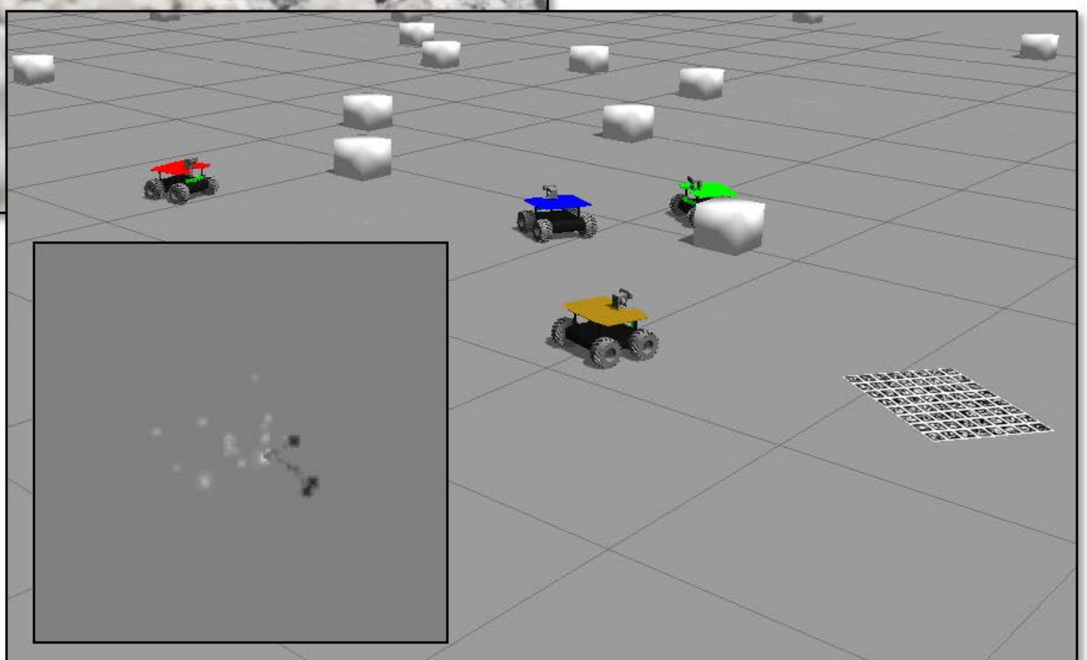
NASA, Engineering, and Swarming Robots



Kurt Leucht
NASA Software Engineer
Kennedy Space Center, FL

About Kurt

- Kurt Leucht (Loyt)
  - husband and father of 2 boys
  - NASA software engineer
  - 24 years with NASA
  - loves computers and software
  - designs and creates command and control software for robotic systems and for launch pad systems
  - also designs and creates advisory systems and development and productivity tools to increase efficiency and productivity of NASA workers

Purpose

- What is NASA’s purpose or vision?


National Aeronautics and Space Administration
NASA
REACH NEW HEIGHTS
BENEFIT ALL HUMANKIND
REVEAL THE UNKNOWN

Questions

- To meet NASA’s vision, thousands of people have been working around the world, and off of it, for more than 50 years, trying to answer some basic questions:

  - What's out there in space?
  - How do we get there?
  - What will we find?
  - What can we learn there, or learn just by trying to get there, that will make life better here on Earth?

STAND BACK

I'M GOING TO TRY

SCIENCE

Science vs. Engineering

- What’s the difference between Science and Engineering?
  - science is the study and understanding of the physical world and all it contains
  - engineering applies that scientific knowledge to solve problems and to make new things
- In other words…
  - science is about knowledge and engineering is about invention

Scientist vs. Engineer

- It's not a contest! Both are needed in the world!

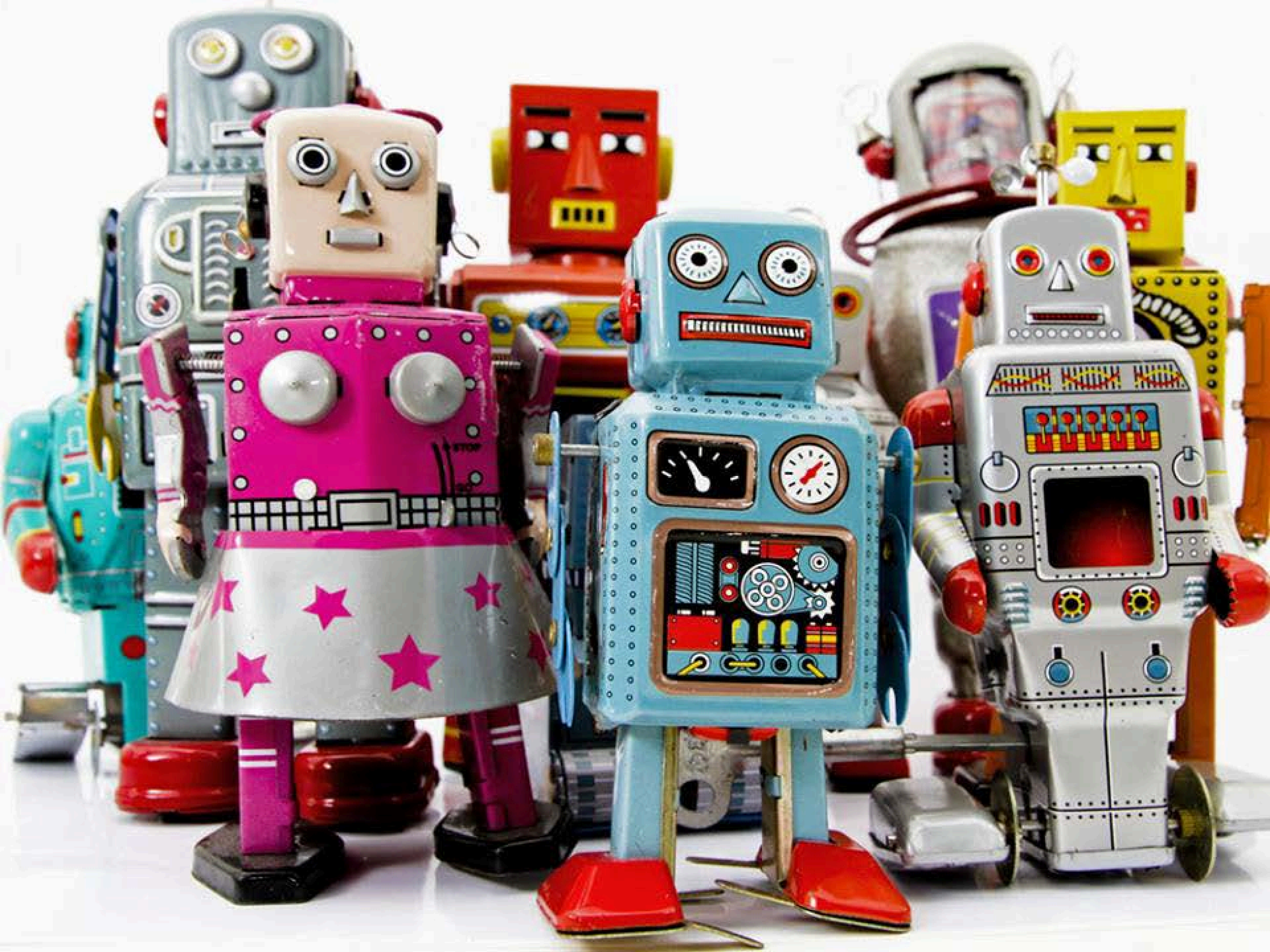
- Both scientists and engineers need a strong knowledge of science, math and technology.

NASA Engineer

- Since I’m a NASA Engineer, I solve problems for NASA and I also invent new things for NASA.

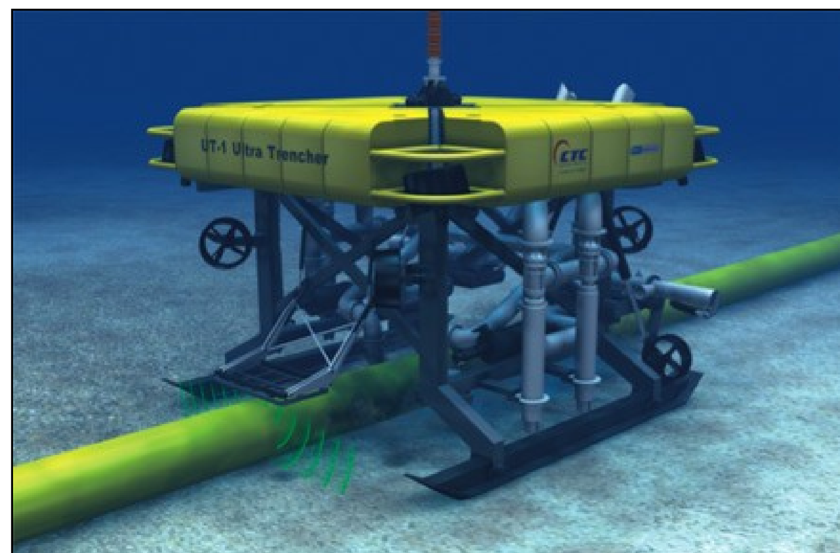
- Can you think of some unique problems that NASA might have?

Solutions to NASA Problems



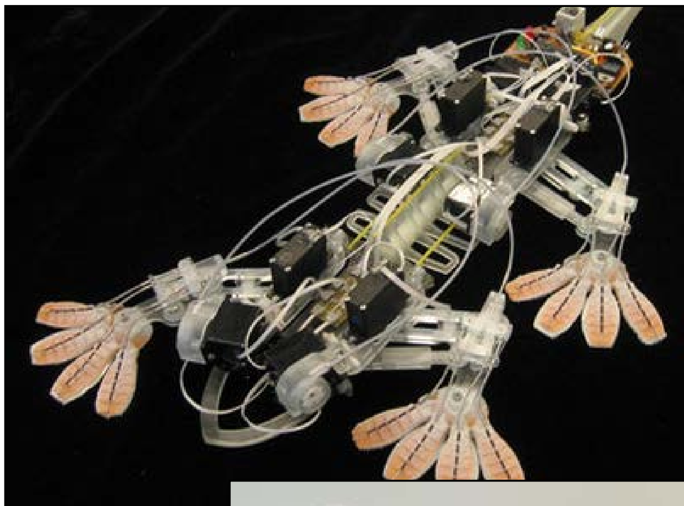
Robots

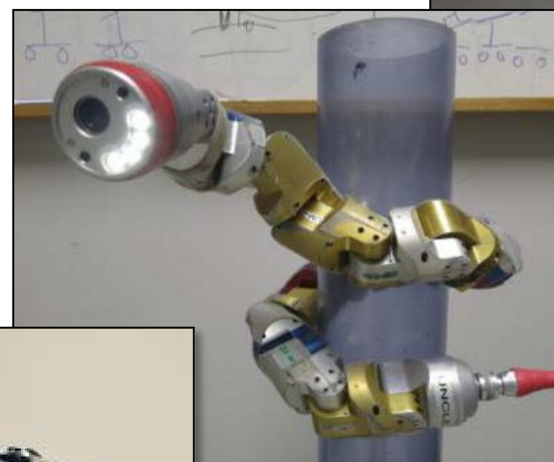
- Why were robots invented?
- The three D's:
  - to do work and tasks that are **Dull**, **Difficult** or **Dangerous**



Copying Nature

- Why do we sometimes copy animals and people when we invent robots?






- Sometimes the best way to do a task has already been perfected by nature, I guess.

Ant Colonies

20 million ants per colony: No foreman, no blueprints, no one in charge

Amazing Ants

- How do such tiny ants with such tiny brains accomplish so much?
  - build a complex nest that supports the colony
  - find and gather food and water … enough to support the entire nest

Wait. What?

- Did you say that ants are good at these things even with tiny brains?
  - build a complex nest that supports the colony
  - find and gather food and water … enough to support the entire nest

NASA?

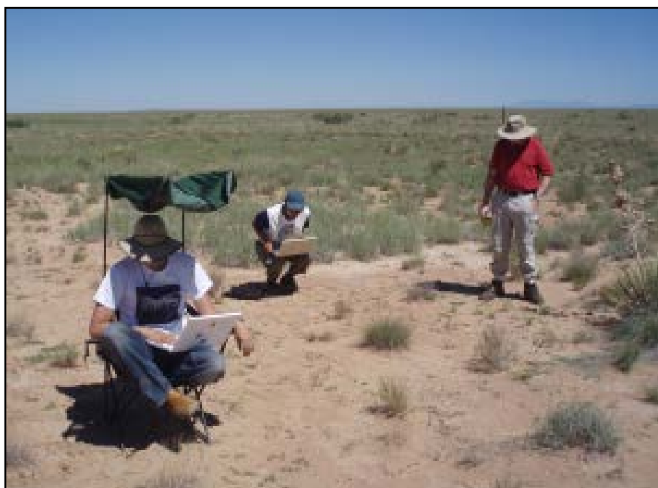
- Might NASA need robots that can do these types of things?
  - build a complex nest that supports the colony
  - find and gather food and water … enough to support the entire nest

Back to Amazing Ants

- How do such tiny ants with such tiny brains accomplish so much?
  - build a complex nest that supports the colony
  - find and gather food and water … enough to support the entire nest

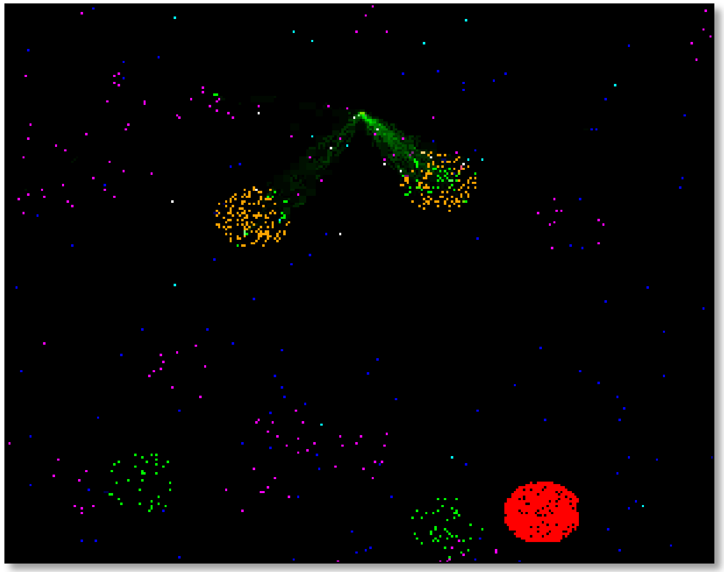
Ant Science

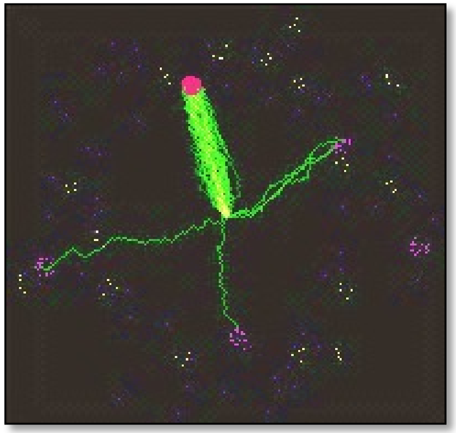
- Scientists have studied ants and have taken note of how they behave when searching for food and bringing that food home to the nest.

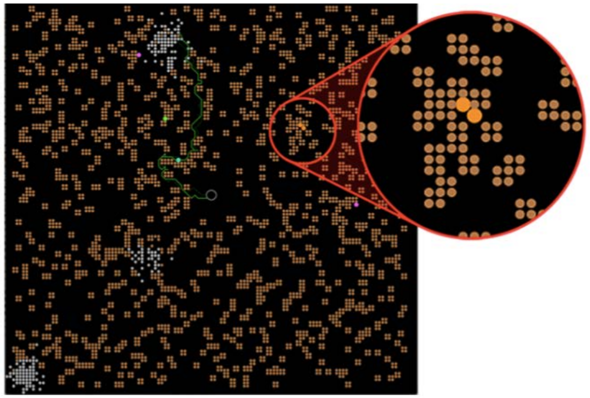


Ant Simulation

- Scientists and engineers have programmed the ant behaviors into a computer simulation.





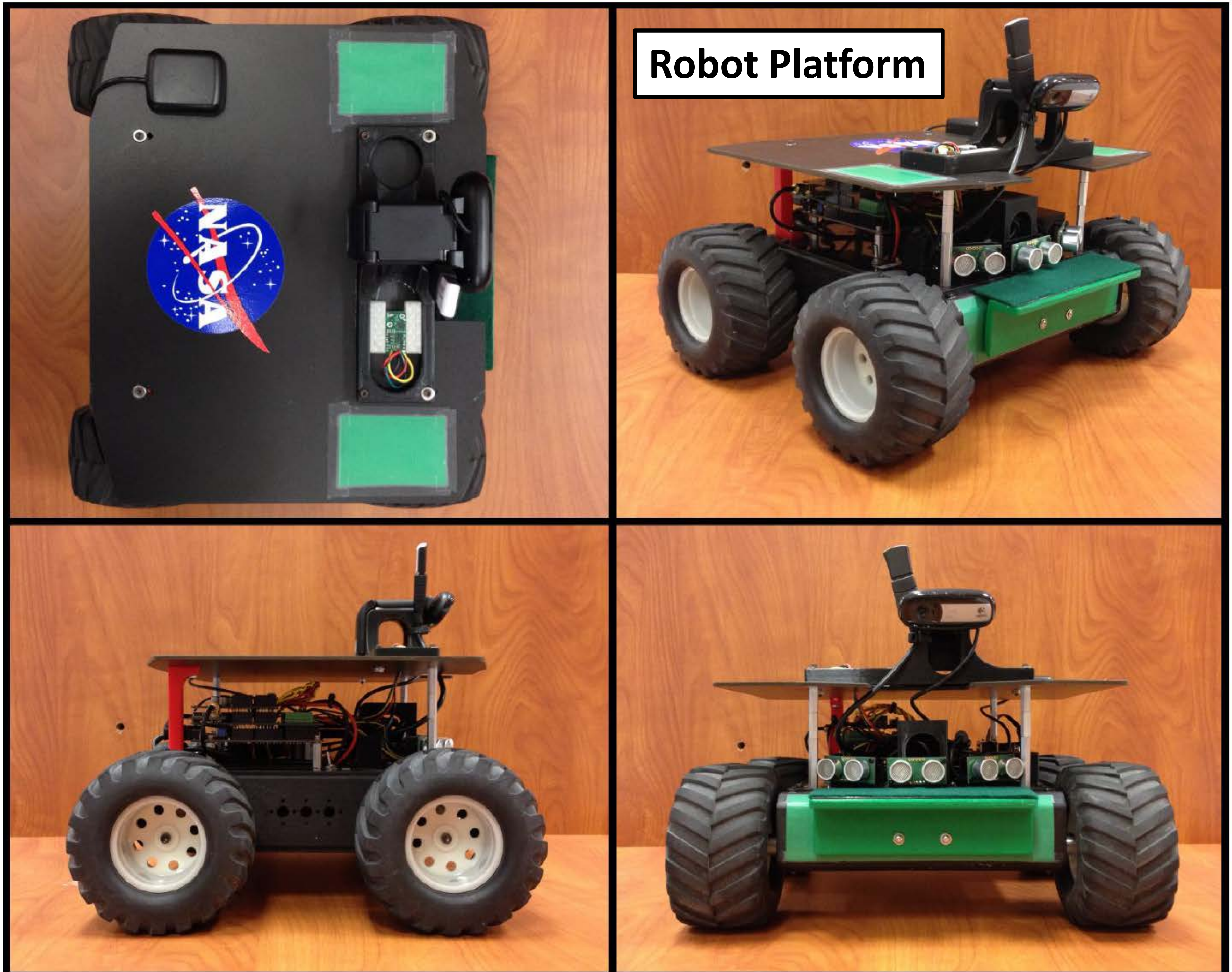


- This verifies that they have properly captured the ant behaviors and that those behaviors work in simulation the same way they work in real ants.

Ant Robots

- NASA has programmed the same ant behaviors into a group of small robots.

- **Meet the NASA Swarmies!**


Robot Platform
NASA

Robot Platform

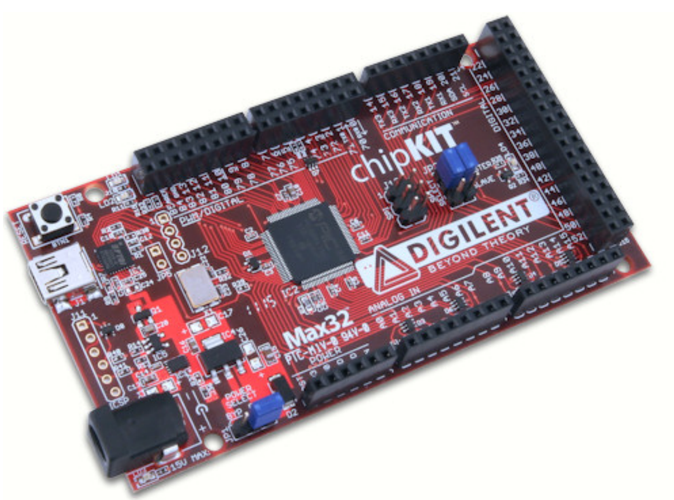
The Swarmie robot platform is a low-cost, ground-based research and demonstration platform.

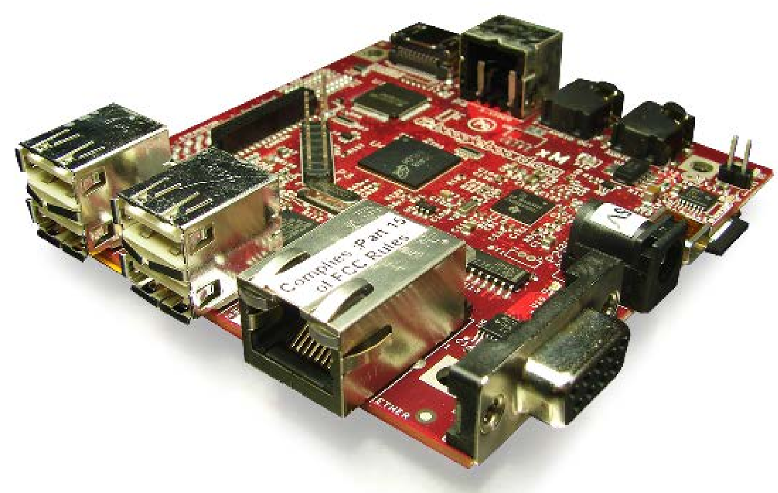
- Locomotion:
  - 4-wheel skid-steer design
  - both motors on each side of the robot are commanded simultaneously by the software
- Obstacle detection:
  - 3 sets of ultrasonic sensors
  - detect solid obstacles in front of the robot
- Localization:
  - global positioning system (GPS) sensor for location
  - inertial measurement unit (IMU) sensor for compass-based heading
- Resource detection:
  - USB web camera
  - AprilTags Visual Fiducial System software library (bar codes)
  - printed AprilTags arranged on the ground

Robot Platform

2 onboard computers with USB serial connection between them:

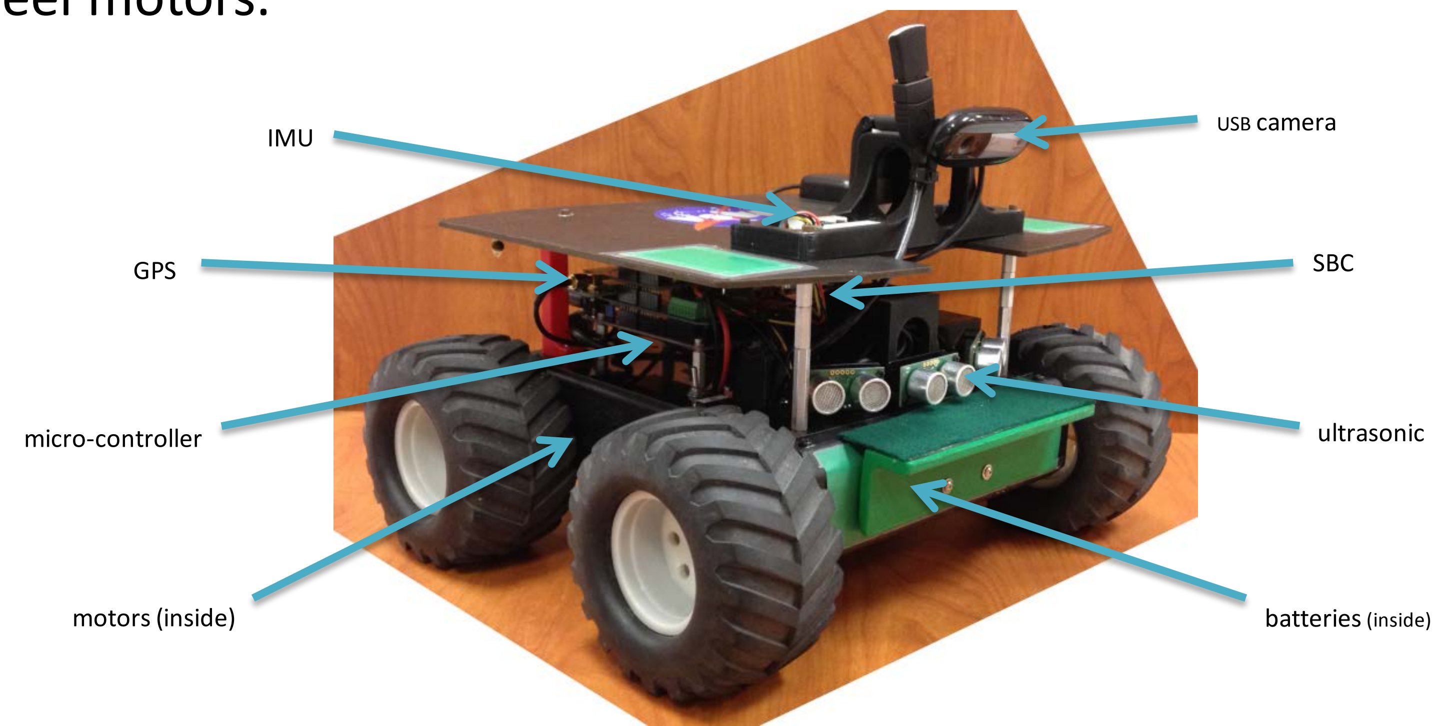
- Arduino compatible micro-controller stack:
  - chipKit Max32 board, Arduino Mega Prototype board
  - data acquisition for GPS, IMU, ultrasonic sensors
  - motor control
- Linux compatible single board computer (SBC):
  - BeagleBoard-xM board
  - image acquisition for USB camera
  - all onboard computation
  - all behavioral programming



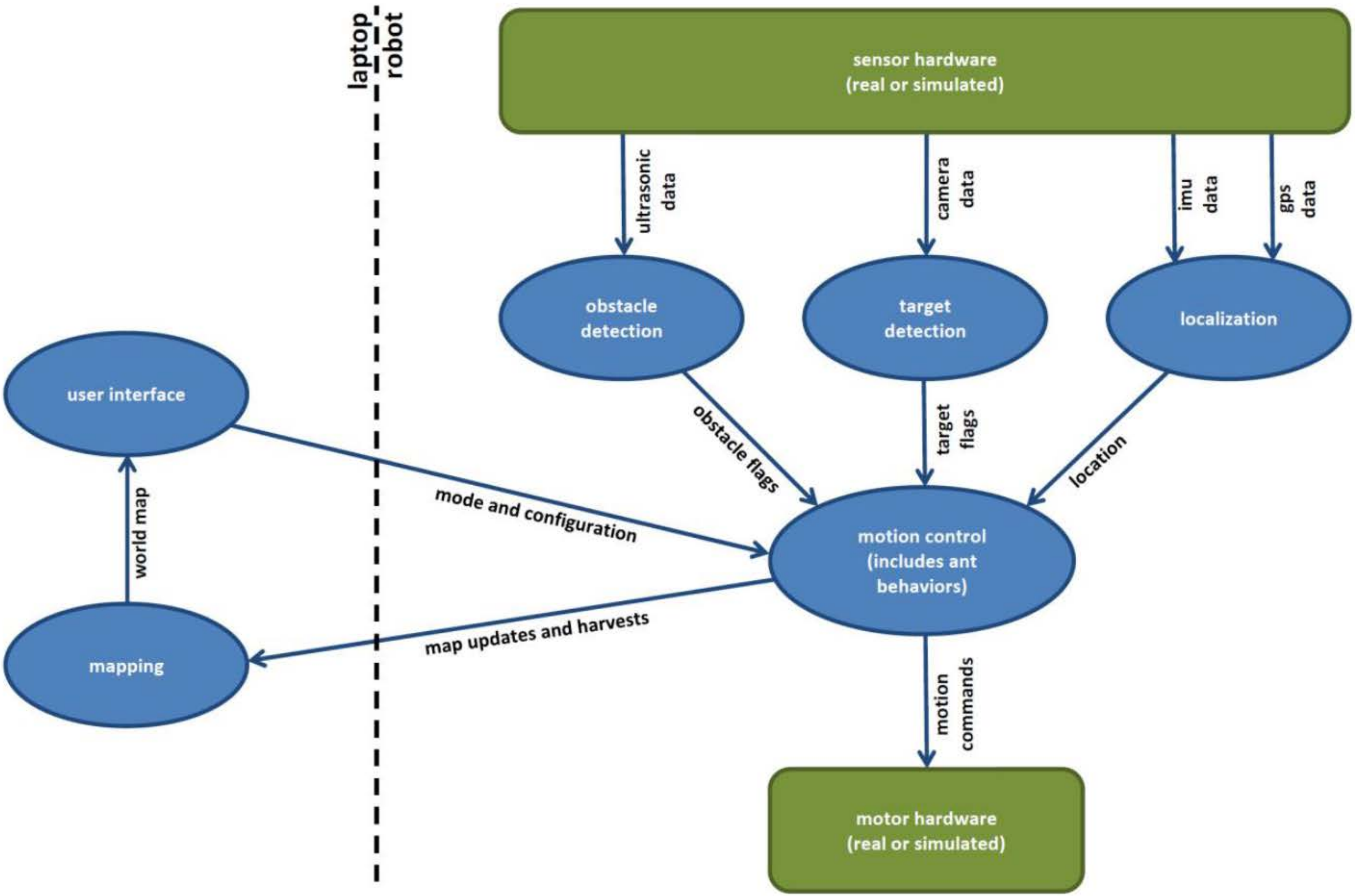


Robot Platform

- Wheel motors and batteries are housed inside the enclosed chassis.
- Micro-controller stack, SBC, and GPS and ultrasonic sensors are mounted on top of the enclosed chassis.
- USB web camera is mounted on top of the robot's protective lid to get a better angle on the printed AprilTags that are placed flat on the ground.
- IMU sensor is mounted on top next to USB web camera to distance that sensitive magnetic field sensor from electromagnetic noise emitted from wheel motors.



Robot Software



Robot Software

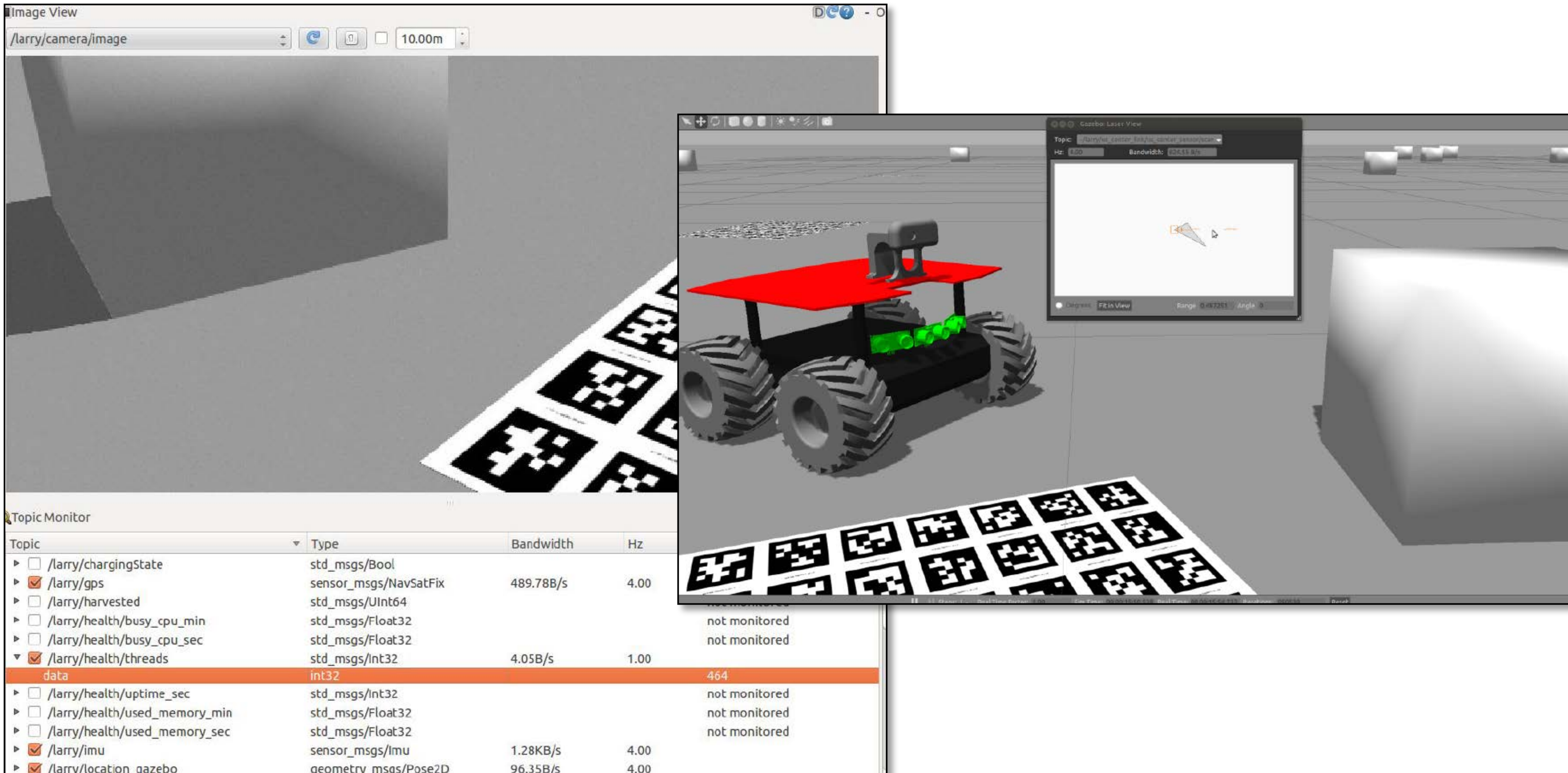
Installed on BeagleBoard-xM SBC:

- Ubuntu Linux operating system
- Open source Robot Operating System (ROS) framework
  - tools, libraries, data types, conventions
  - simplifies task of creating robot behavior in software

Support Software

Two open source software systems were heavily utilized by the project and were critical to its success:

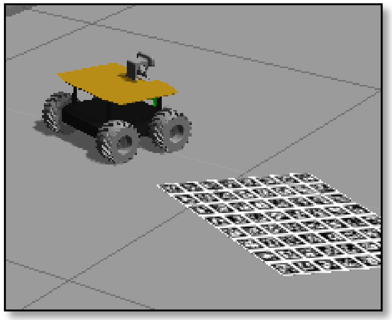
- Robot Operating System (ROS) and associated packages
- Gazebo robot simulator and associated plugins



Experimental Trials

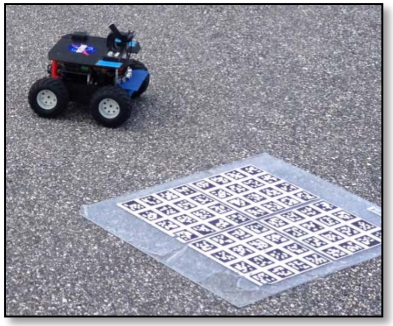
19 Gazebo simulation trials were performed:

- 2 hour trials
- 4 simulated Swarmie robots
- 256 resource tags arranged in 4 tight clusters of 64
- 50 obstacles
- arena size of 400 square meters



10 real Swarmie robot trials were performed:

- 2 hour trials
- 4 real Swarmie robots
- 256 resource tags arranged in 4 tight clusters of 64
- 0 obstacles
- arena size of 400 square meters



17 additional long term Gazebo simulation trials were performed:

- 12 hour trials
- 4 simulated Swarmie robots
- 256 resource tags arranged in 4 tight clusters of 64
- 50 obstacles
- arena size of 400 square meters

Results

✓ The robots worked!

- They found and gathered simulated food from an unknown area that was filled with obstacles.
- They used simulated pheromone trails to communicate with others.
- They simulated robot battery charging which could be necessary for future Mars missions.
- They worked together to increase the efficiency of the colony.
- They accomplished all this using inexpensive computers and inexpensive sensors.

Take Away

Biologically inspired cooperative robots are a promising new research area and could provide great benefits to future space exploration missions.

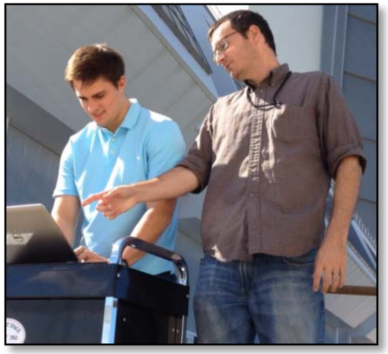
Another Take Away

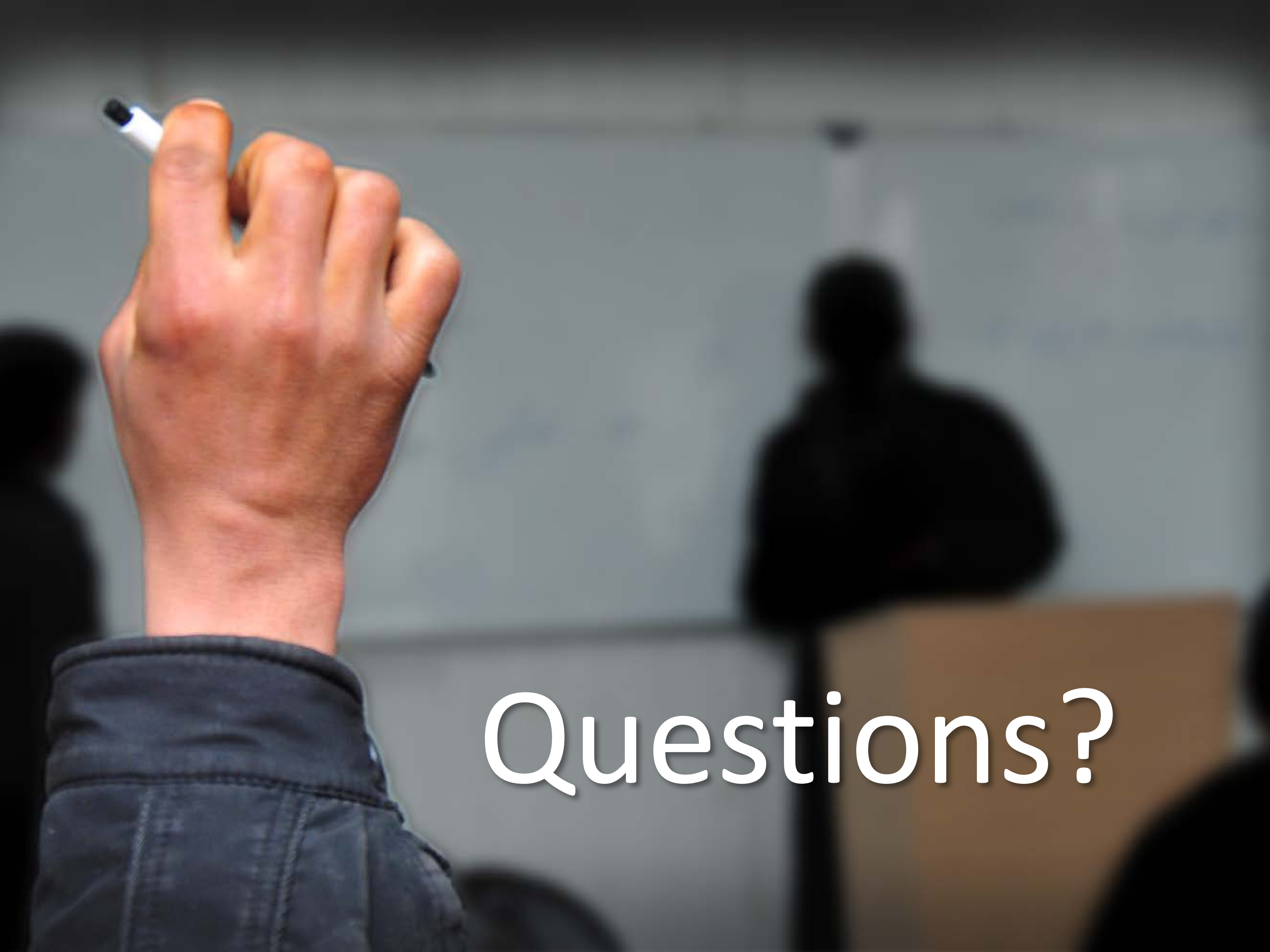
Students just like you will someday perform research and solve technical problems that will help humans live and work on Mars.

Team

- **Kurt Leucht** - NASA KSC Principal Investigator, Software Lead
- **Caylyne Shelton** - NASA KSC Software Engineer
- **Lien Moore** - NASA KSC Software Engineer
- **Cheryle Mako** - NASA KSC Supervisor
- **Karl Stolleis** - University of New Mexico Graduate Student
- **Joshua Hecker** - University of New Mexico Doctoral Student
- **Dr. Melanie Moses** - University of New Mexico Associate Professor
- **Matt Nugent** - Sierra Lobo Software Engineer
- **Gil Montague** - Baldwin Wallace Univ. Undergraduate Student




Questions?