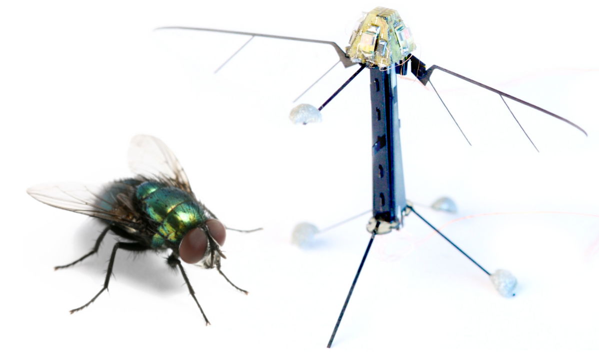

ME 586:
Biology-inspired robotics

Lecture 1

Prof. Sawyer B. Fuller

Goals:

- Describe the need for “biology-inspired robotics”
- Describe how this course works
- Introduce crazyflie helicopter & course project
- Introduction to simulation and dynamical systems

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overview from syllabus

- prerequisites
- meeting times
- office hours
- we will use canvas + course website:

http://faculty.washington.edu/minster/bio_inspired_robotics/

Course objectives

- Inspire you to explore biology-inspired solutions to challenges in robotics
- Gain working knowledge of Python and Robotics Operating System
- Learn how to design a controller and sensor-based state estimator for an aircraft
- Efficiently find, read, explain, and note strengths and deficiencies in a research paper
- Describe and promote your ideas and discoveries

4 parts to this course:

1. Problem sets assigned early in the corder to cover basic elements of python and good software design, systems dynamics and simulations, and control systems for small aircraft. Part of homework entails working with crazyflie helicopter robot.

2. For some class sessions, you will read and review research papers taken from original research in the field of biology-inspired robotics. (7–10 papers during the quarter)

    - **a review is due online** the day before

    - come prepared to discuss (your grade depends in part on class participation)

3. You will be responsible for **presenting a paper** during one of the class sessions. The paper is assigned based on a lottery and your preferences (turn in pref sheet by next Monday!)

    - days with 2 student presenters: one presents background, other presents paper

    - days with 3 student presenters: one presents background, other two present 1 paper each

    - presenters will then **lead a discussion** on the paper(s), and grade other students' paper reviews

4. **Term project, in teams of 3—5:**

    - option A: flight control on provided palm-sized helicopter

    - option B: simulation topic of students choice (or robotic implementation, pending instructor approval)

term project is research-oriented

- basic output is a *research proposal*
- during the quarter, you will use the crazyflie helicopter or a simulation of your choice
- this will constitute the preliminary work section that shows “proof-of-concept” of your idea.
- report format is 1-2 pages per student team member, in graduate fellowship application format
    - could be used to for an actual application
- at the end of the quarter:
    - poster/demo session
    - NSF-style peer review of proposals. criteria: quality of preliminary results, future promise
- top proposal gets funding — free coffee to start the research!

course schedule

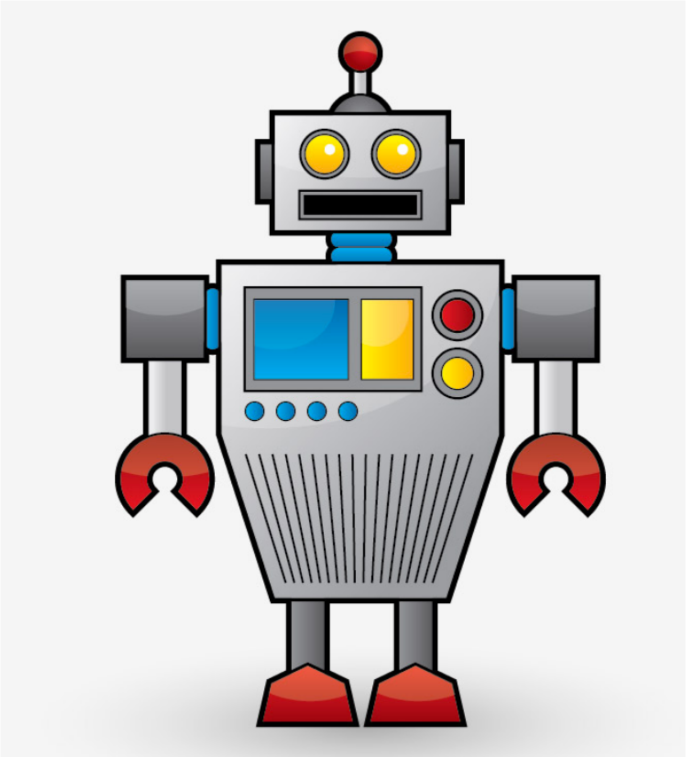
Course schedule (subject to change)

Dates	Topic	paper reviews	project/homework
week 1	**Mon:** overview, dynamic systems & linearization **Wed:** paper 0 presentation, Python tutorial	paper 0 summary	
week 2	**Mon**: linear quadratic regulator, project & team selection **Wed:** paper 1 presentation, Crazyflie tutorial	paper 1 summary	pset 1 due
week 3	**Mon: MLK holiday** **Wed:** sensors & Kalman Filter, ROS tutorial	paper 2 summary	pset 2 due
week 4	**insect-inspired control**	paper reviews	pset 3 due
week 5–6	**robot learning and evolution**	paper reviews	pre-proposal due
Weeks 7–8	**mechanical intelligence**	paper reviews	progress update
Week 9	**project work sessions, guest speakers**	paper reviews	
Week 10	**project presentations and project peer review**		poster session, proposal due

“biology-inspired robotics”

Robot (*noun*)

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



Related UW Classes
(many take a classical approach to robotics)

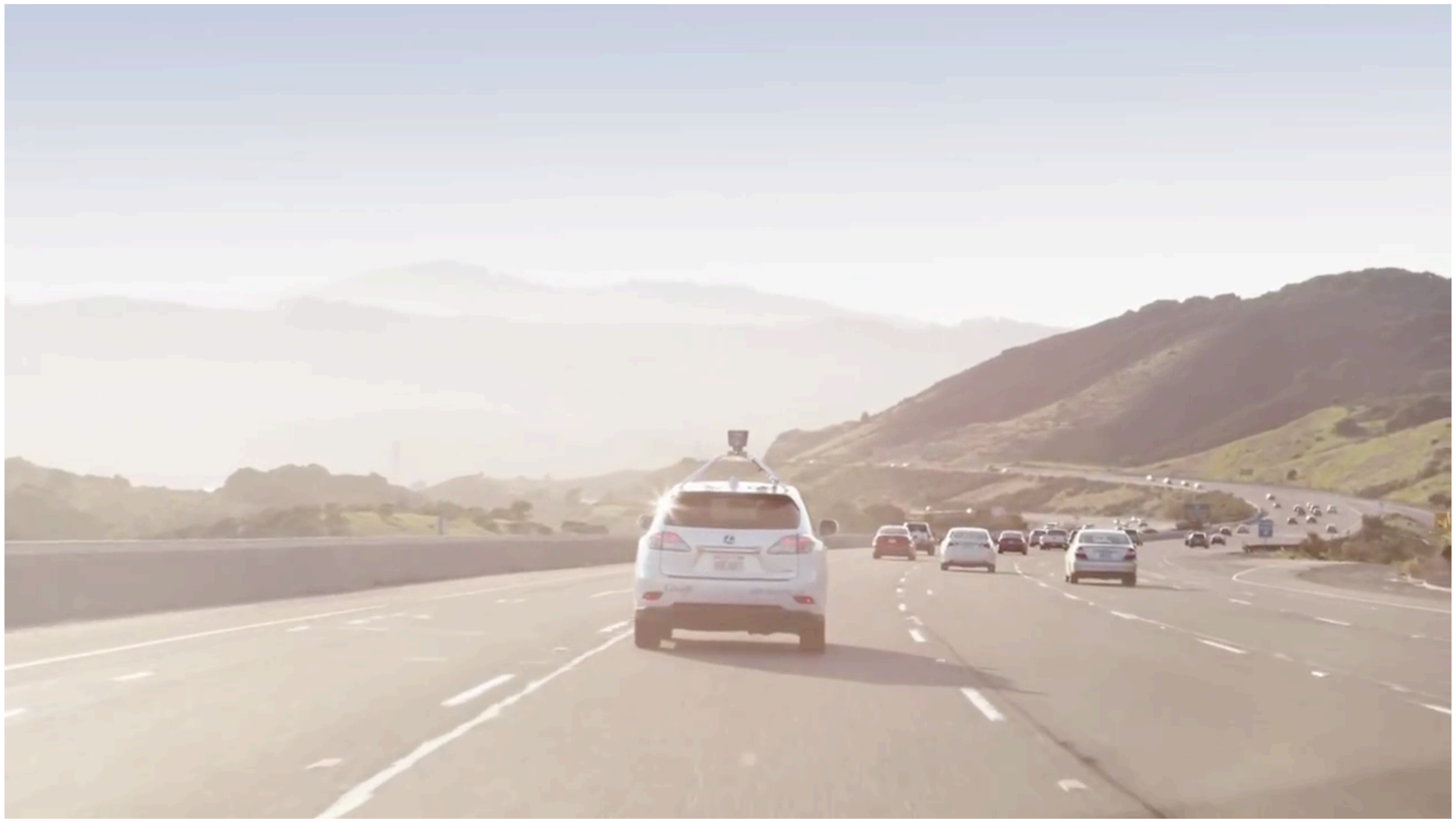
- Mechatronics:
  - ME581: Digital control systems (spring)
- Dynamics and control:
  - EE 543/544: Kinematics and dynamics of robot arms/manipulators
  - ME583: Nonlinear control
- Perception and planning:
  - EE 576: computer vision and robotics (spring)
  - CSE 571 Probabilistic Robotics: Perception,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

Classic robotics

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

- rich behavioral repertoire


BBC

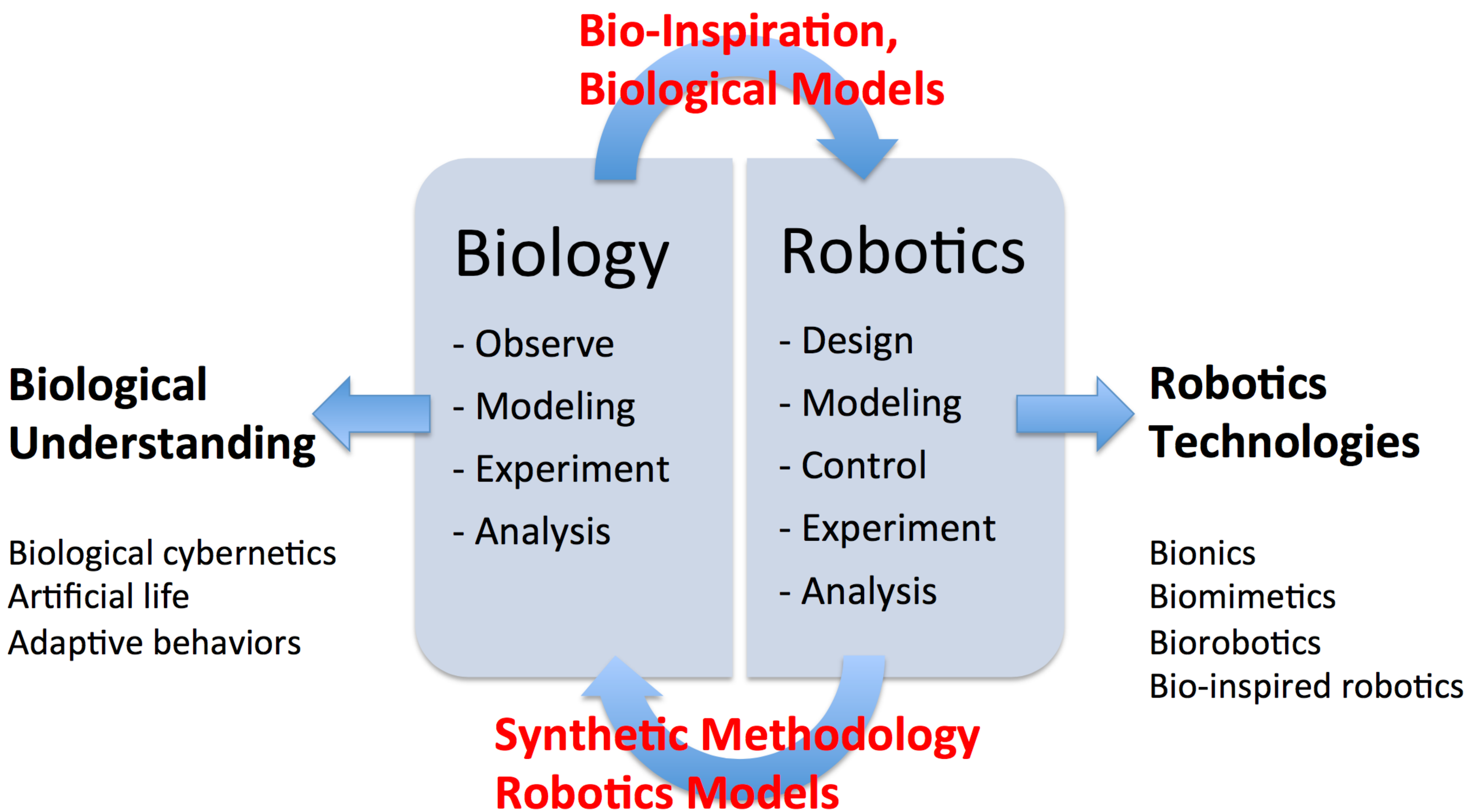
- aggressive, dynamic motions

- complex environments
- minimal energy expenditure on computation

why are animals so much more capable (agile, robust) than current robots?

one answer:
we are still finding out!

biology-inspired robotics



this course takes the view that biology beats robotics for two reasons:

1. better at adapting through evolution and learning
2. mechanical intelligence

mechanical intelligence

this fish is dead!

- system is stable without active feedback

Liao, 2004

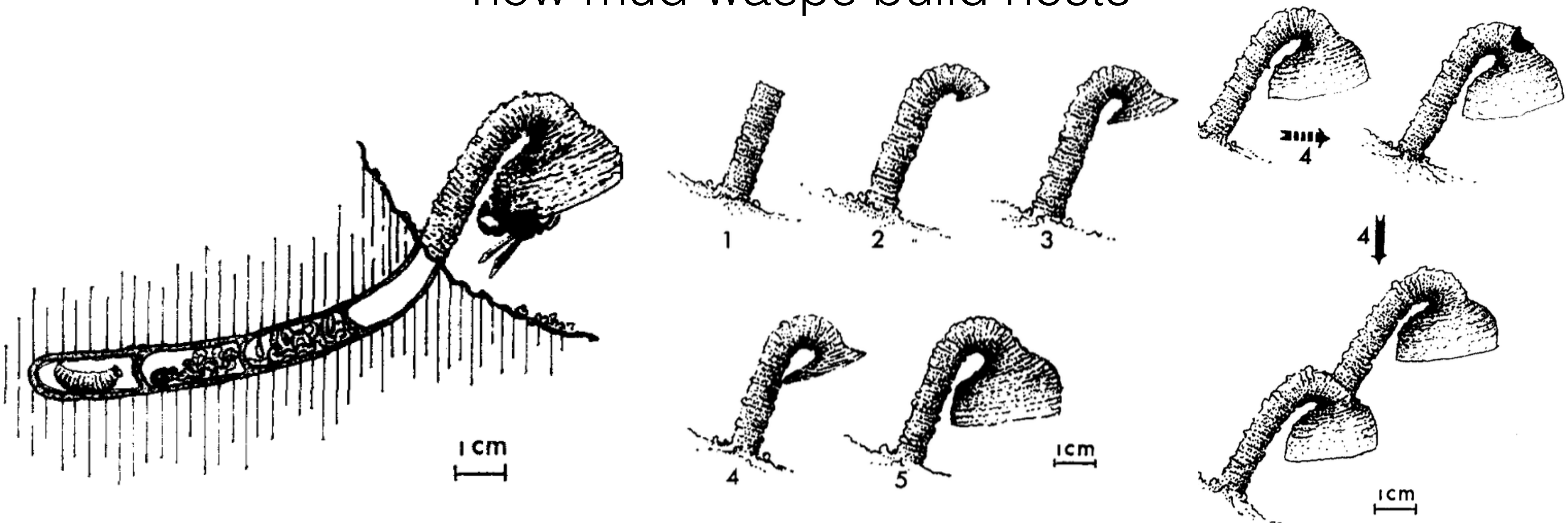
robot mechanical intelligence

walks with no feedback and very little power

collins 2001

example of adaptation: reflexive/model-free control

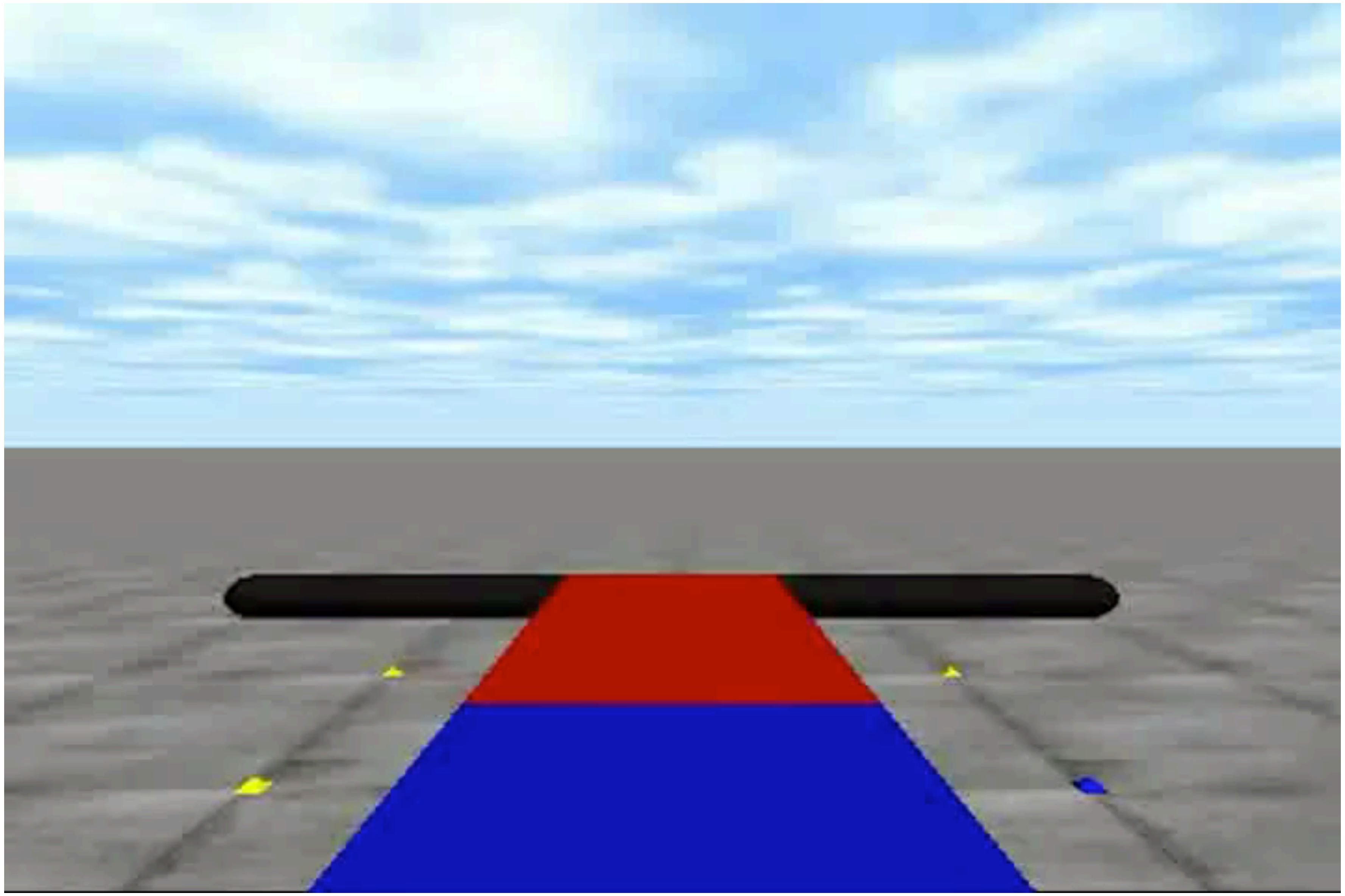
how mud wasps build nests



- minimal internal representation
- cascaded behaviors

Smith, 1978

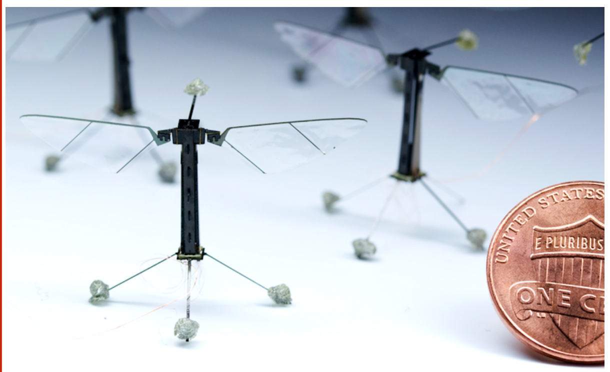
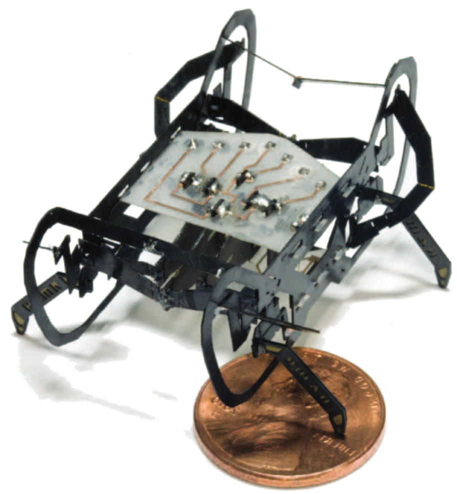
example of model-free control



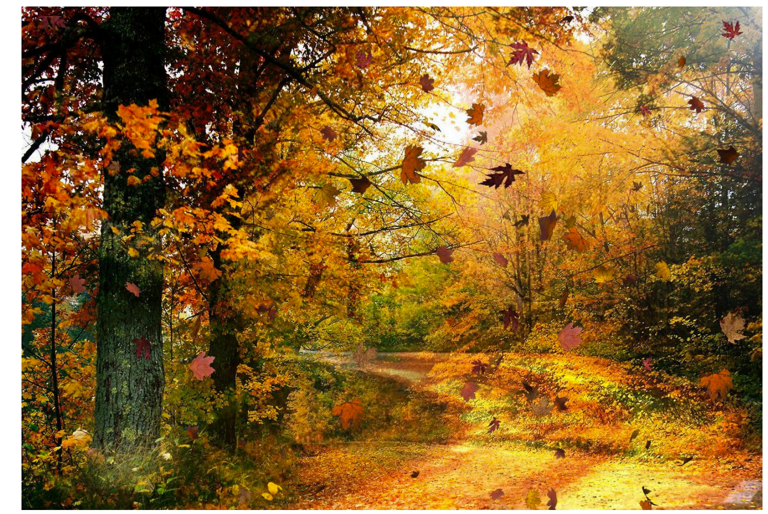
a gait learned by a neural network

bongard 2011

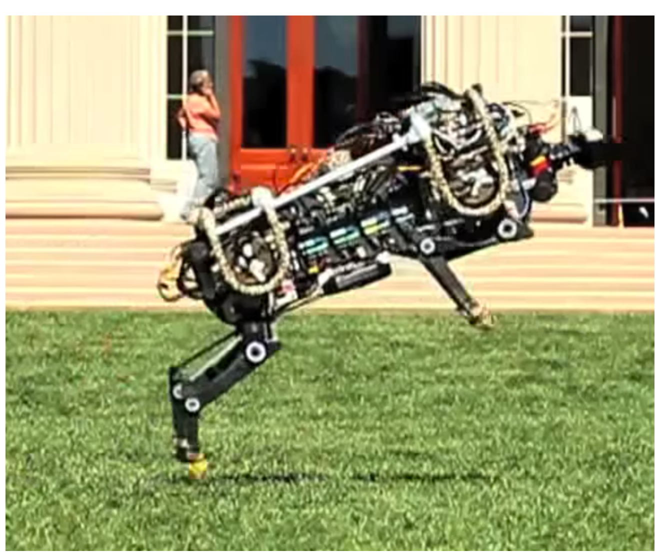
application areas where current robotics is still outperformed by nature

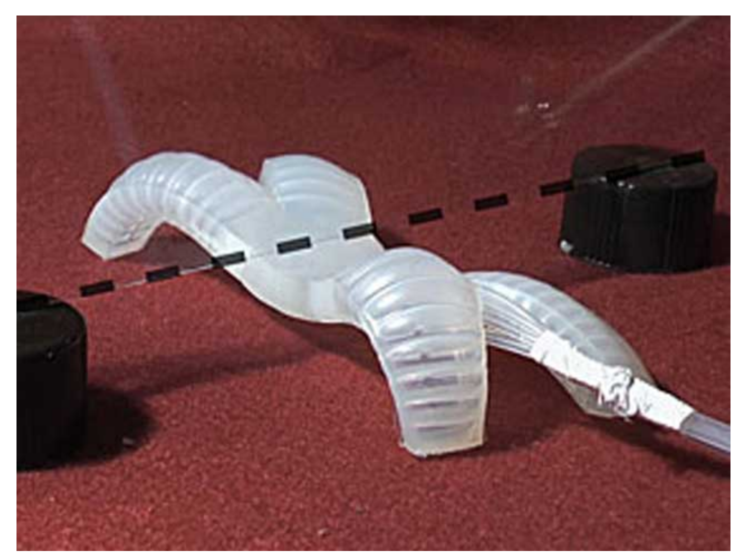
tiny robots
(minimal computation,
limited sensing)



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

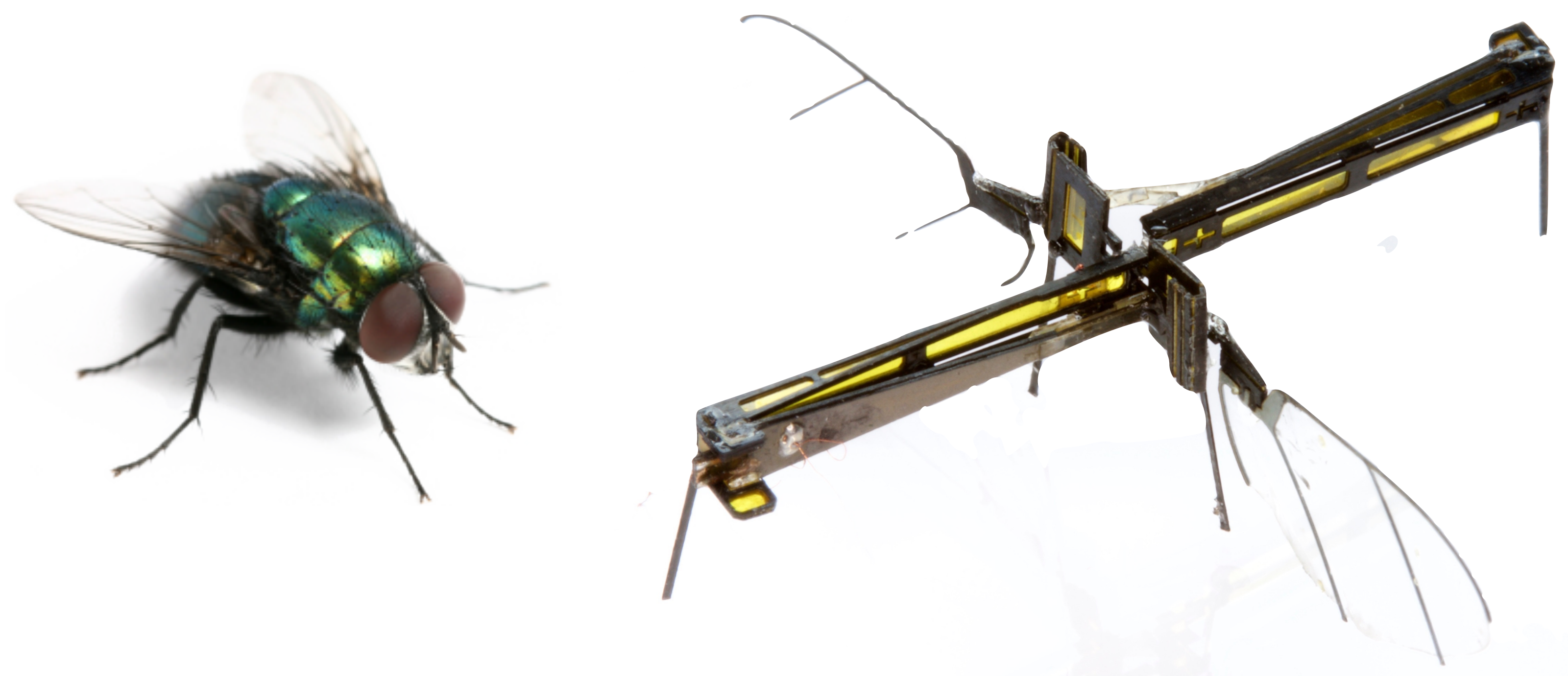


agile robots
(limited time
to compute)



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

My research: Insect-sized robotics



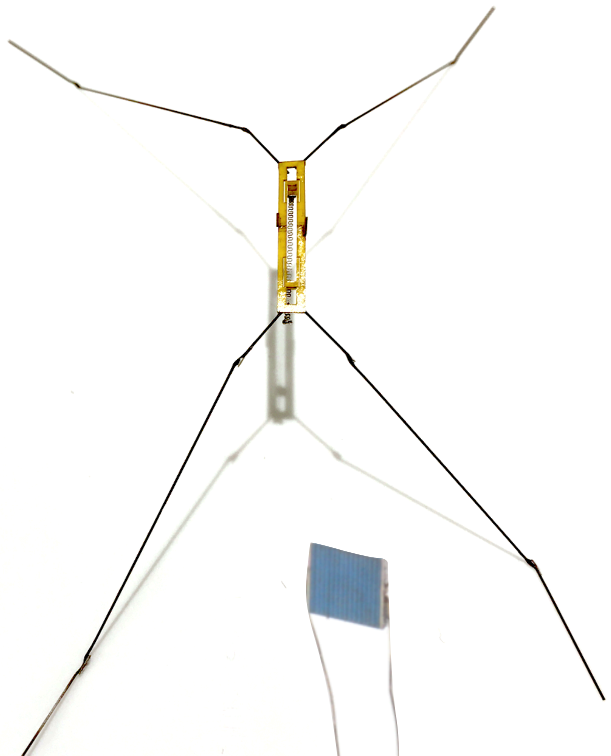
(images to scale)

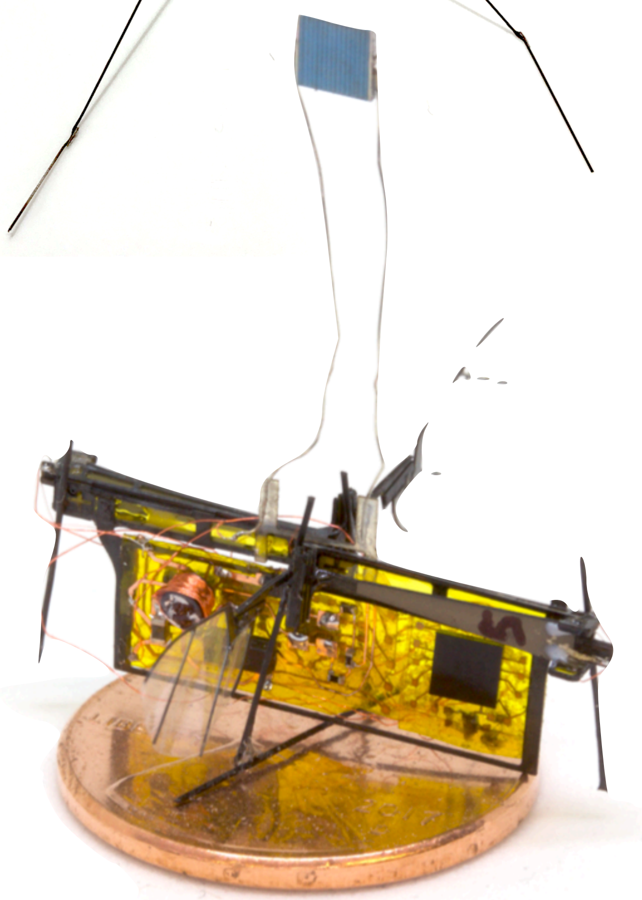
Dr. Sawyer B. Fuller
Assistant Professor

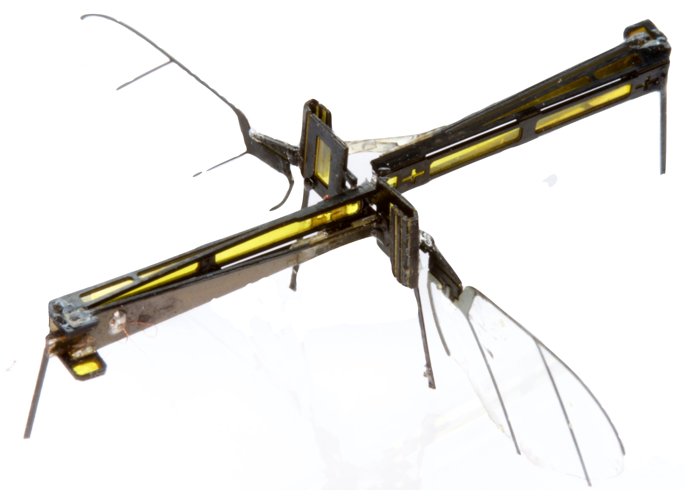
UNIVERSITY *of* WASHINGTON
MECHANICAL ENGINEERING

Autonomous Insect Robotics Laboratory

Est. 2015







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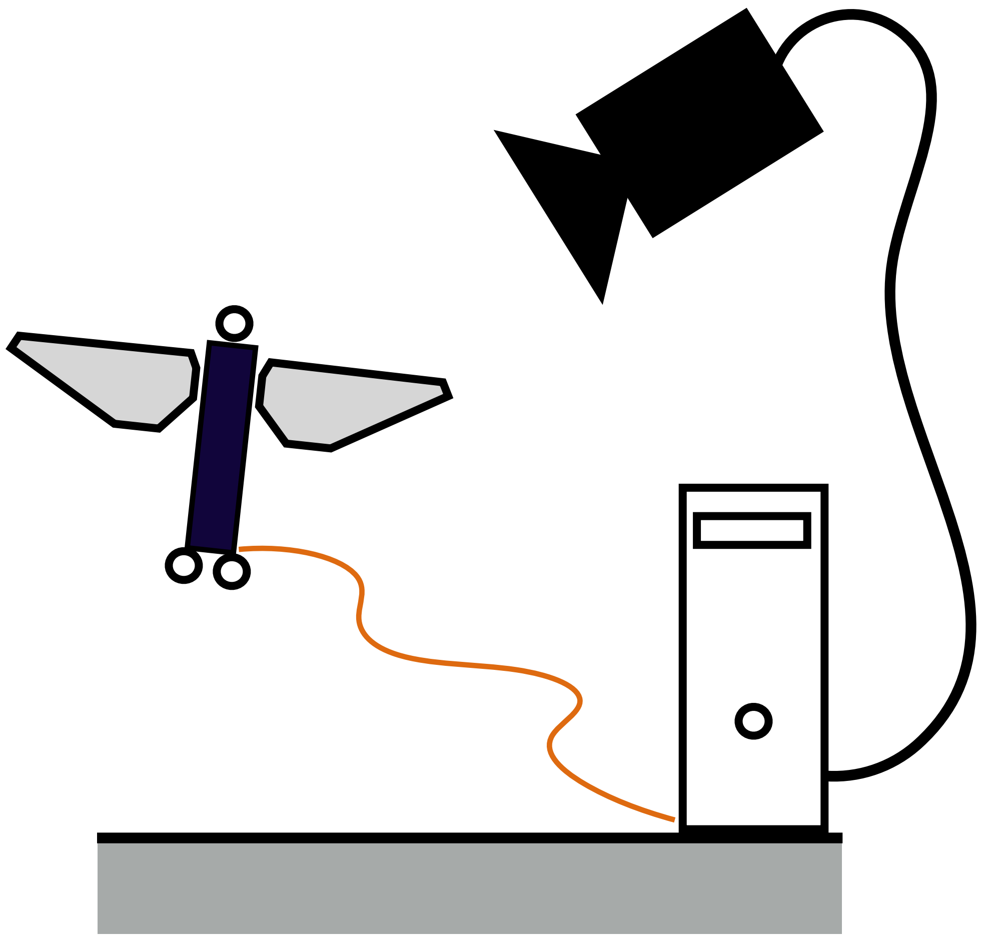
MECHANICAL ENGINEERING

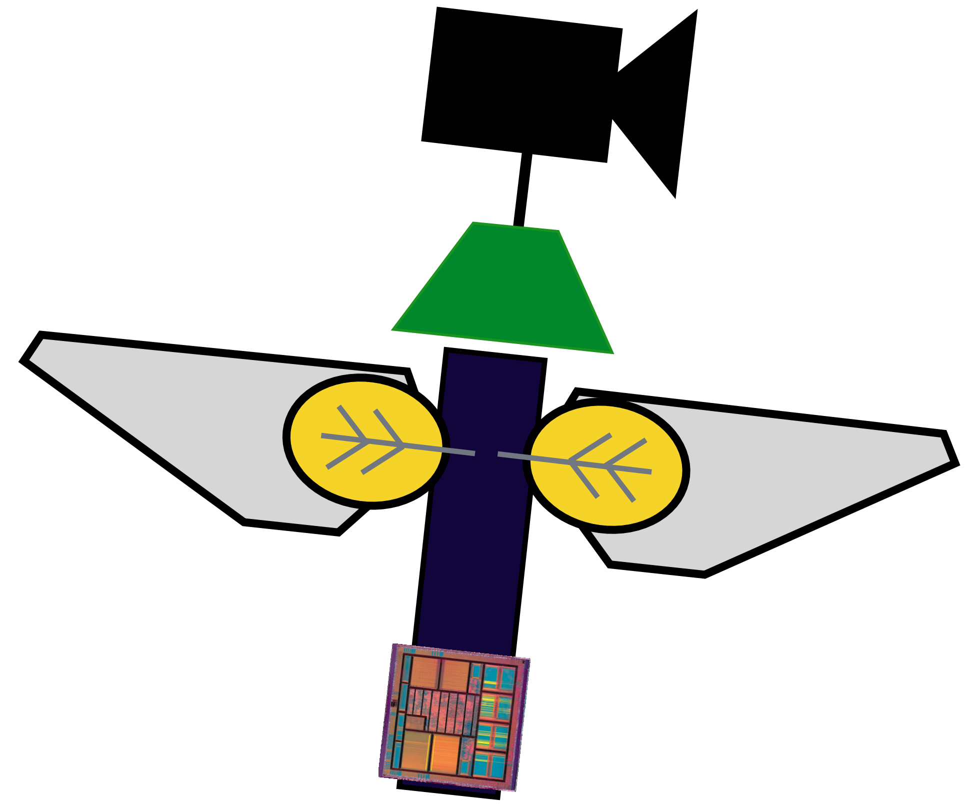
Ma, Chirarattananon, Fuller, and Wood, *Science* 2013

previous work



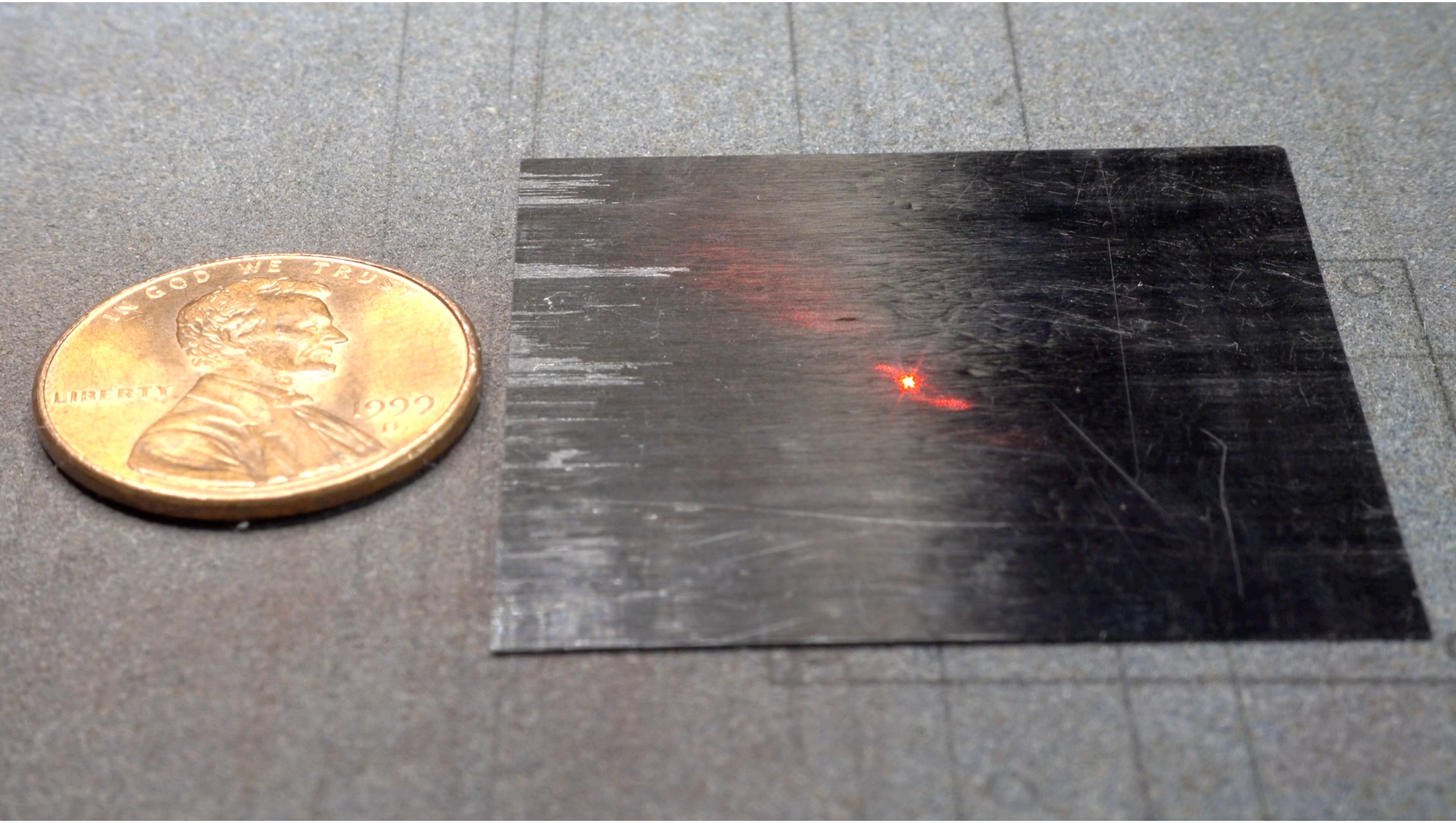
- external power
- external sensing
- external computation

current research

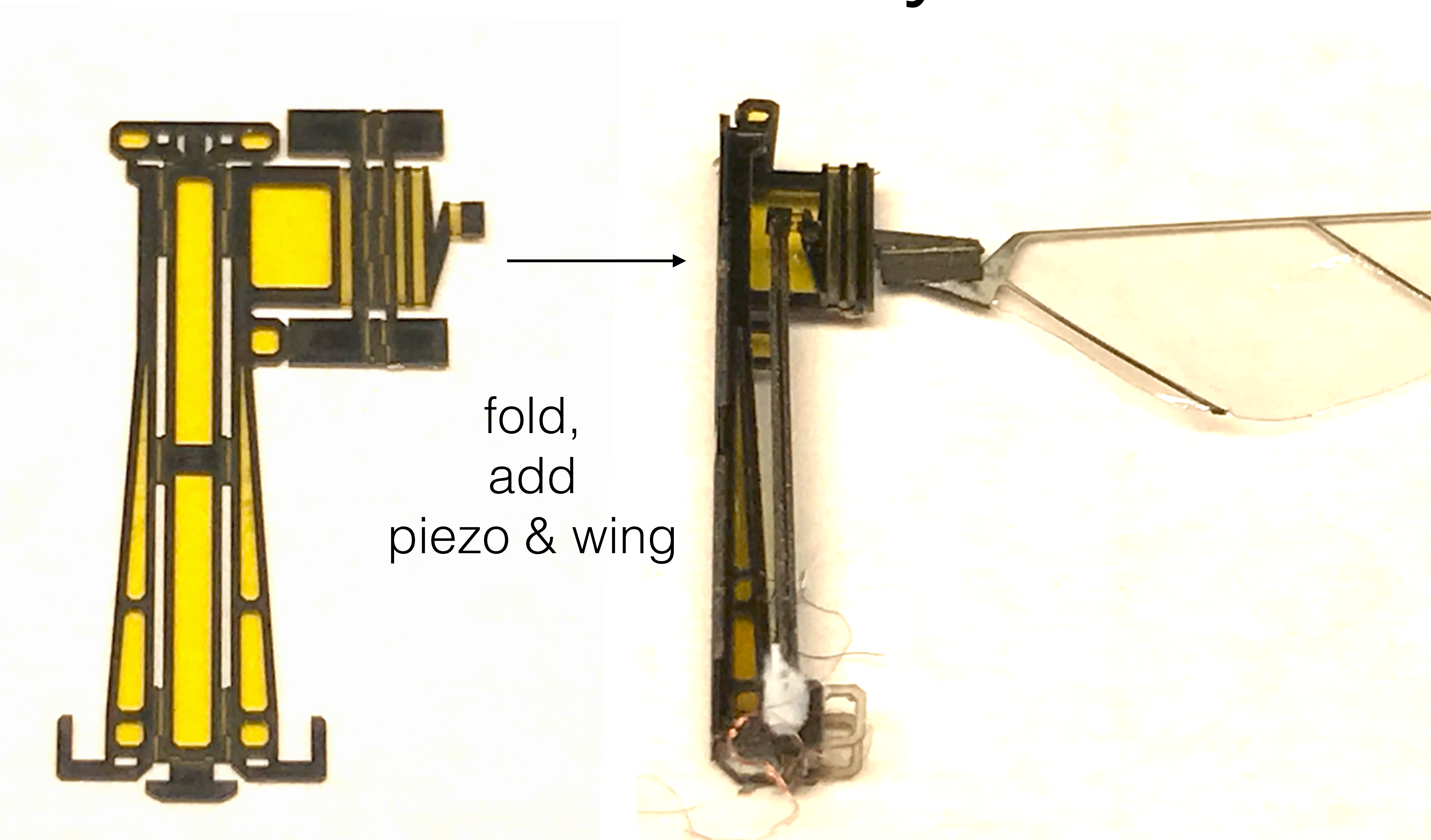


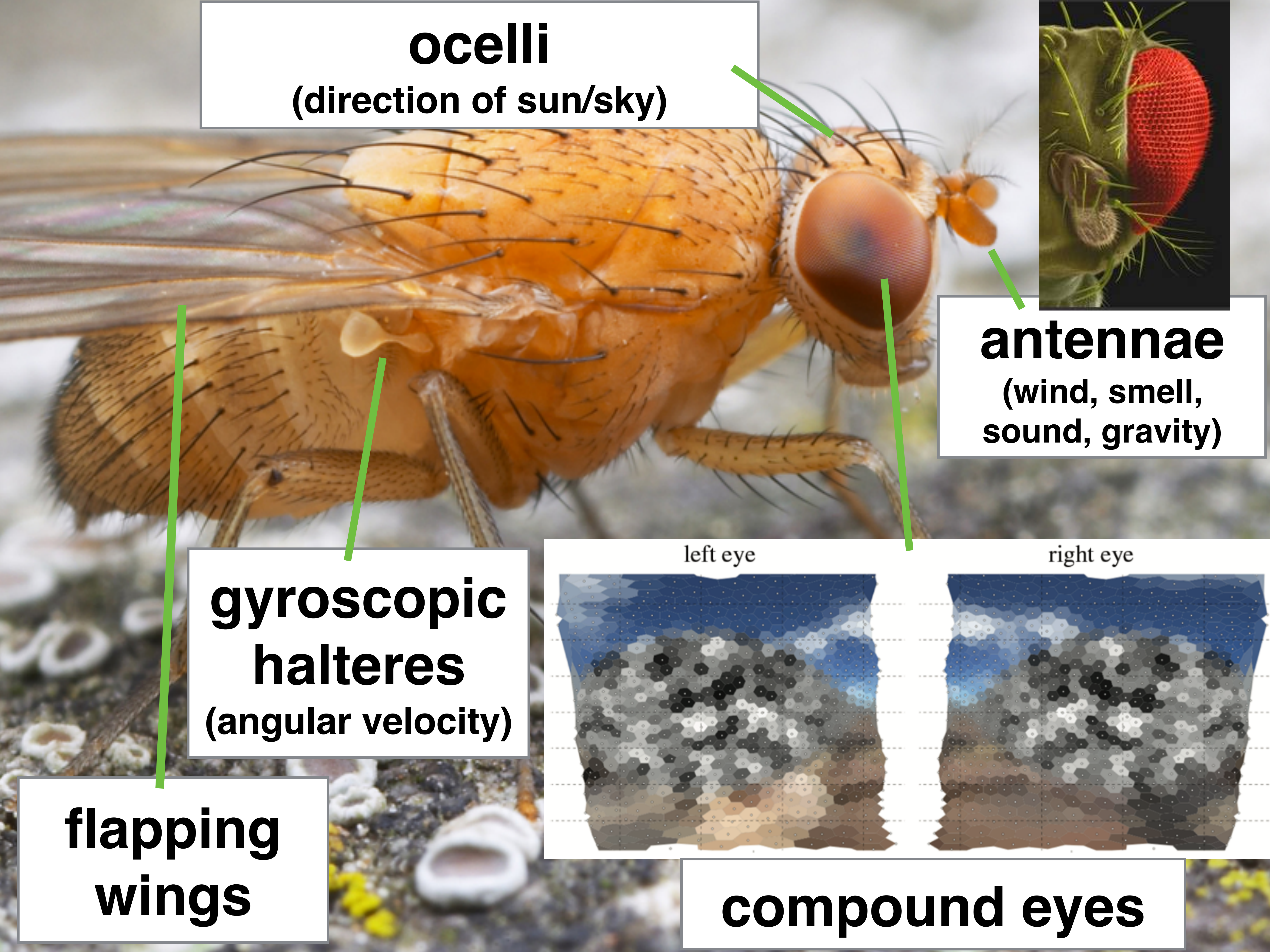
- improved capabilities
- onboard sensing
- onboard computing
- onboard power

355 nm laser micromachining

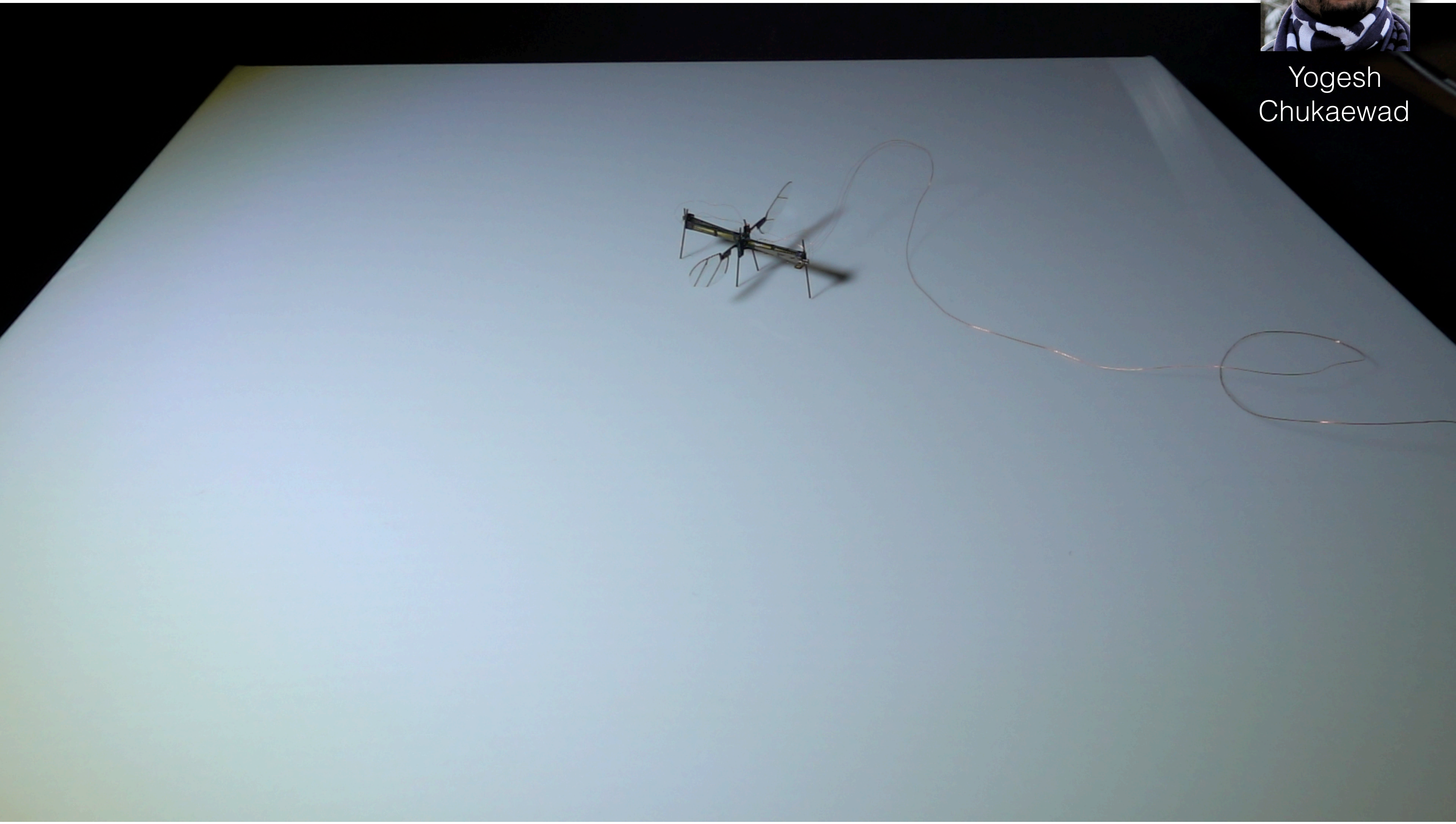


assembly



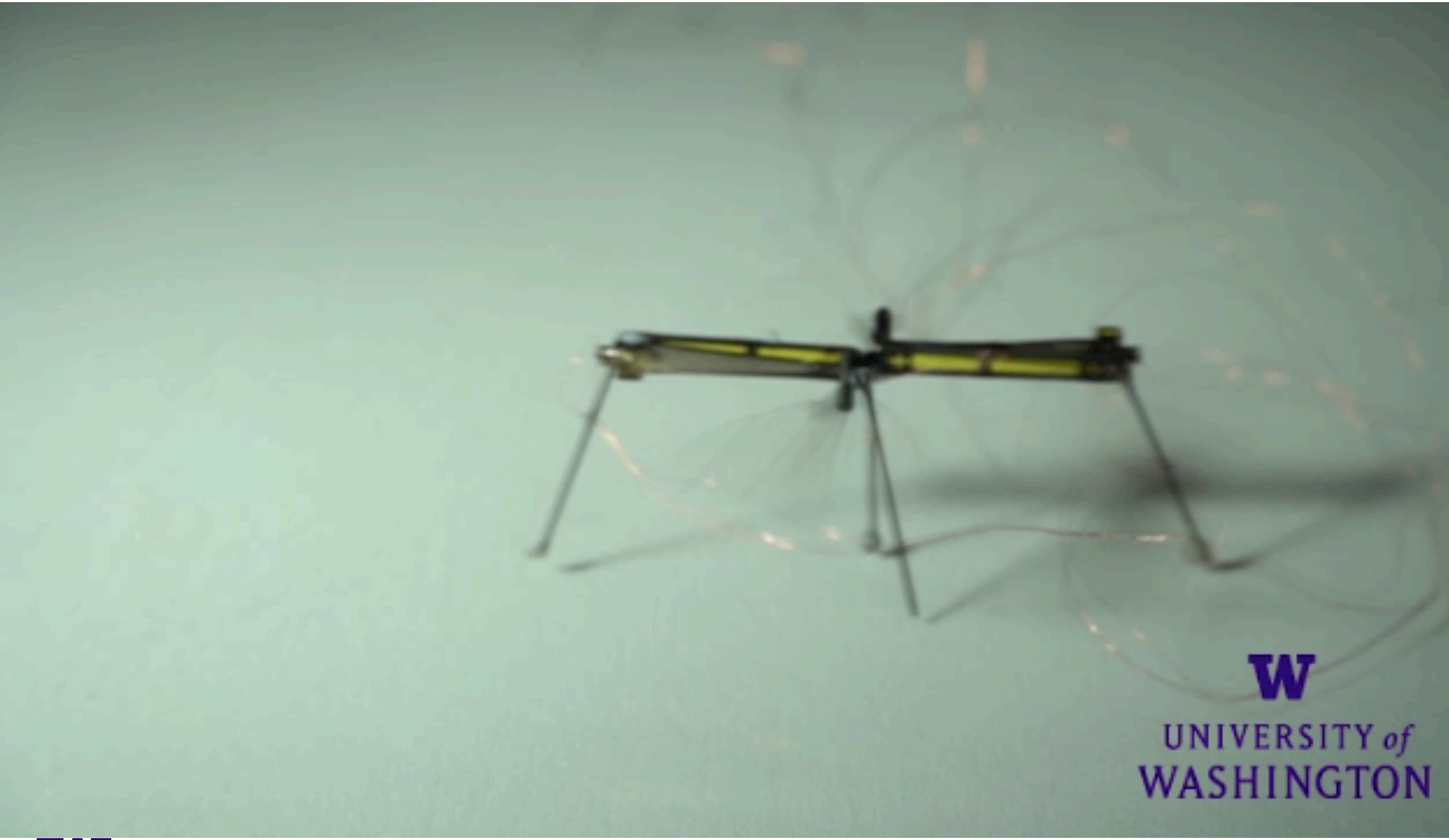

ocelli
(direction of sun/sky)
antennae
(wind, smell,
sound, gravity)
gyroscopic
halteres
(angular velocity)
left eye
right eye
flapping
wings
compound eyes

takeoff and landing

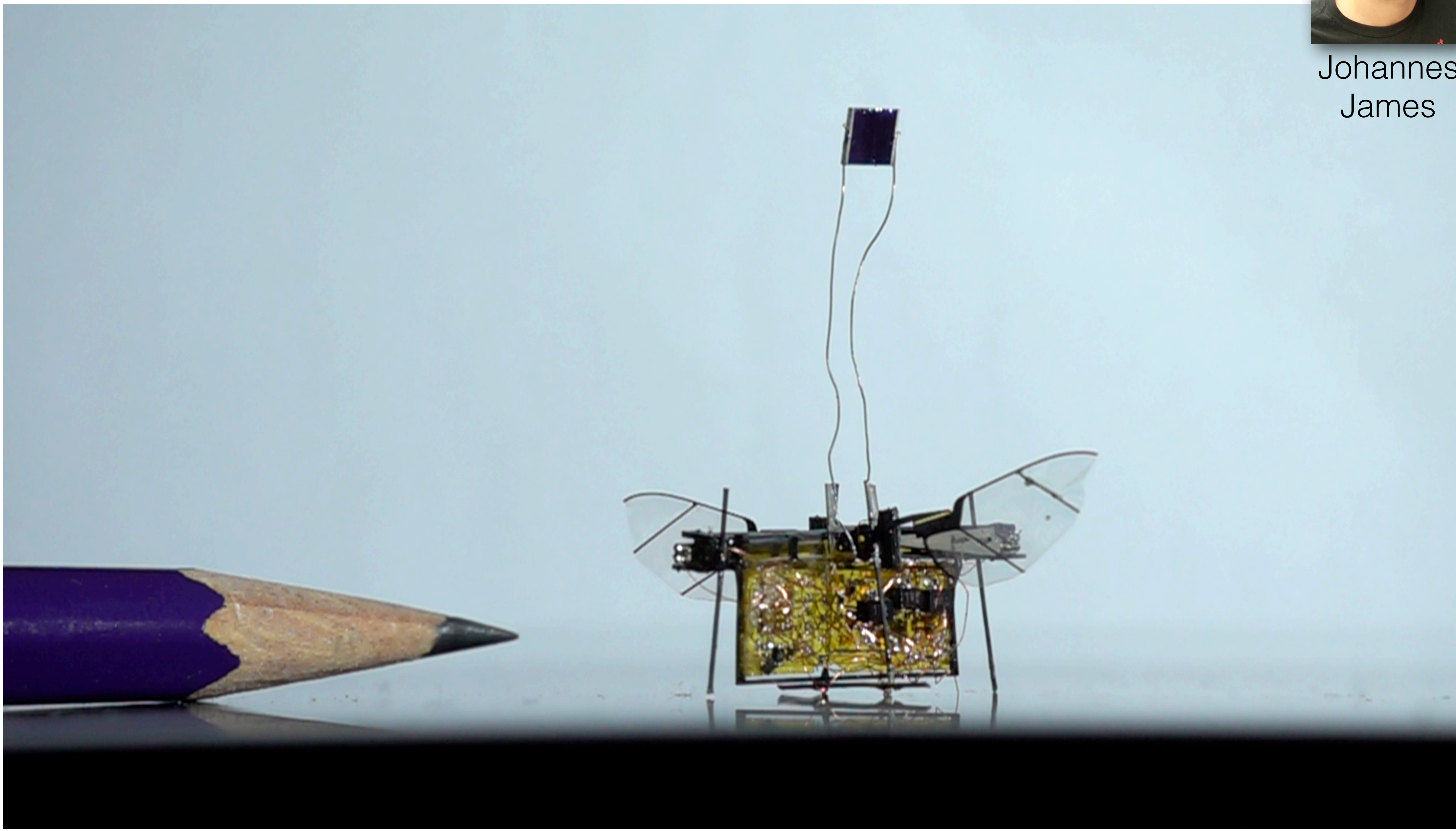


Yogesh
Chukaewad

Ground ambulation



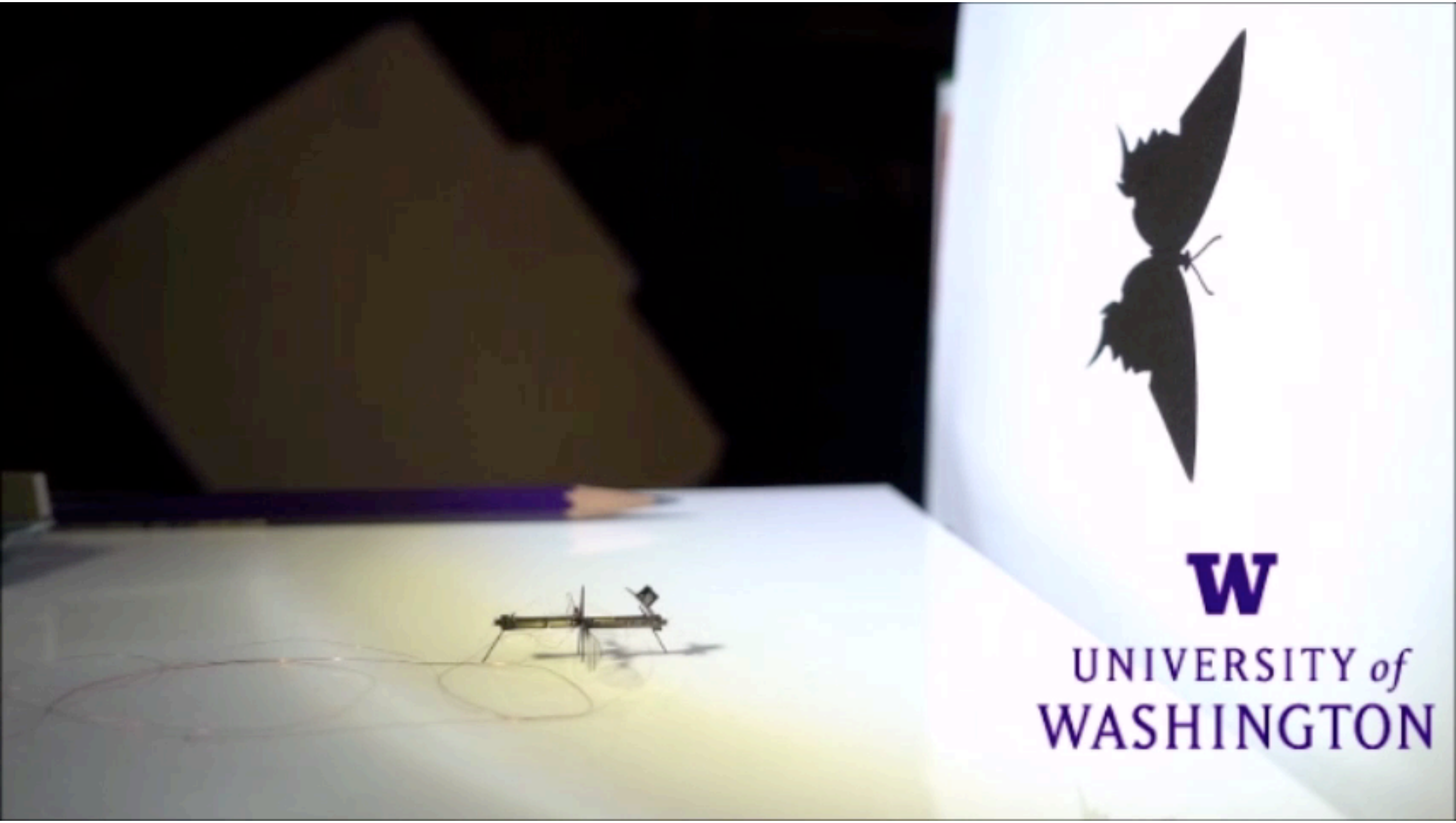
first untethered flights (powered by laser)



Johannes James

James, Iyer, Chukewad, Gollakota, and Fuller, *ICRA 2018* (under review)

sight



robotic plume tracking

Melanie
Anderson

Tom
Daniel