ME 599/EE 546:
Biology-inspired robotics

Lecture 1

Sawyer B. Fuller

Goals:

- Describe the need for “biology-inspired robotics”
- Describe how this course works

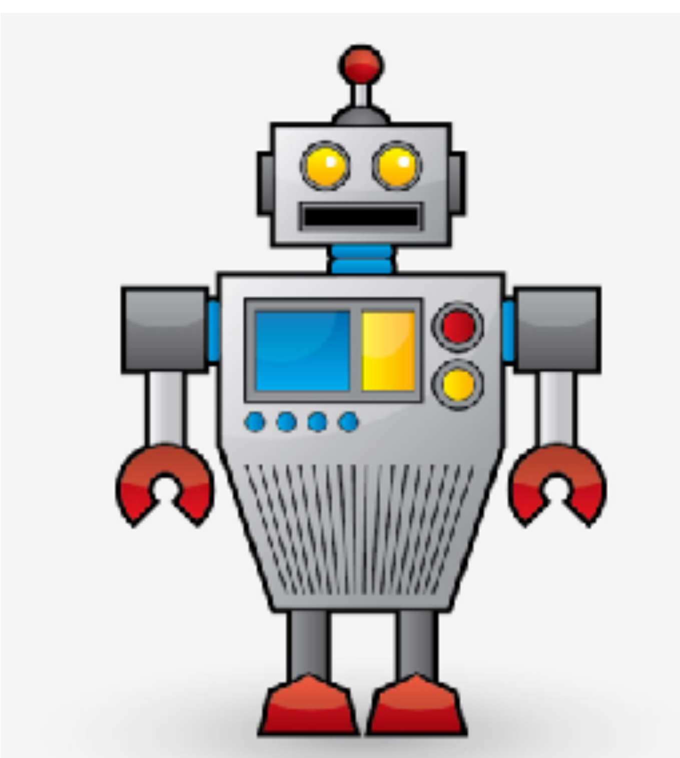
UNIVERSITY of WASHINGTON

biology-inspired robot control

- MW 10:30-11:50 in MEB259
- Instructor: Prof. Sawyer B. Fuller (minster@uw.edu)
- Office hours: Wednesdays 1:30-2:20 in MEB 321
- Prereq’s: an undergraduate degree in ME, EE, or Aero
- Website: http://faculty.washington.edu/minster/bio_inspired_robotics/
  - lecture slides, papers, and other materials will be posted there
  - submit all coursework on Canvas

Robot (*noun*)

a machine capable of carrying out a complex series of actions *automatically*



UW Classes that take a more classical approach to robotics:

- Mechatronics:
  - ME581: Digital control systems (spring)
- Dynamics and control:
  - EE 543/544: Kinematics and dynamics of robot arms/manipulators
  - ME583: Nonlinear control
- Perception and planning:
  - EE 576: computer vision and robotics (spring)
  - CSE 571 Probabilistic Robotics: Perception, localization, mapping (fall)
  - AMATH / CSE 579: Intelligent control through learning and optimization (Emo Todorov)
  - ME599: Advanced Robotics: Perception and multi-robot control (fall. Ashis Banerjee)
- Also:
  - CSE 590: Robotics colloquium seminar (weekly speakers)
  - BI 427: Animal biomechanics (fall, Tom Daniel)

“biology-inspired robotics”

current state of the art

Honda's Asimo

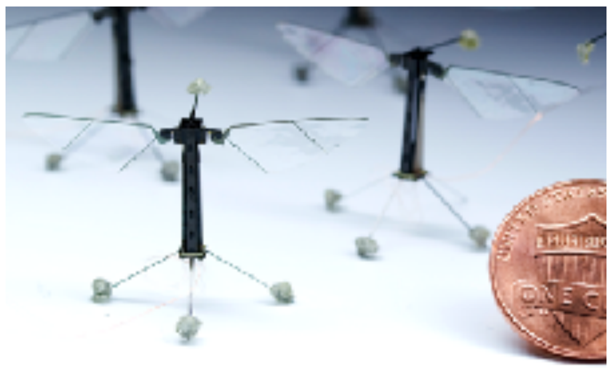
- very power hungry (20x human of same weight)
- only in controlled environments

current state of the art

Google's self-driving car

- power hungry - requires a bank of computers
- only in controlled environments

application areas where current robotics is still outperformed by nature




tiny robots
(minimal computation,
limited sensing)


complex environments and robots
(models are inadequate
and behavior must be learned)

agile robots
(limited time
to compute)

soft robots
(nonlinear
stress/strain curve
hard to model)

animal locomotion

- rich behavioral repertoire

animal locomotion

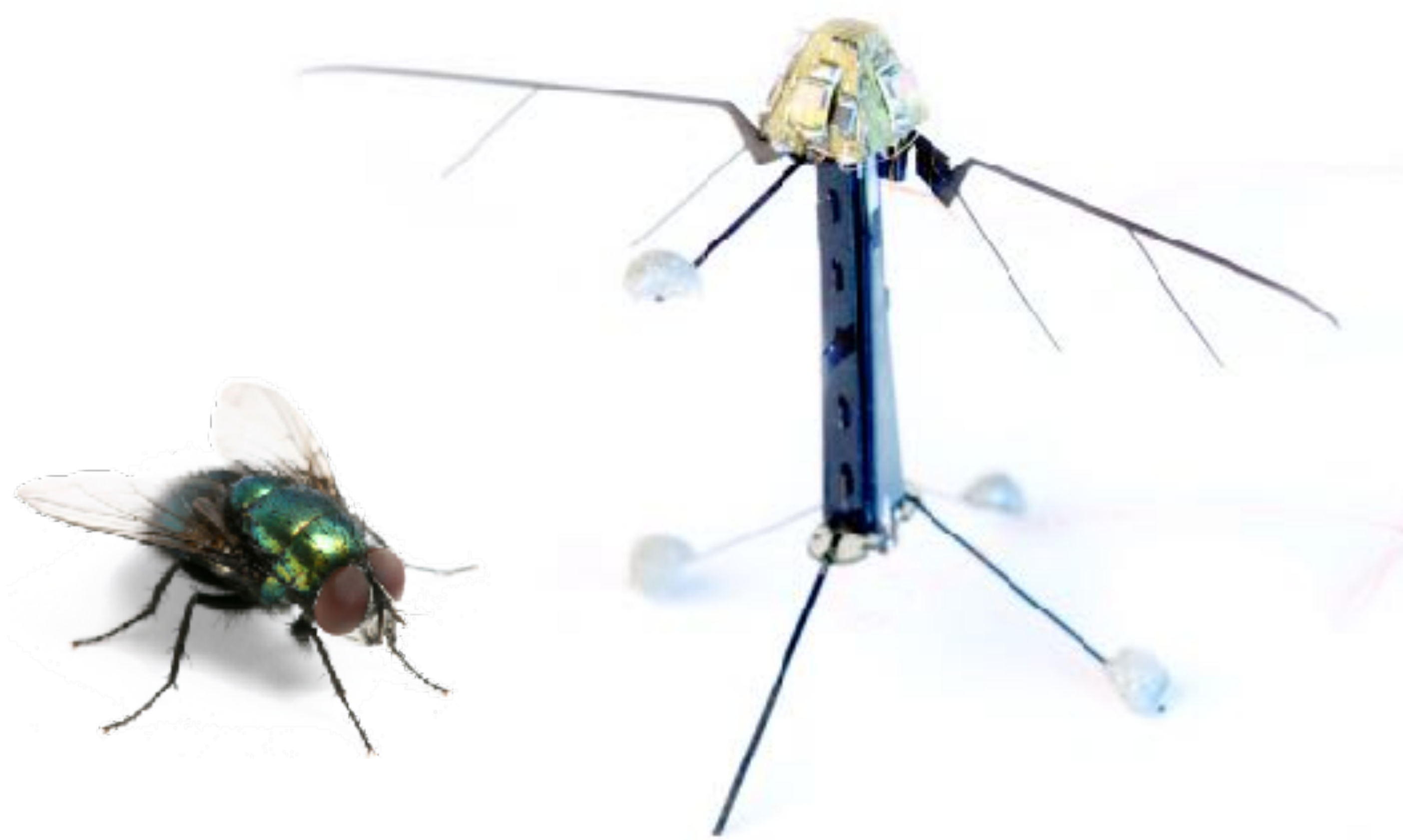
Animal locomotion

- aggressive, dynamic motions

Animal locomotion

- complex environments
- minimal energy expenditure on computation

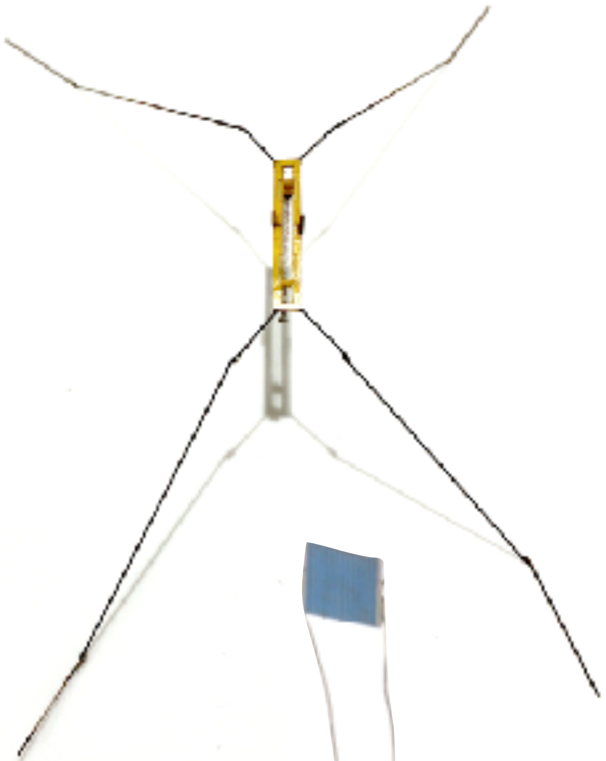
Aerial autonomy at insect scale

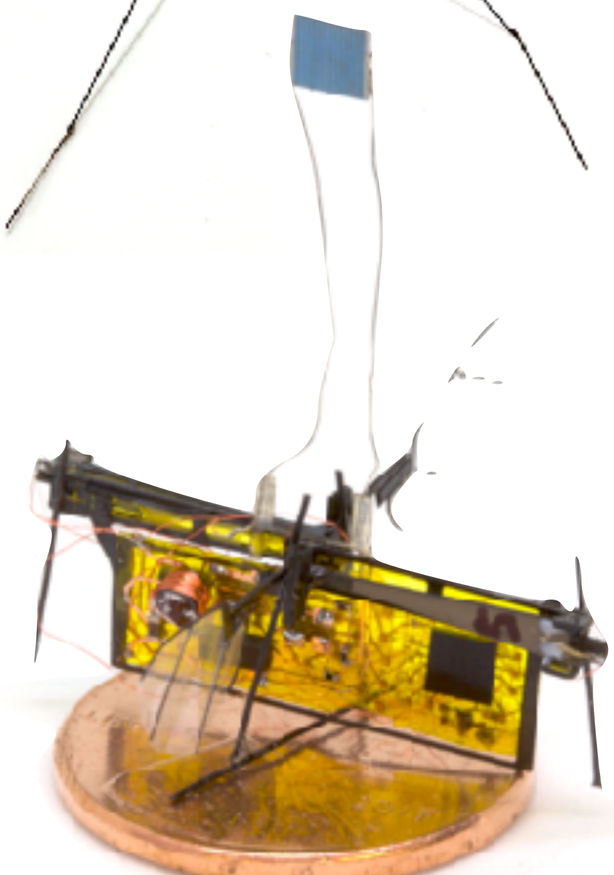


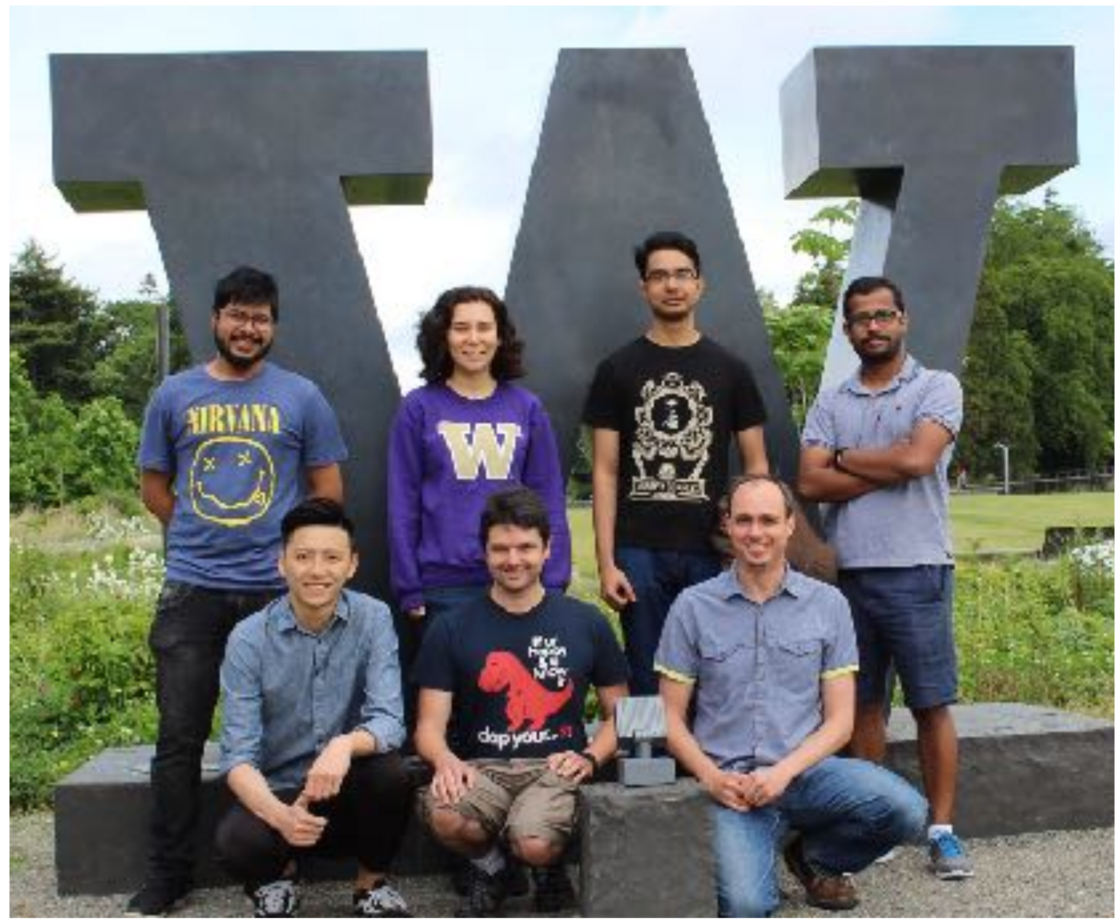
(images to scale)

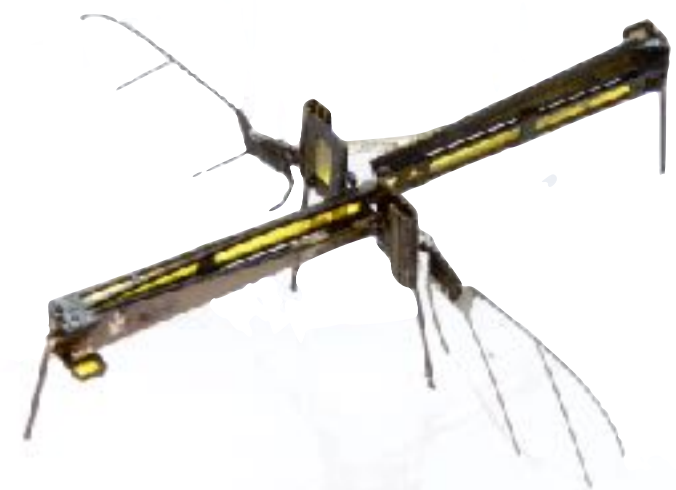
Autonomous Insect Robotics Laboratory

Est. 2015





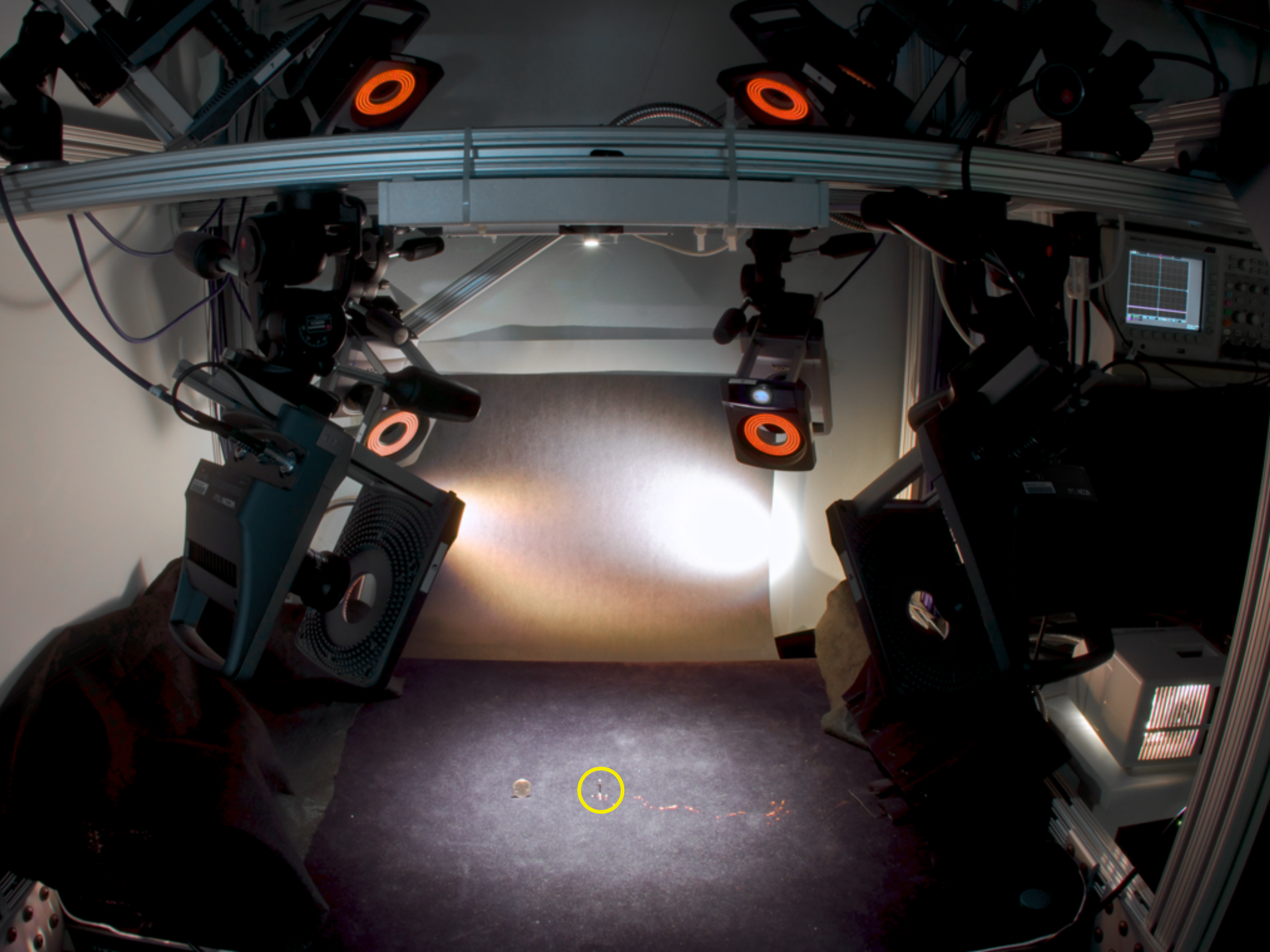




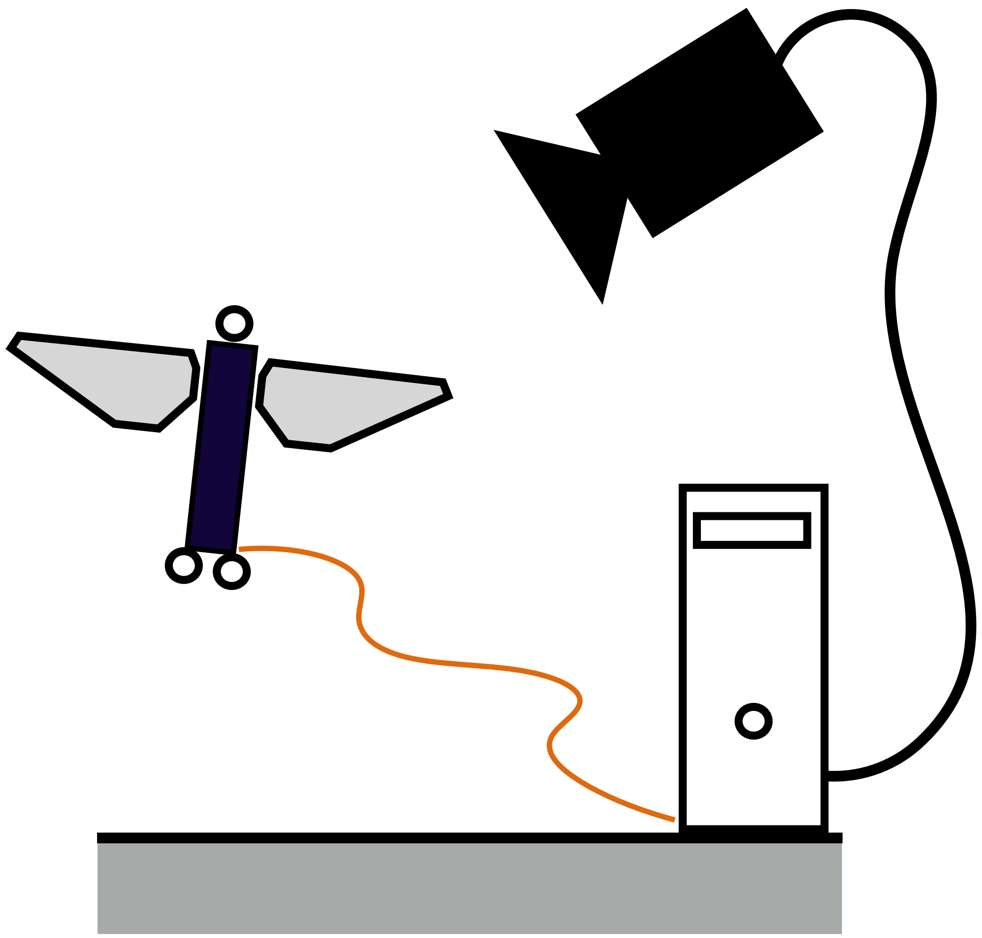
UNIVERSITY *of* WASHINGTON

MECHANICAL ENGINEERING

Ma, Chirarattananon, Fuller, and Wood, *Science* 2013

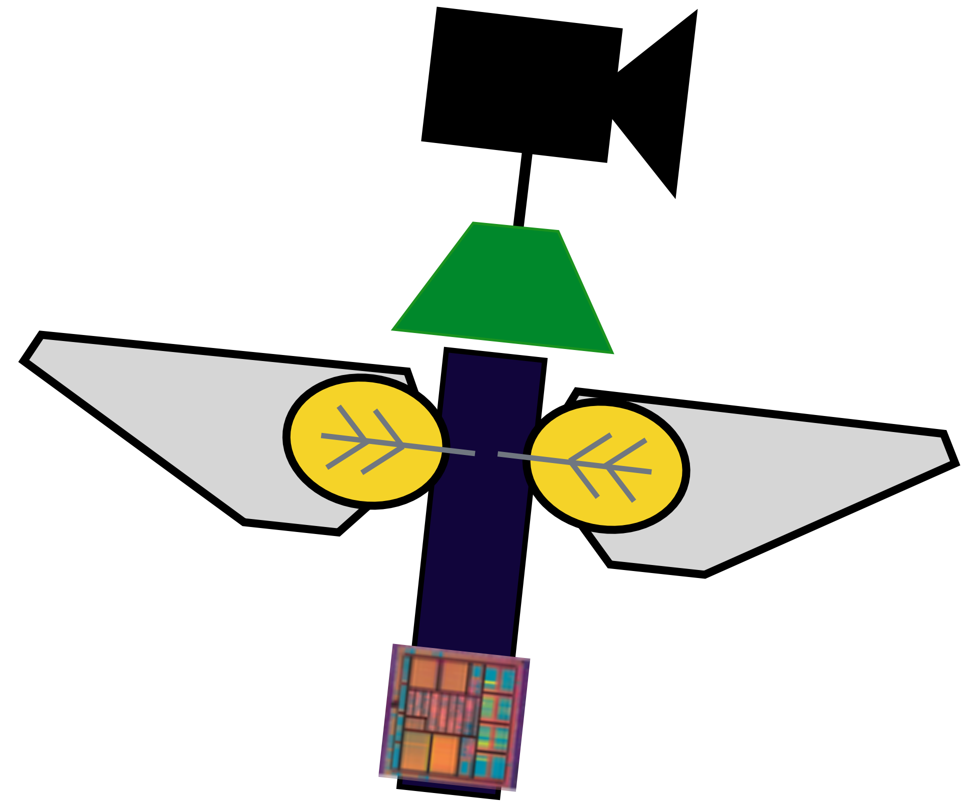


previous work



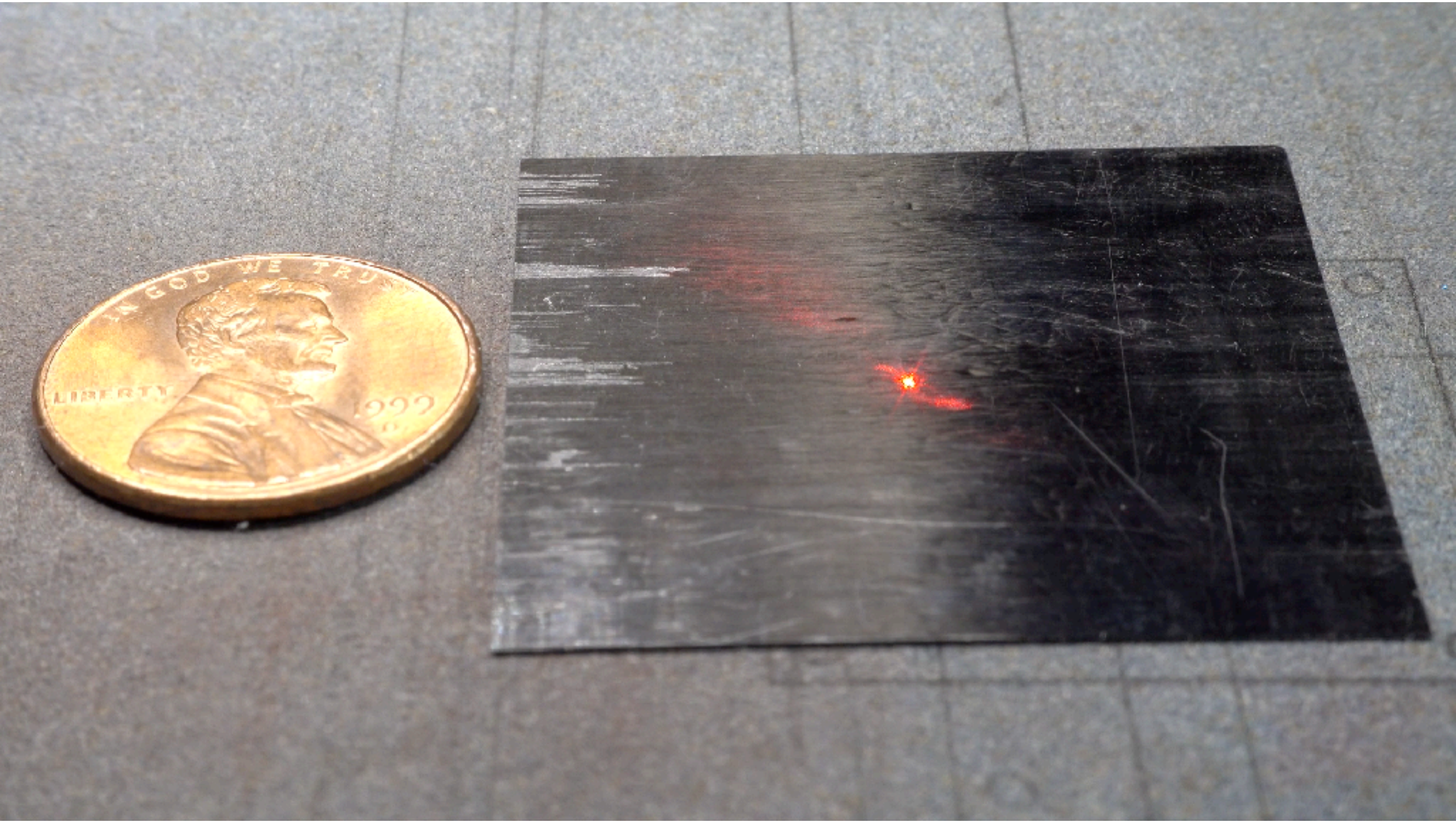
- external power
- external sensing
- external computation

current research

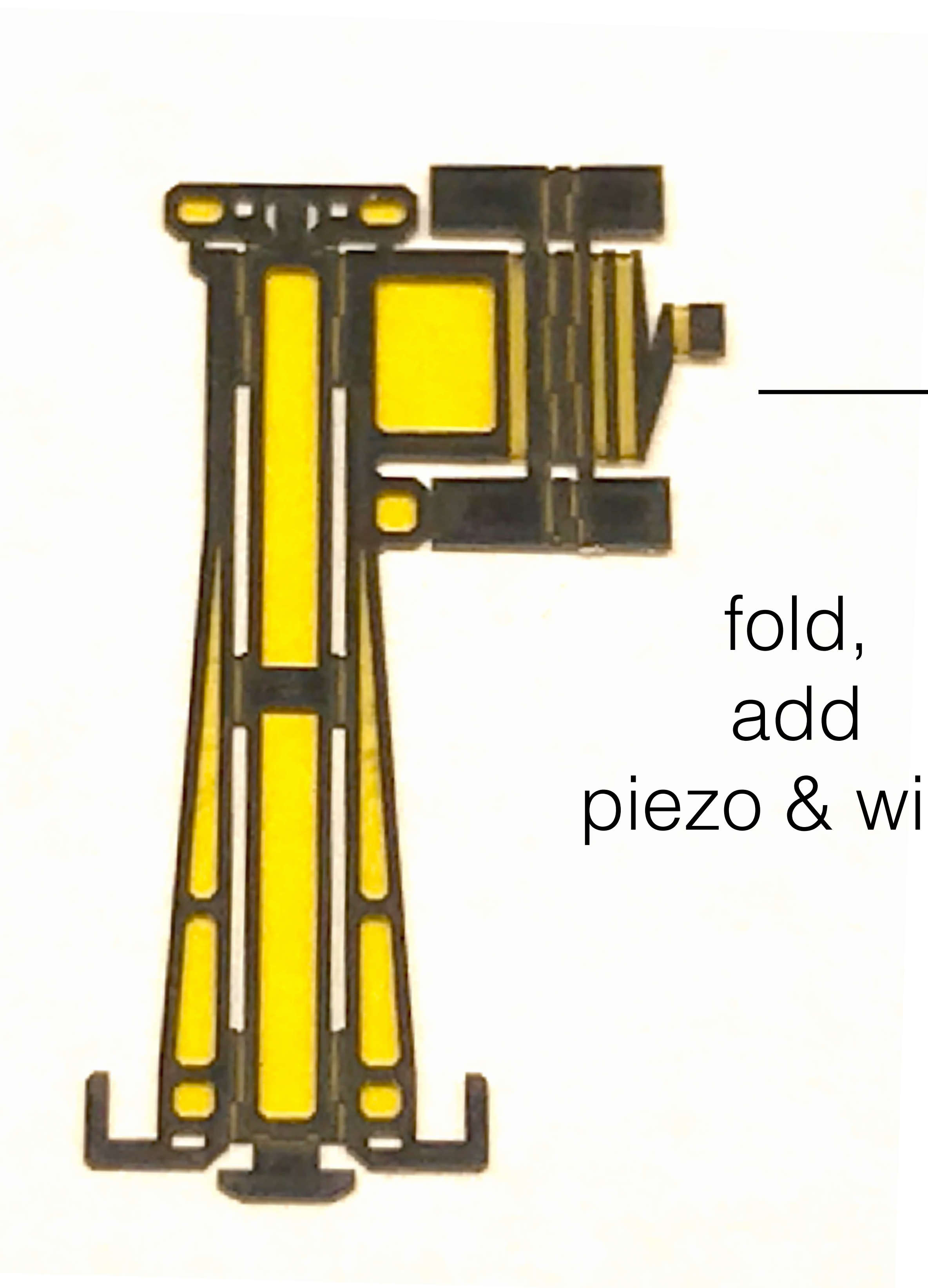


- improved capabilities
- onboard sensing
- onboard computing
- onboard power

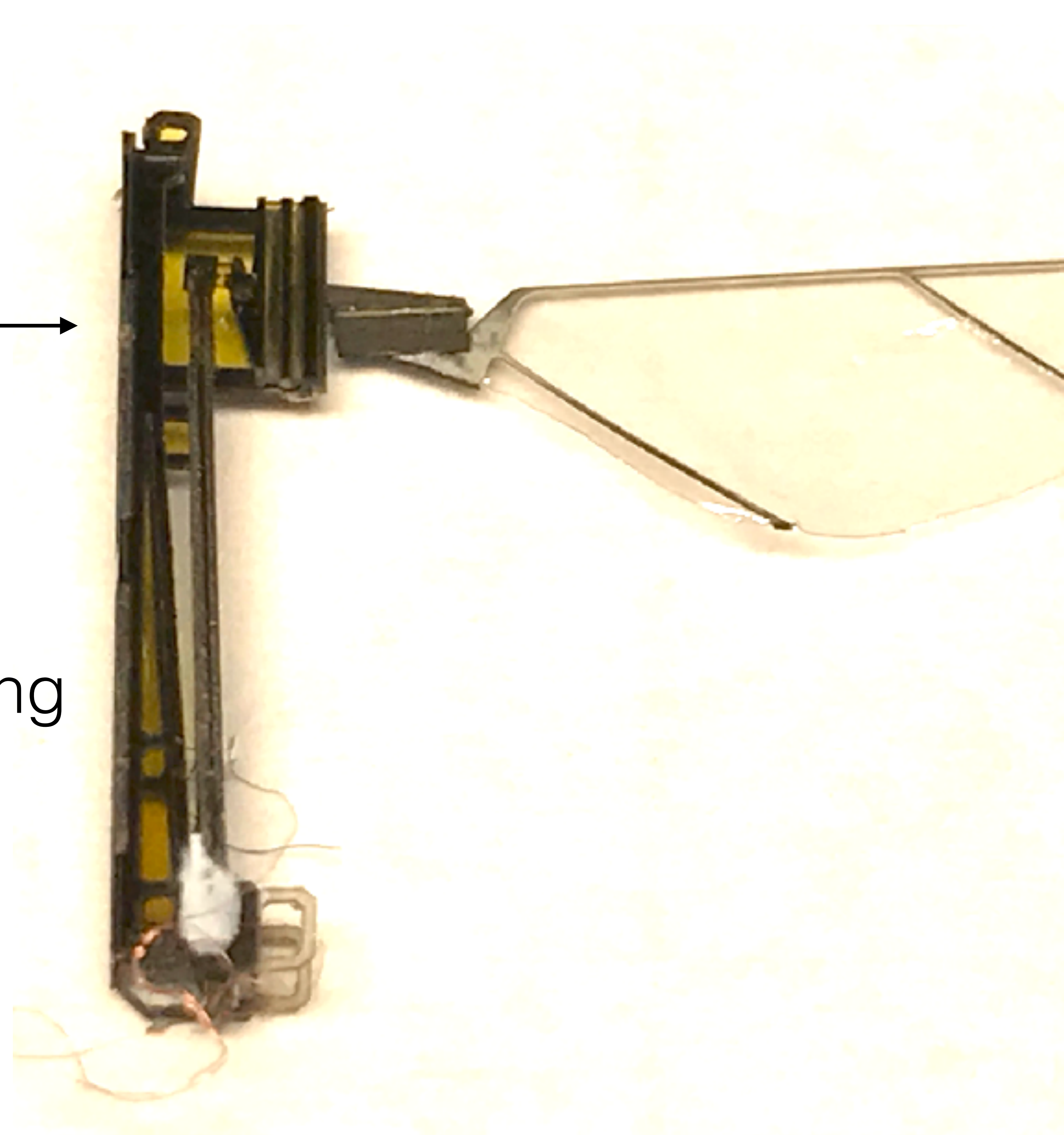
355 nm laser micromachining



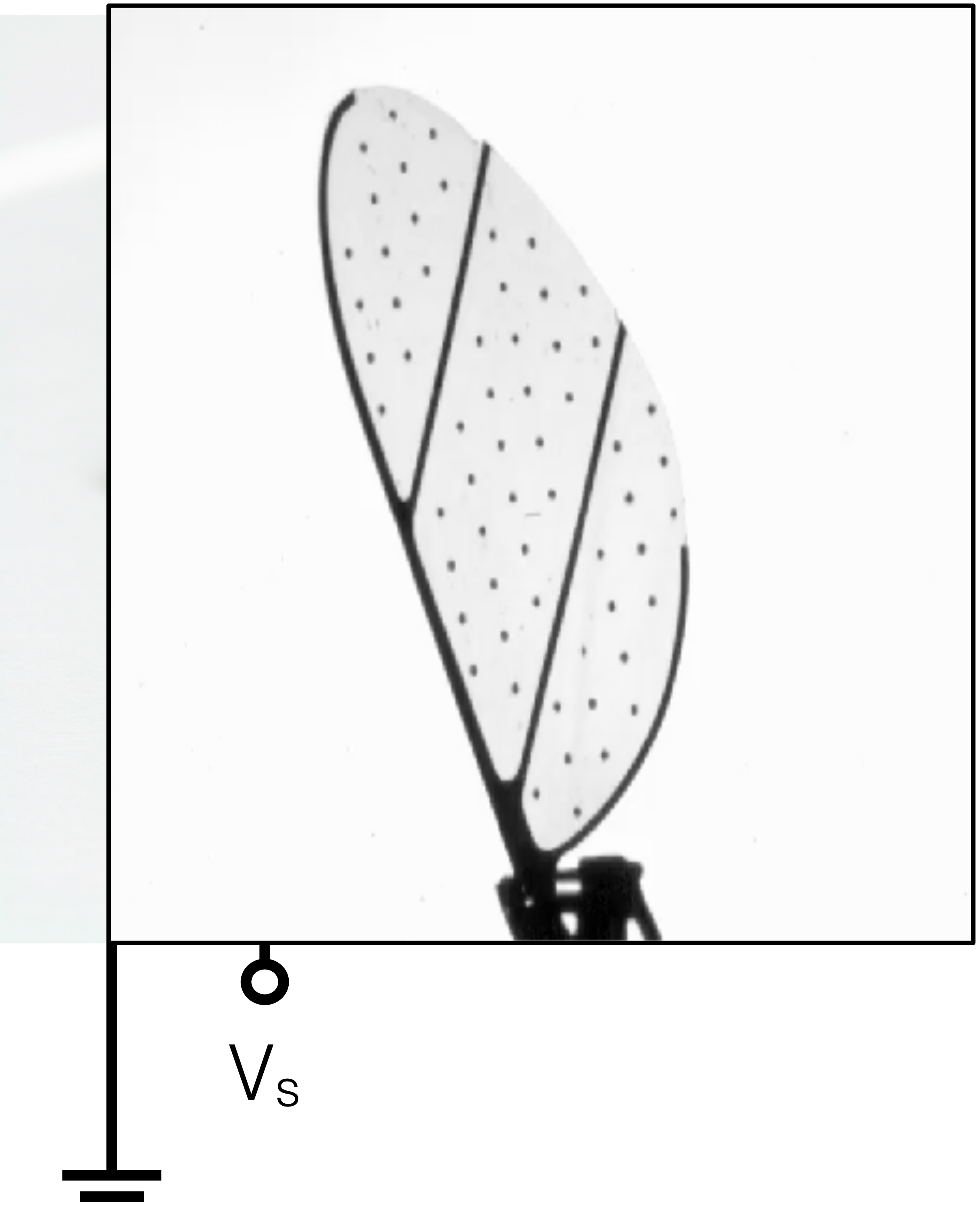
assembly

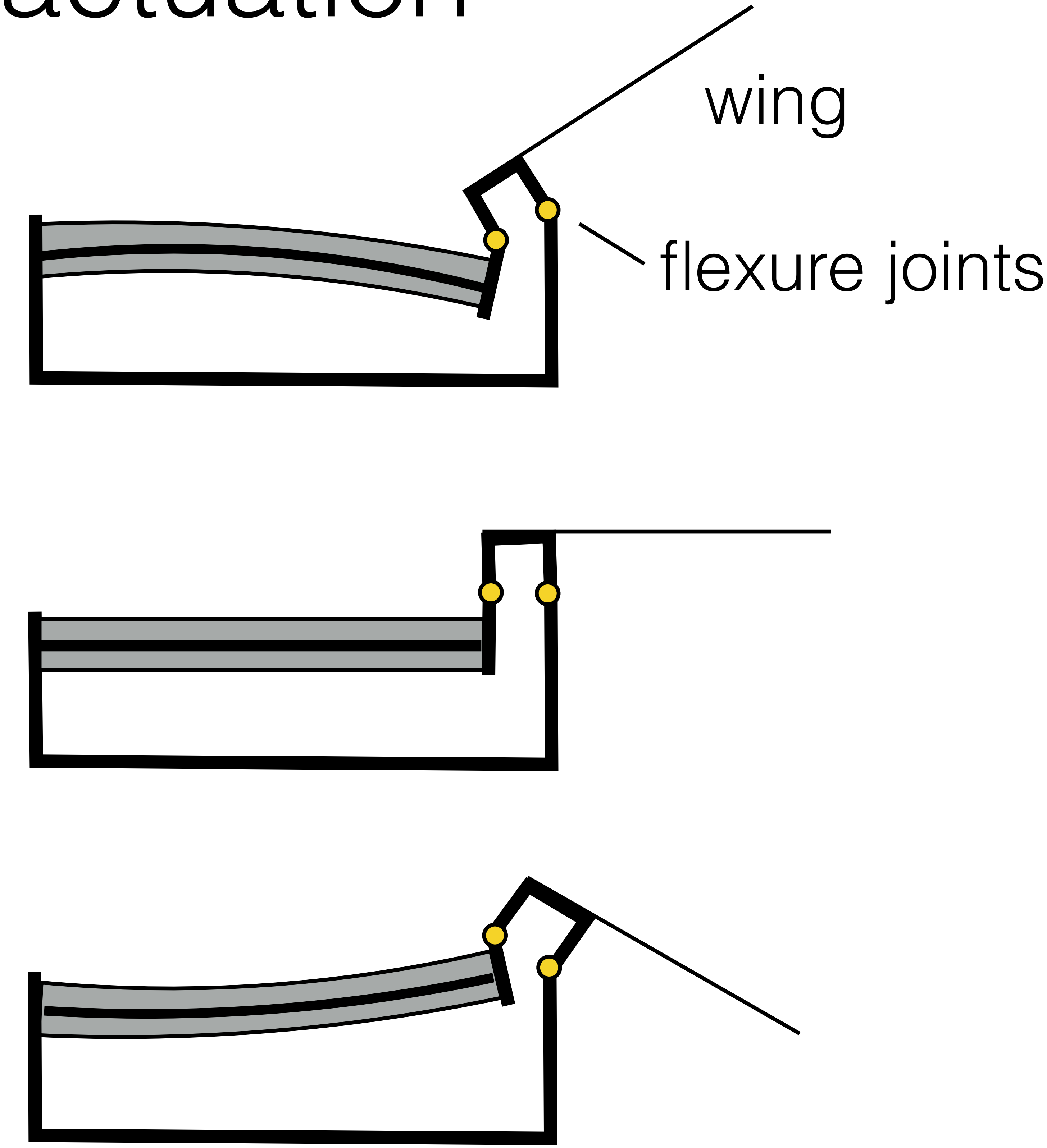


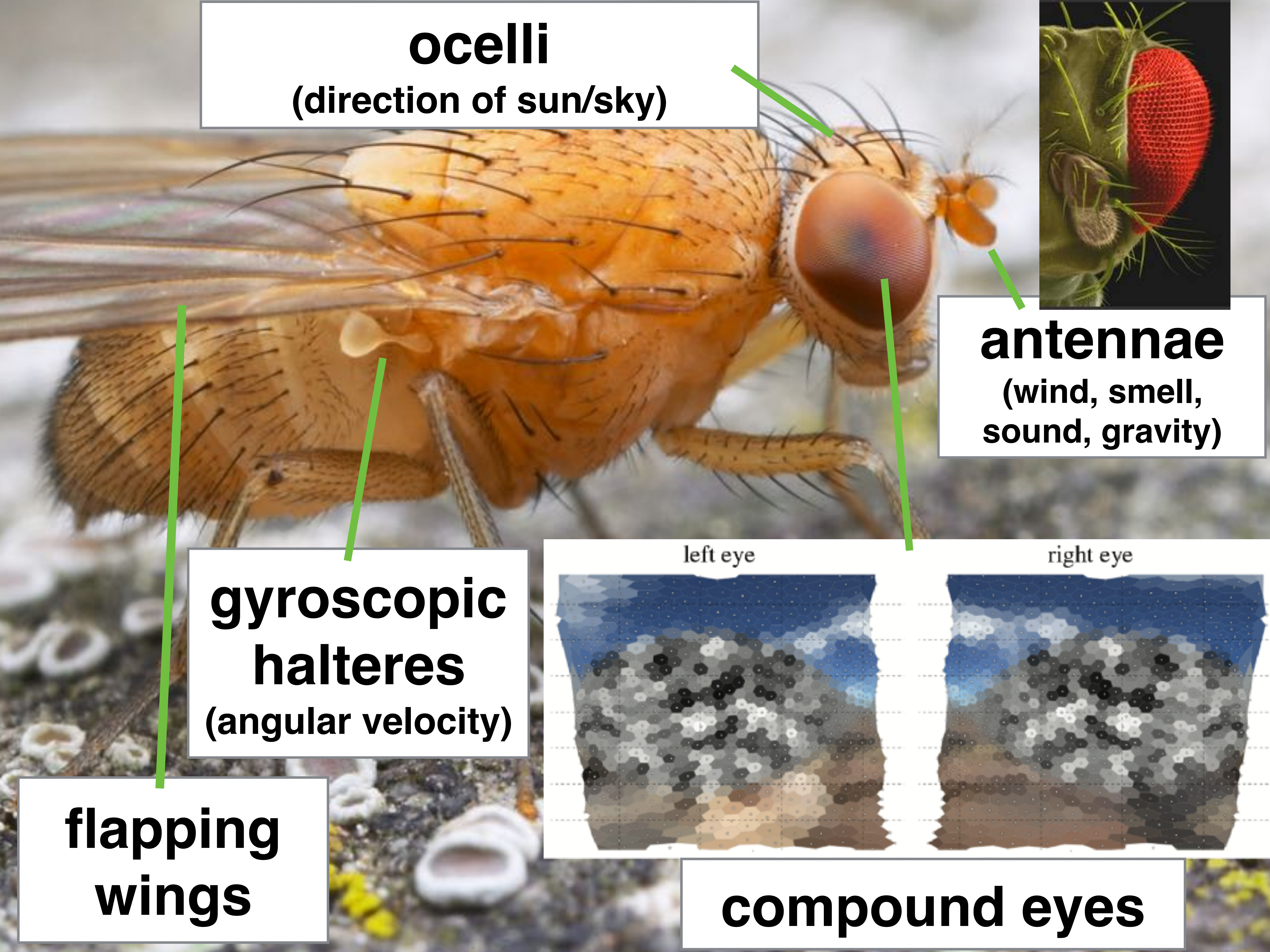
fold,
add
piezo & wing



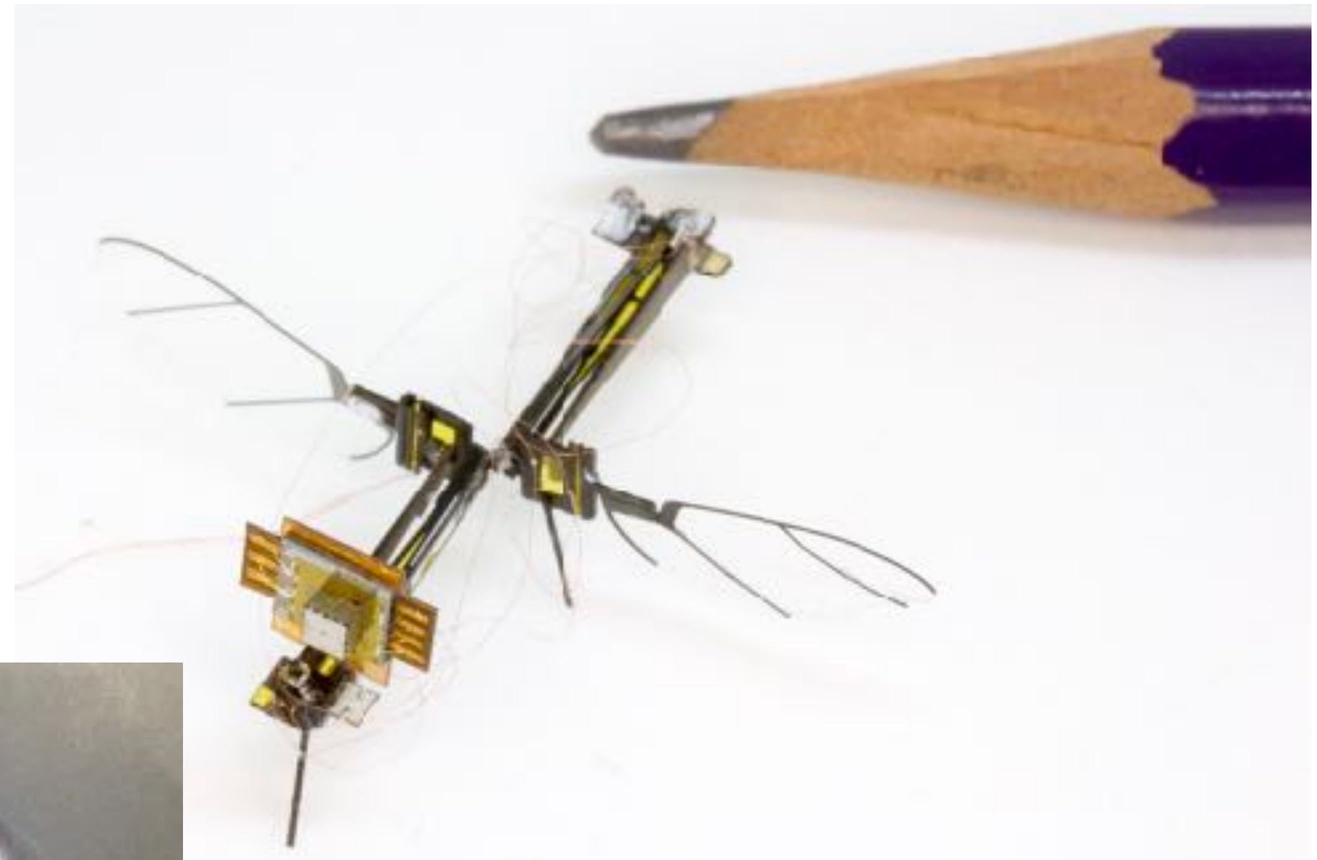
piezo actuation





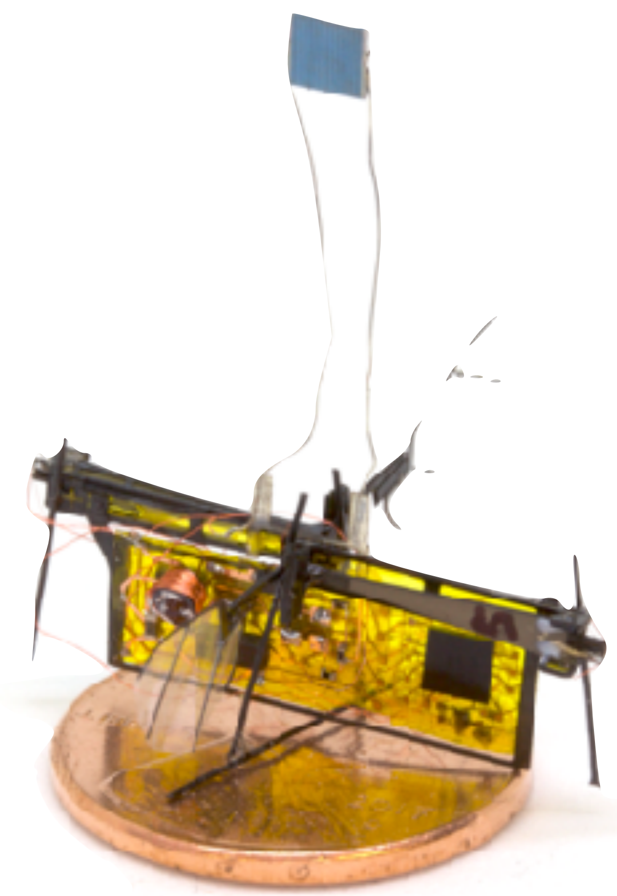

ocelli
(direction of sun/sky)
antennae
(wind, smell,
sound, gravity)
gyroscopic
halteres
(angular velocity)
left eye
right eye
flapping
wings
compound eyes

current research



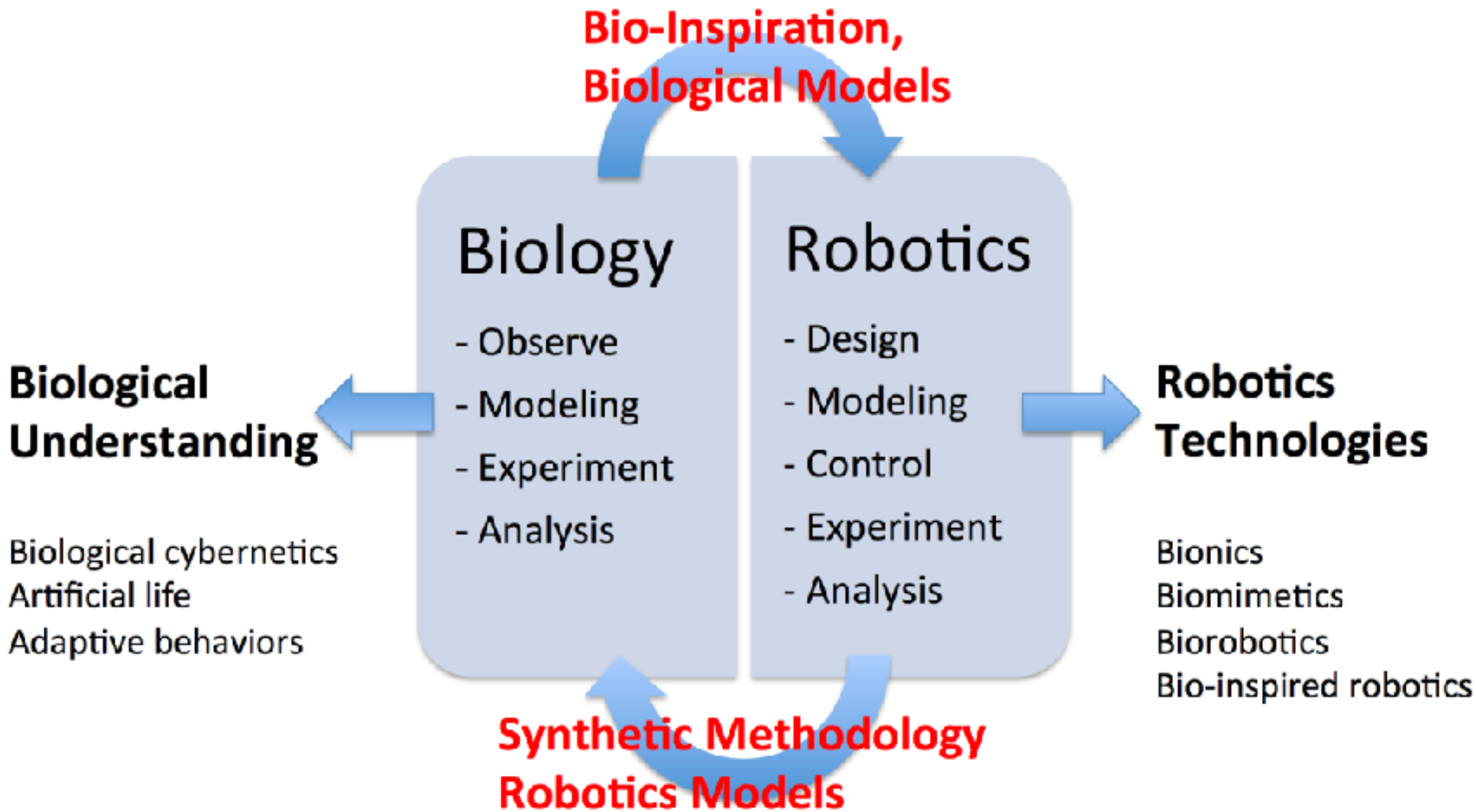
vision (tiny camera)

odor (using moth antenna)



onboard power

biology-inspired robotics



this course focuses on two areas where biology excels

1. mechanical intelligence
2. adaptation through evolution and learning

mechanical intelligence

this fish is dead!

- system is stable without active feedback

Liao, 2004

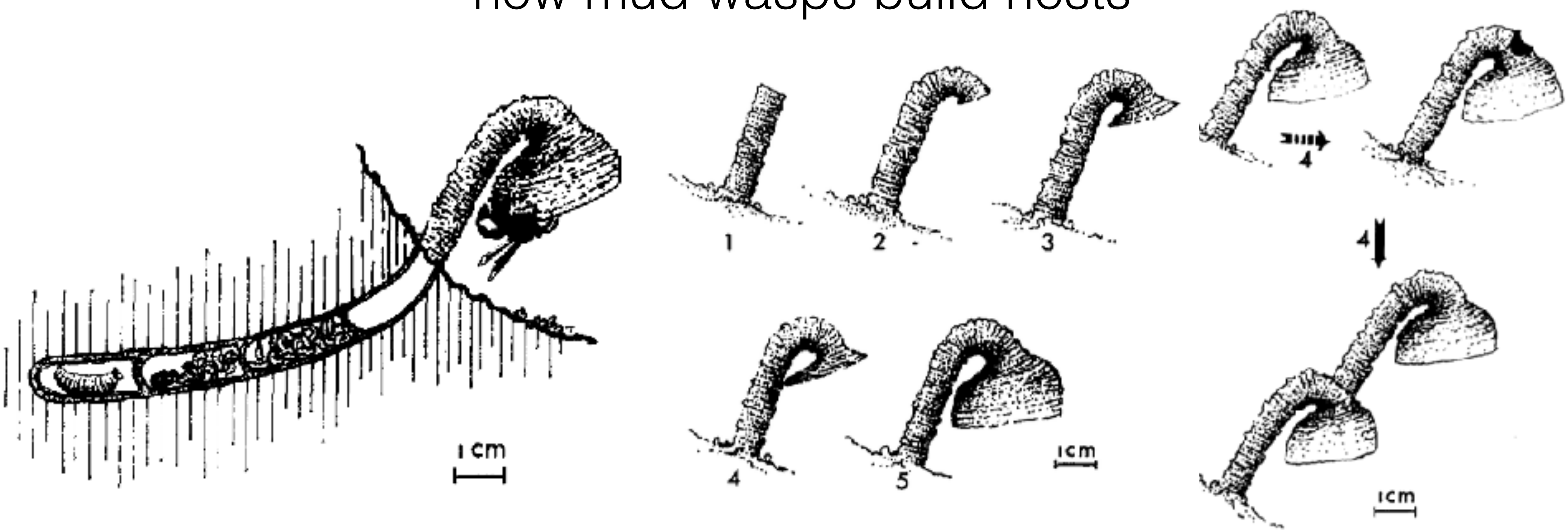
robot mechanical intelligence

walks with no feedback and very little power

collins 2001

example of adaptation: reflexive/model-free control

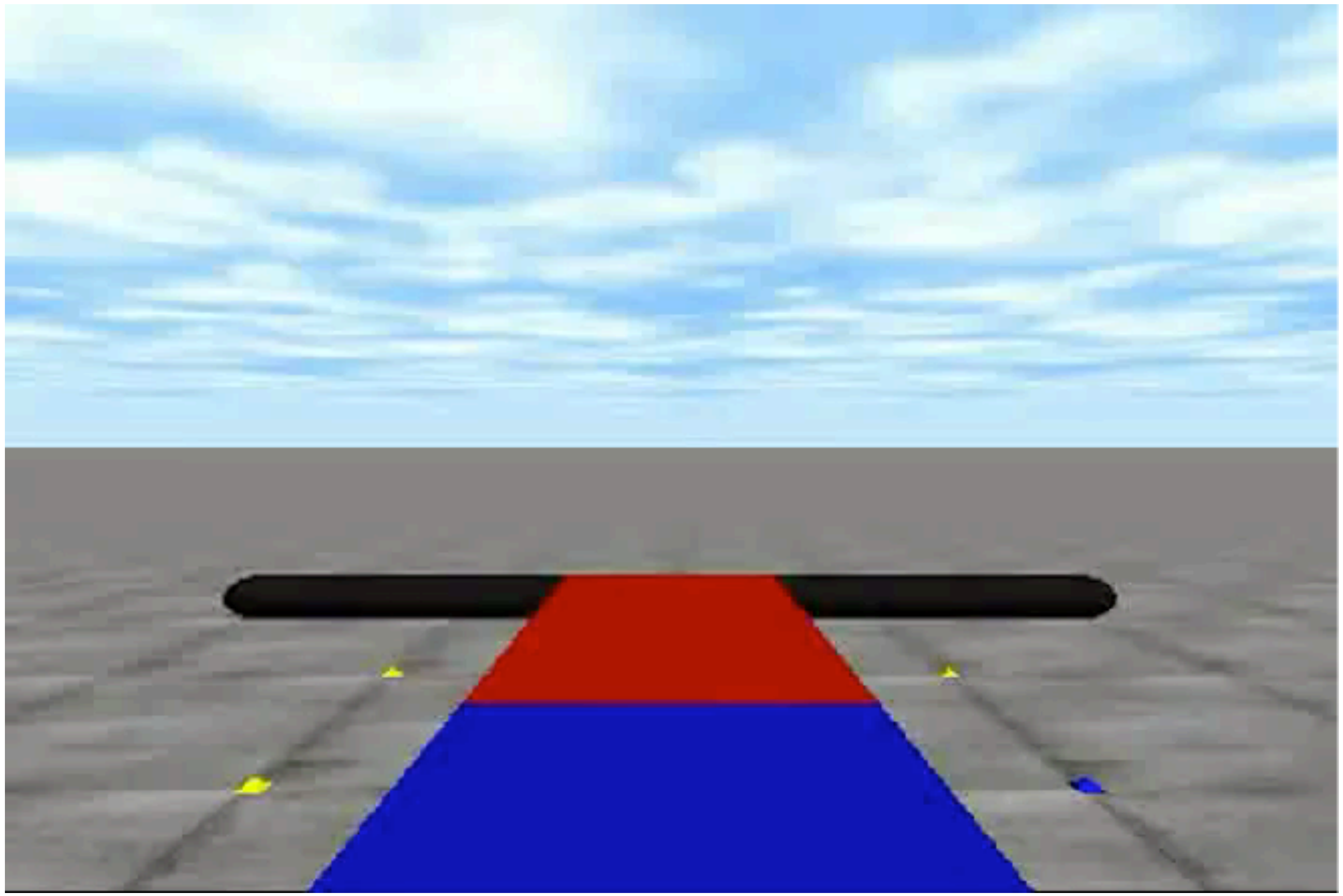
how mud wasps build nests



- minimal internal representation
- cascaded behaviors

Smith, 1978

example of model-free control



a gait learned by a neural network

bongard 2011

how this course works

- This is a research-oriented course
- Three parts to the coursework:

1. **Reviewing and discussing** 1-2 assigned papers per class session
2. **Presenting** 1-2 papers to the class
    - assigned based on a lottery and your preferences
3. **Final project**
    - this year: you're the funding agency

This year's final project

- You're the funding agency!
- each team/individual submits a *research proposal* at the end of the quarter
    - format: 3 pages, NDSEG graduate fellowship format
    - includes preliminary work you did in this course
        - show a "proof-of-concept" initial work in some aspect of biology-inspired robotics, probably in simulation
    - can be used to for your actual application
- There will be a peer vote for best proposals
    - criteria: quality of preliminary results, future promise
- top 3 proposals split the money

Wednesday

- due by Tuesday 9pm: Review of paper 0
  - because of the short time available, only complete part 1 (synopsis) of the four elements of the review.

next week

- paper 1 review due Sunday
- paper 2 review due Tuesday