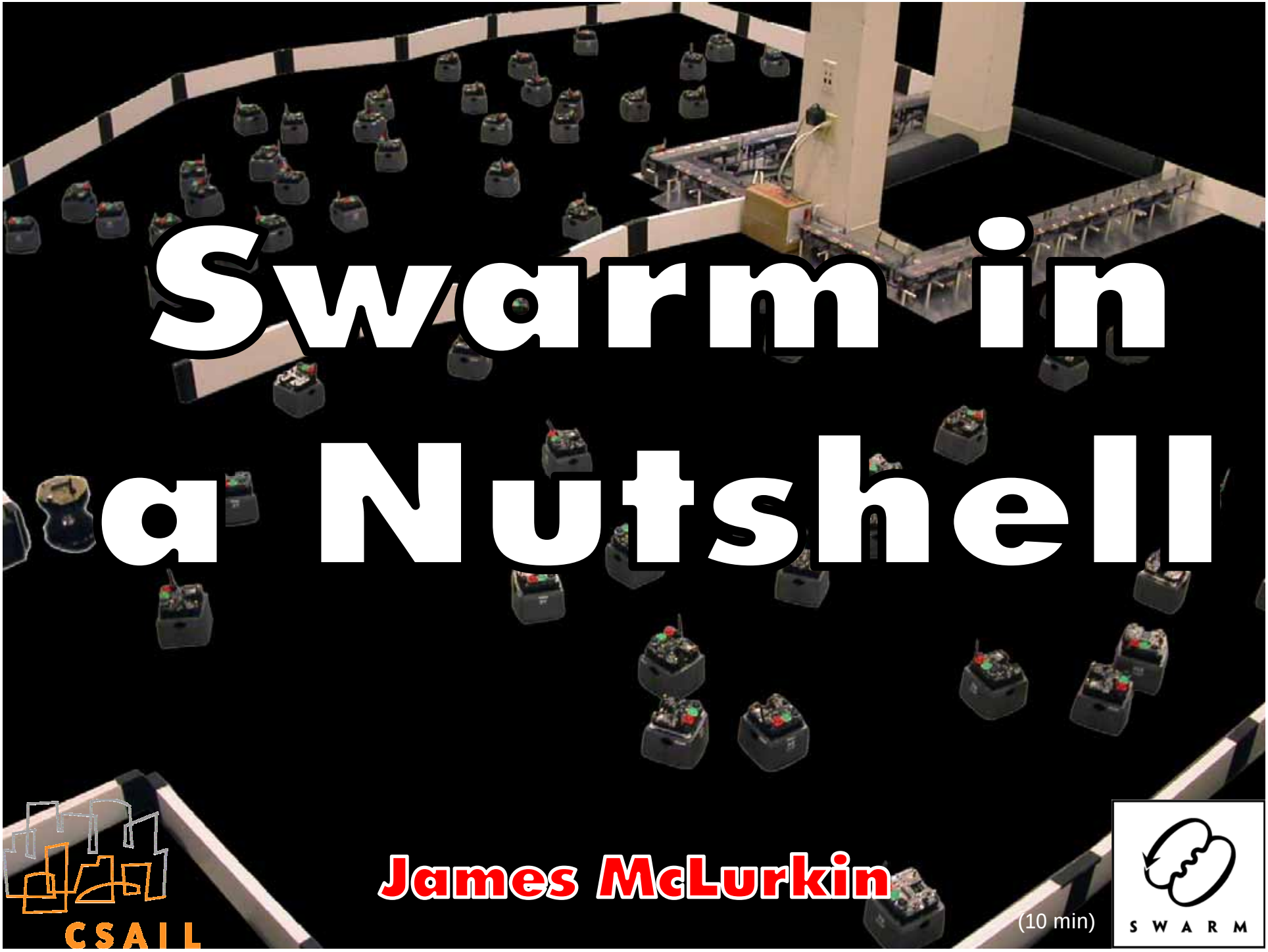

Swarm in a Nutshell
James McLurkin
(10 min)
CSAIL
SWARM

Swarms are the Future of Robotics

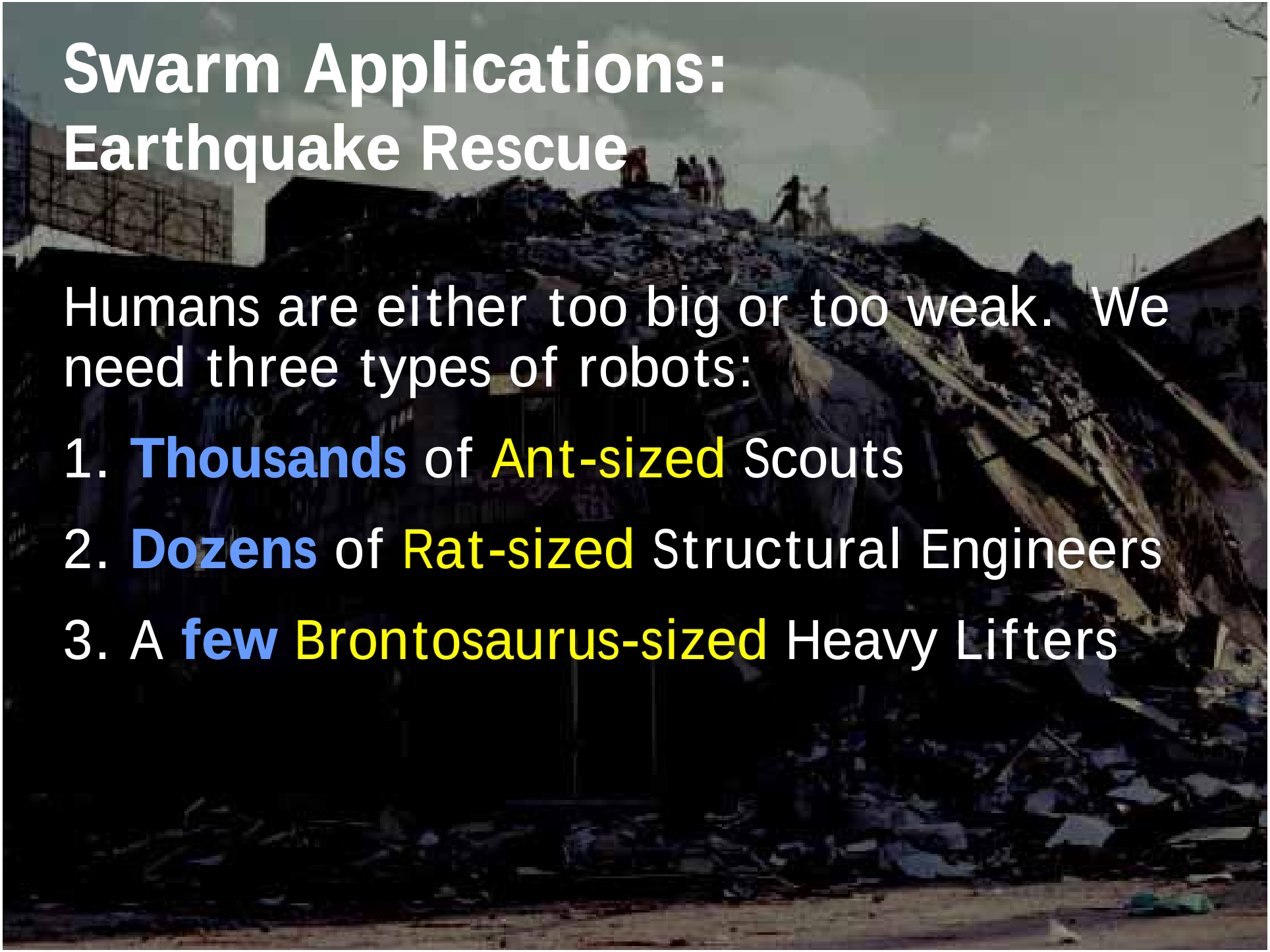
Robots are best at jobs that are **Dangerous**, **Dirty**, or **Dull**.

Many of these jobs can be performed more effectively by groups of robots working together, a.k.a. **Swarms**.

But programming large groups of robots is hard.

(Heck, programming individual robots is hard!)

My goal is to develop tools to make programming swarms of robots easier



Swarm Applications: Earthquake Rescue

Humans are either too big or too weak. We need three types of robots:

1. **Thousands** of Ant-sized Scouts
2. **Dozens** of Rat-sized Structural Engineers
3. A **few** Brontosaurus-sized Heavy Lifters

NASA's Spirit and Opportunity

What if we sent

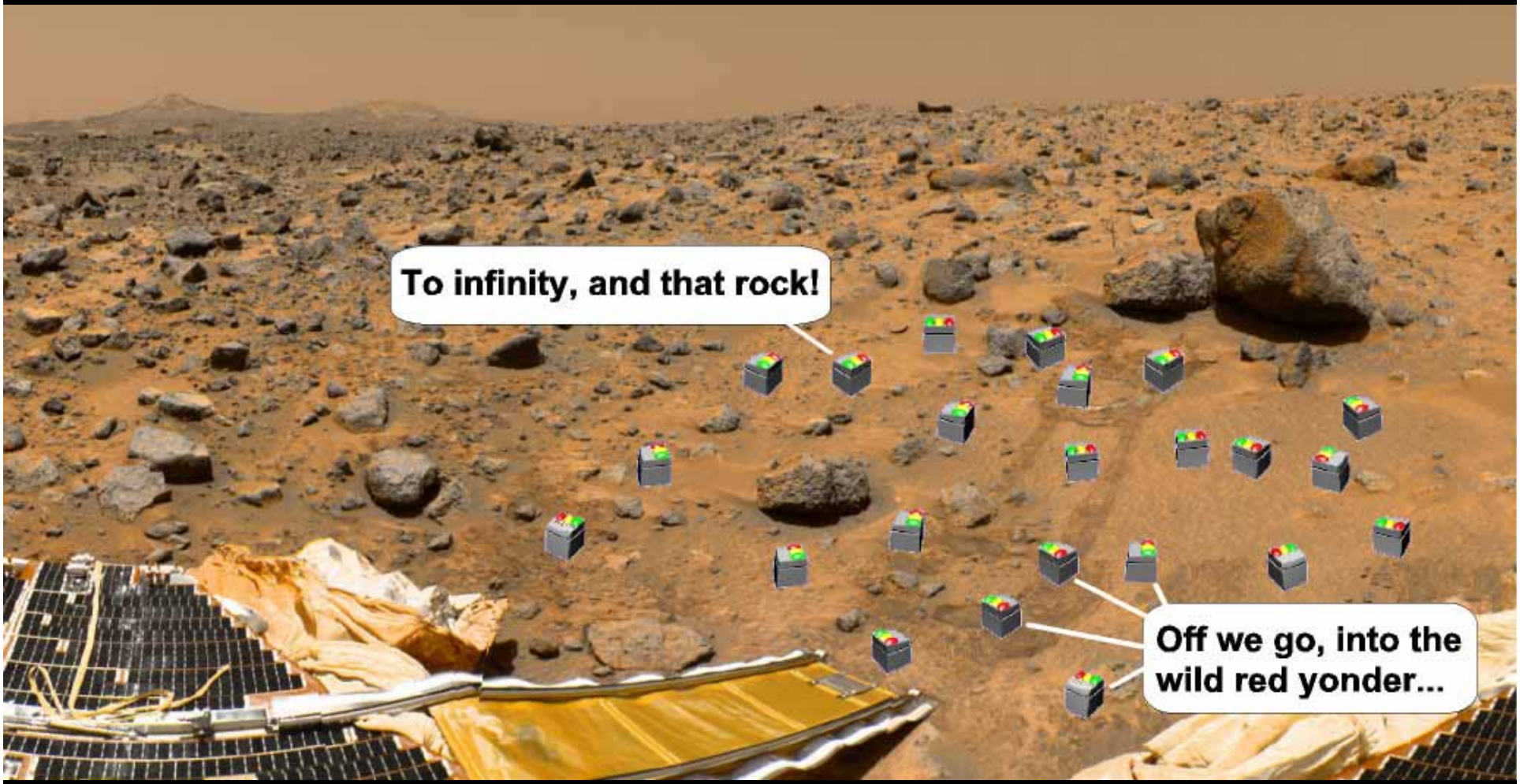
2,000

robots to Mars?

Deploying

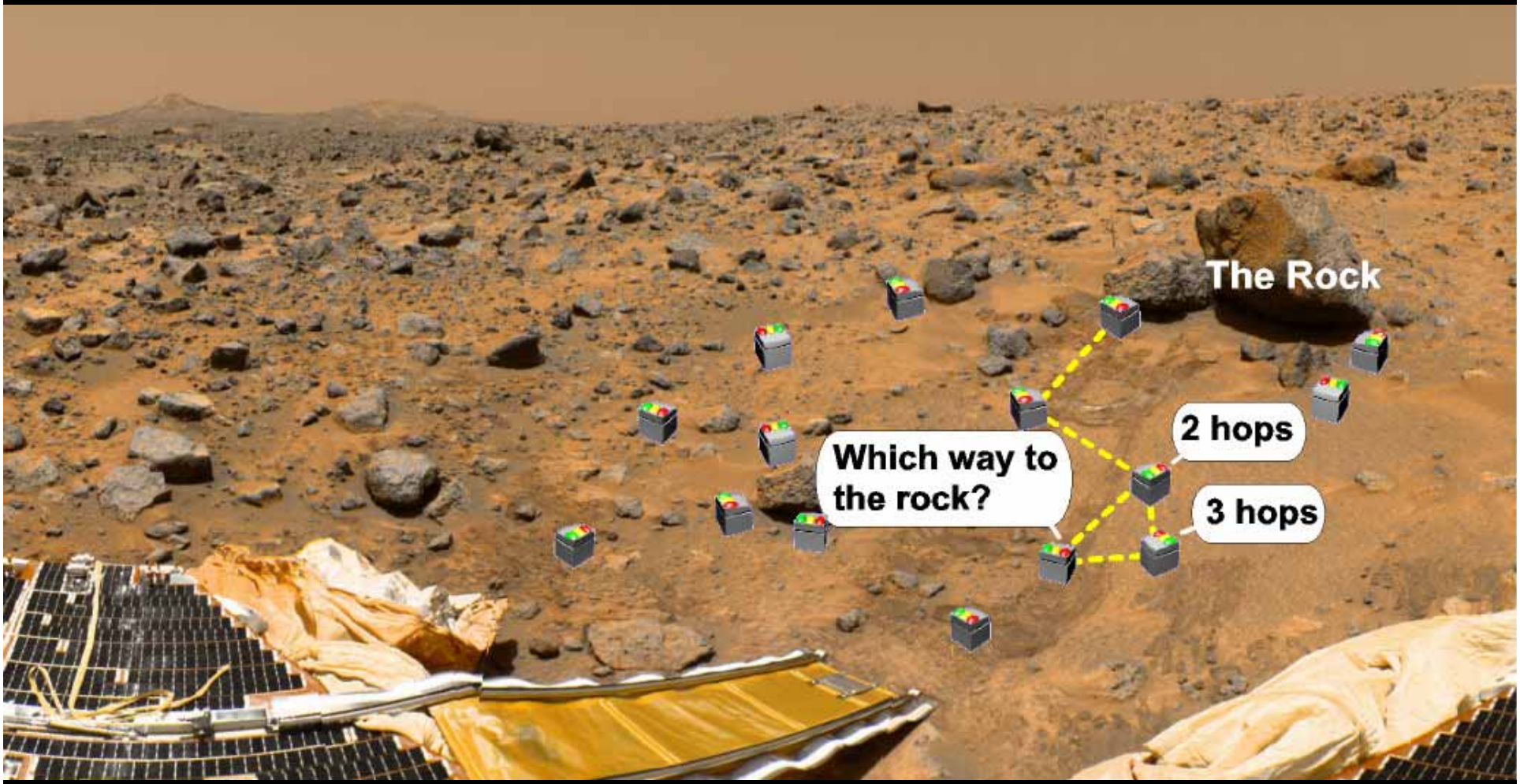
Follow the leader

Exploration



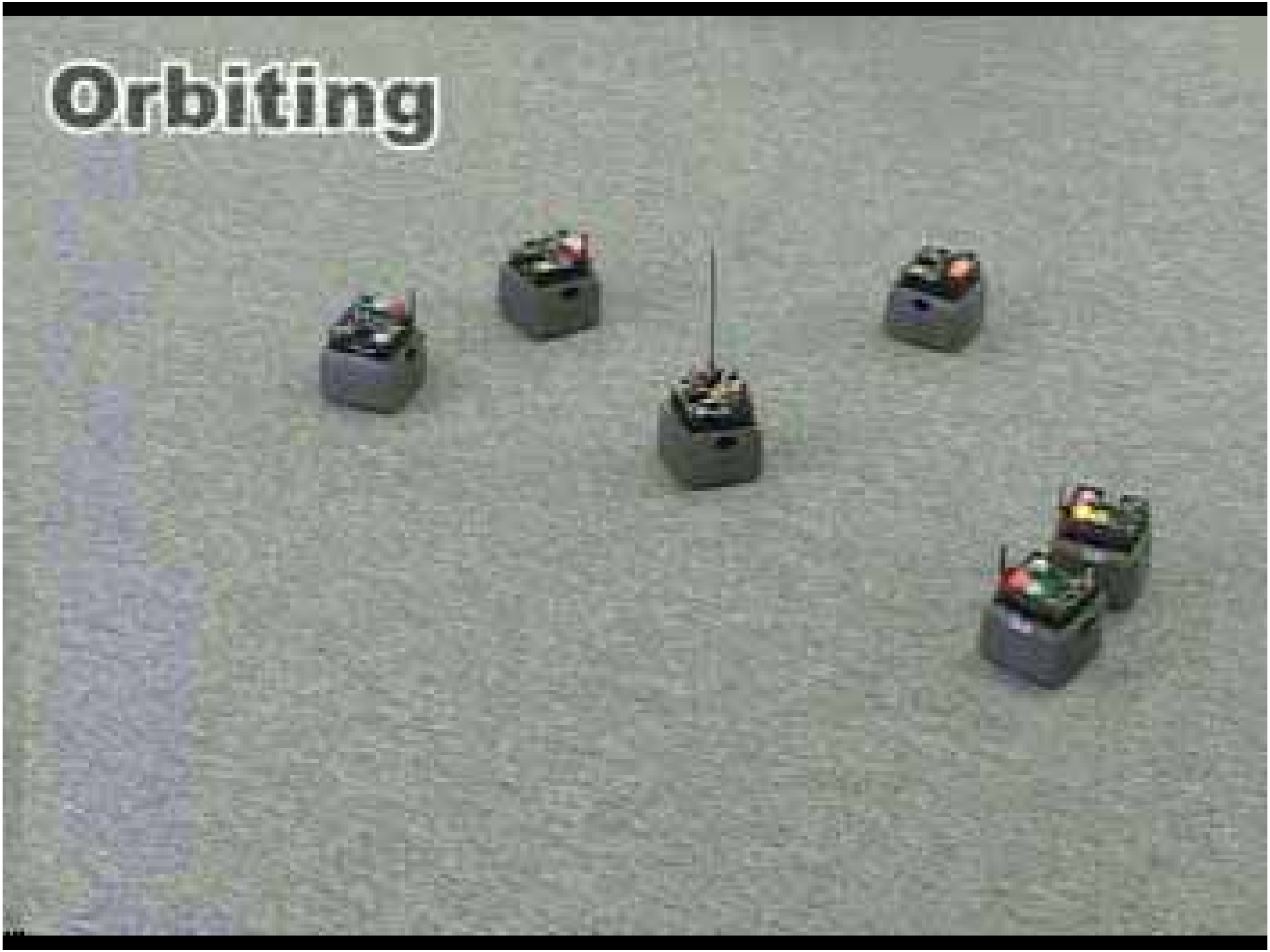
Dispersing

Navigation



Navigation

Security

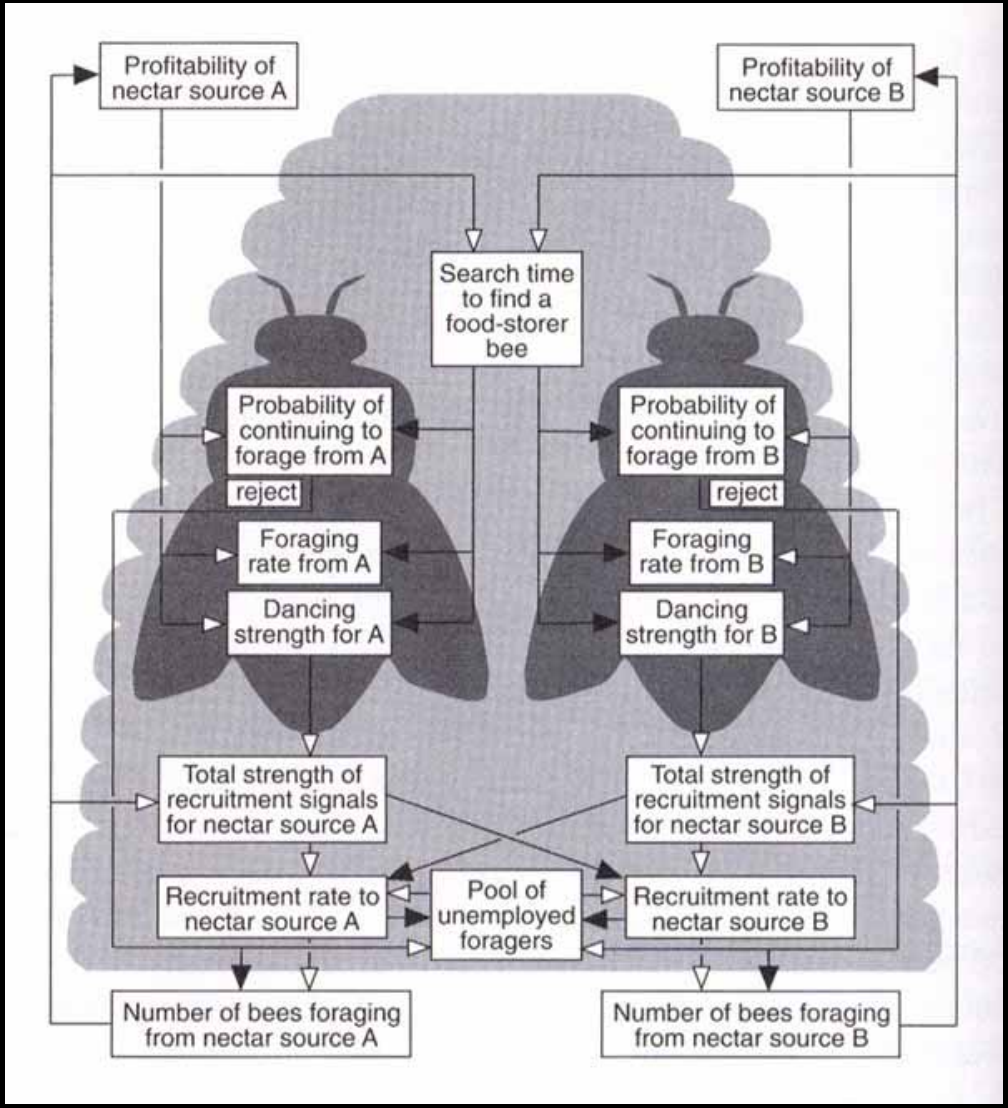

Orbiting

How do you Program 2,000 Robots?

Natural systems can provide insight on these very hard programming problems

(And they make good pets)

Nectar Collection in Bees



Foraging bees communicate with worker bees in the hive

Arrows indicate information transfer between individual bees

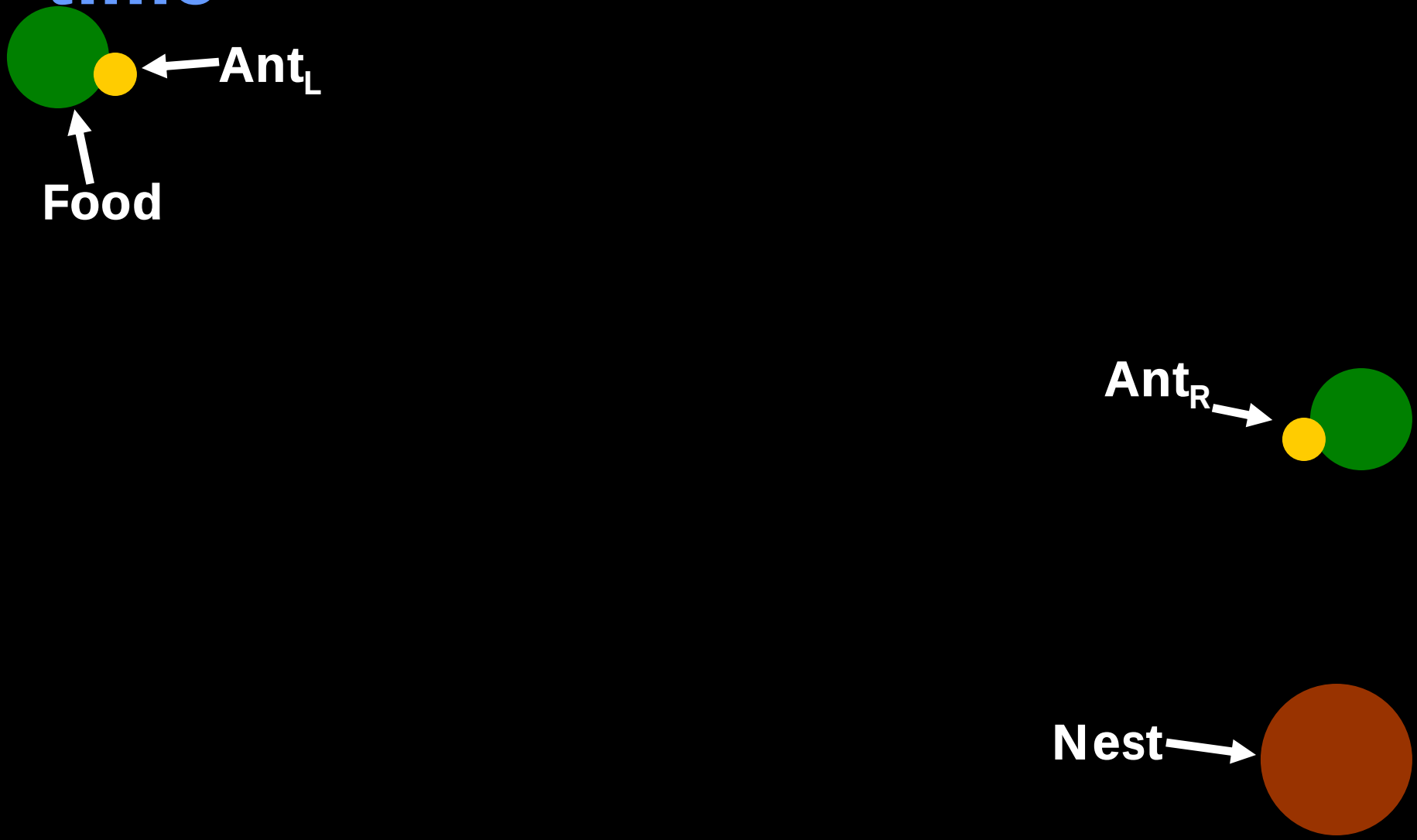
This is essentially a program for bees

Can I run this software on my robots?

Seeley, T.D., 1995. *The Wisdom of the Hive*. Harvard University Press: Cambridge, MA

Ants Foraging with Scent Trails

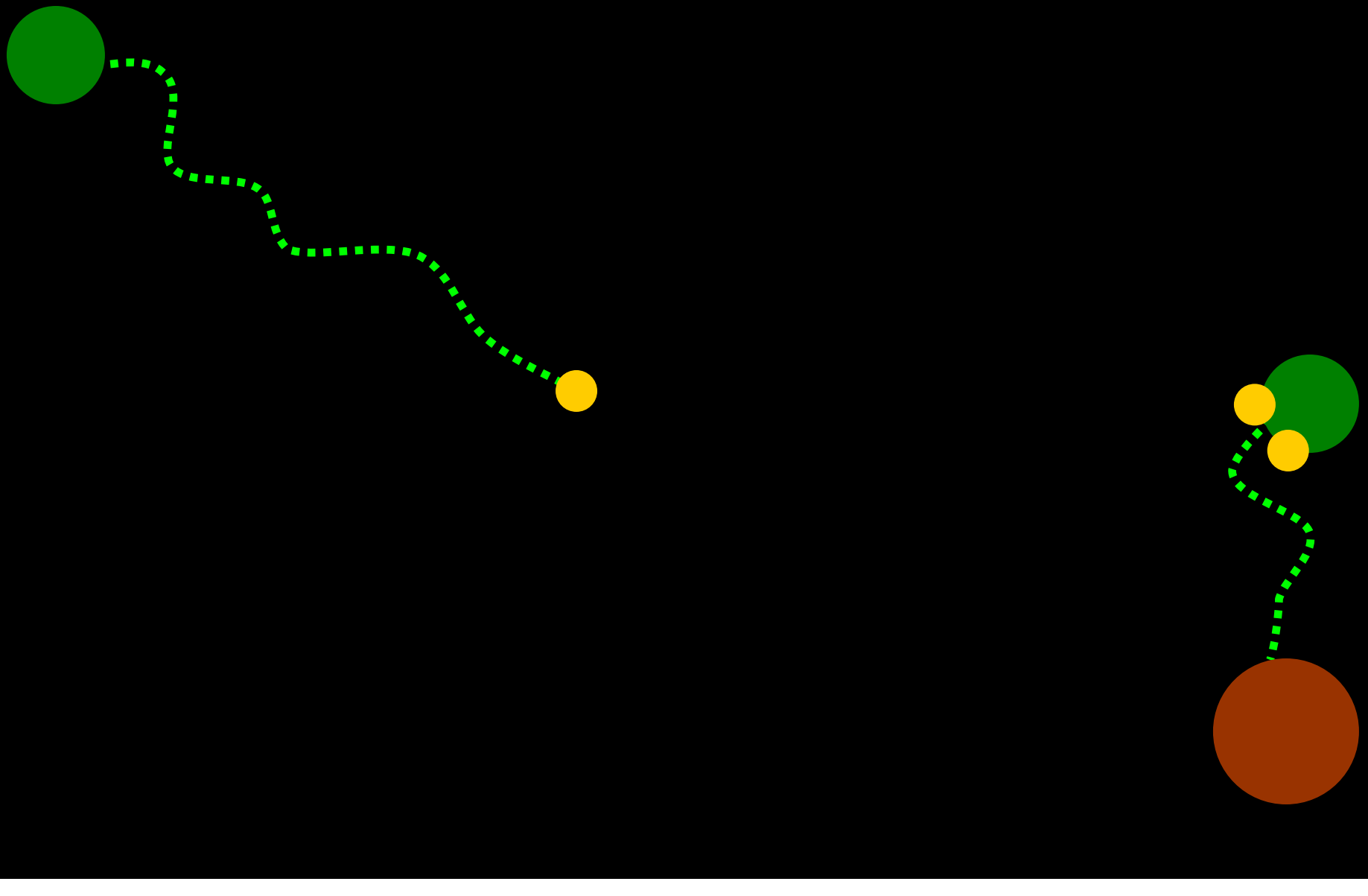
Both ants find food at the same time



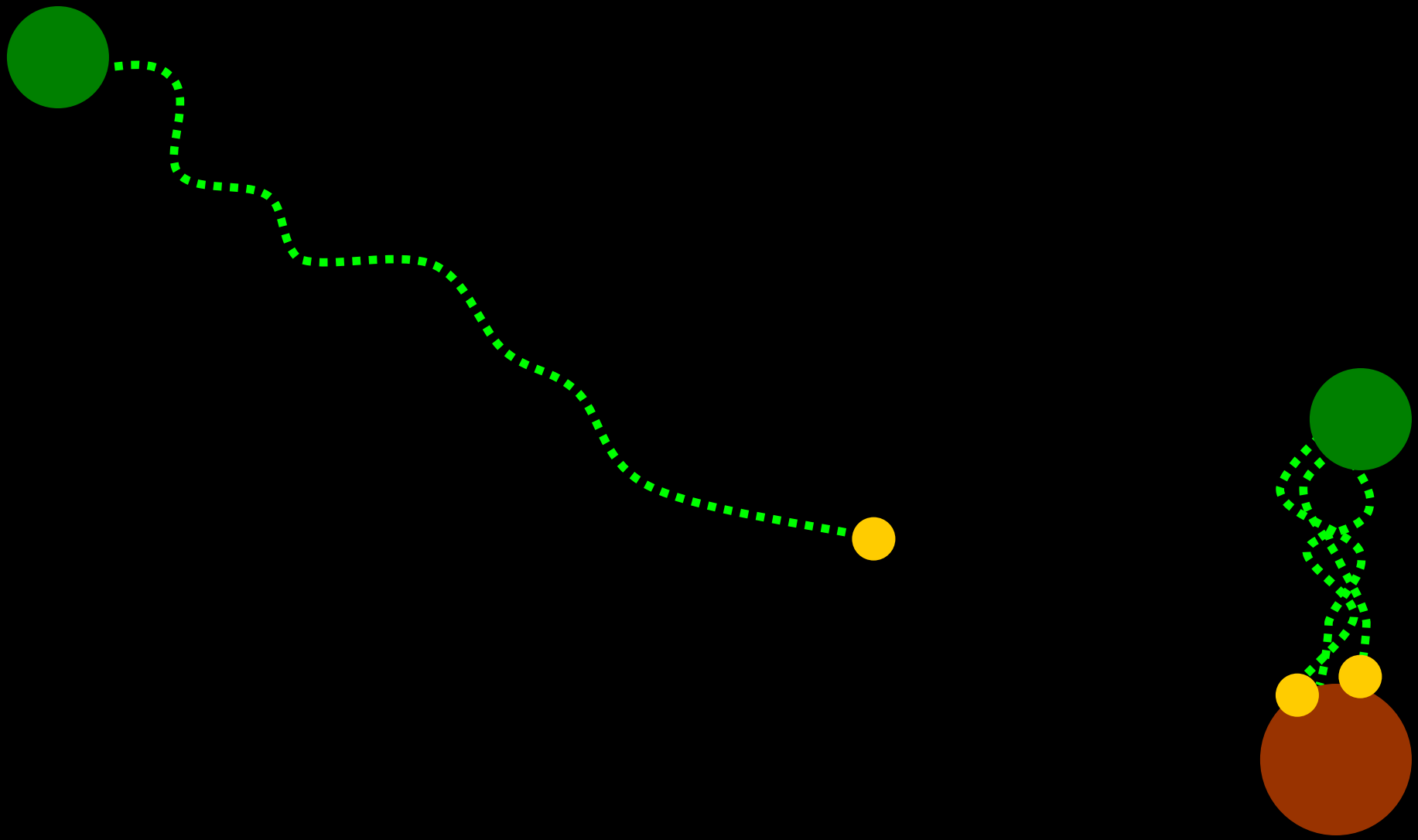
Right ant gets home first

Another ant finds right trail

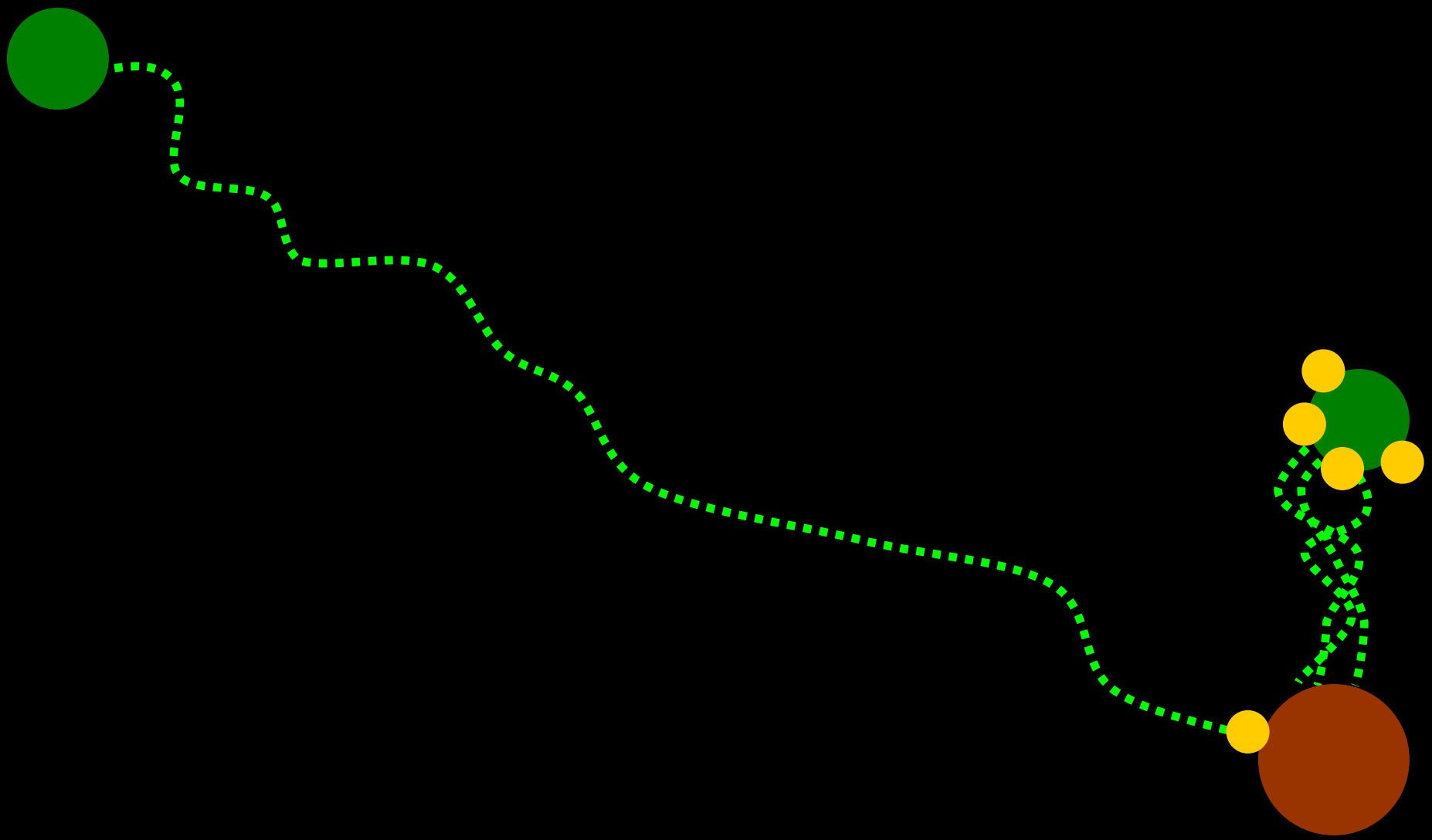
The left ant is still walking...



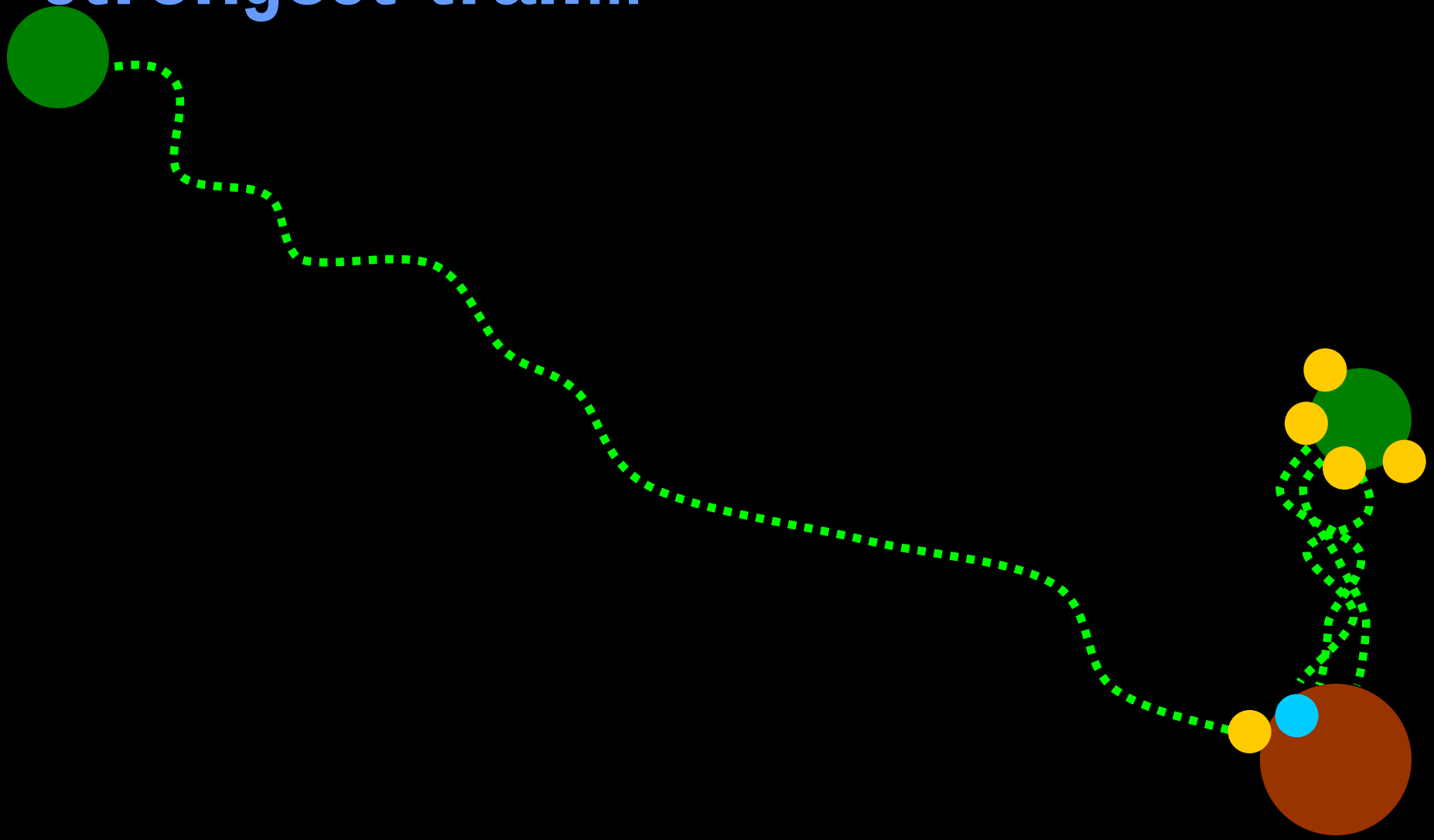
The left ant is still walking...



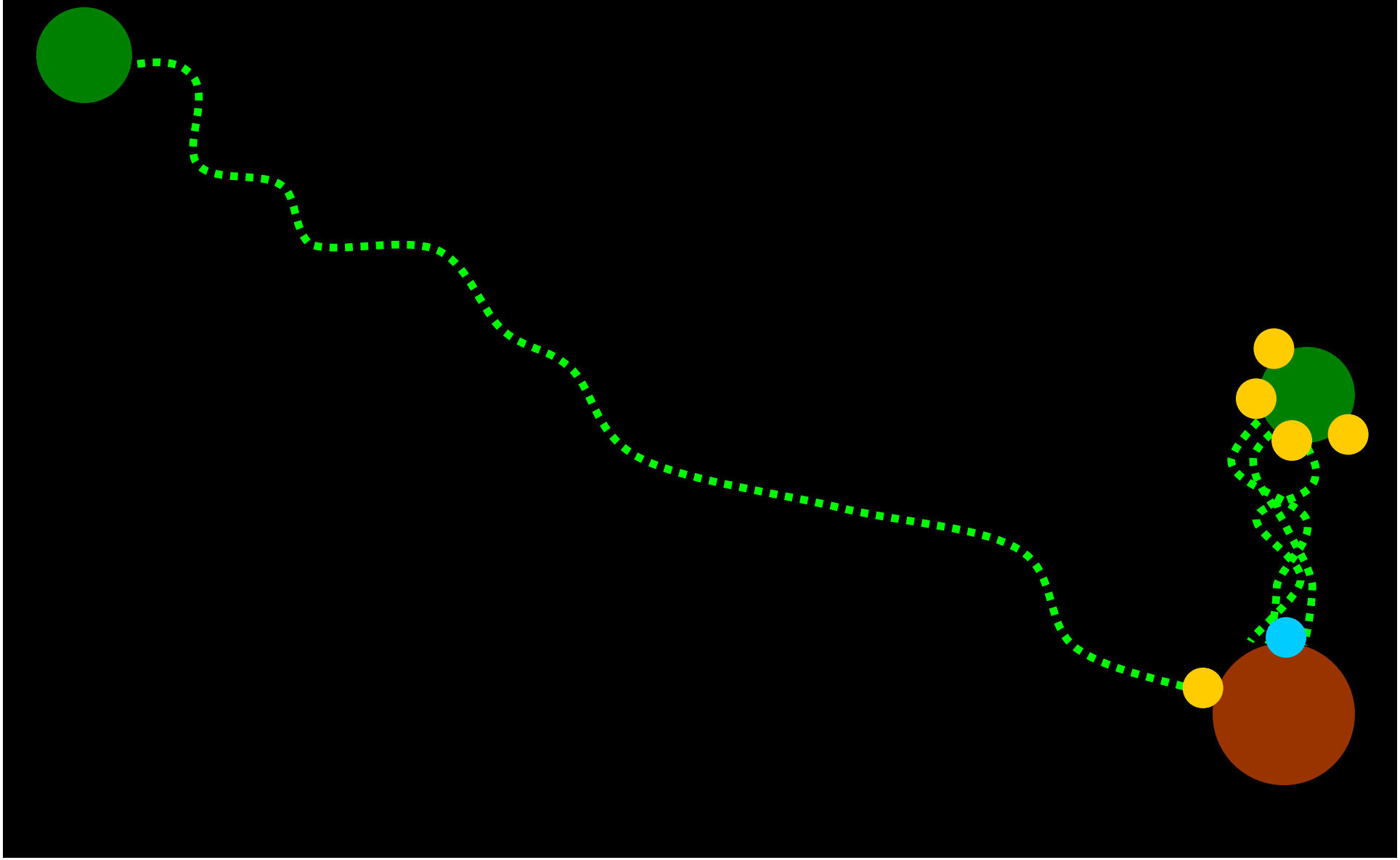
The left ant is home (finally)



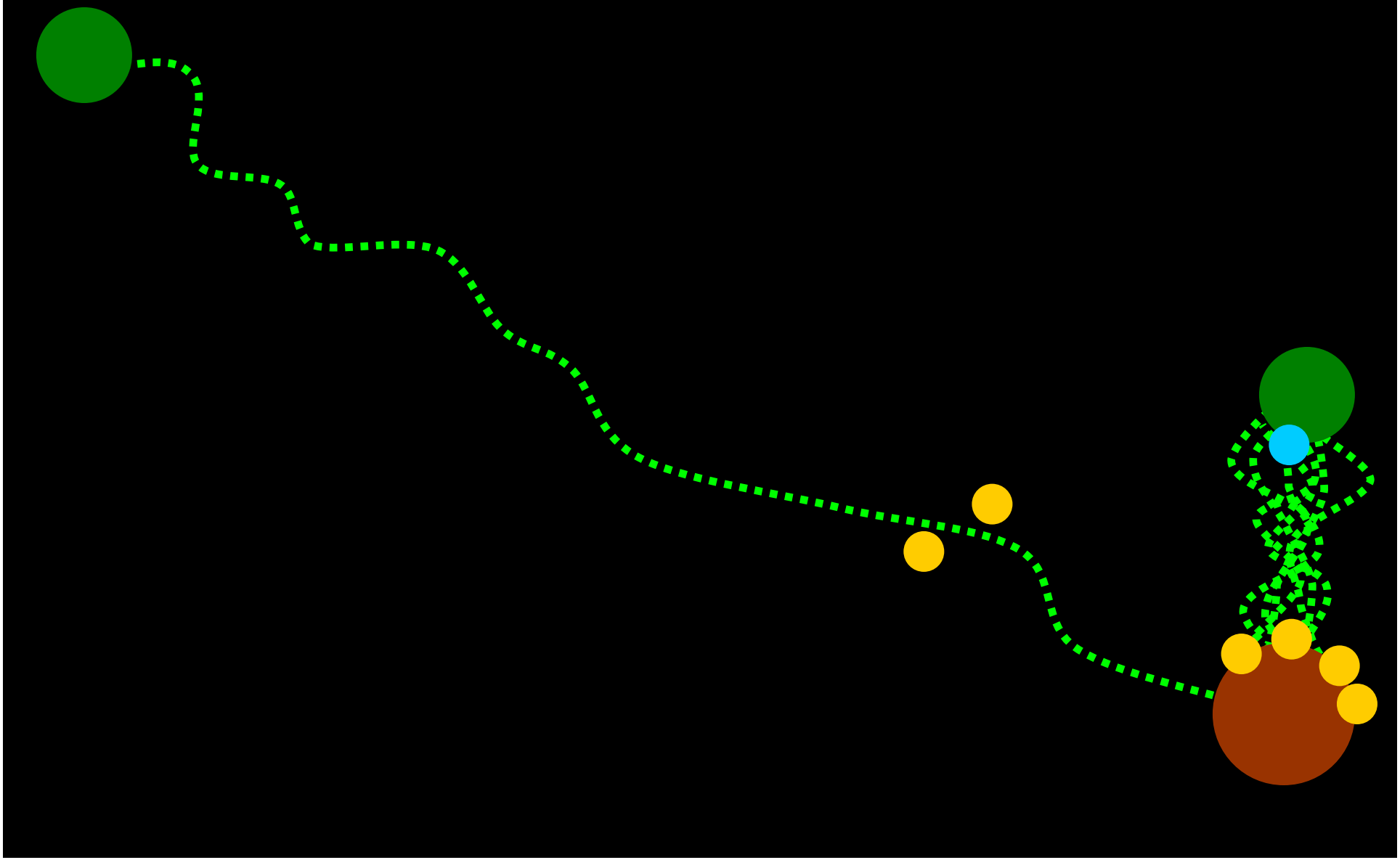
The blue ant will select the strongest trail...



...and move to the closest source

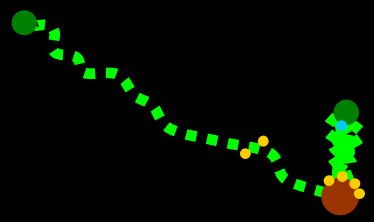


...the “right” source



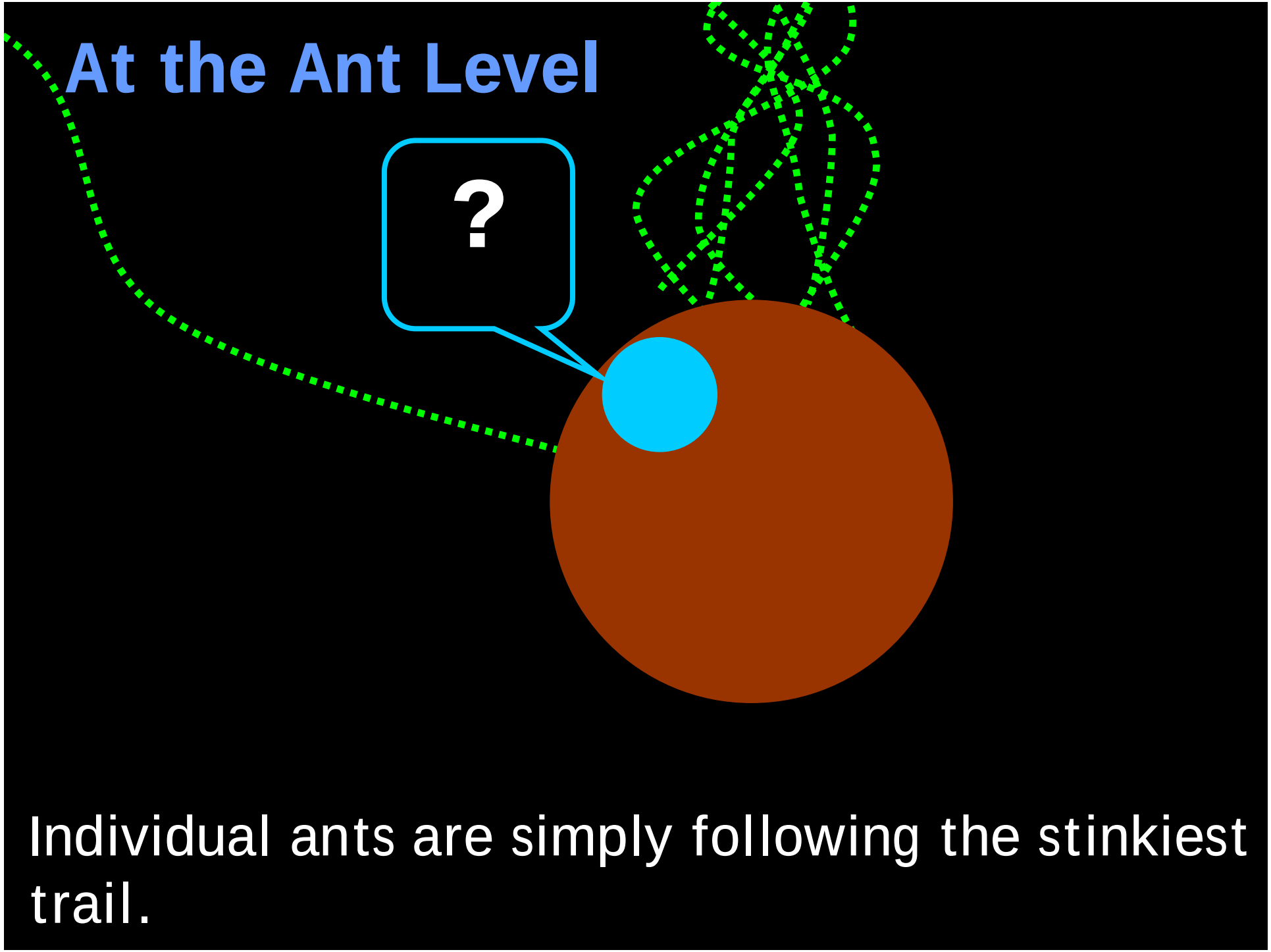
From High Altitude

The ants are foraging in a globally optimal* fashion – by exploiting the closest food sources first



*Actually not quite, but that would require many more slides…

At the Ant Level



Individual ants are simply following the stinkiest trail.

The Magic of Complexity

Simple local interactions form complex group behaviors

This is how insect communities work (and schools of fish, weather, traffic jams, etc…)

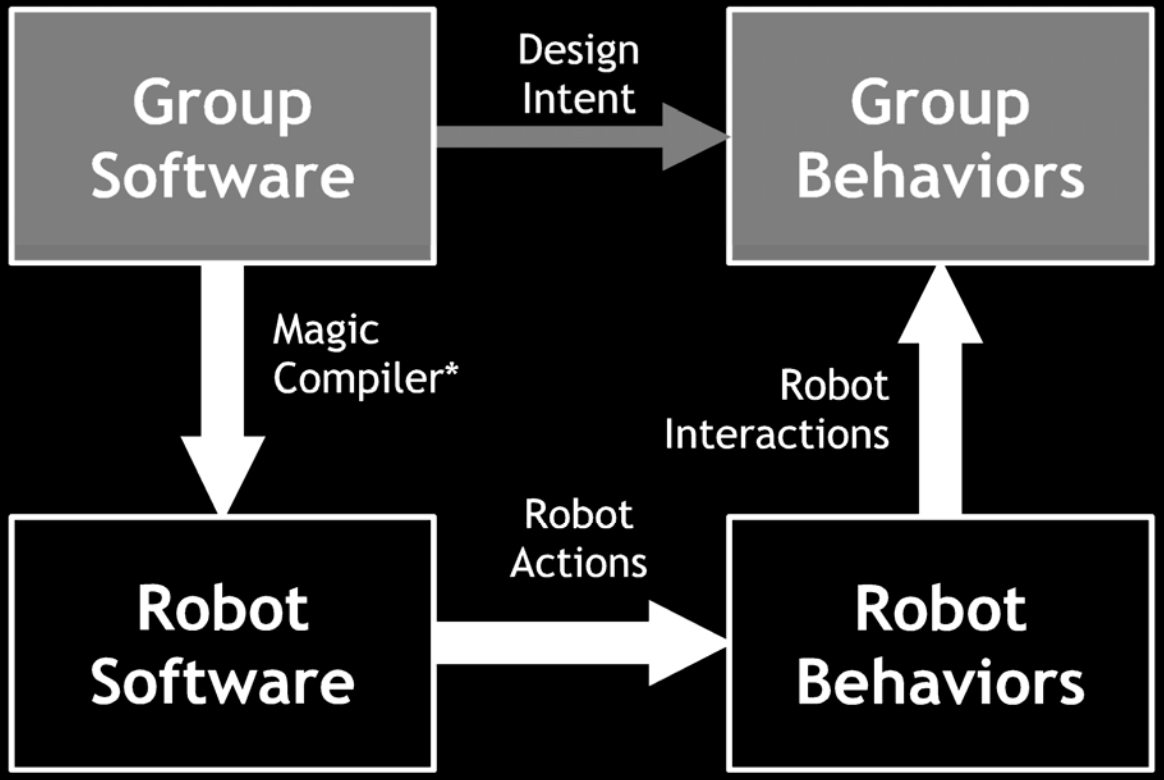
Things like this are called

Distributed Systems

It's interesting research, but makes a robot swarm difficult to program

The Tao of Swarm Software Development

The path from group software to group behaviors is complex



*my thesis

My Research Goals

Software for large numbers (10,000) of robots

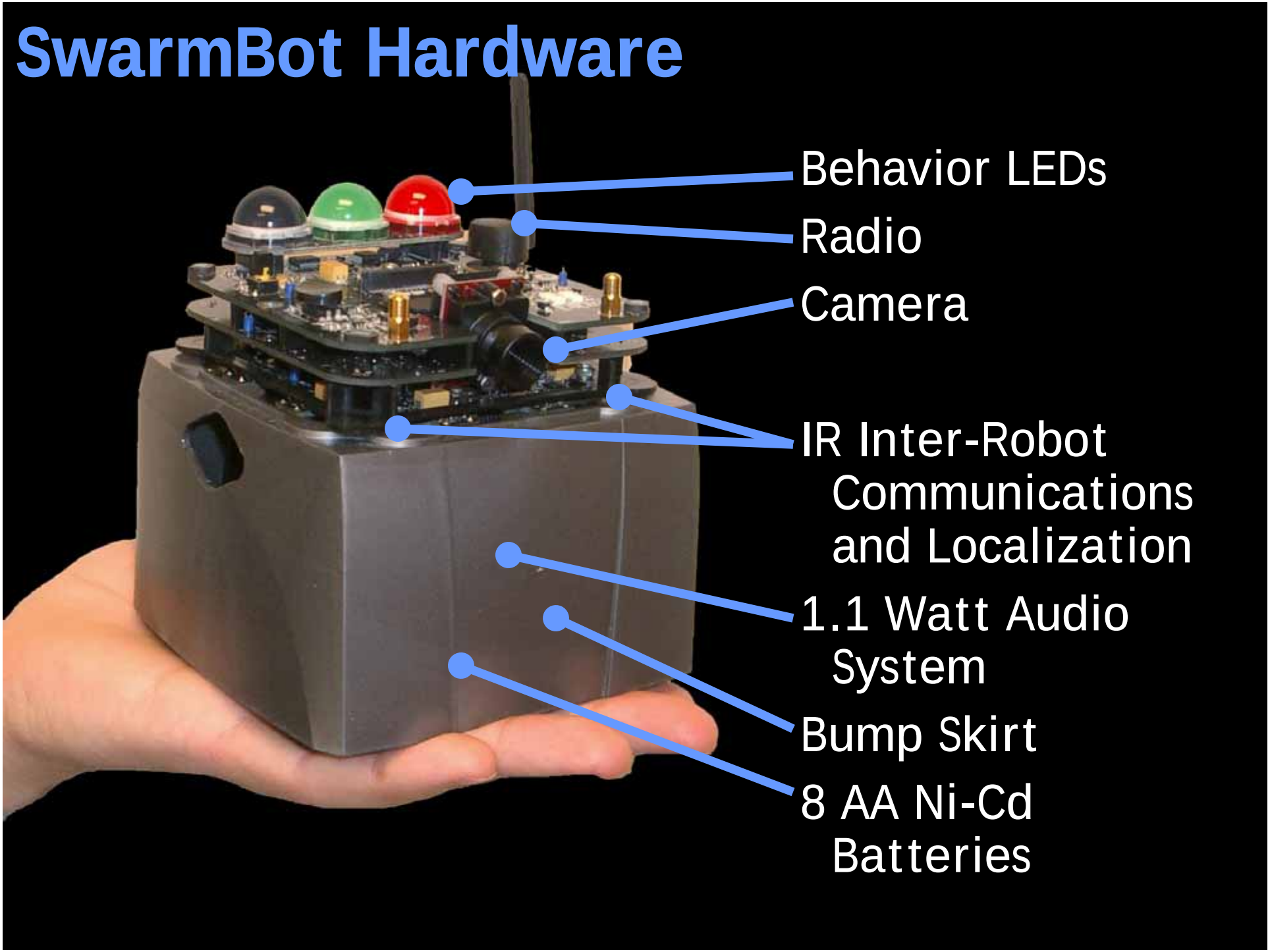
- The über goal is to program swarm behaviors at the group level, not at the individual level

But this is too hard, so…

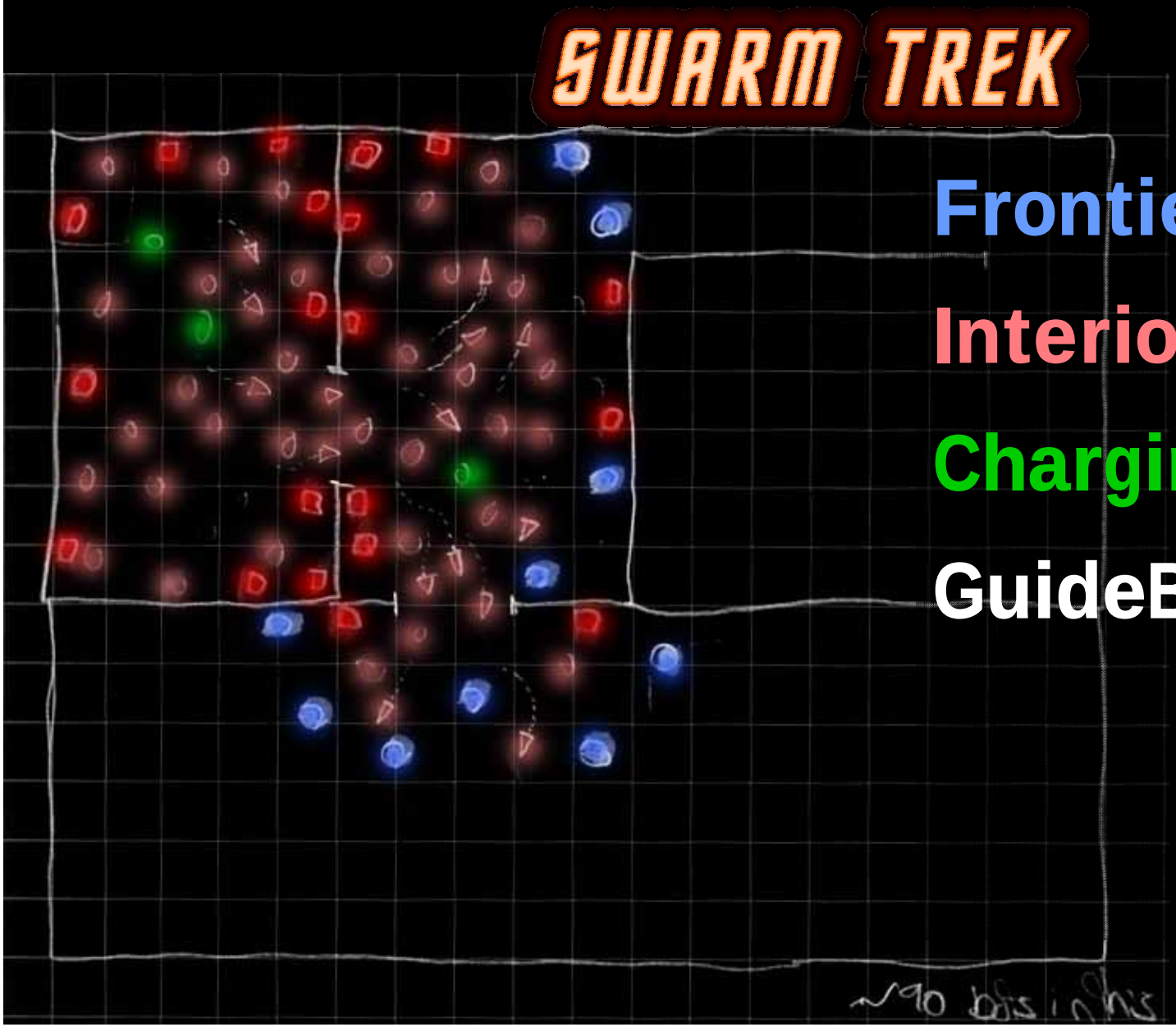
- I design distributed algorithms that perform simple tasks, like clustering and counting.
- These form a library of "group behavior building blocks" that can be combined to build complex programs
- I'm developing a language that uses this library to make it easier to write swarm software

Swarm Behavior Library

SwarmBot Hardware



Application: “Directed Dispersion”



FrontierBot

InteriorBot

ChargingBot

GuideBot

Thu Jan 29 18:49:06 2004
Blue=Frontiers
Red=Interior
Green=Charging
White=Guides

Thu Jan 29 13:15:44 2004

The Perils of Small Robots in Big Buildings

Return Home Behavior Not Perfected Yet…

This work brought to you by the letters:

iRobot

CSAIL

SWARM

jamesm@csail.mit.edu

Insect Trivia

The Queen is not in charge of the ant colony - she just eats and lays eggs

The weight of ants on the planet is equal to the weight of people on the planet…

…and it takes about 2,000,000 ants to weigh as much as one person!

The Honeybee brain is the densest neural tissue in nature

All worker ants, bees, and wasps are female

(I think my robots are all female too, but it's hard to tell)