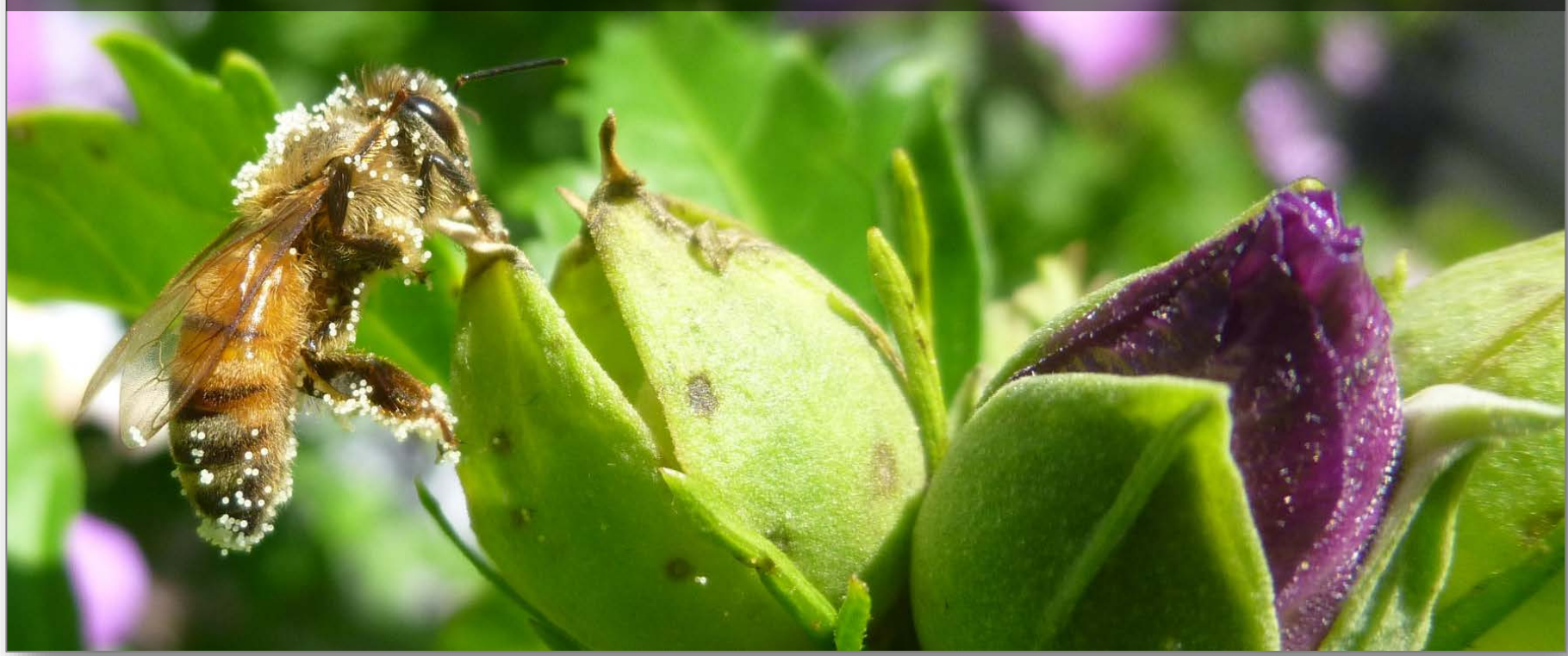


Leveraging Honey Bees as Bio-Cyber Physical Systems

Haron Abdel-Raziq¹, Daniel Palmer¹, Michael Smith², Caroline Chu¹, Junyi Huang¹, Prof. Alyosha Molnar¹, and Asst. Prof. Kirstin Petersen¹

Challenge:

SOCIAL INSECTS ARE CAPABLE OF LONG TERM OPERATION IN COMPLEX ENVIRONMENTS



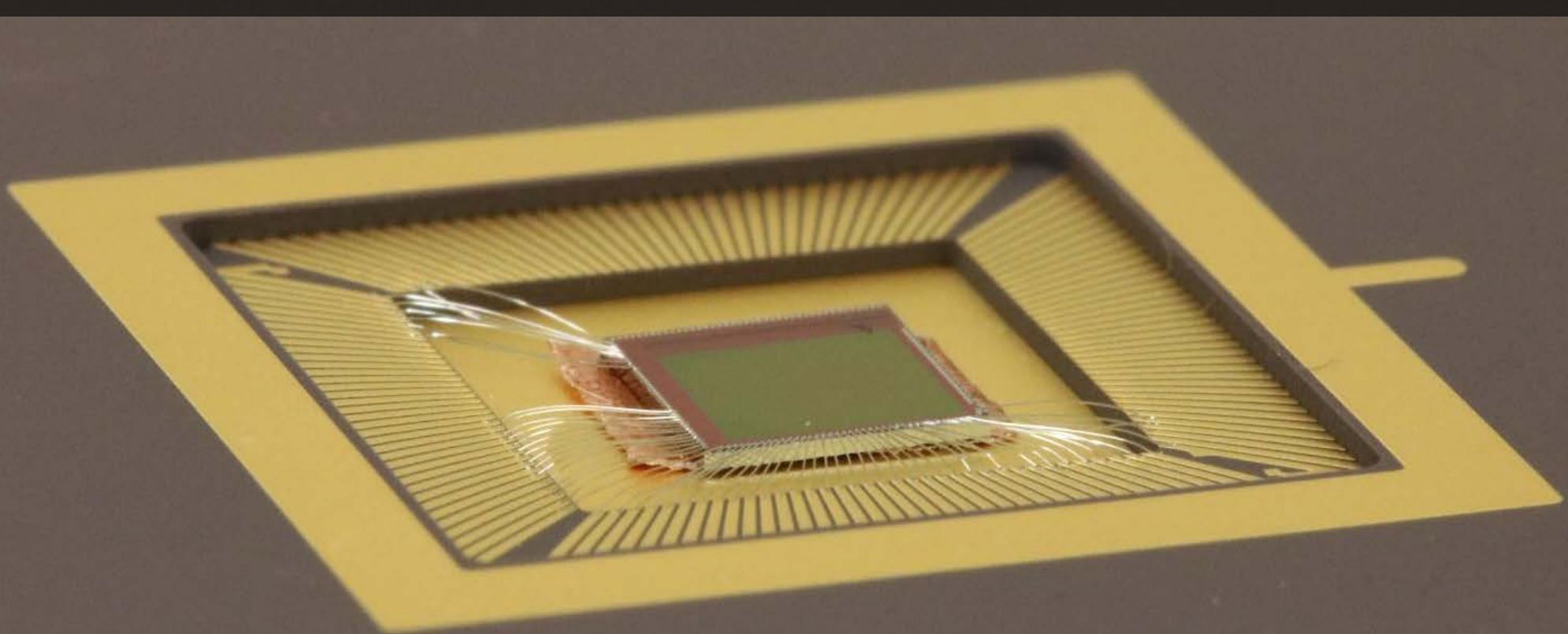
ENGINEERED CYBER PHYSICAL SYSTEMS ARE TASKABLE AND HAVE PERFORMANCE GUARANTEES



Can we improve upon the ability of social insects to sense and interact with the physical world, while providing data acquisition and control on par with explicitly engineered systems?

Solution:

MICRO-SCALE FLIGHT RECORDERS TO BE MOUNTED ON HONEY BEES



1) Visual scene capture and analysis, 2) thermal and mechanical sensors, 3) clock, 4) storage, 5) processing, 6) photovoltaic chargers, and 7) short range communication

WESTERN HONEY BEE (*Apis Mellifera*):



- Foragers in a colony: 20,000
- Flight distance: 600m
- Max flight distance: >10km
- Flight speed: 24-32km/h
- Forager payload: 55-65mg

EXPLORATORY TESTS ON LARGE-SCALE BEE-MIMICKING DRONE FLIGHTS

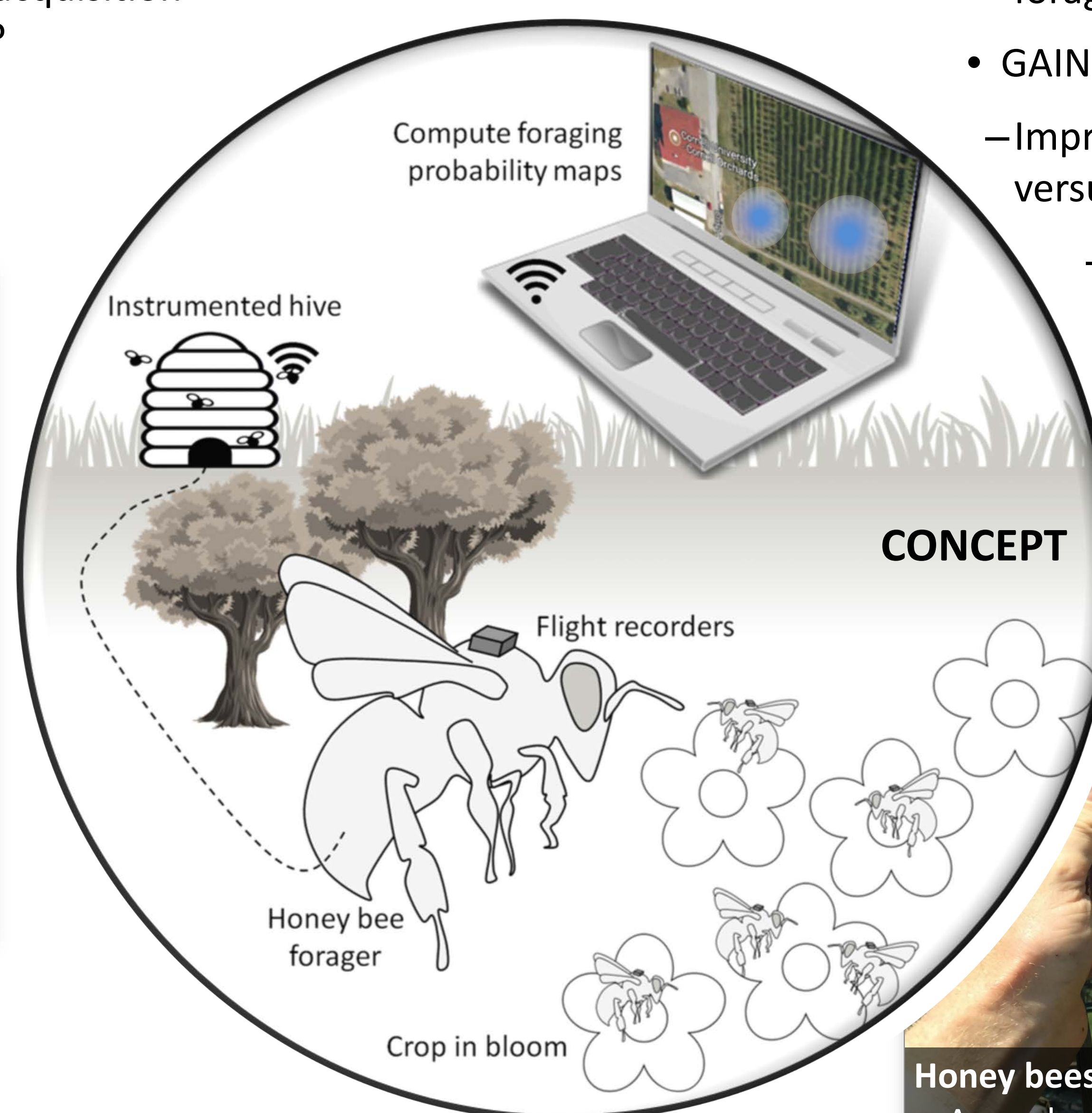


BEE-MIMICKING SHAKER TO ELICIT MORE POLLINATION AND FASTER DATA ACQUISITION

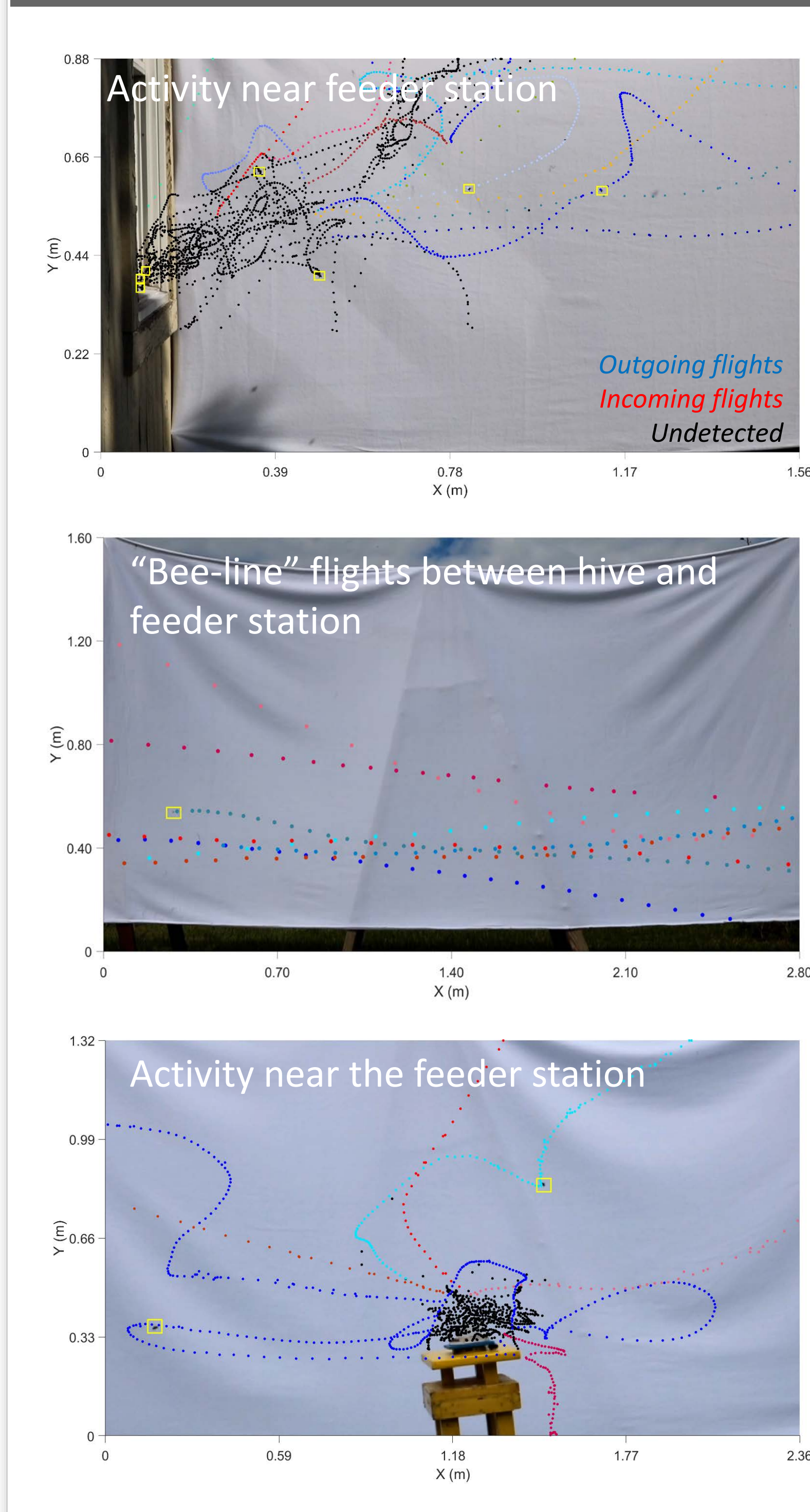


16Hz, 2 sec
20 times/min

A rotating magnet induces motion through glass in observation hives



HONEY BEE FLIGHT MODELS, TO BE USED FOR SLAM AND FEATURE RECOGNITION ON CHIP



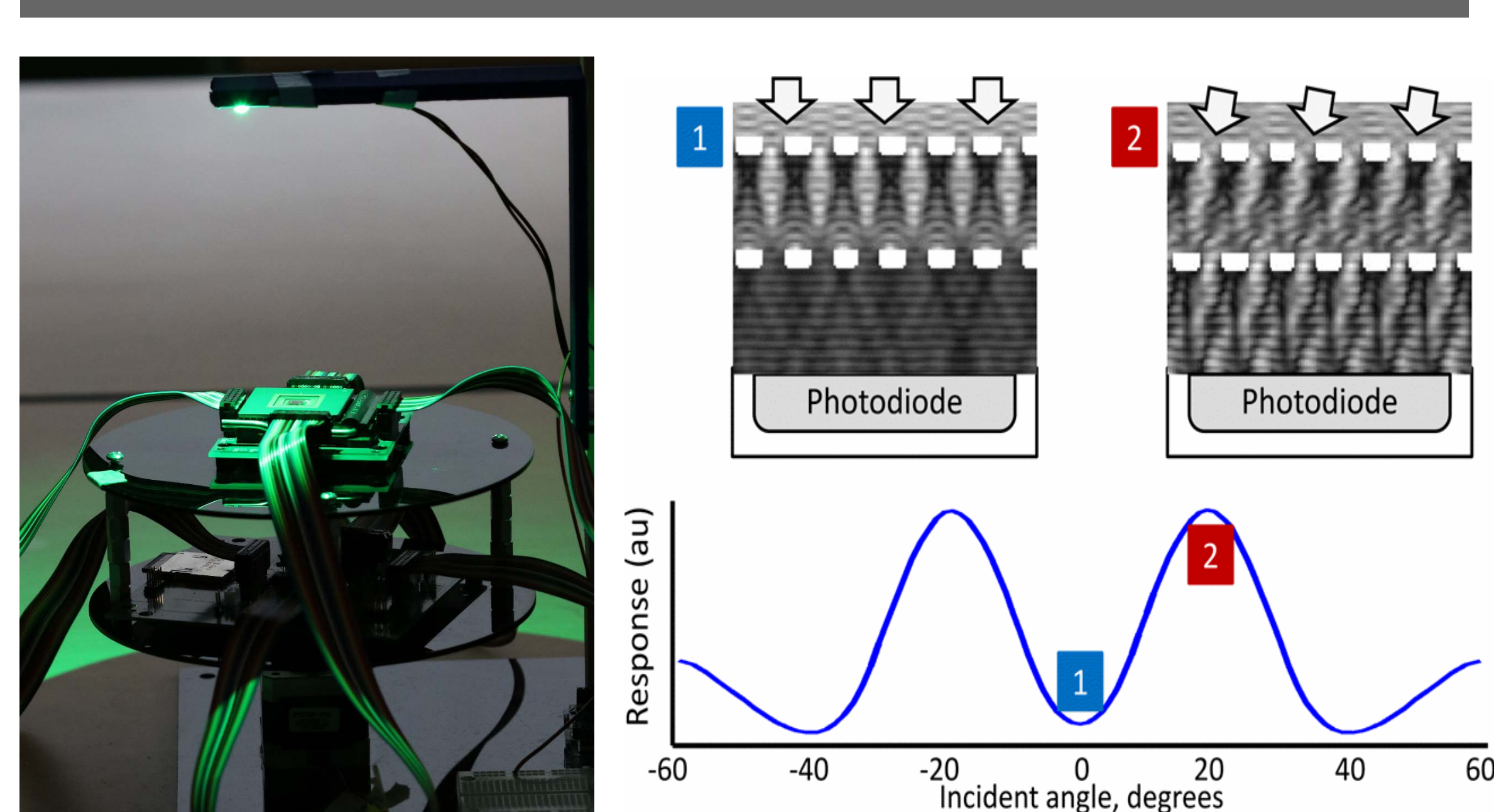
Impact:

- ULTRA-LOW POWER ELECTRONICS AND SENSING
 - Micro-scale, power autonomous, integrated circuits for flight recording and analysis
- PROBABILISTIC INFERENCE FROM LARGE-SCALE DISTRIBUTED DATA SOURCES
 - Fusion of heterogeneous sensor data
 - Finding trends in large incomplete bio-datasets
- FEEDBACK CONTROL OF BIO-HYBRID SYSTEMS
 - Towards gains for both data acquisition and improved foraging
- GAINS TO APICULTURE AND ENTOMOLOGY
 - Improved knowledge of how bees forage in cultivated versus natural landscapes
 - Improved models of how bees advertise the location of food sources
- GAINS TO PRECISION AGRICULTURE
 - Instrumented hives for farmers with hourly updates on busts and blooms
 - Improved output by control of colony activity level

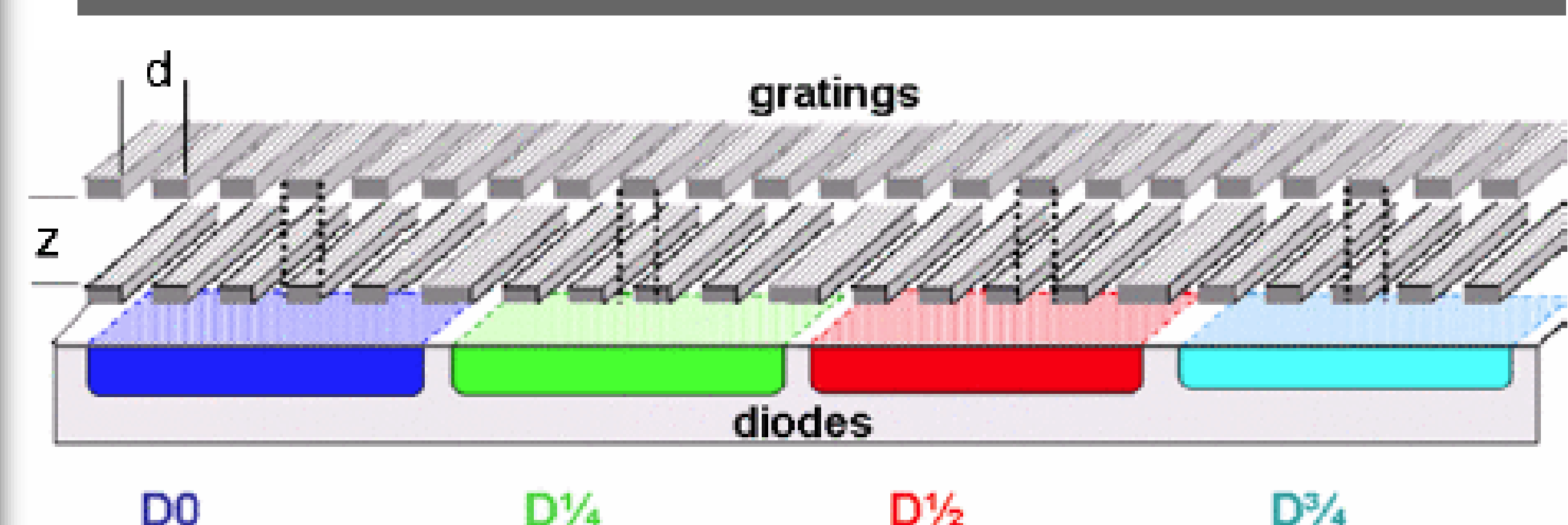
Honey bees in numbers:

- Annual revenue world wide: \$150B
- No. of U.S. commercial colonies: 2.4M
- Colony collapse disorder has increased rental fees up to 20%

AUTOMATED CALIBRATION RIG FOR FLIGHT RECORDERS

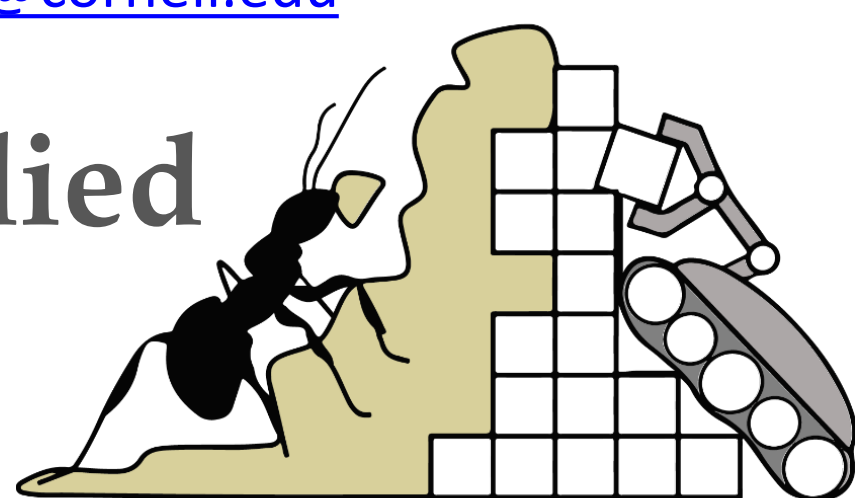


ANGLE SENSITIVE PIXEL STRUCTURE



Cornell University
School of Electrical and Computer Engineering
Rhodes Hall 324, Ithaca NY-14853, USA
Haron Abdel-Raziq contact: hma49@cornell.edu
Prof. Kirstin Petersen (PI) contact: kirstin@cornell.edu

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