Simbeeotic: Enabling MAV Swarm Research

Bryan Kate
Harvard University

Jason Waterman
Harvard University

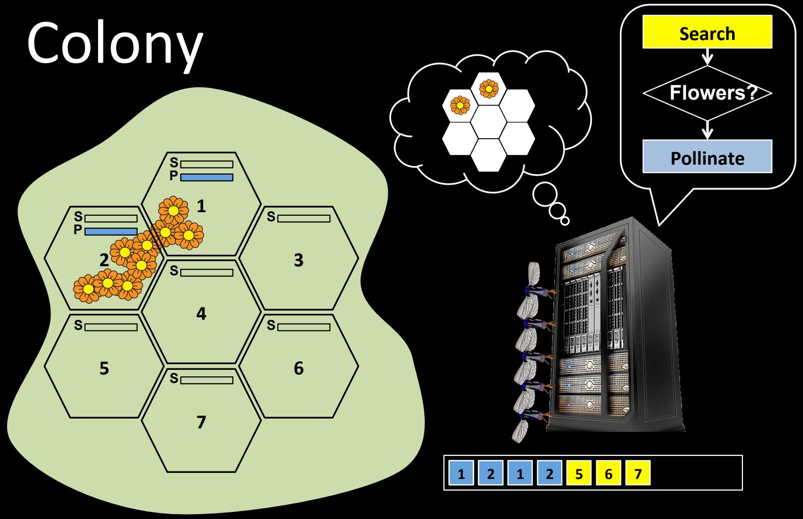
Karthik Dantu
Harvard University

Matt Welsh
Google, Inc.

Motivation: Robotic Bees!

- Convergence of Body, Brain, and Colony
- 3rd year of NSF Expeditions grant

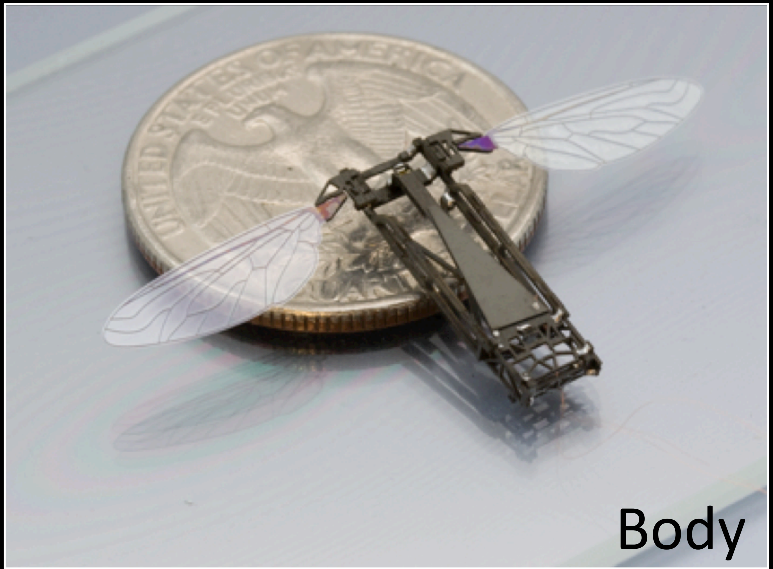
Colony



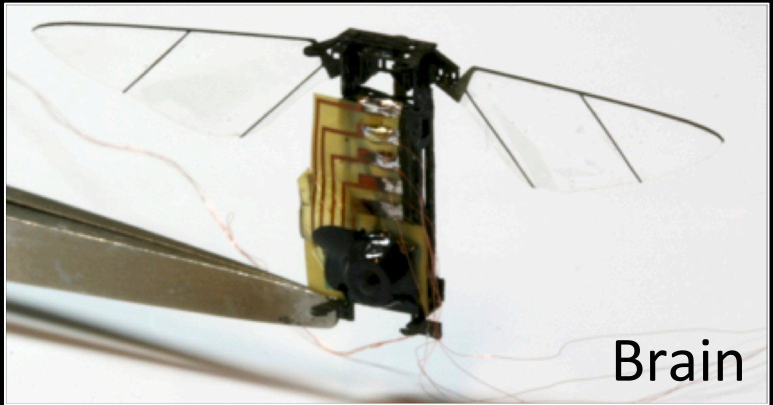
Search

Flowers?

Pollinate



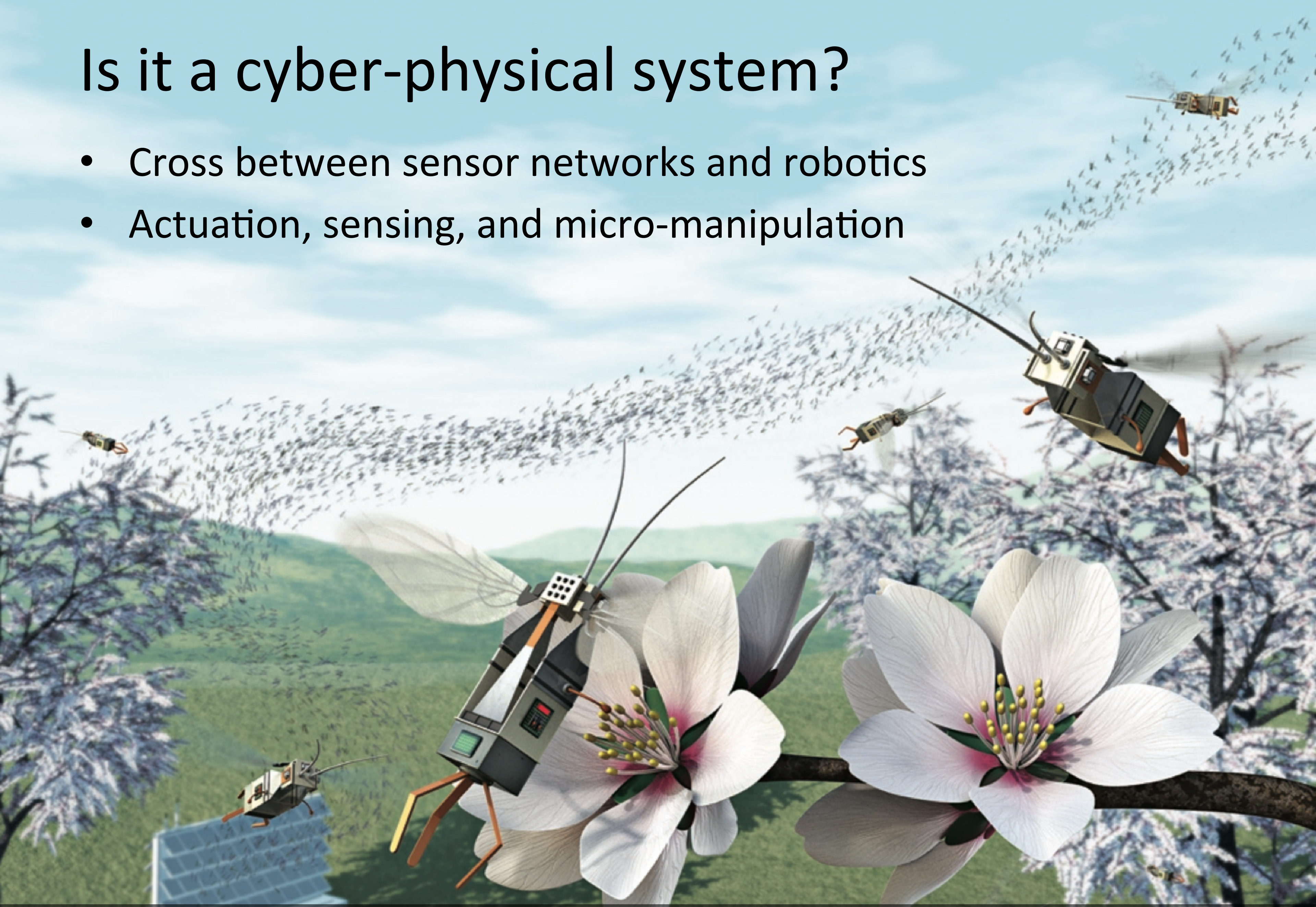
Body



Brain

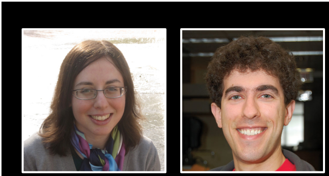
Is it a cyber-physical system?

- Cross between sensor networks and robotics
- Actuation, sensing, and micro-manipulation



Differing Use Cases

Swarm Algorithms



- Searching and foraging
- Emergent behaviors
- High level modeling

Don't really care about the low level details.

Swarm Systems

- Resource management
- Communication
- Programming

Need realism, but not too much.

Simulator Goals

1. Scalability
2. Variable Fidelity
3. Completeness
4. Staged Deployment

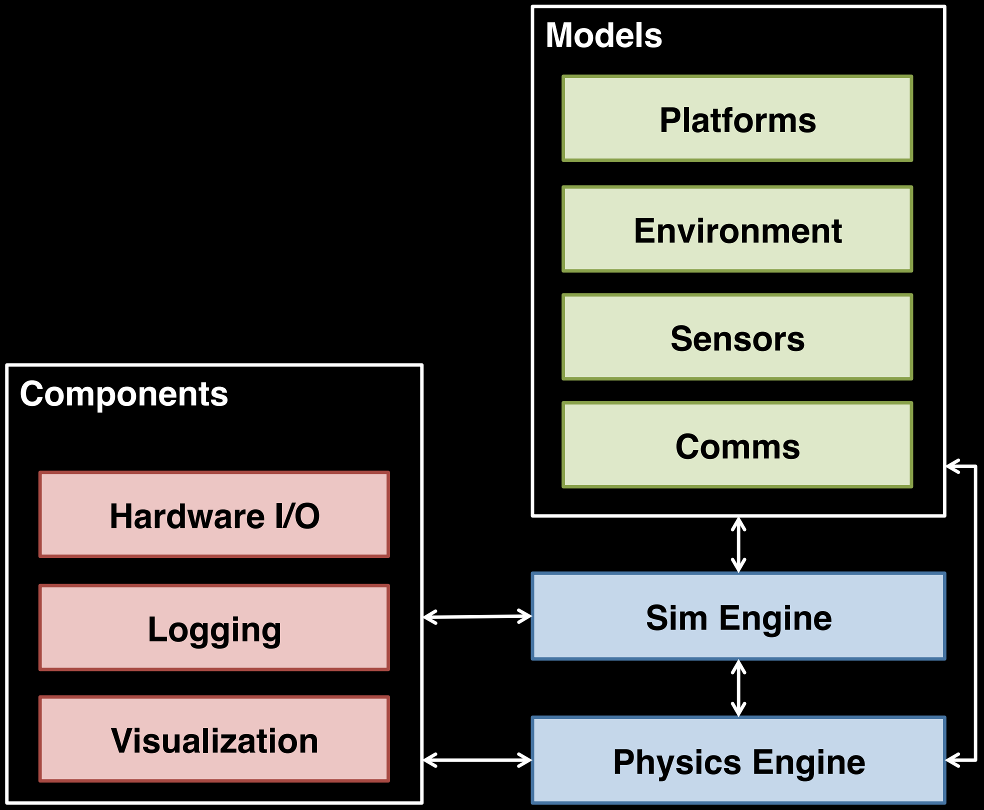
Reduce, Reuse, Recycle

- Multi-agent simulators
  - Breve, Swarm, MASON
- Robotic simulators and tools
  - Player-Stage-Gazebo, Webots, ROS
- Networking, Sensor Network simulators
  - ns3, TOSSIM, EmStar

Borrow good ideas from prior work to create a simulator that meets our research needs.

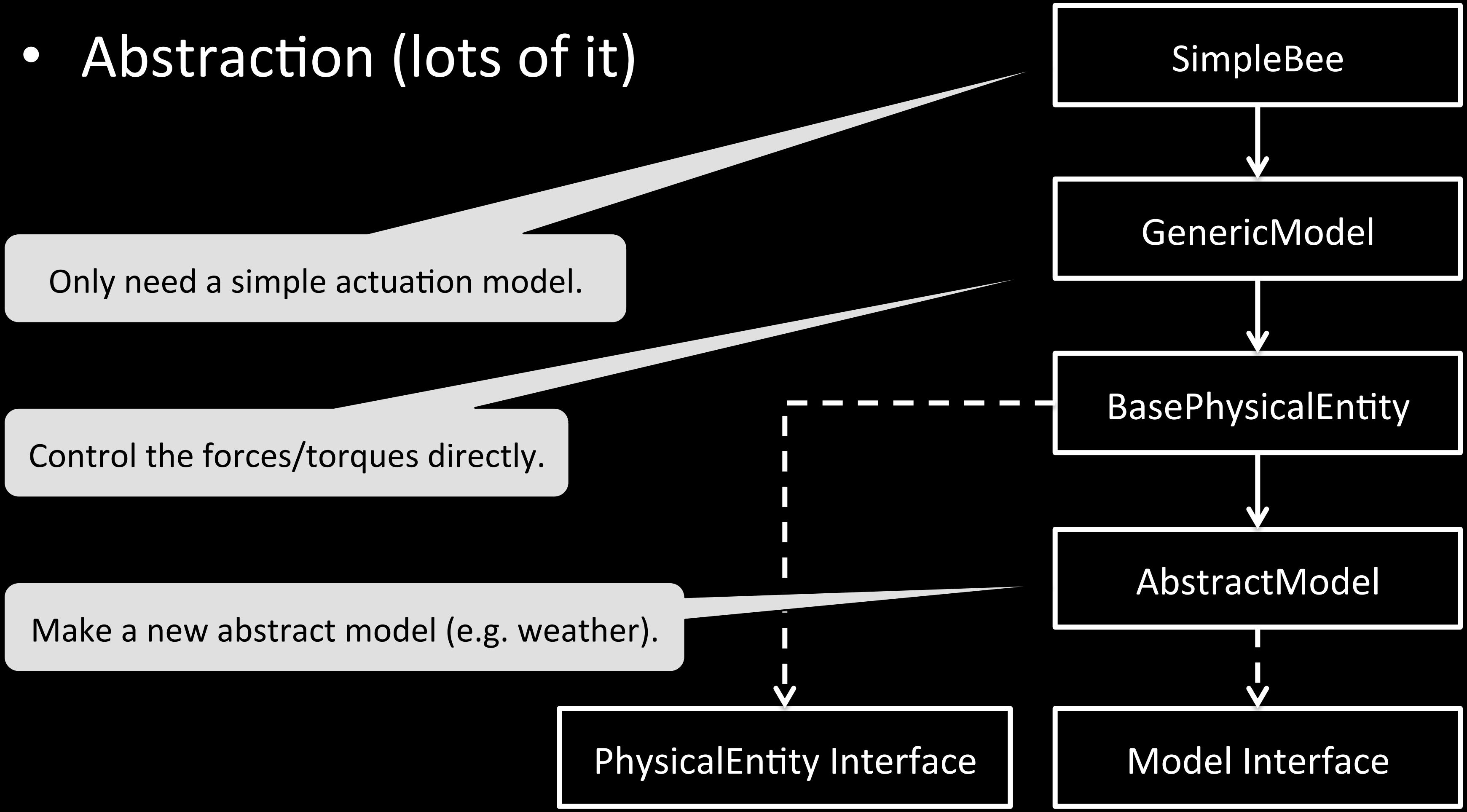
Simulator Architecture

- Event-driven simulation
- Rigid body physics engine
- Plugin models and components
- Deployment time configuration



Variable Fidelity

- Abstraction (lots of it)



SimpleBee

GenericModel

BasePhysicalEntity

AbstractModel

PhysicalEntity Interface

Model Interface

Only need a simple actuation model.

Control the forces/torques directly.

Make a new abstract model (e.g. weather).

Completeness

- For MAV swarm research we need to model *actuation*, *sensing*, and *communication*
- The physics engine helps us do this!
  - Define body shape and mass
  - Integrate kinematic state between events
  - Define sensors using builtin collision detection and ray tracing
- Basic RF physical layer
  - Antenna, propagation, and radio models

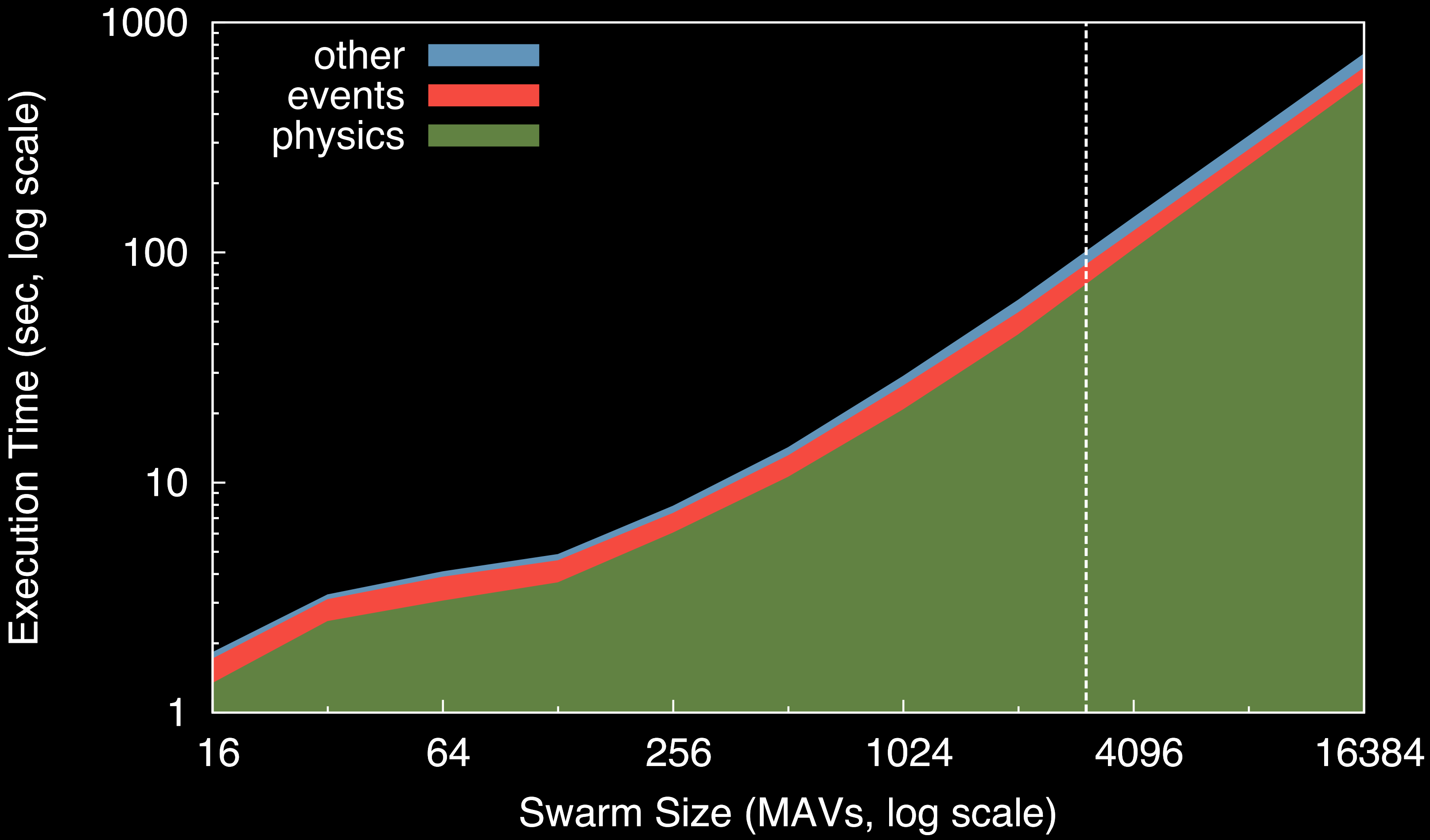
Scalability

- Events processed sequentially in single thread
- Physics engine must integrate object states in between events

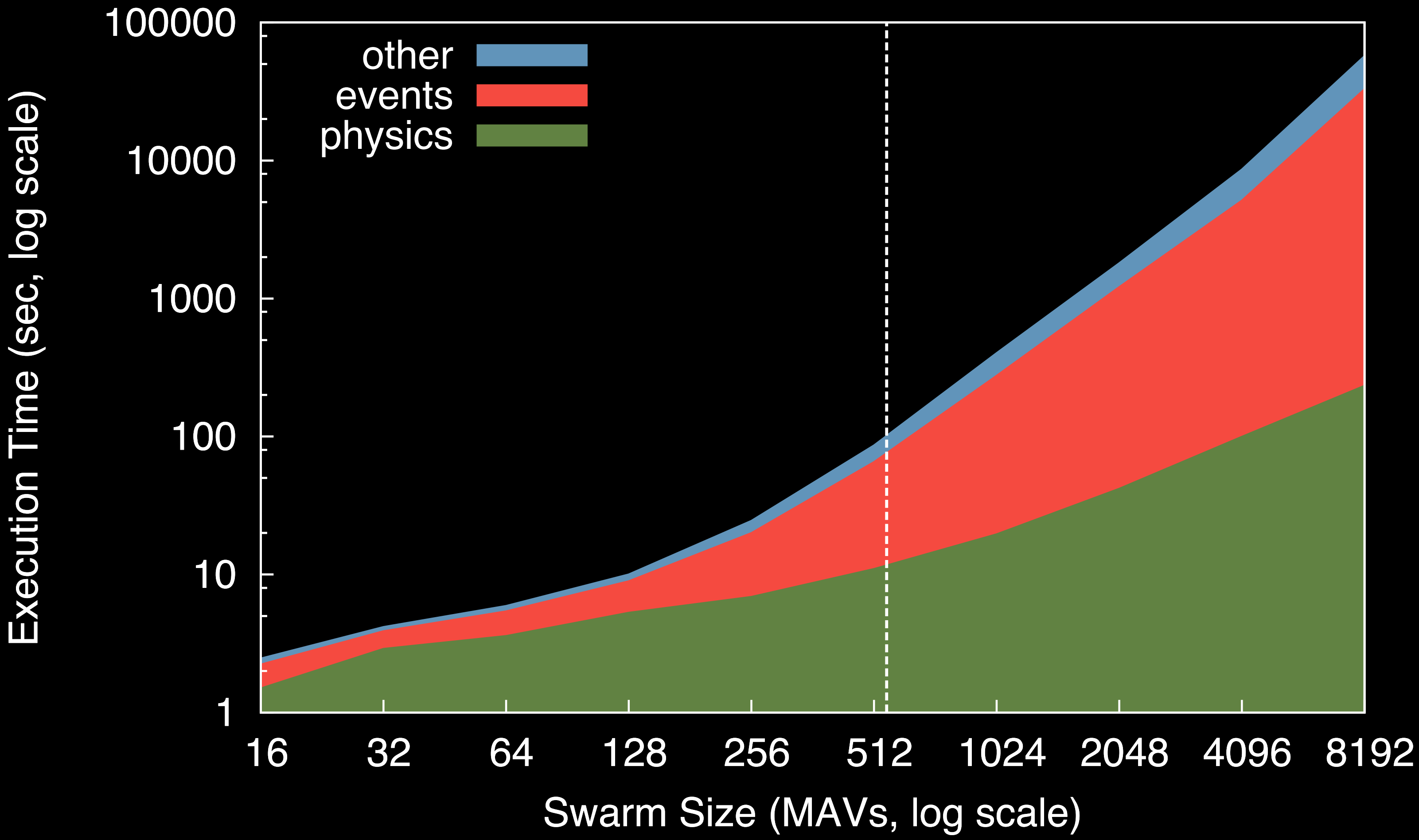
Can we model large enough swarms to support our research?

What is the relative cost of processing events and updating kinematic states?

Scalability (Basic Workload)

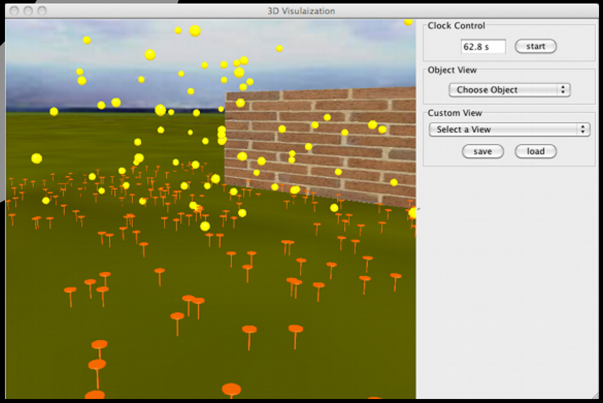


Scalability (Complex Workload)



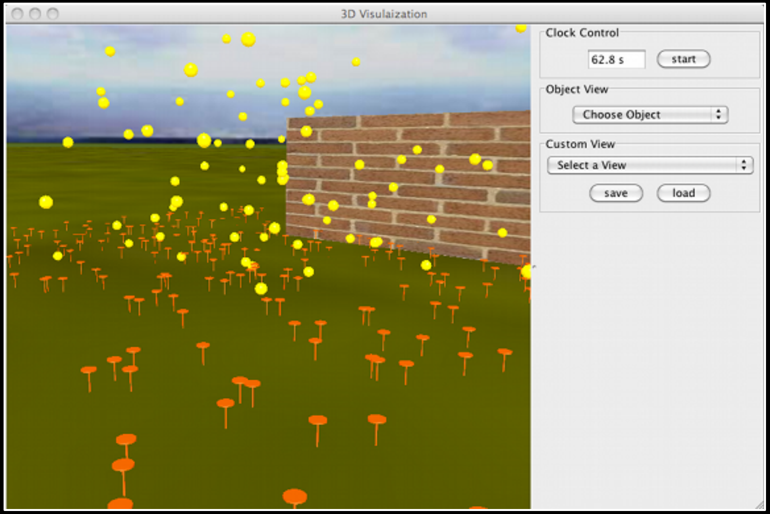
Staged Deployment

HWIL



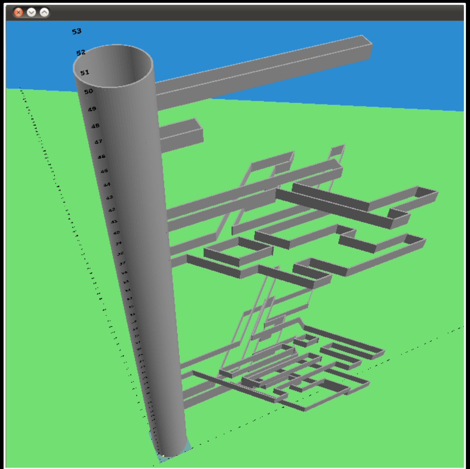
HWIL Example

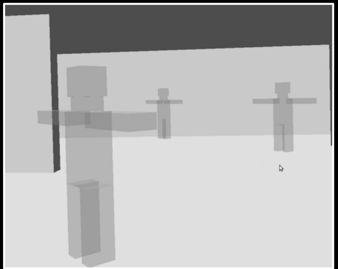
Case Study: Concept Exploration



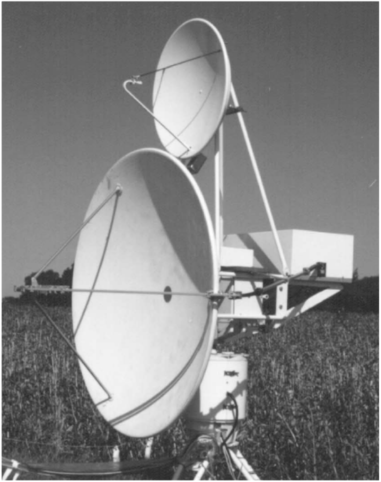
3D Visuallization
Diana Cai ‘13

Camera
Joseph Schiavone ‘13

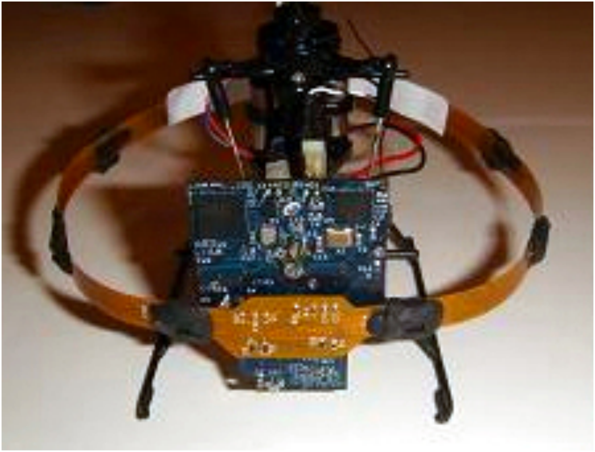




Structure Generation
Matthew Chartier ‘12

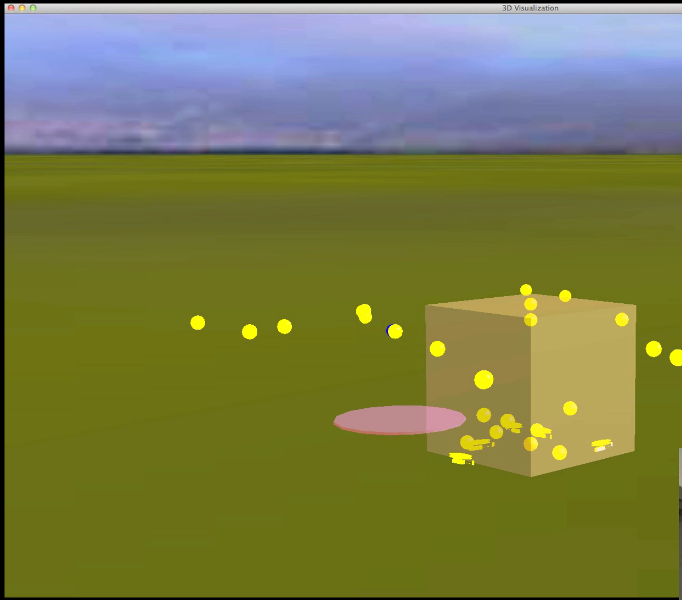


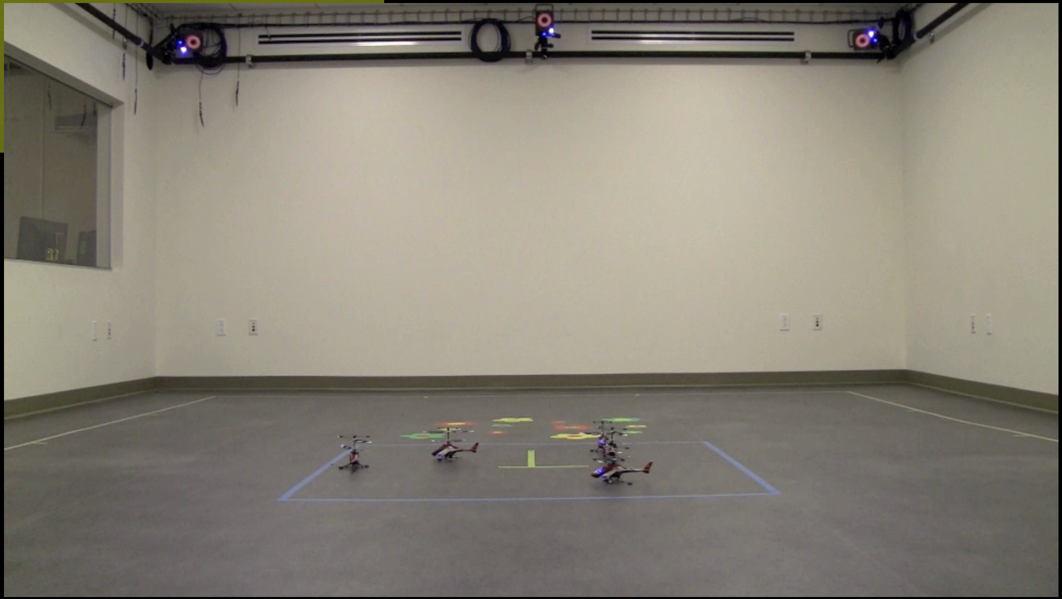
Harmonic Radar
Rose Cao ‘11



Optical Flow
Lucia Mocz ‘13

Case Study: Swarm Management





Karthik Dantu, Bryan Kate, Jason Waterman, Peter Bailis, and Matt Welsh. Programming Micro-Aerial Vehicle Swarms with Karma. SenSys '11.

Ongoing Work

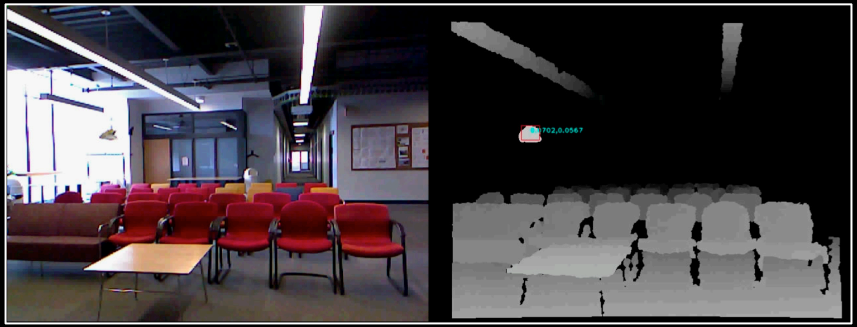
Recharging

- Batteries last 5-7 minutes!
- Land on charging pad

Lisa Liu '14

Poor Man's Vicon

- Track helicopters indoors with Kinect sensors
- Use with onboard sensing



JV Hong '12

Come to our Simbeeotic/Kinect HWIL demo!

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Summary

- Extensible, scalable simulator for modeling mobile sensing systems
- HWIL allows for incremental autonomy

https://github.com/RoboBees/simbeeotic