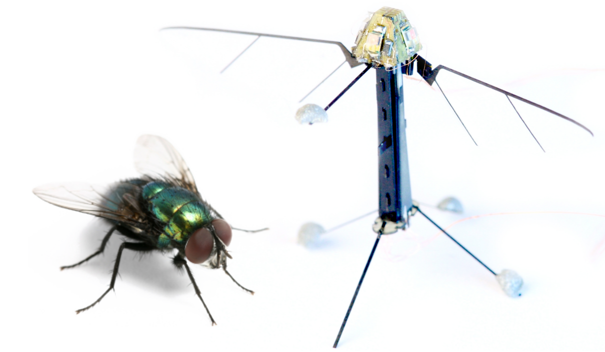


ME 586:
Biology-inspired robotics

Lecture 1

Prof. Sawyer B. Fuller

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

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
- 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. **Three problem sets**
   - systems dynamics and simulations, and control systems for insects or small aircraft, Python, good software design
2. **Read and review a small number of assigned primary research articles**
   - review is due online the day before
   - come prepared to discuss (your grade depends in part on class participation)
3. **Present one article and lead a discussion on it (in teams of 2–4)**
   - articles assigned based on a lottery and your your preferences (assignment posted soon)
   - groups will present one article, possibly a related article, and provide an introduction to the area
   - you will also grade other students' reviews of the article
4. **Term project, in teams of 2—4**
   - simulation topic of students choice (or robotic implementation, pending instructor approval)

term project is research-oriented

- like an advanced problem set where you explore a new area and create your own simulation
- area is your choice (suggestions will be provided)
- basic output is a *presentation and/or poster session*
- you will be teamed with other students with a similar interest
- at the end of the quarter:
  - poster/demo session
  - NSF-style peer review of results. criteria: quality of preliminary results, future promise

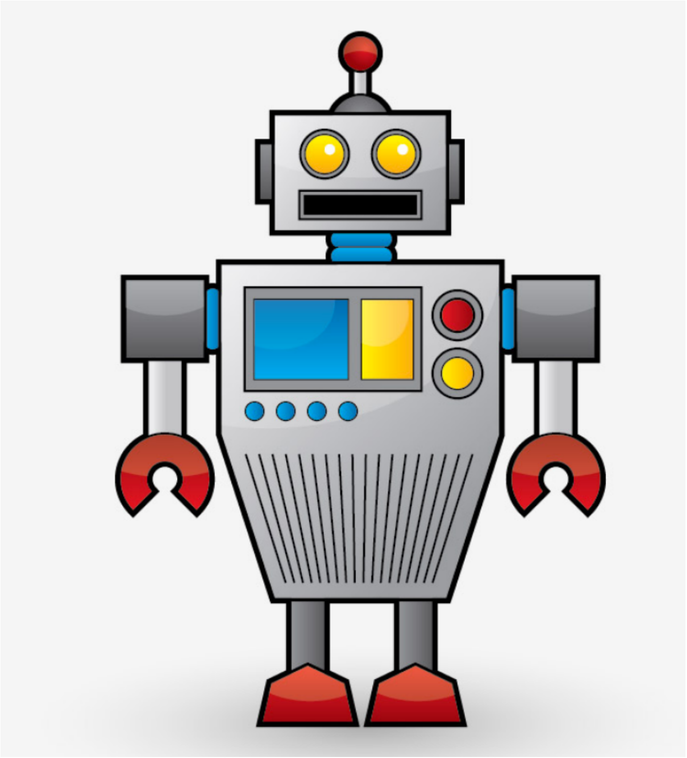
course schedule
(subject to change)

Dates	Topic	paper reviews	project/homework
week 1	**Mon:** overview		
	Wed: aircraft dynamics, systems & linearization, Python tutorial		
week 2	**Mon**: paper 0 presentation (parsimony)	paper 0 summary	
	Wed: dynamics II, project & team selection		hw1 due
week 3	**Mon: MLK holiday**		
	Wed: linear quadratic regulator		
week 4	**Mon**: paper 1 presentation (robot learning and evolution)	paper 1 review	
	Wed: sensors & optic flow, Kalman Filter		hw2 due
week 5	**Mon**: paper 2 presentation (mechanical intelligence)	paper 2 review	
	Wed: project work session (and extra time to make up lecture)		proposal due
weeks 6–9	**paper presentations, project work sessions, guest speakers**	paper reviews	hw3 due
Week 10	**project presentations and project peer review**		poster session

“biology-inspired robotics”

Robot (*noun*)

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



classic robotics

Honda's Asimo

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

current state of the art

Google/Waymo self-driving car

- “Boil the ocean” approach: constructs a detailed model of world and other vehicles moving through it
- downsides:
  - power hungry - requires a bank of computers
  - inflexible - only works in specific environments

Biology

- rich behavioral repertoire

The goshawk

- aggressive, dynamic motions

- complex environments
- minimal energy expenditure on computation

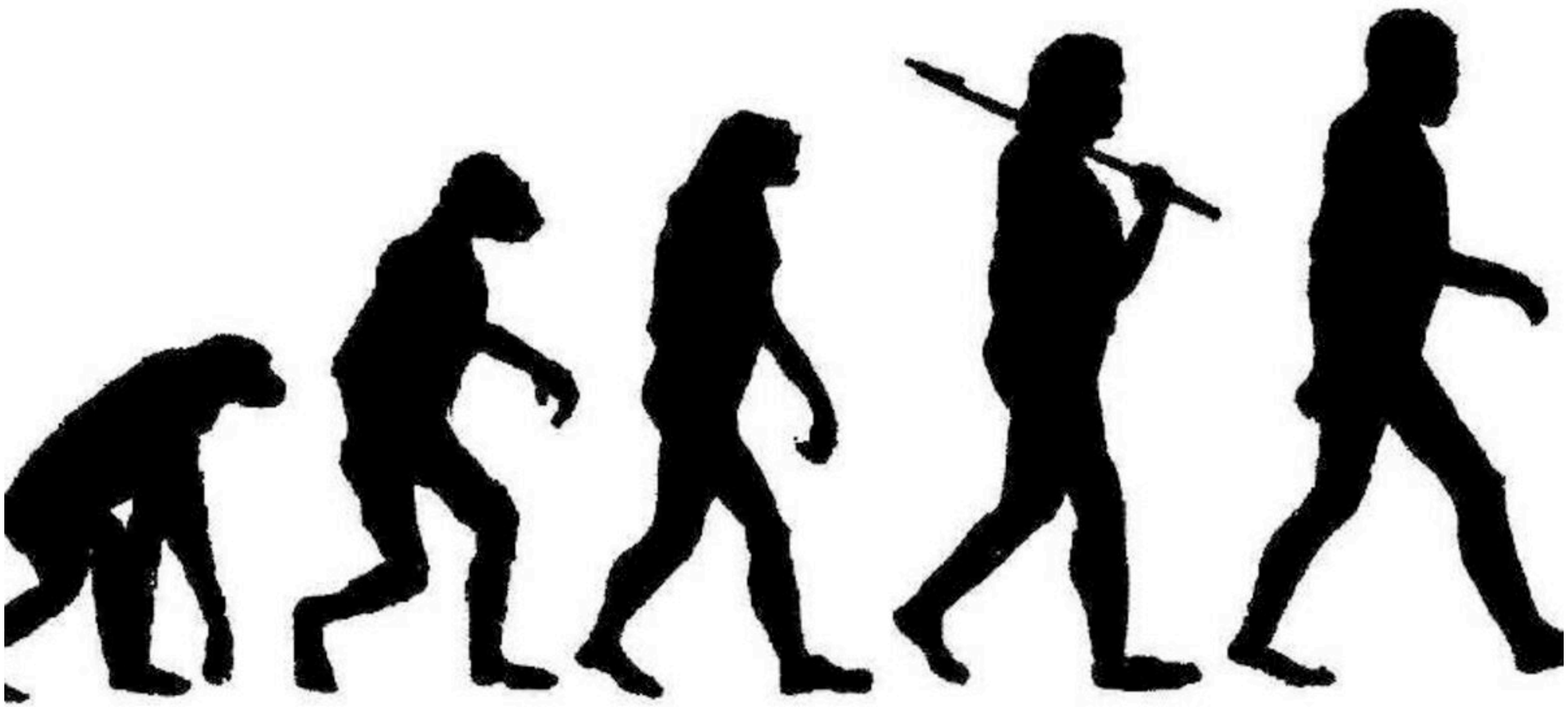
Baby grasping

Where does biology excel relative to engineering (and vice-versa)?

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

1. ability to adapt through evolution and learning
    - This leads to two important characteristics in animals:
2. mechanical intelligence
    - the use of mechanics to reduce or eliminate the need for feedback control
3. parsimony
    - simple and efficient solutions

Evolution & learning



Example of mechanical intelligence

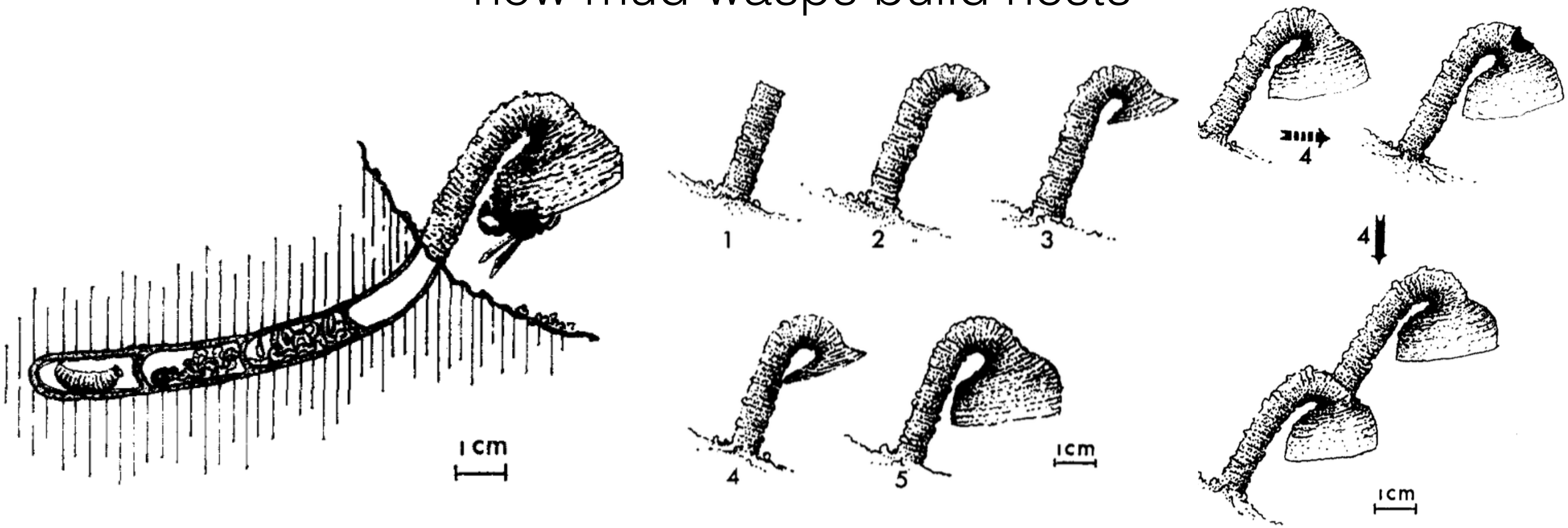
this fish is dead!

- system is stable without active feedback

Liao, 2004

example of parsimony: reflexive/model-free control

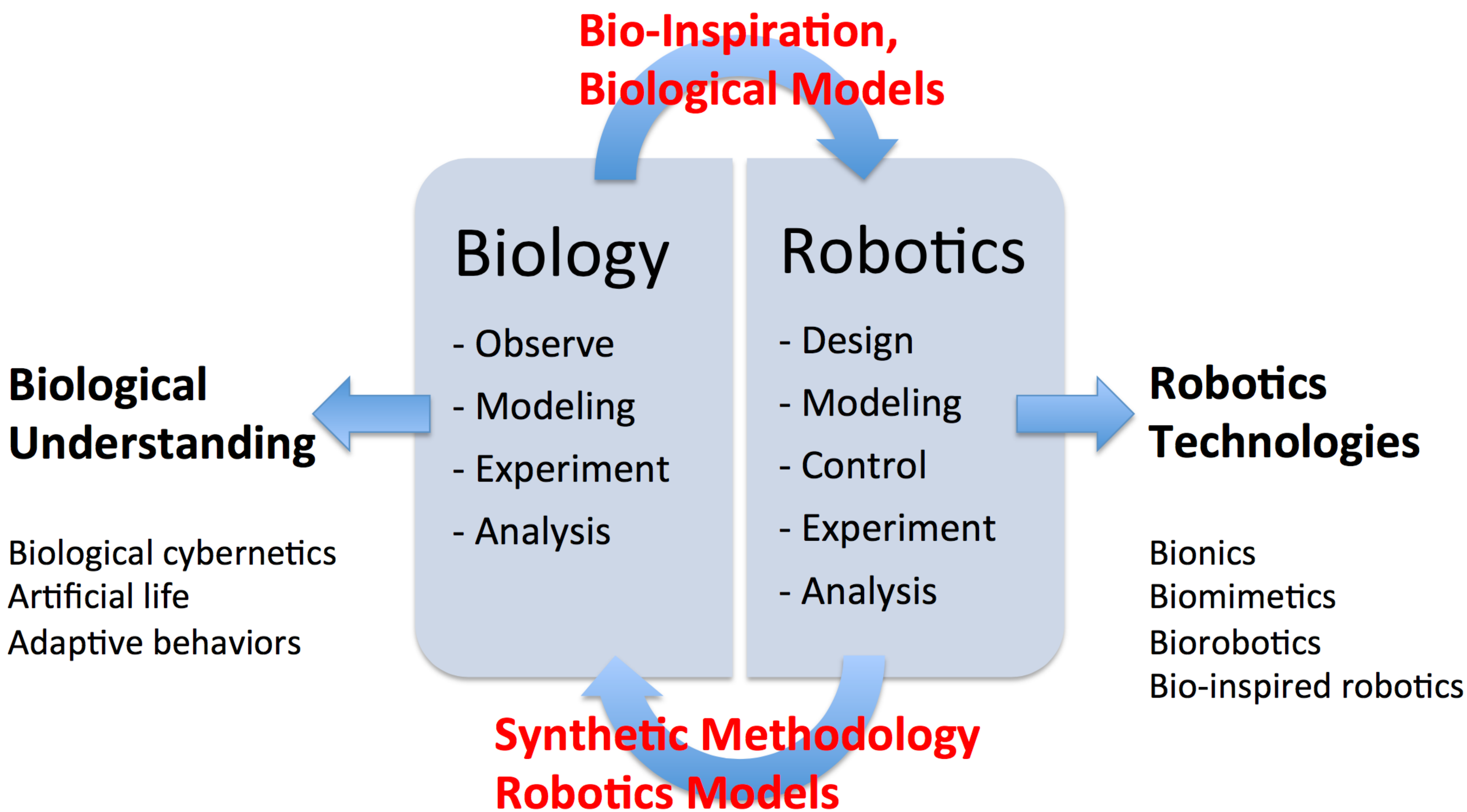
how mud wasps build nests



- minimal internal representation
- cascaded behaviors

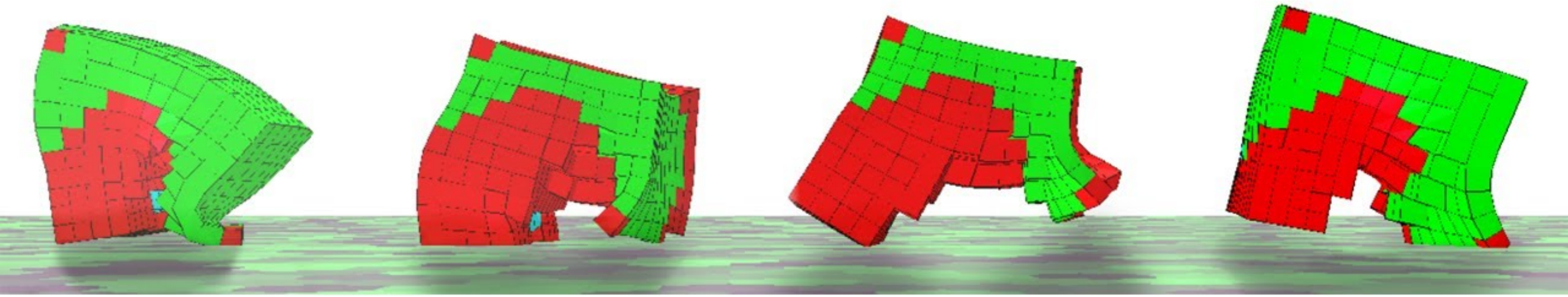
Smith, 1978

biology-inspired robotics

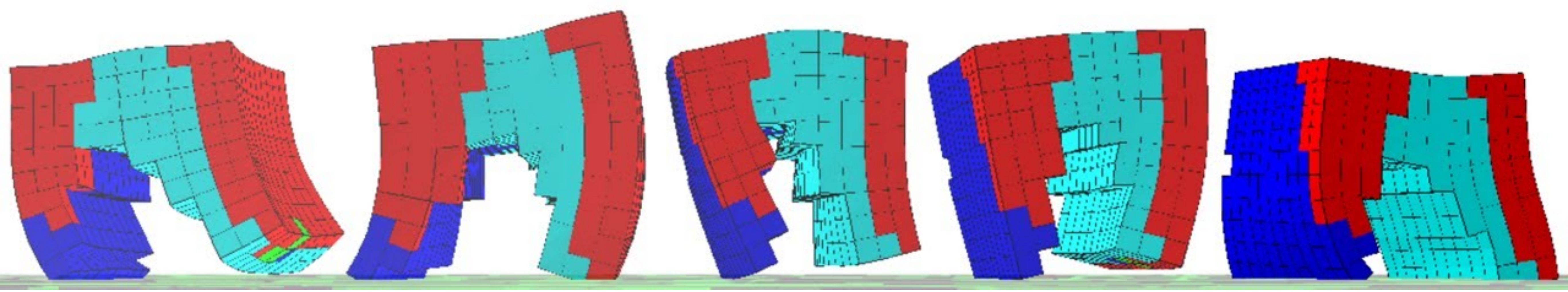


one answer:
we are still finding out!

Evolutionary robotics



Evolution in Action!



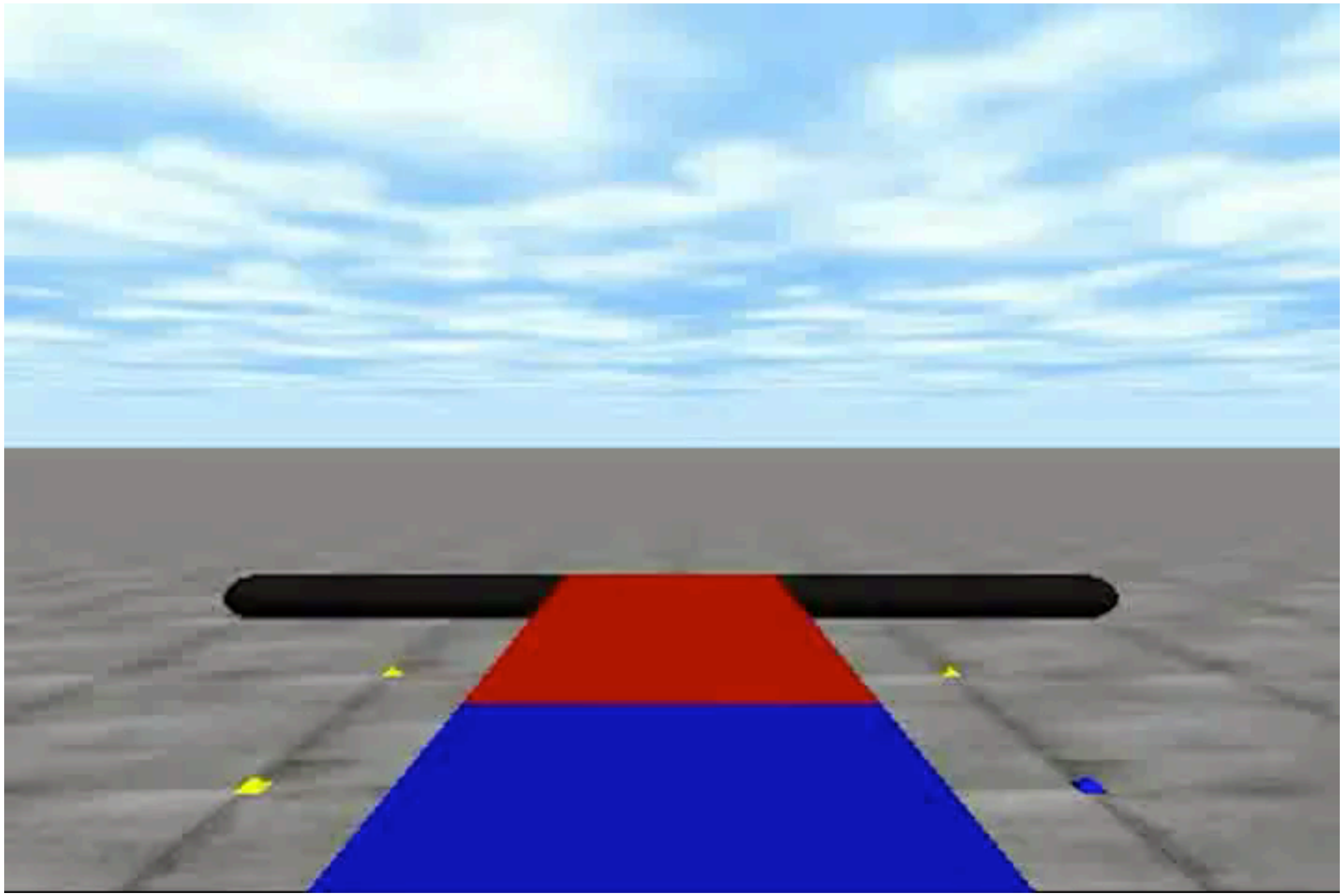
cheney 2013

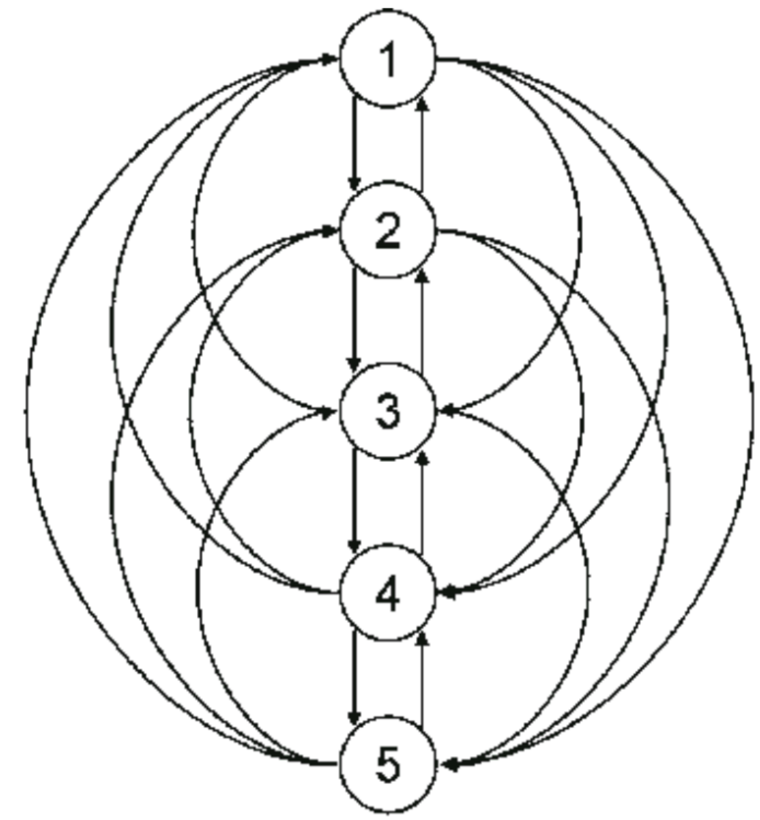
mechanical intelligence

walks with no feedback and very little power

collins 2001

parsimonius (model-free) learning and control



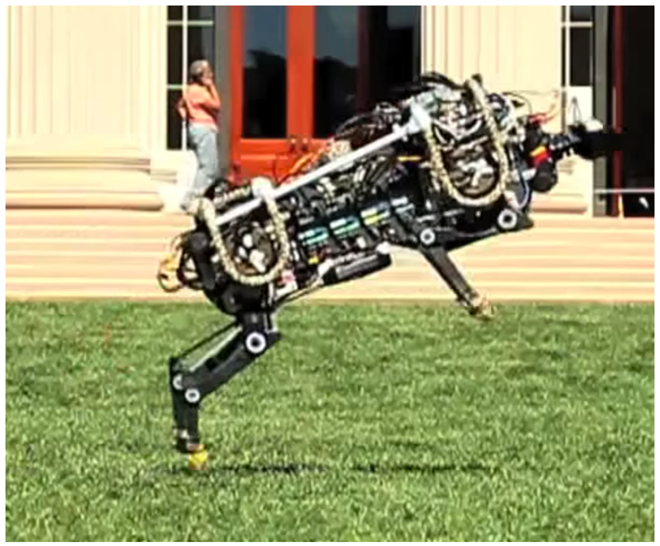


neurons = 16

a gait learned by a neural network

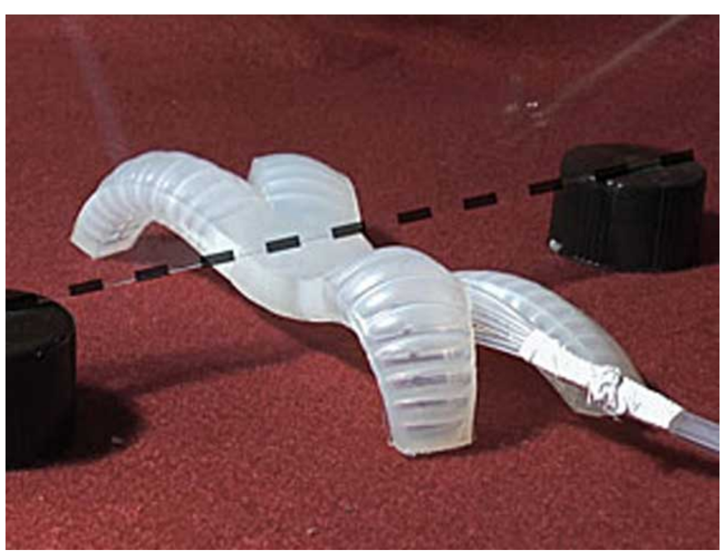
bongard 2011

grand challenges in robotics
biological inspiration needed!

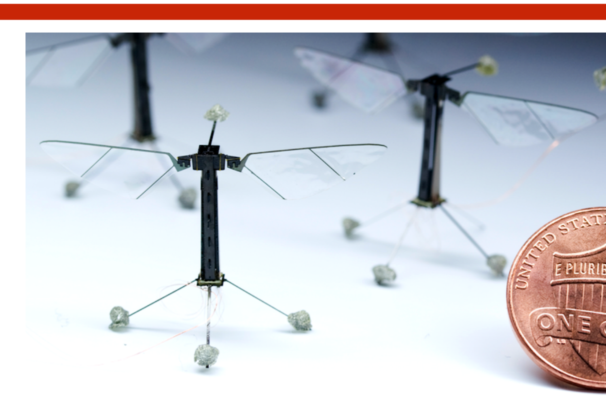


agile robots that
are robust
(limited time
to compute)

grasping and manipulation
(models are inadequate
and behavior must be learned)

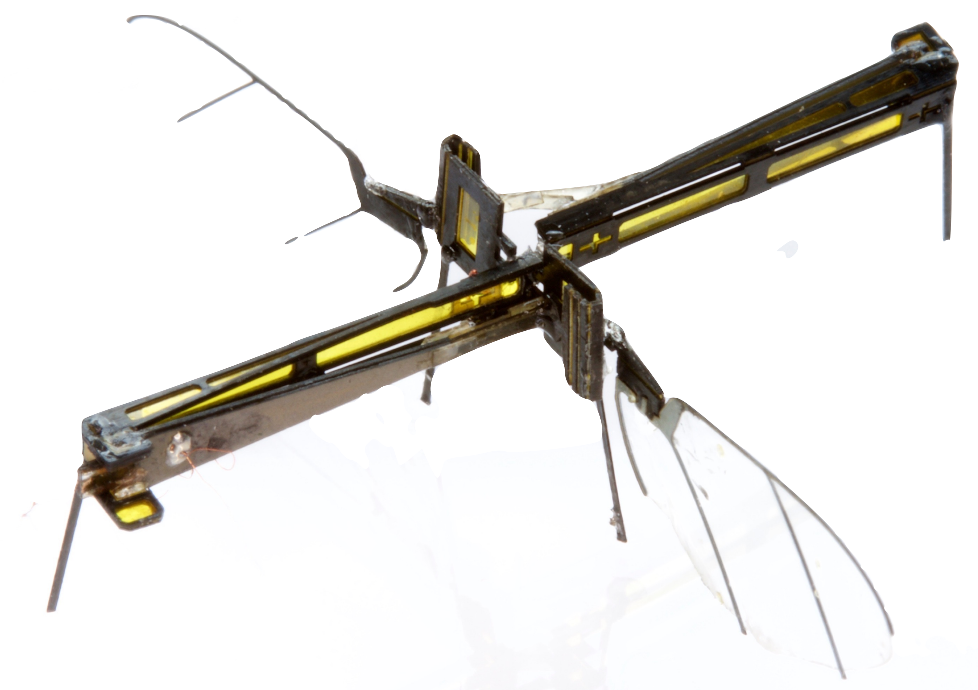


design of soft
robots
(large
deformations are
hard to model)



tiny robots
(minimal computation,
limited sensing)

My research: Insect-sized robotics

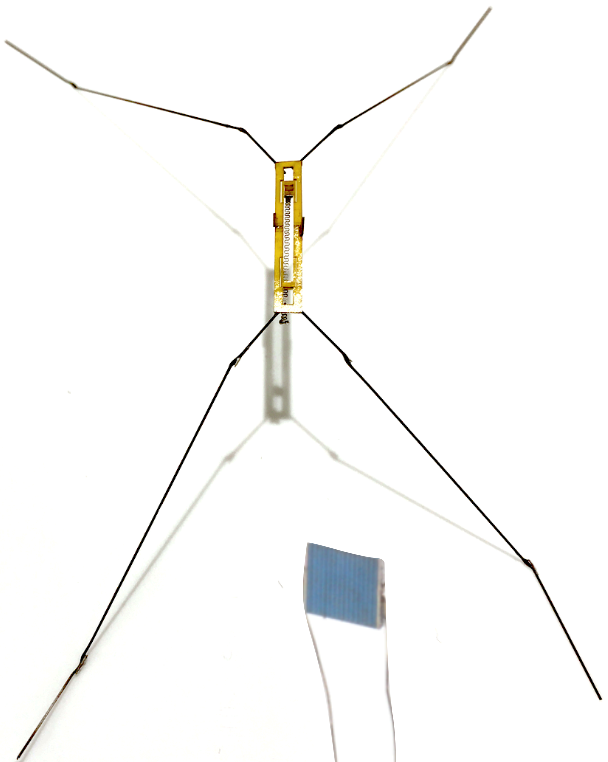
(images to scale)

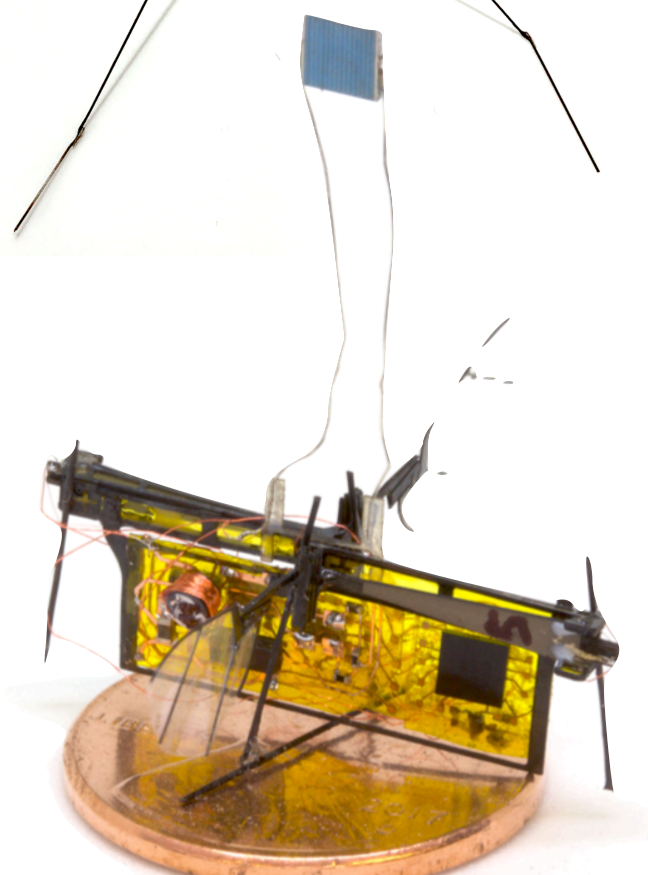
Dr. Sawyer B. Fuller
Assistant Professor

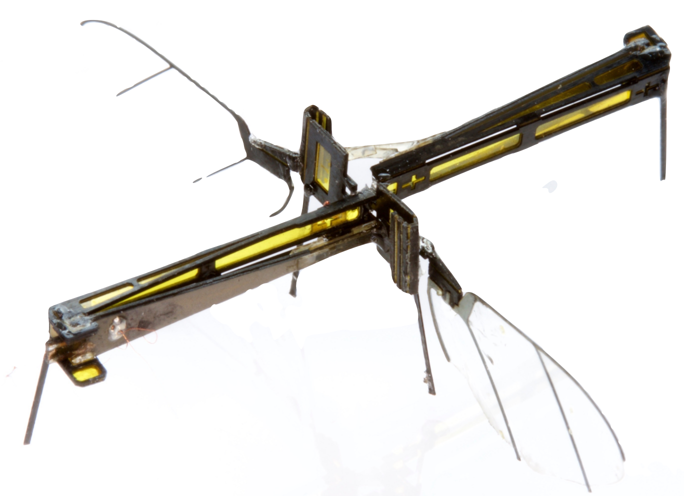
UNIVERSITY *of* WASHINGTON
MECHANICAL ENGINEERING

Autonomous Insect Robotics Laboratory

Est. 2015







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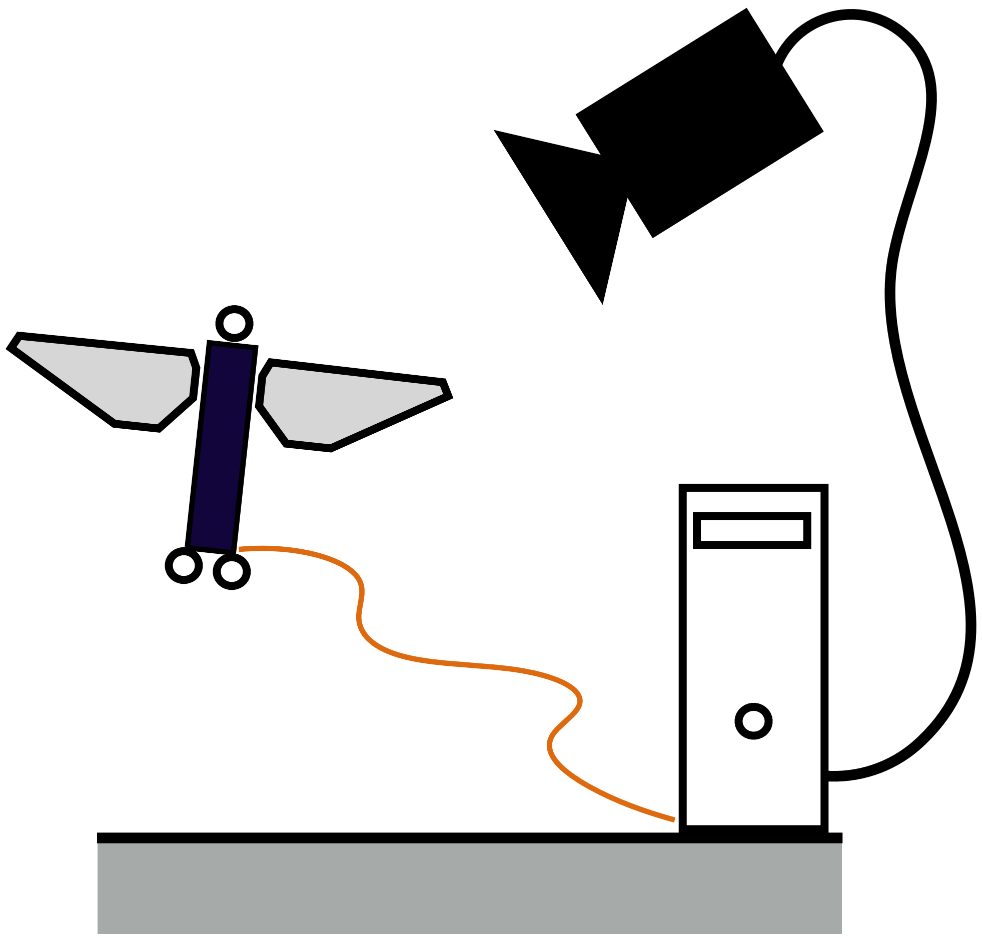
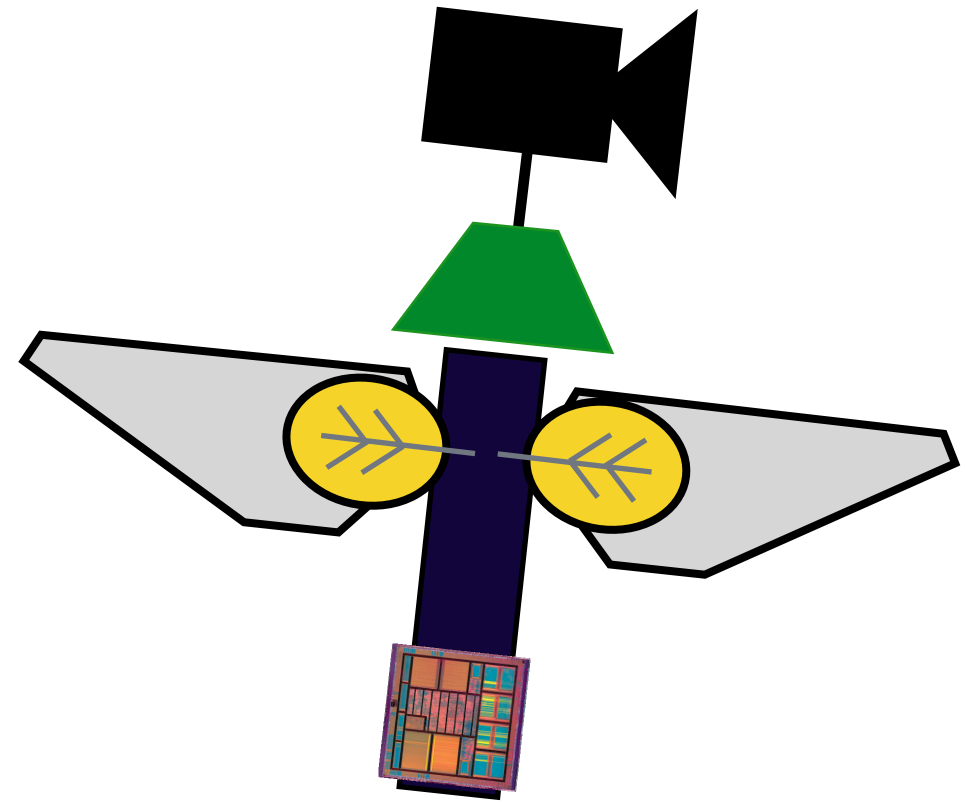
Ma, Chirarattananon, Fuller, and Wood, *Science* 2013

previous work



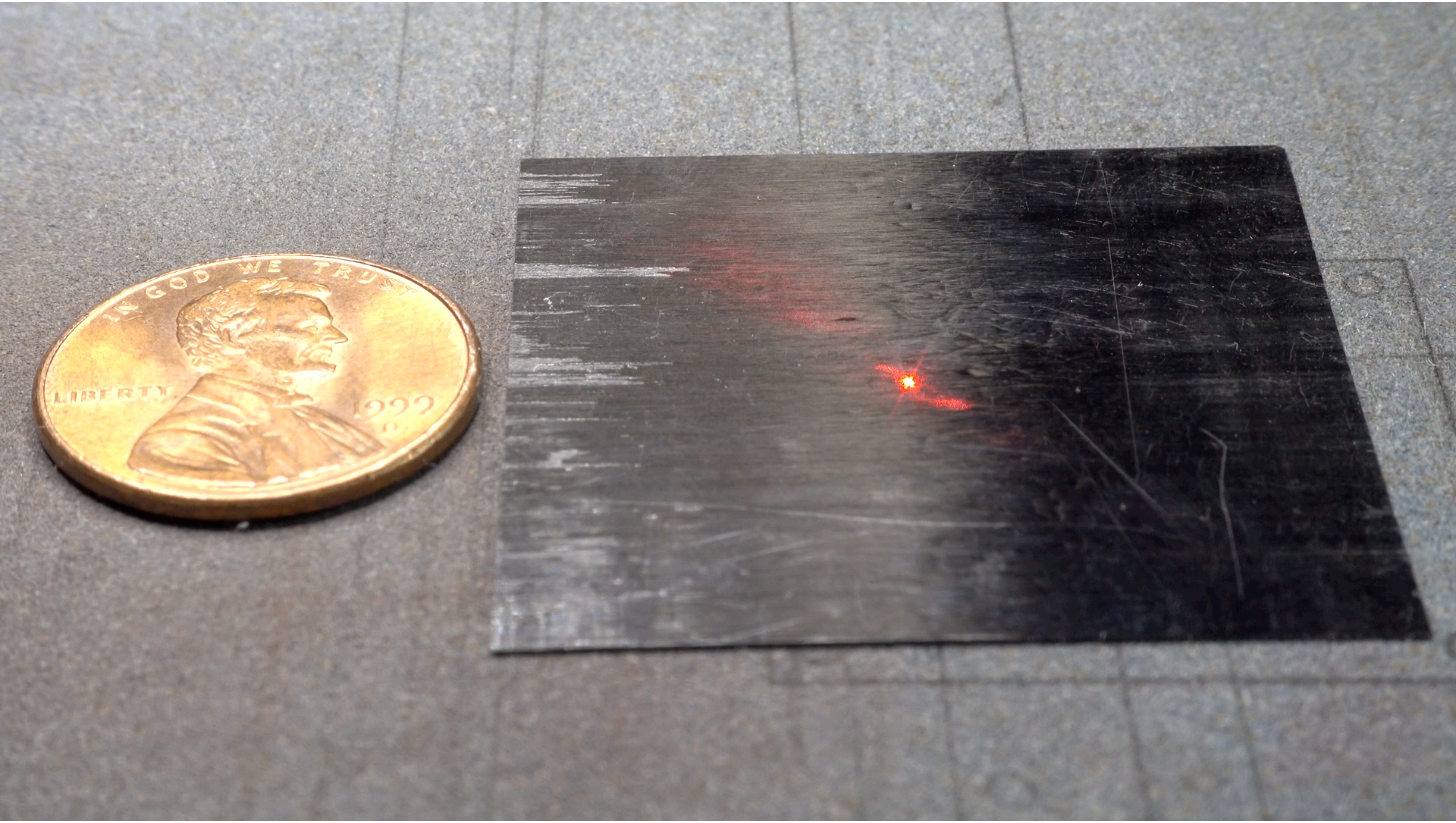
- external power
- external sensing
- external computation

current research

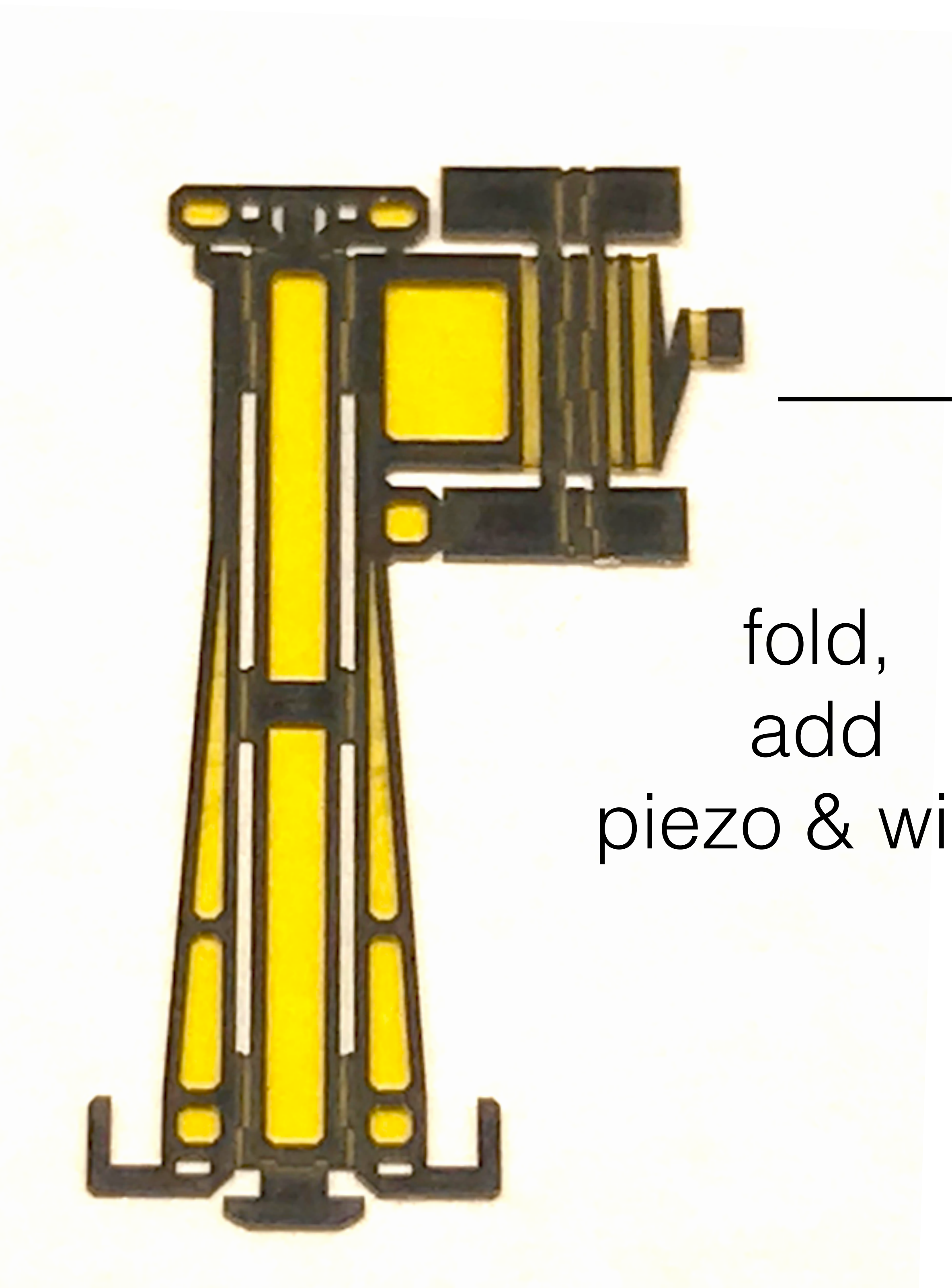


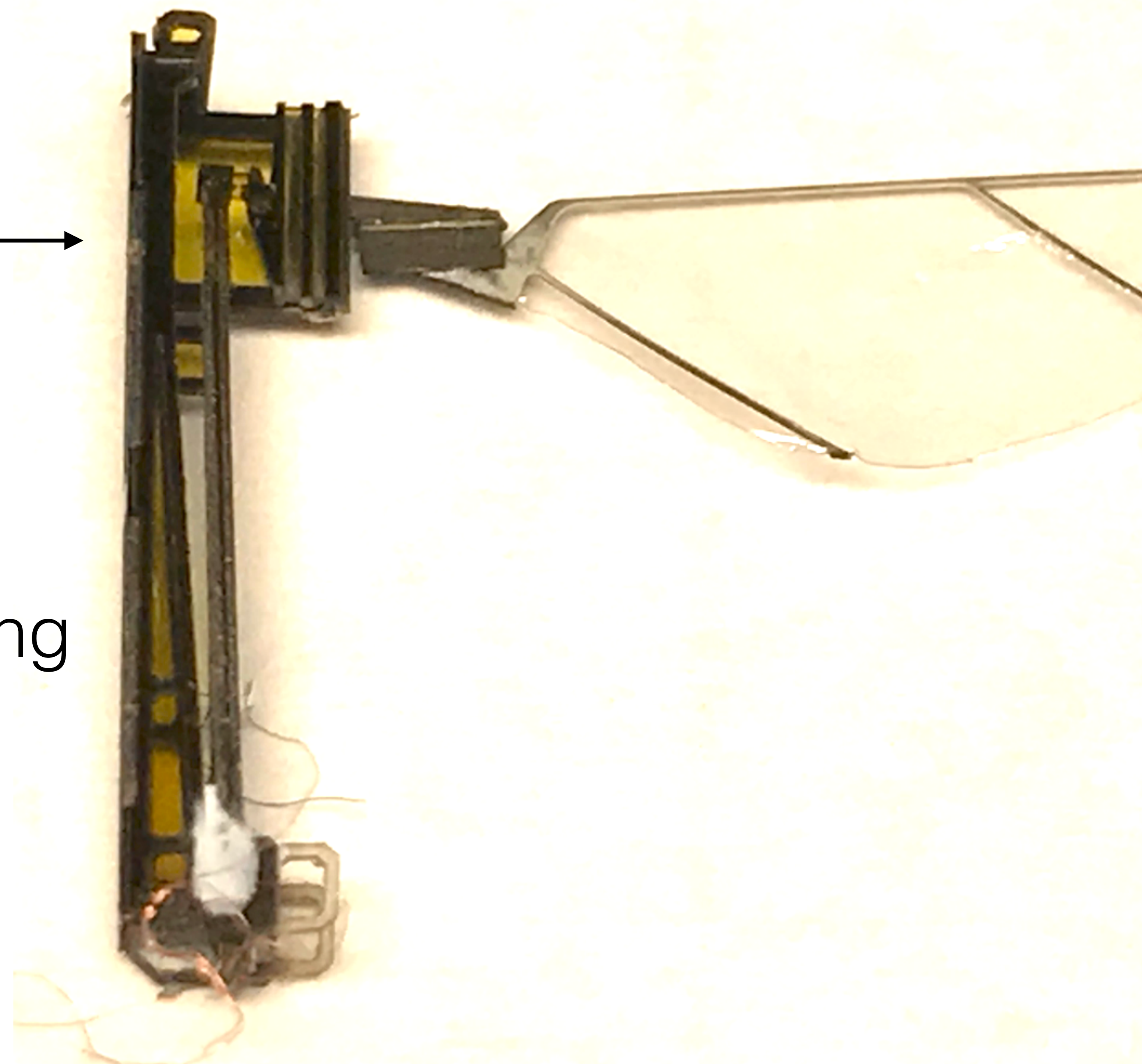
- improved capabilities
- onboard sensing
- onboard computing
- onboard power

355 nm laser micromachining

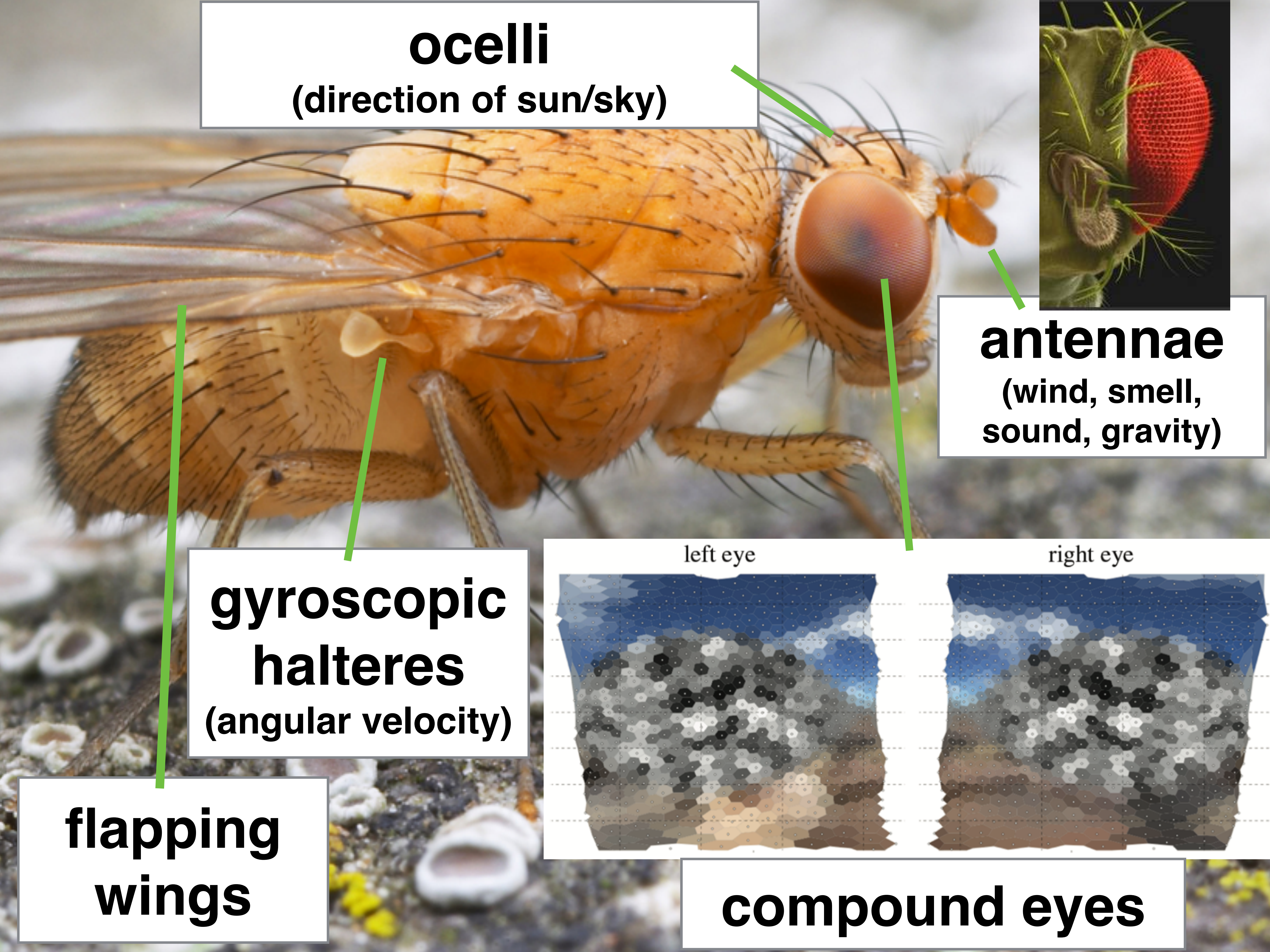


assembly

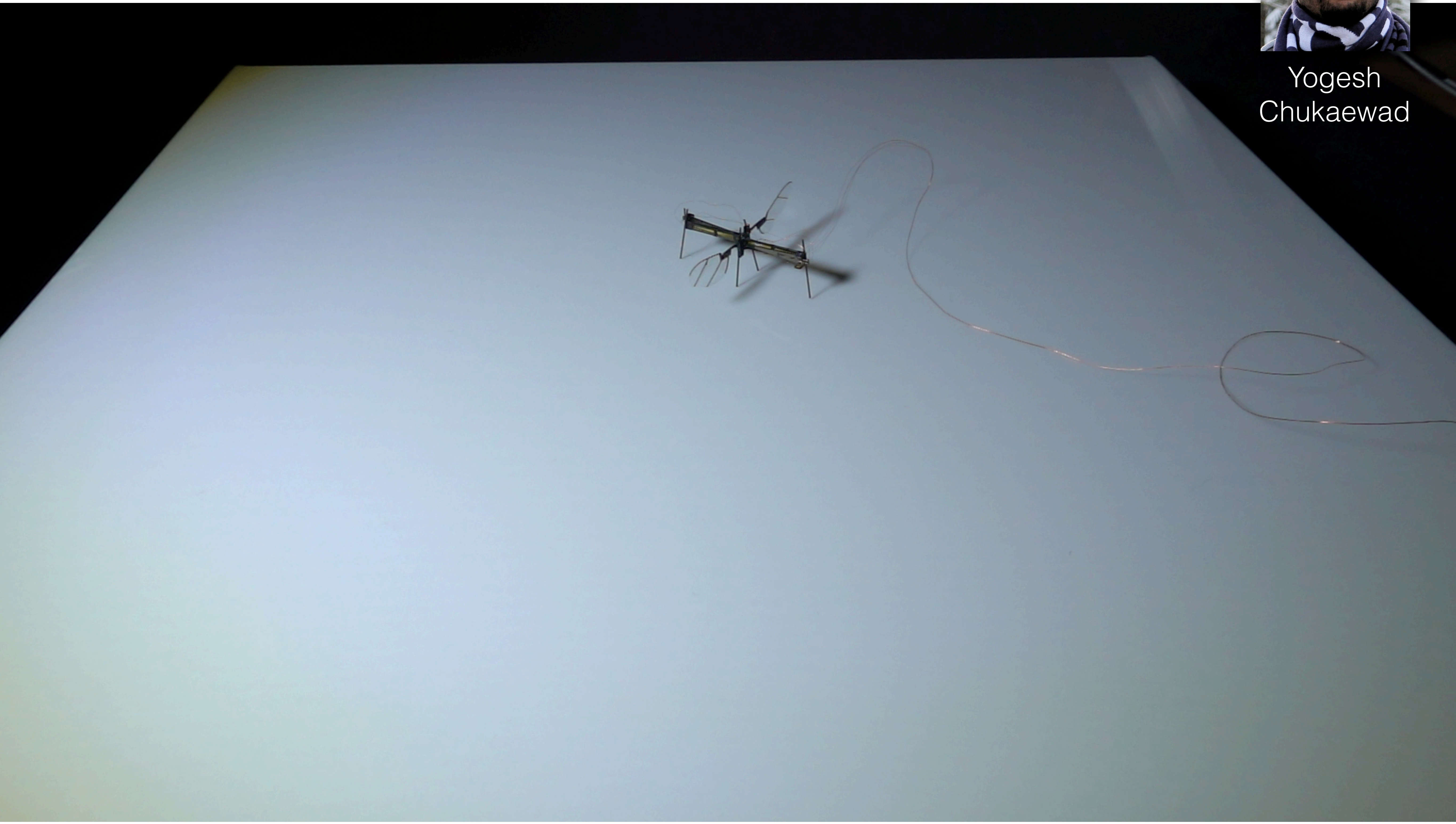




fold,
add
piezo & wing

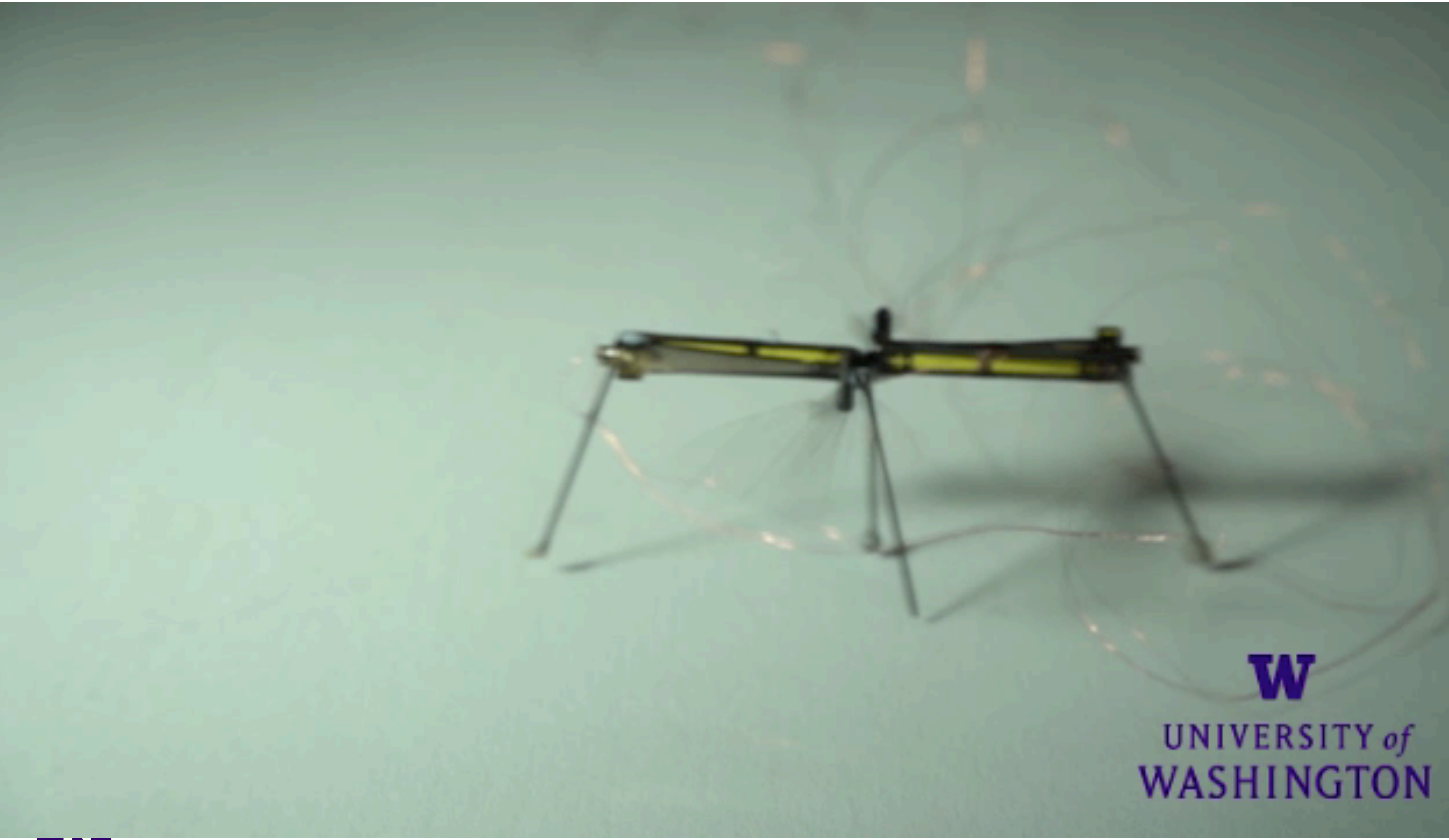

ocelli
(direction of sun/sky)
antennae
(wind, smell,
sound, gravity)
gyroscopic
halteres
(angular velocity)
flapping
wings
left eye
right eye
compound eyes

takeoff and landing

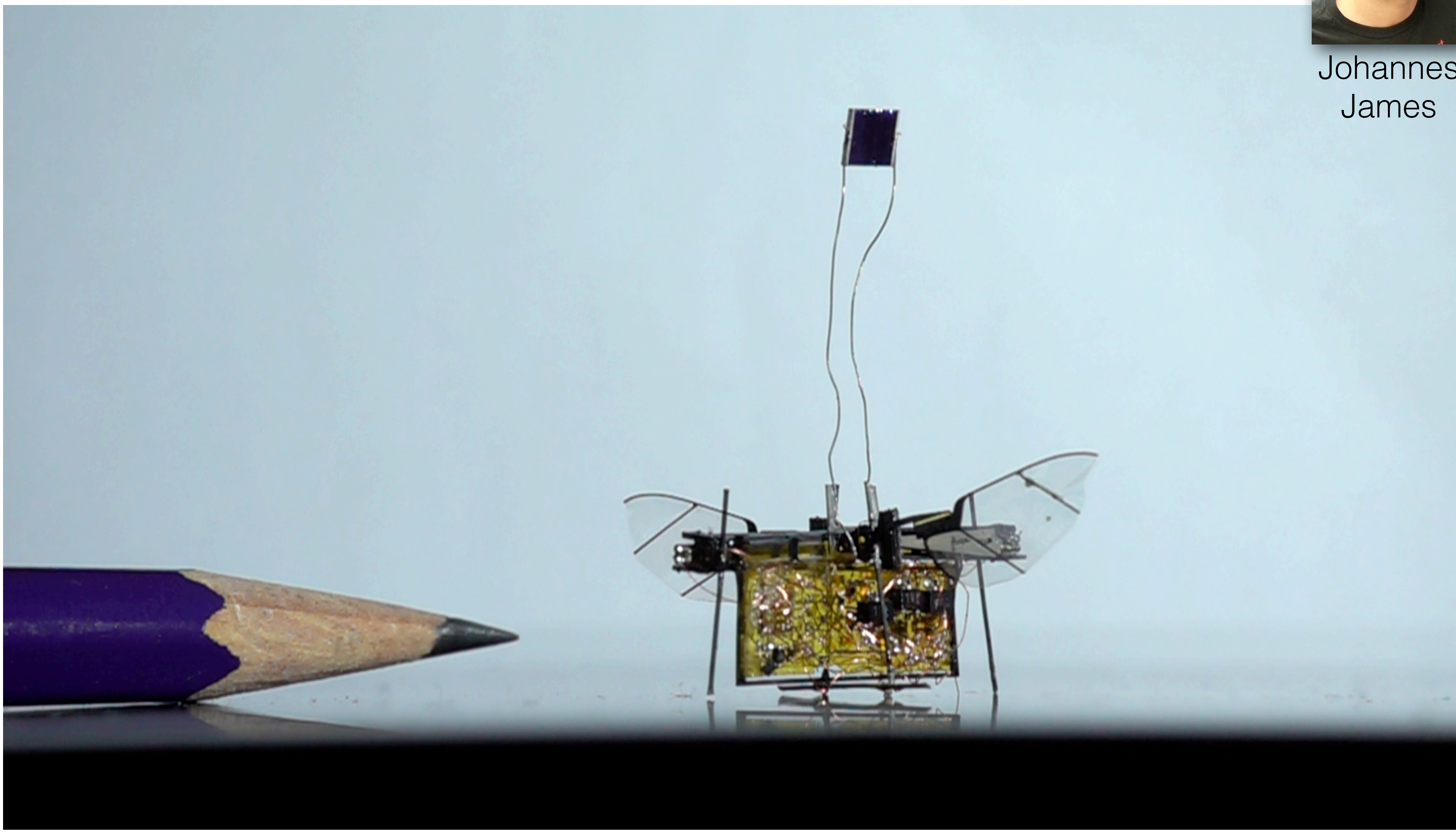


Yogesh
Chukaewad

Ground ambulation



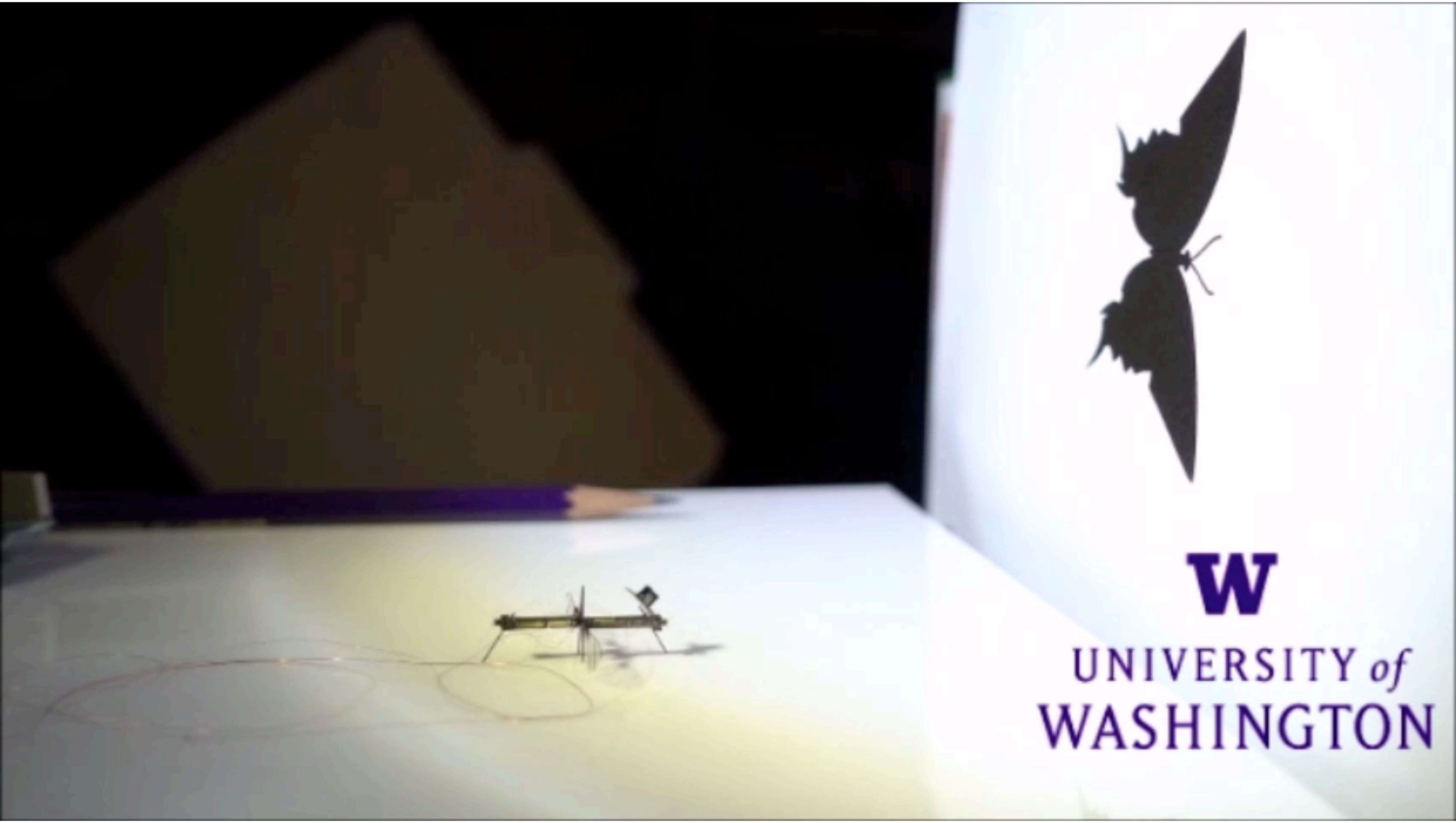
first untethered flights (powered by laser)



Johannes James

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

sight



robotic plume tracking

signal amplifier

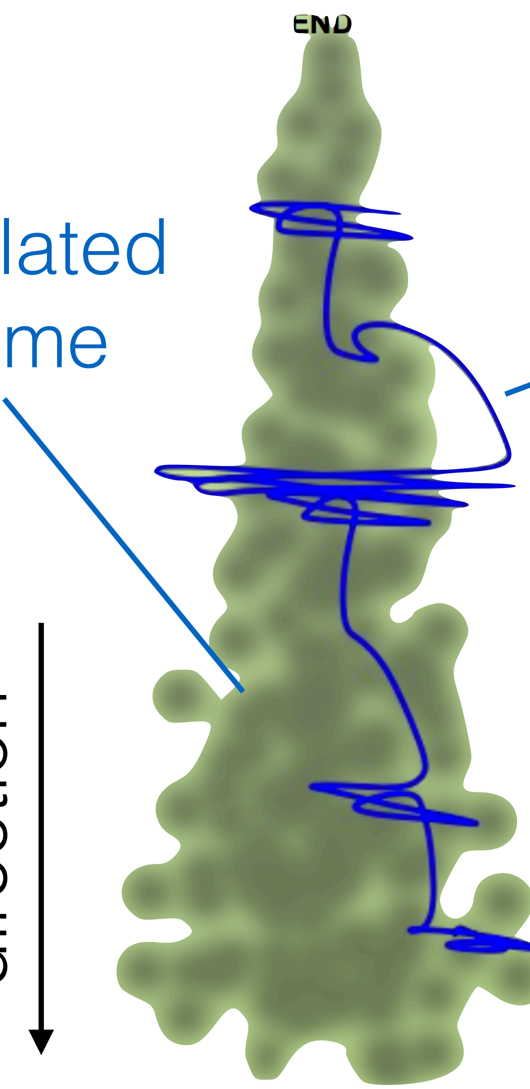
moth antenna

Melanie Anderson

Tom Daniel

simulated plume

path of real robot



wind direction