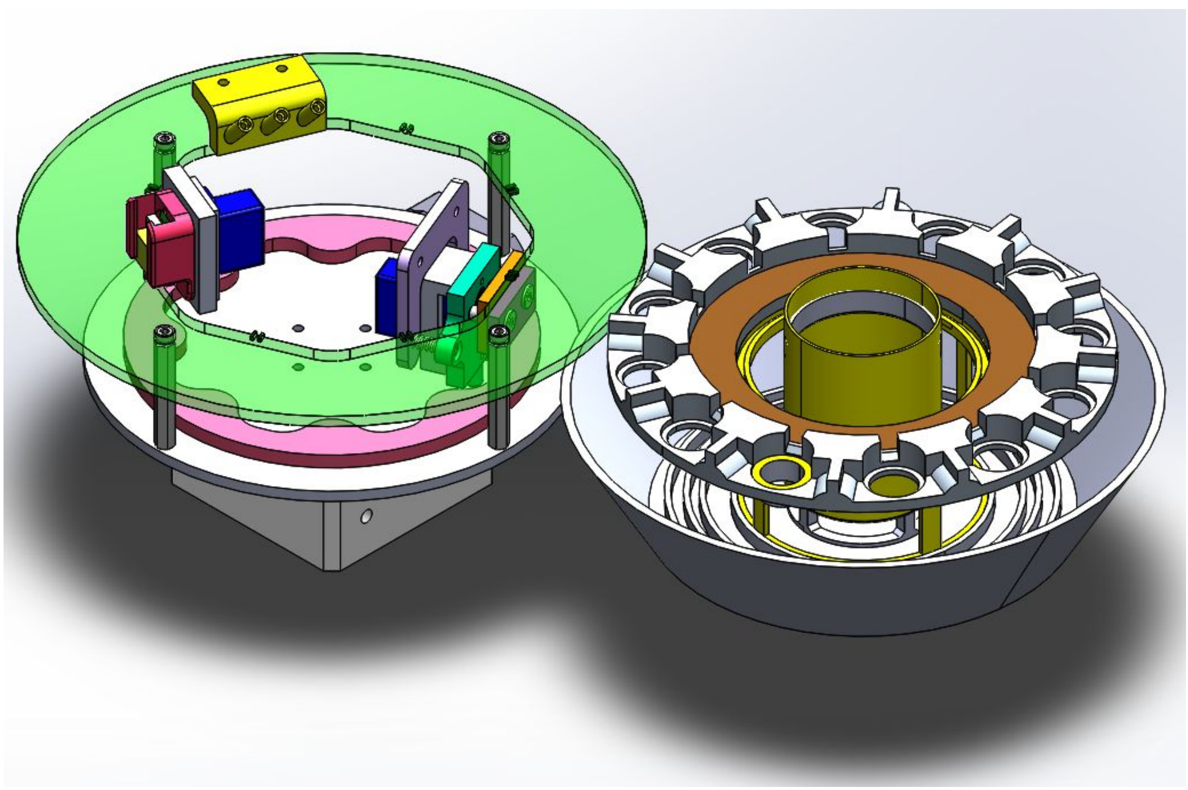


Figure 9. Isometric view of the new system and how we plan to interface with the feeder system.

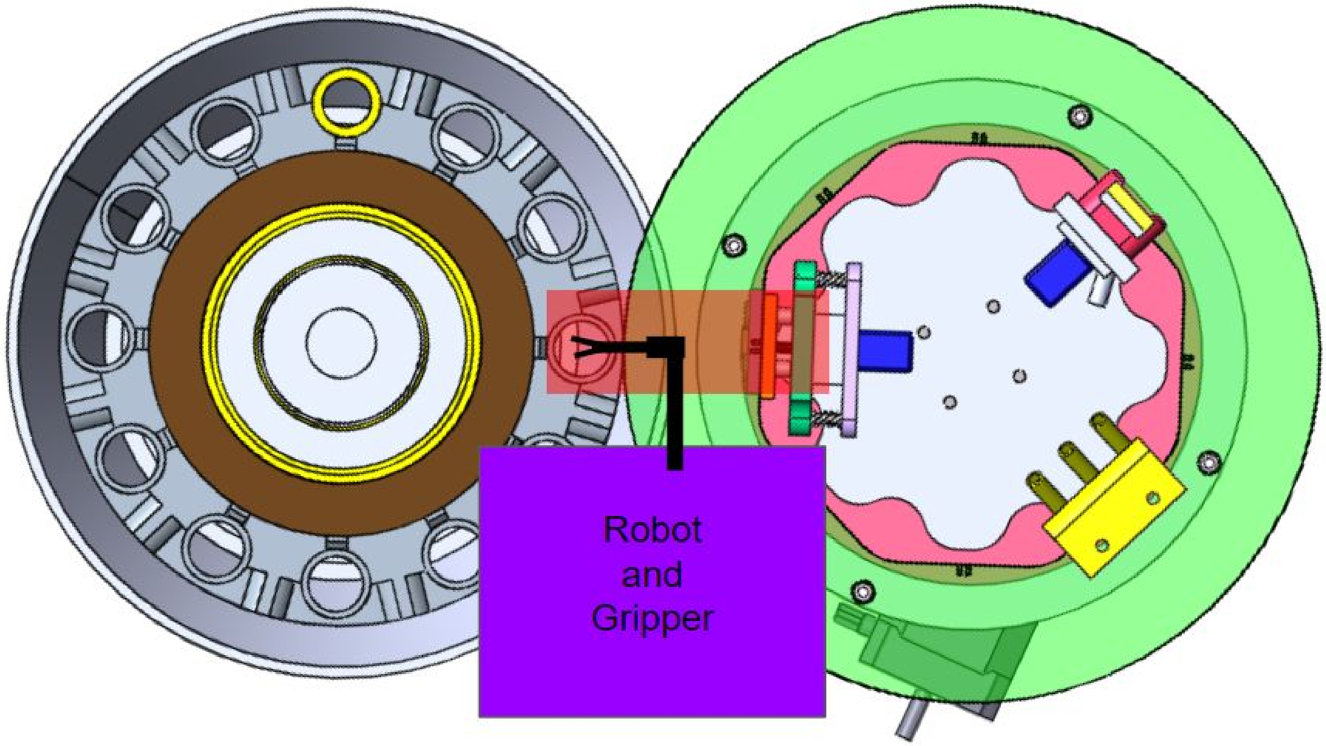


Figure 10. Rough idea of robot position relative to the system. Red highlighted area is relative workspace of robot gripper end effector shown in black.

Other Notes -

Old Drive-Train Details:

Website: http://www.harmonicdrive.net/products/rotary-actuators/hollow-shaft-actuators/fha-mini

P/N: FHA-8 C-xx-12S17bE-C (where xx is 30, 50 or 100 specifying a reduction ratio of the Harmonic gear box of xx:1)

Other design work:

There has also be work done on designing a new gripper actuation unit for grasping of mosquitoes. The original design is complex and has some tolerancing design issues. The goal was the take the general idea of the current system and simplify it. Currently the system uses a simple rotary servo motor and a cam to actuate along a linear slide. There are some tolerance issue that lead to rocking of components that need to remain straight. A precision slide added to improve this problem but only did so much. The current plan is to use a linear actuator with PWM control similar to the servo motor and replace the servo and cam with this. The precision linear slide will remain in use to help constrain the system. There is significantly fewer components in this design which means less things to go wrong. There are two block one for holding the outer sleeve of the gripper and the other to hold the inner tube with the tweezer end. The gripper block is mounted on the linear slide and attached to the linear actuator and is what acccuate the tweezer wend of the gripper. The design is not yet finalized but is near completion. It will be designed to be machinable so that it can be manufactured about of stiff materials easily. It is also designed with the the user in mind making it easy to replace broken gripper components and install them more easily and with greater accuracy. It also will fix issue with the tweezer end not having enough clearance do to certain design issues with the original design.

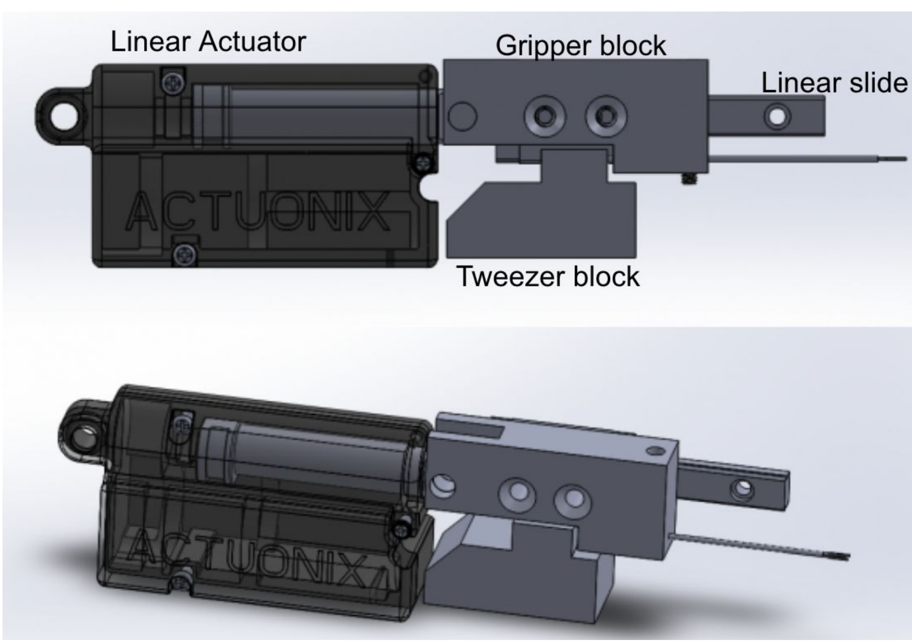


Figure A1. *Version 1 of new gripper design.*