DRAPER

DragonflEye

IMAPS NE Symposium 2017

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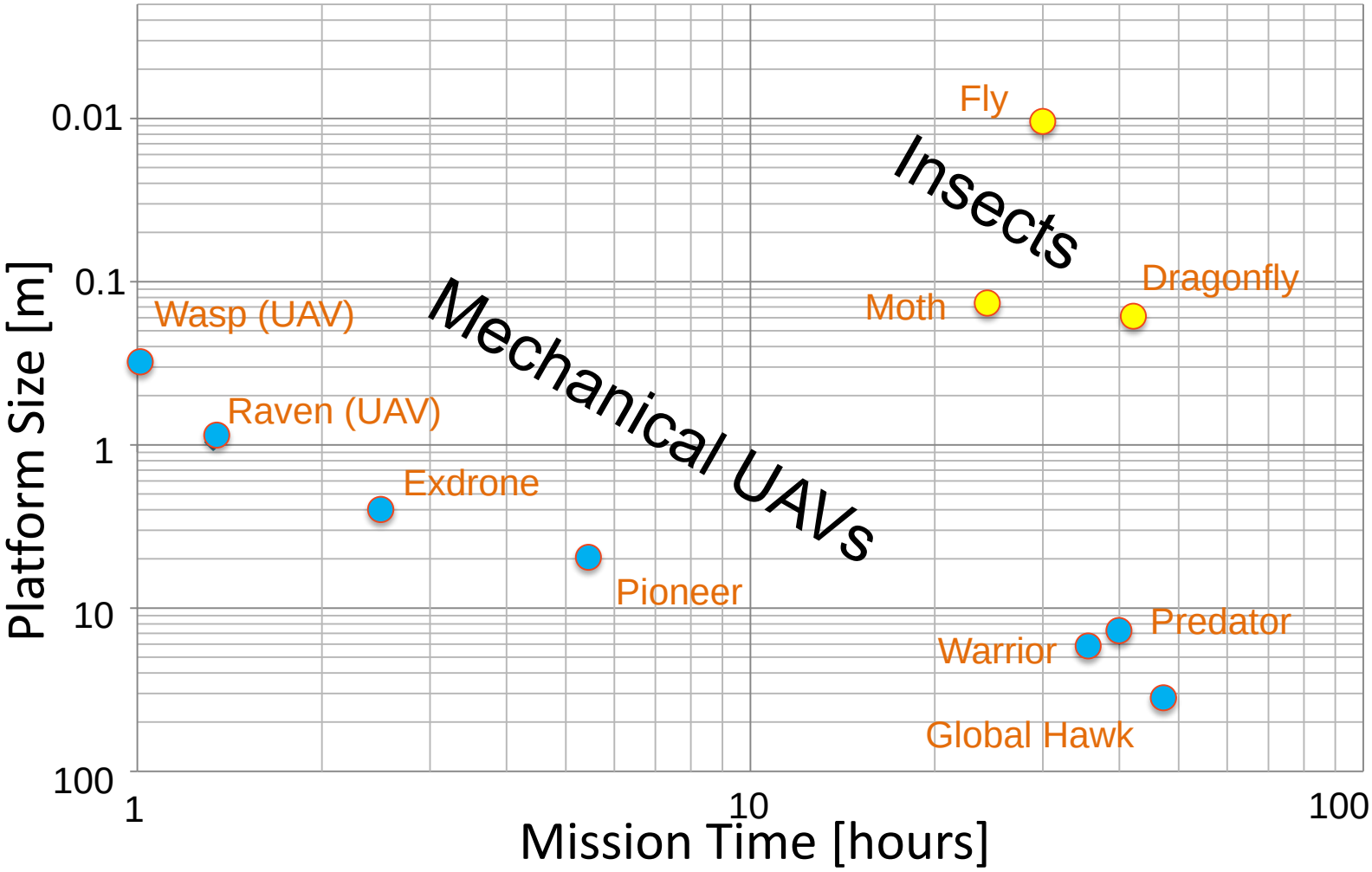
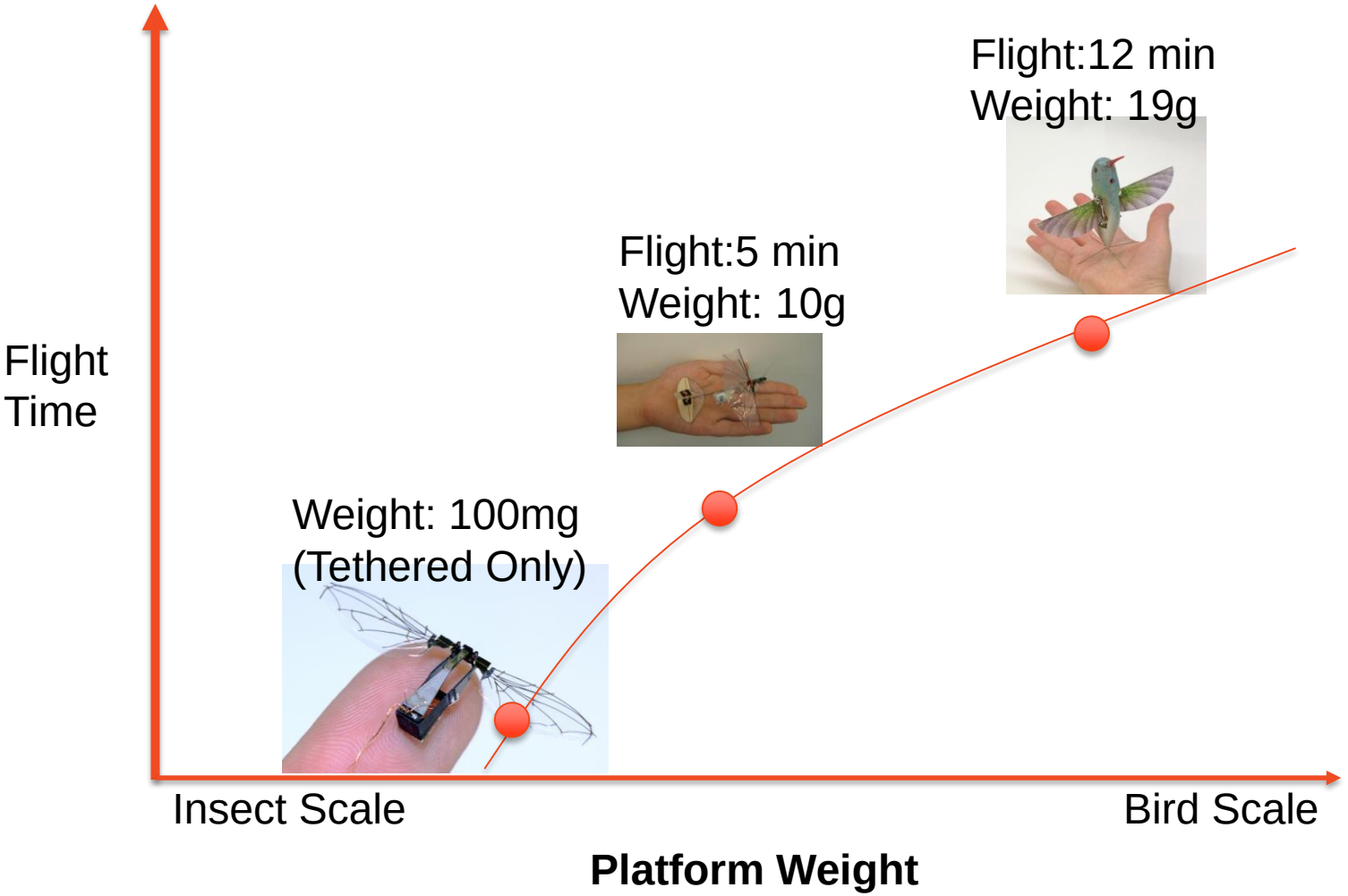
May 2nd, 2017

Platform Size vs Standoff



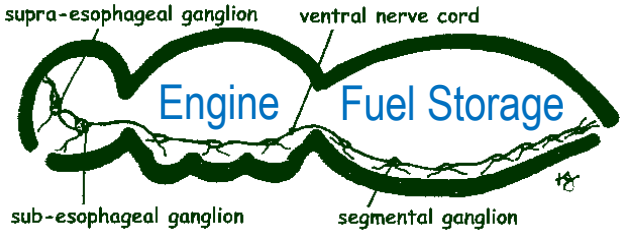
Energy Storage Limits of Current Technology

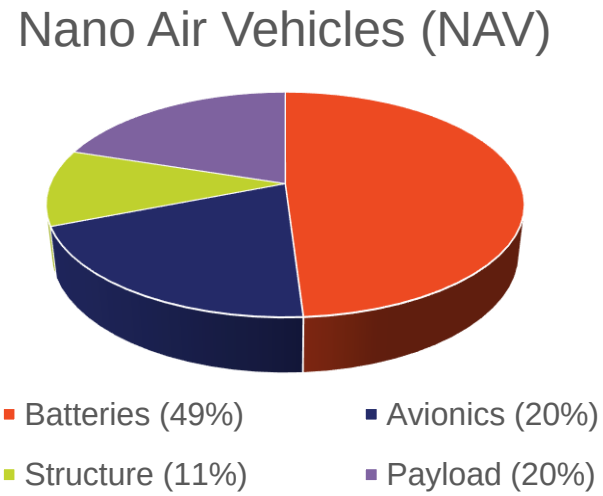


Key Insight: Biology Excels in Efficiency

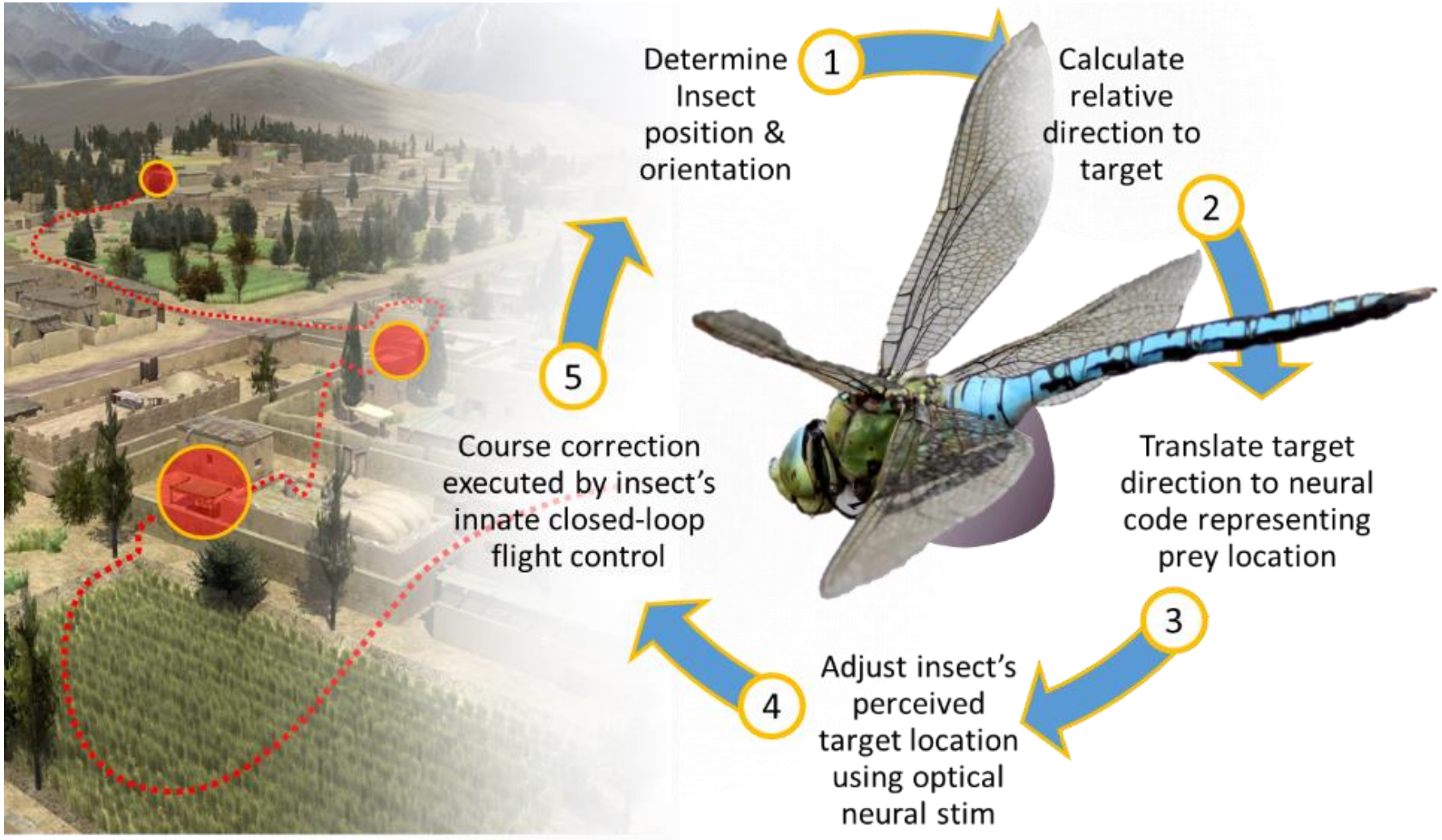
Dragonflies are strong, stealthy, and efficient

- Size: 5-20 cm
- Weight: 400mg – 1.5g
- Payload: up to 300mg
- Distance: up to 100s kilometers per day
- Speed: 10 mph ave, 35 mph max
- Agility: 4g linear accel, 9g sharp turns





Solution: Harness Biohybrid Systems

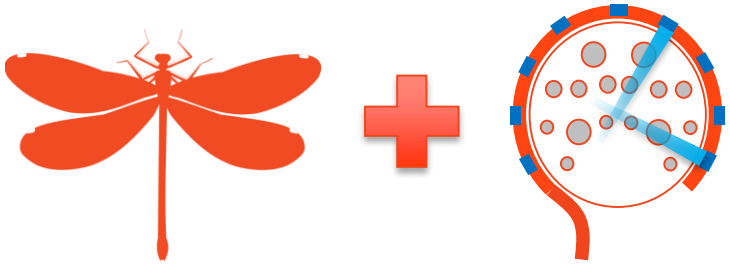


The Cybernetic Approach

Robotic MAV

Energy Storage Limited

Complex Control



Cybernetic Insect MAV

Efficient and Eats In Flight

Existing Biological Control System

Challenges

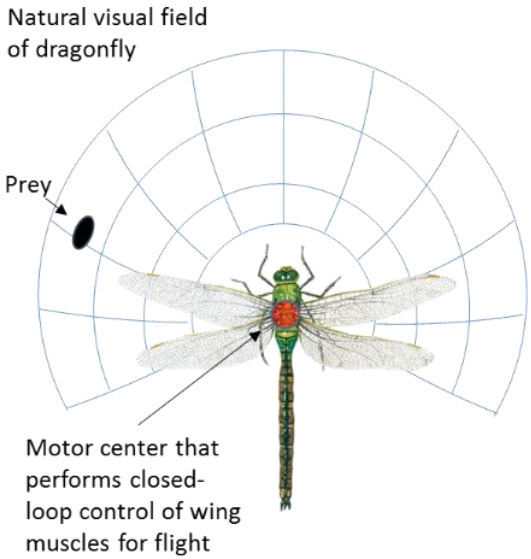
Previous attempts to control insect flight failed due to:

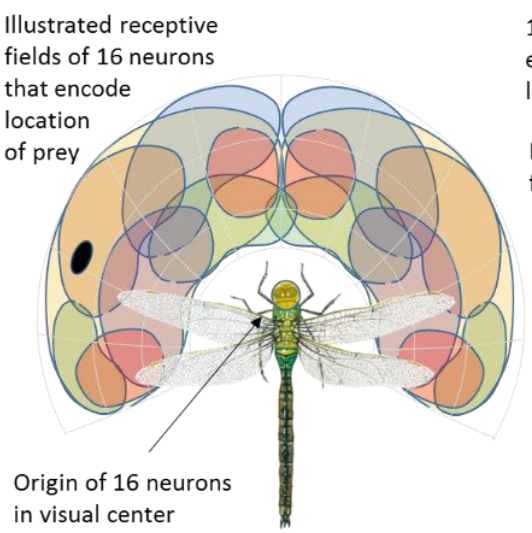
1) A lack of understanding of the neuromuscular mechanisms controlling flight and disruption of innate closed-loop control
2) Poor spatial resolution and selectivity of electrical stimulation which undesirably activates all neurons and muscle fibers in the vicinity of the electrode
3) Heavy or tethered electronics modules that destabilize flight

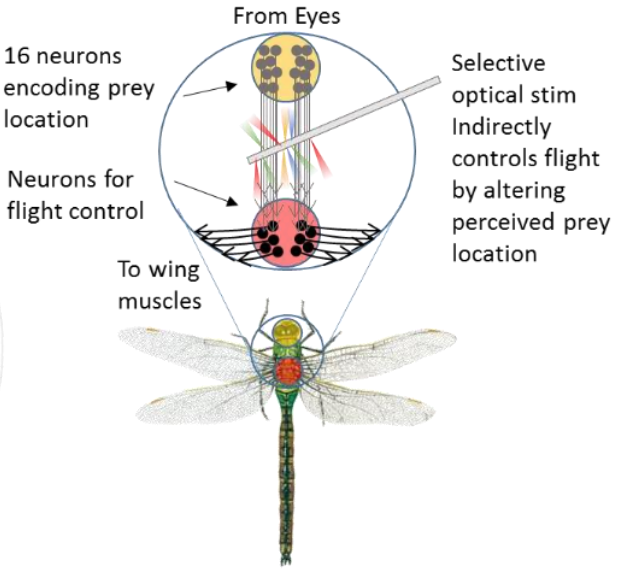
New solutions

1) A lack of understanding of the neuromuscular mechanisms controlling flight and disruption of innate closed-loop control

8 pairs of neurons found to encode flight direction to prey





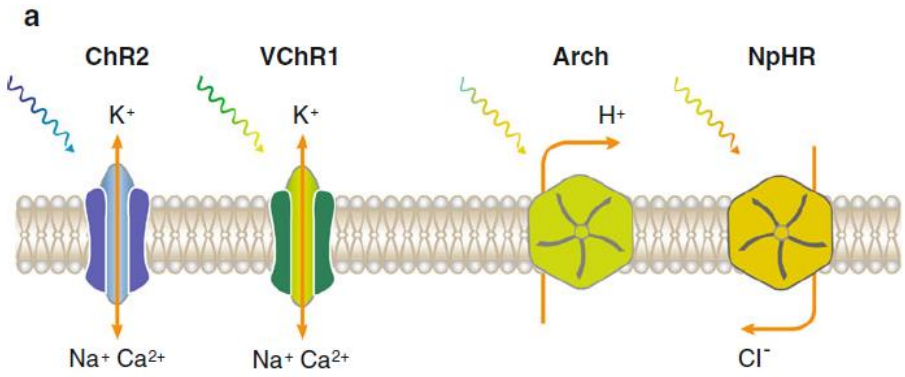


Source: Janelia Farm

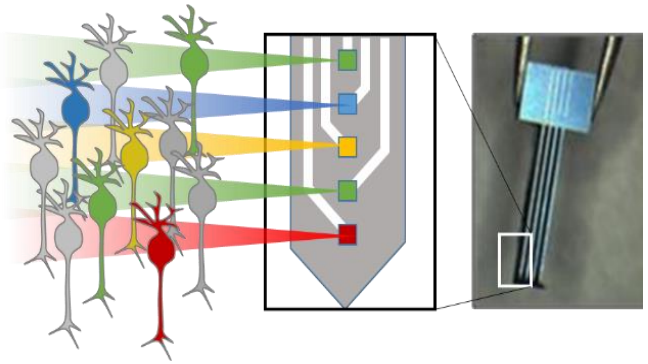
New solutions

2) Poor spatial resolution and selectivity of electrical stimulation which undesirably activates all neurons and muscle fibers in the vicinity of the electrode

Optogenetic neuromodulation uses new gene editing tools to make targeted neurons responsive to light, allowing more precise activation patterns than electrical stimulation



a) Optogenetic tool achieve cell response upon light stimulation



b) Optrode designs can achieve micron-scale precision in spatial illumination patterns and light multiplexing

New solutions

3) Heavy or tethered electronics modules that destabilize flight

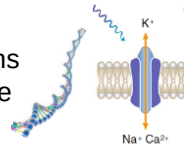
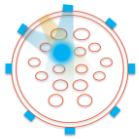
ASIC design, flexible miniaturized packaging, novel antennas, and light-weight air cell or solid-state batteries can be leveraged for extreme ultra-light payloads

Source: Janelia Farm

1st Gen: Solar cell and supercap for ~5sec of neural recording from a single channel

2nd Gen: Wireless power and data from 1 recorded channel using RF power and backscatter

Thrust Areas & Impact / Applications

Technical Area	DRAGONFLeye Focus	Who would care
GENETIC ENGINEERING Make neurons light-sensitive 	Use of optogenetics to provide higher precision neural modulation	Medical Community Agricultural Community Materials Science Community
NEURAL ENGINEERING Neural code for steering flight direction  Janelia Farm, HHMI	Guided flight of dragonflies	Avionics Community Ecologists & Disease Control Intelligence Community
PRECISION OPTRODE Precision neuro-modulation 	Precision high-density neural modulation with light	Neuroscience Community Medical Community Communications Community
ULTRA-LIGHT PAYLOAD Navigation Processing Optic drivers Power 	Navigation system light enough to be carried by small insects	Medical Community Wearable Tech Community Intelligence Community

Ultra-light Payload: Target Weight

150 mg Payload

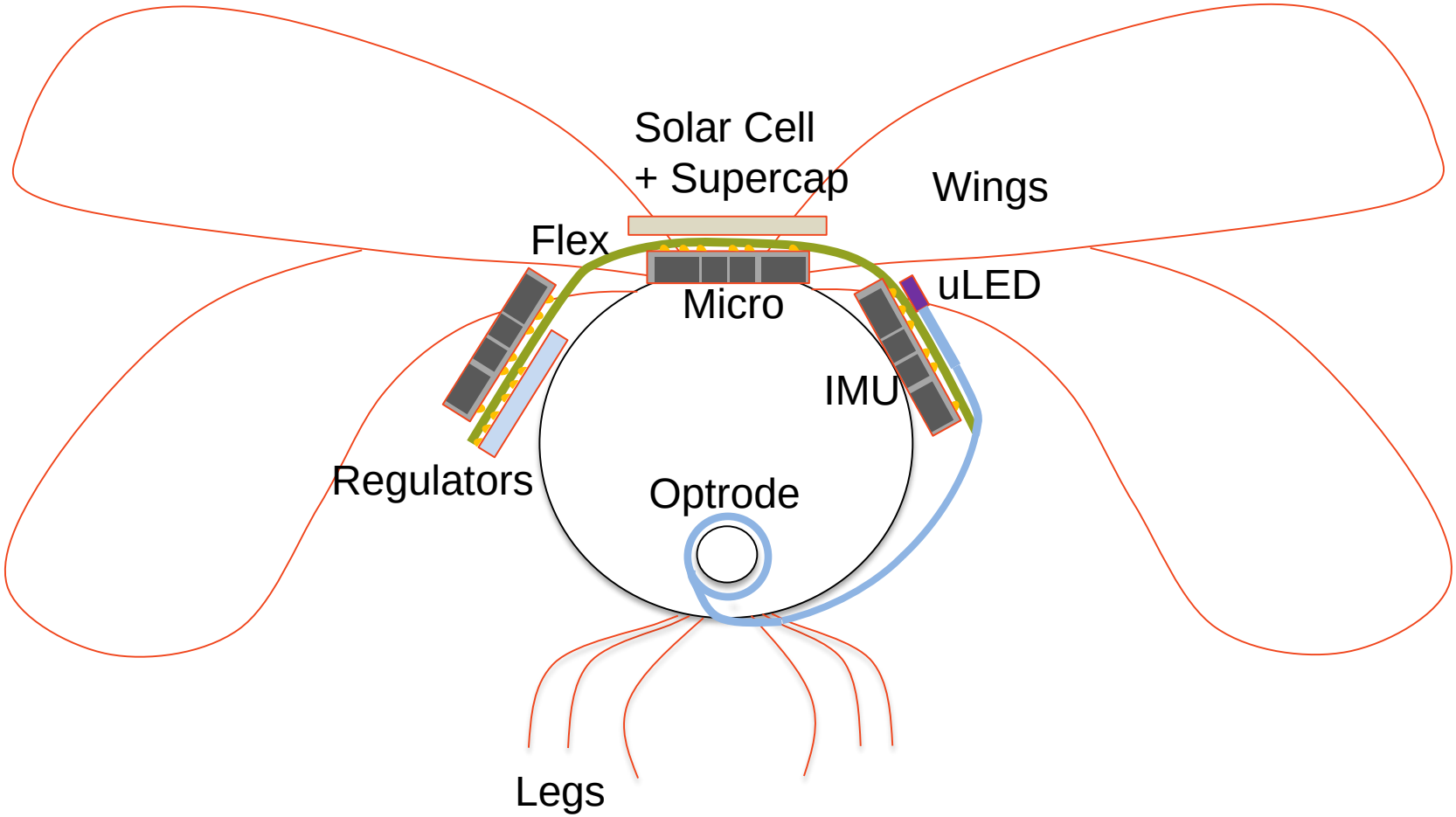
Payload

- Energy Storage
- Computation
- Inertial Guidance
- Solar Energy Harvesting
- Communication
- Optical Sources/Drivers
- Flexible Optrode

34 Grains of Sand
1 Matchstick

Ultra-light Payload: Packaging

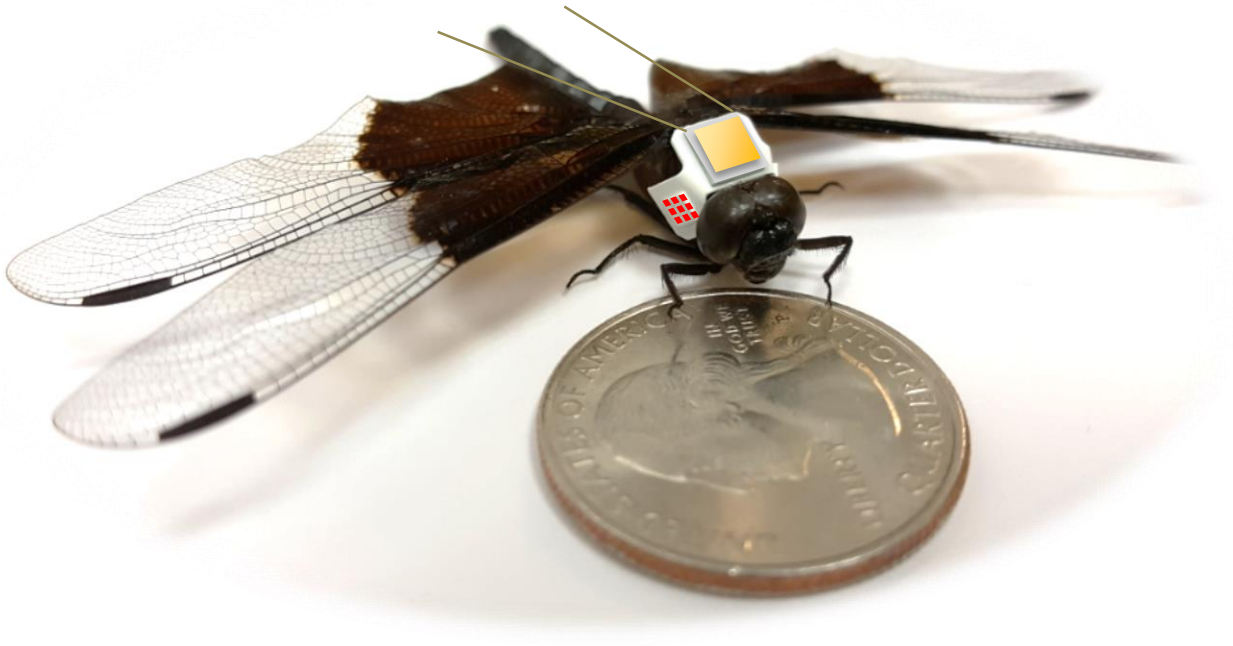
Current Concept



Current Approach - Payload

Autonomous determination of desired flight direction and optical stimulation control

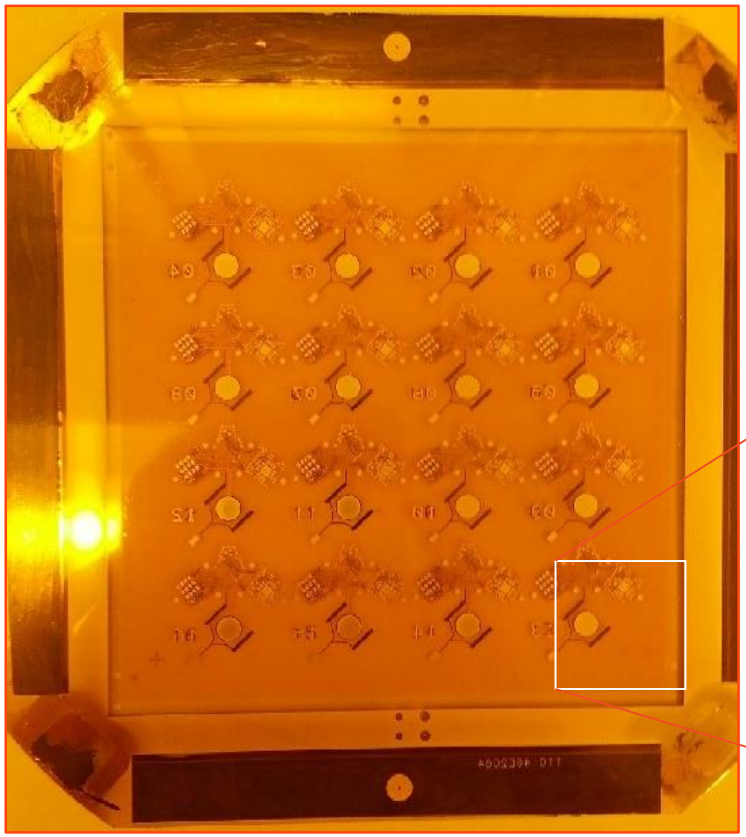
Power + Light Source + Tracking (+ Wireless Data)



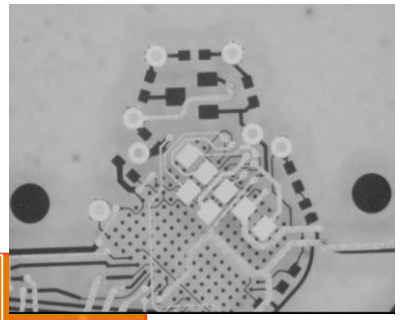
POWER	Solar Cell Energy Harvester Super Capacitor
LIGHT	uLED Array Optrode
TRACKING	9 DOF IMU Microcontroller Backscatter

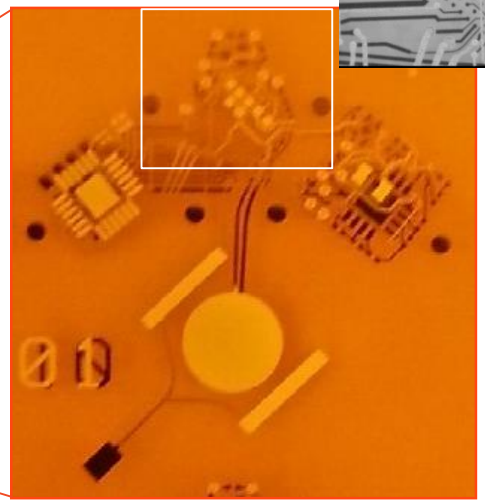
Payload Thrust Achievements

Panel of DragonflEye Backpacks



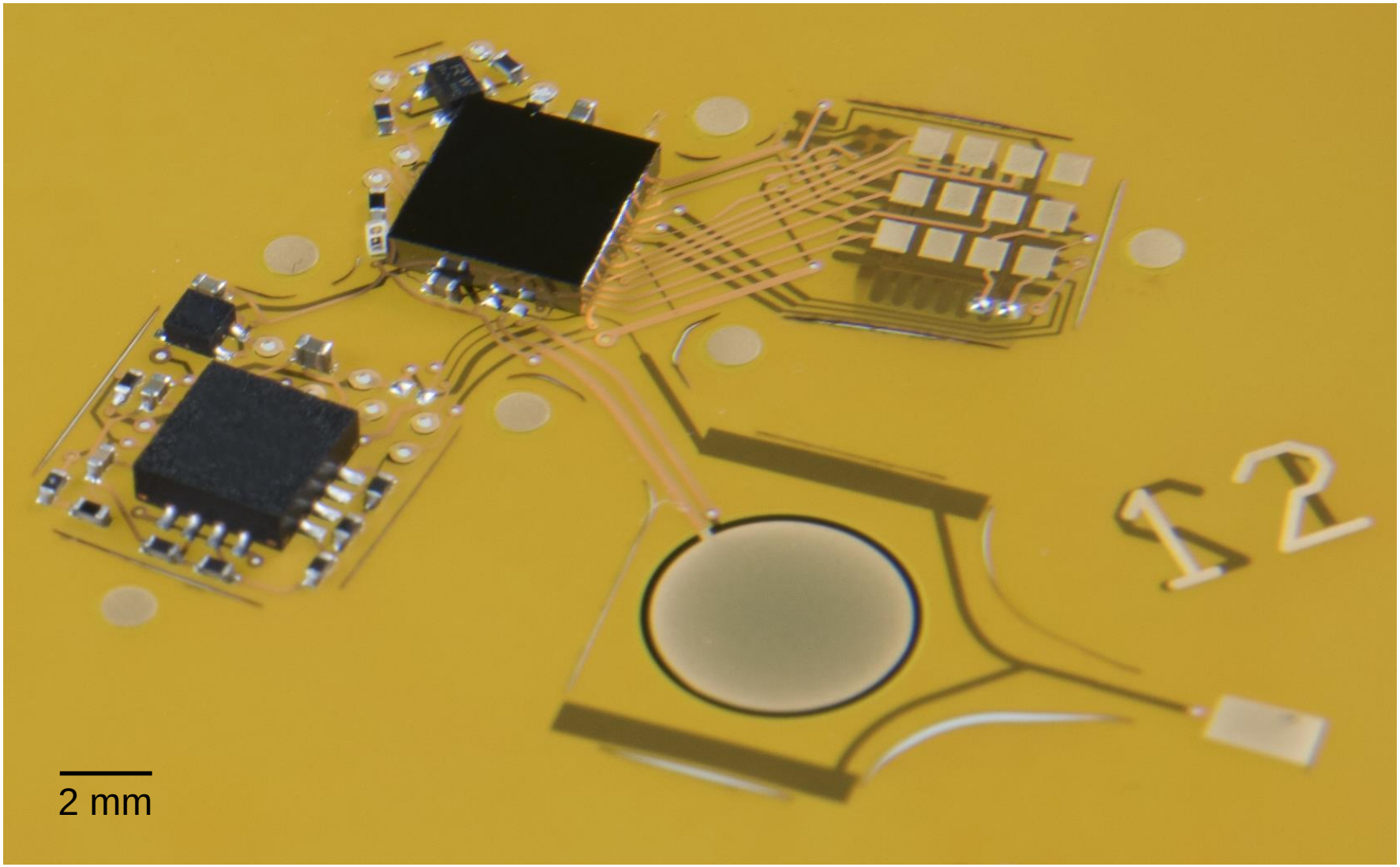
X-ray of boards





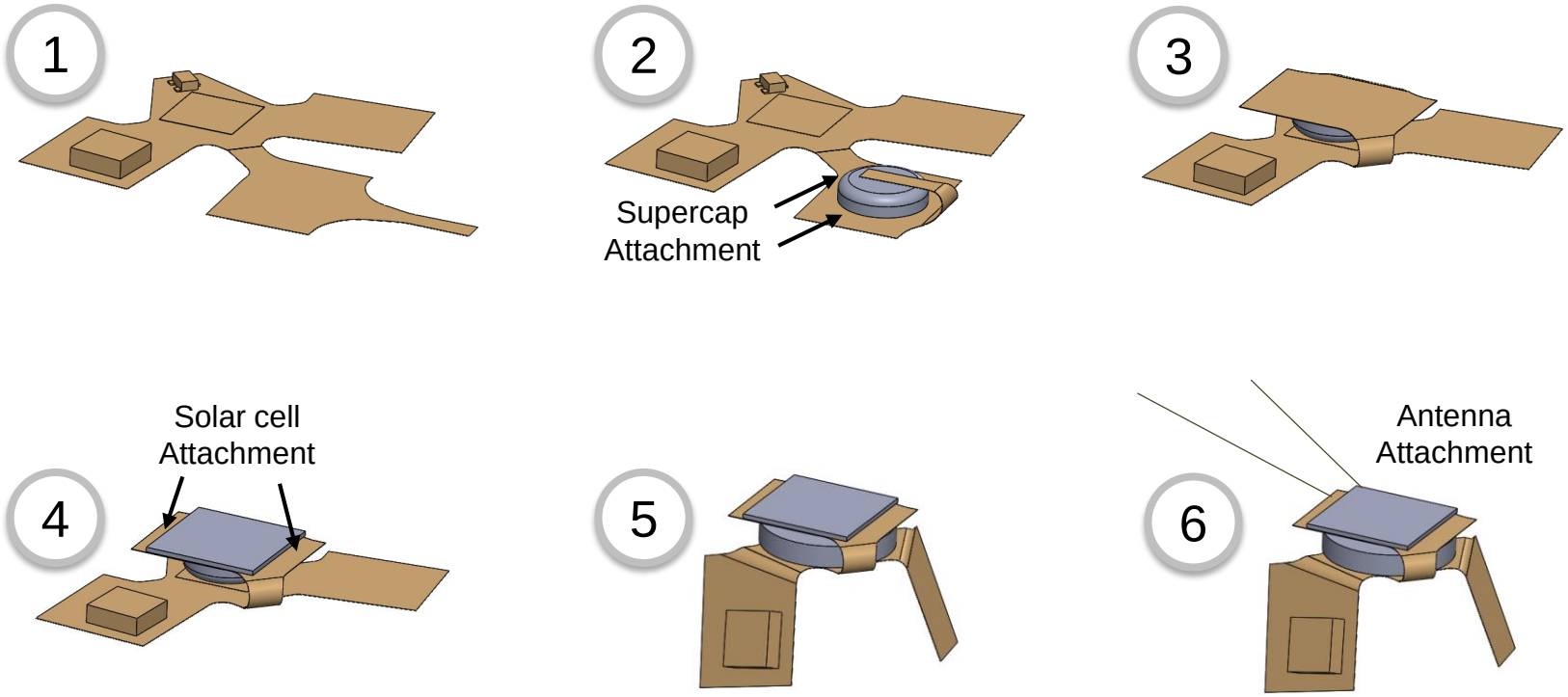
1.5 mil trace/space on 1 mil PI substrate

Partially Assembled Flex Circuit

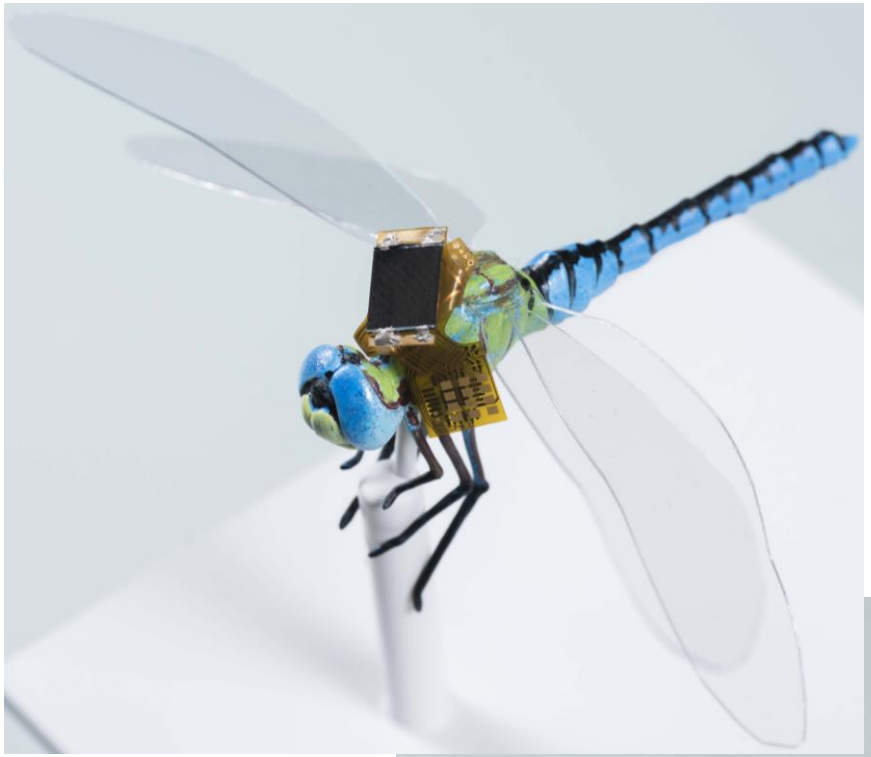


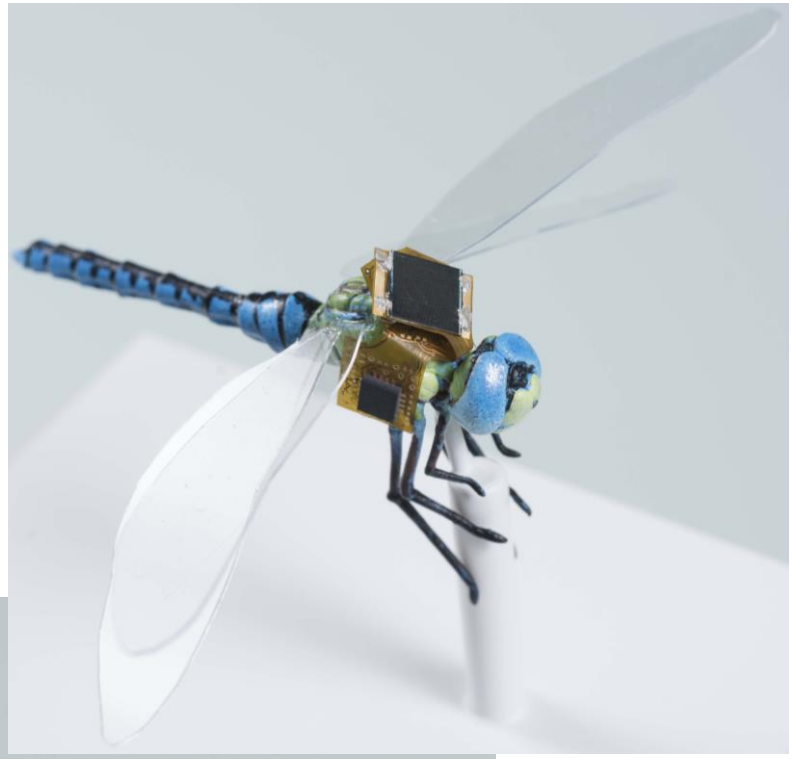
Assembly Sequence

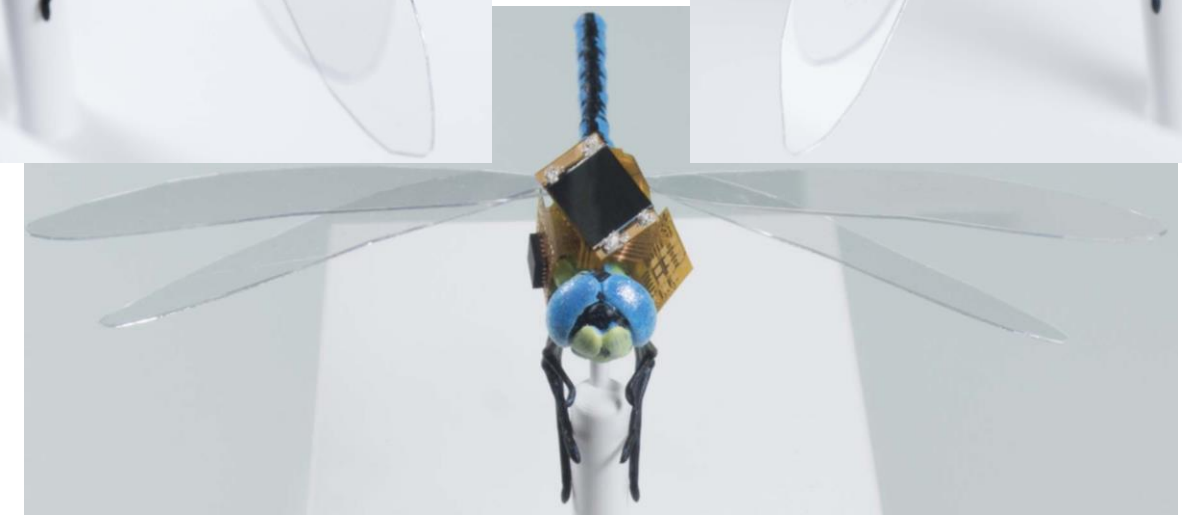
First generation backpack with compact ‘origami’ assembly and COTS parts



Mock-Up Model







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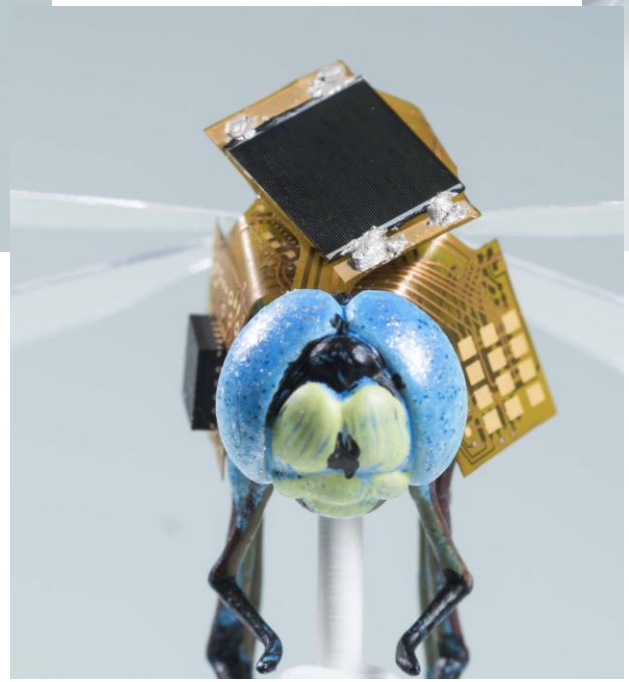
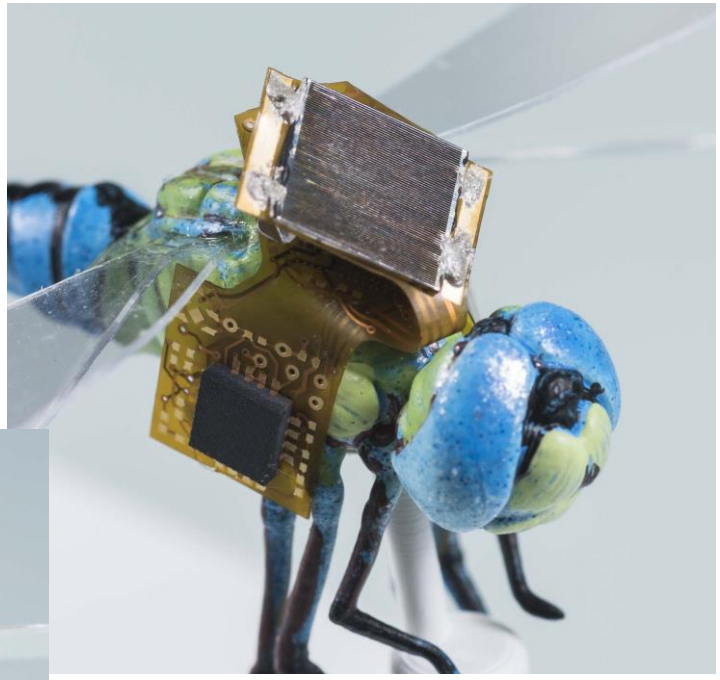


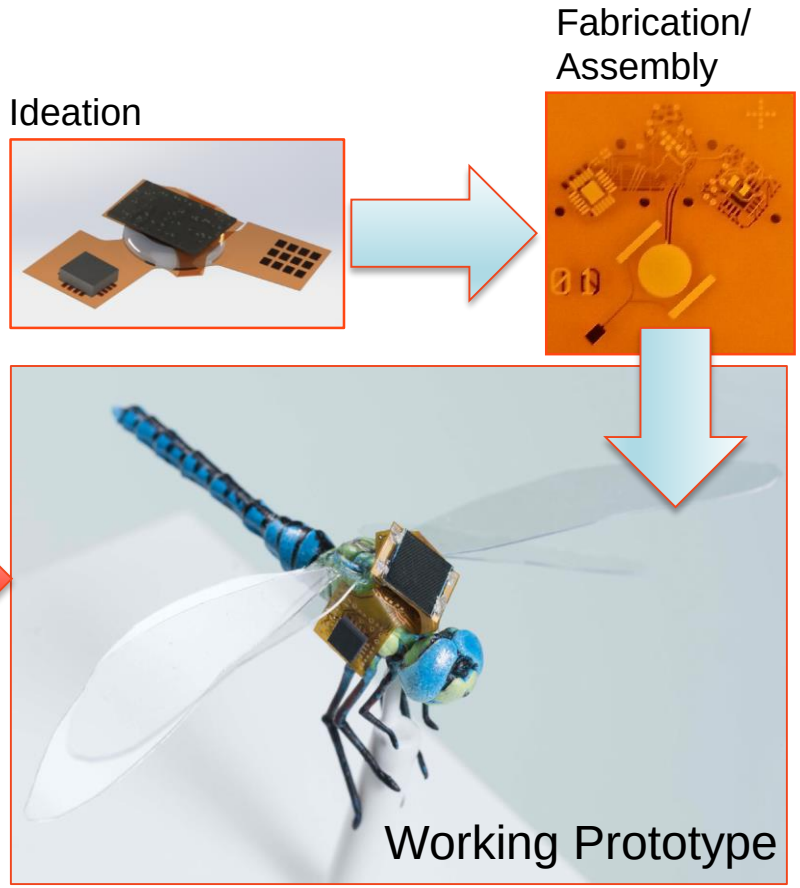


Summary

1 Year Point

Payload

- ✓ Energy Storage
- ✓ Computation
- ✓ Inertial Guidance
- ✓ Energy Harvesting
- ✓ Communication
- ✓ Optical Sources/Drivers



Next steps:

- Complete the first airborne testing of the navigation (in the next couple weeks)
- Integrated silicon die of all the major subsystems for space/weight savings.

Thank you!

Questions?