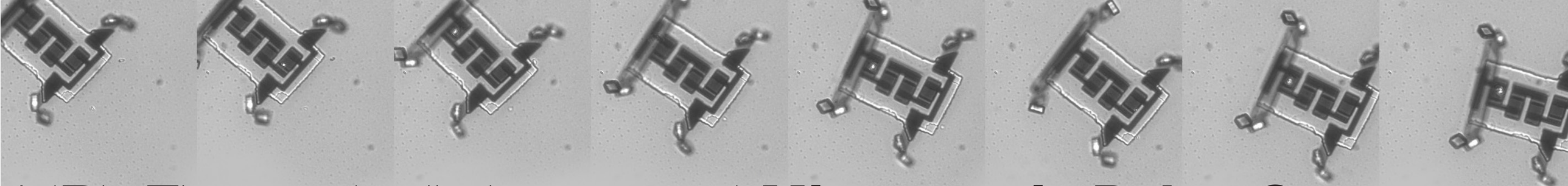


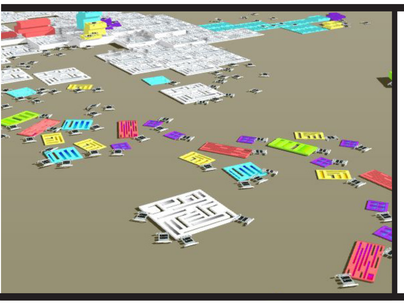
NRI: Electronically Integrated **Microscopic Robot Swarms**

PI: Marc Miskin[1], Co-PIs: David Blaauw[2], Mark Yim[1].

1: University of Pennsylvania, 2: University of Michigan.

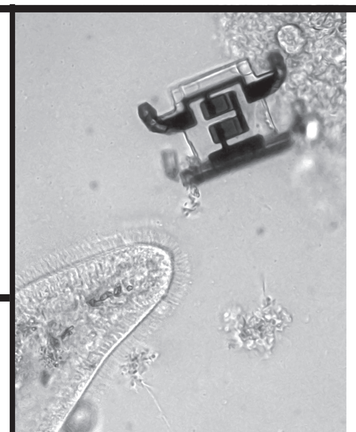
Award: 2221576

2023 FRR & NRI Principal Investigators' Meeting



Key Challenge: Swarms of microscale robots that work together to carry out complex tasks has been an unrealized vision in robotics for 30 years due to two major challenges.

1. Integration: its possible to build tiny sensors, actuators and computers, but how do we put these parts together.
2. micro-physics: how do we design for the new physics of the sub-mm scale?

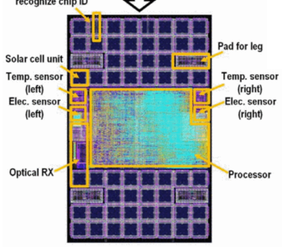


Scientific Impact:

The size of these tiny machines imposes unique constraints on power, memory, and algorithms. Simultaneously, it opens new opportunities like high-speed locomotion, fluid mediated swarming/object manipulation, chemical communication, or swarms 1000x larger than the state of the art. By doing so in a scalable, affordable test bed, we aim open the door to exploring these questions for the community at large.

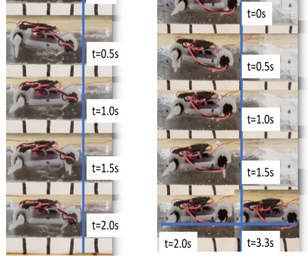
Tiny Robots with On-board Computation

Our group aims to realize swarms of smart microrobots with *integrated*, on-board processors, actuators, sensors, and programmable memory.

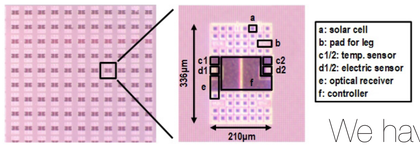


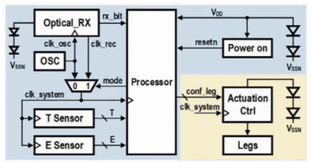
Microscale Locomotion

We are exploring the role of viscous forces in legged locomotion and optimizing and steerable gait patterns with scaled prototypes, simulation, and simple micro-scale walking machines.



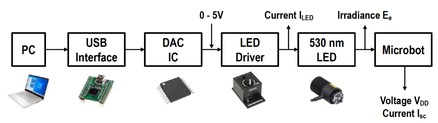
Microscale Computation



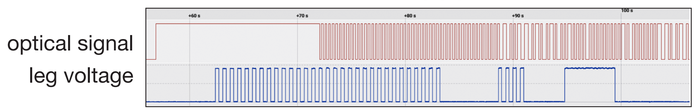


We have designed, fabricated and tested CMOS circuits integrating memory, sensors, and a processor all in a sub 1mm package.

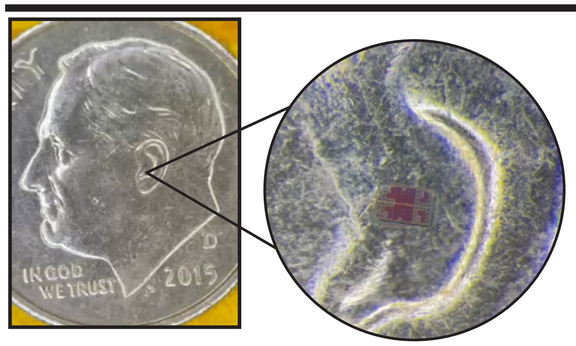
Sensing and Communication



We developed an optical coms. scheme to send data to the robot



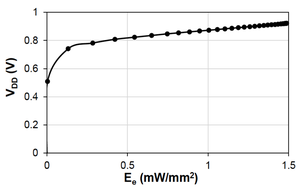
Scalable Fabrication



All robots are built top-down with lithographic processing enabling 10^6 per chip.

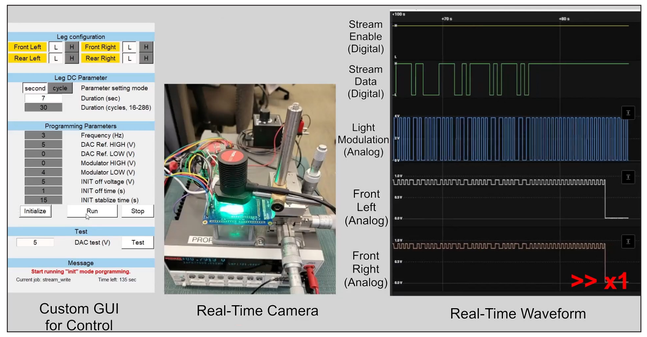
Microscale Power

The robot is powered by on-board solar cells under illumination intensities on par with daylight.



Impact on Society and Education

Each robot in our process costs ~$0.001, opening new applications in medicine, manufacturing and microscale sensing. To facilitate adoption, we are making 25% of our robots available to the community for free and developed an open source programing GUI that can be used to program robots for arbitrary tasks. This cheap, easy to use test bed could create a broad and diverse community in swarms and microrobotics.



In addition, the robots and programming environment will be used in a new course at UPenn, aimed at introducing students to microscale physics with lab studies of small robots.