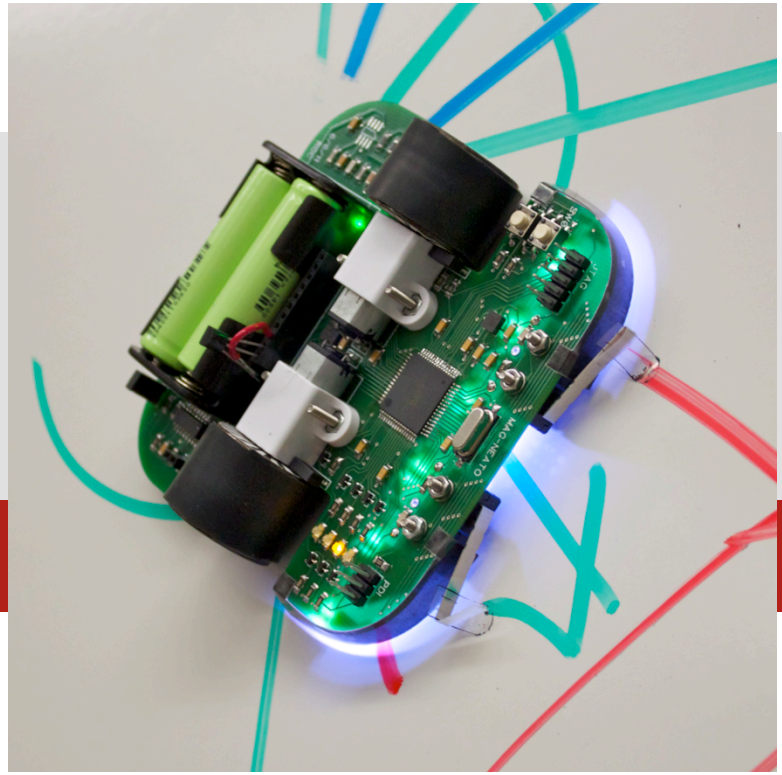
HARVARD UNIVERSITY
Self-Organizing Systems Research Group

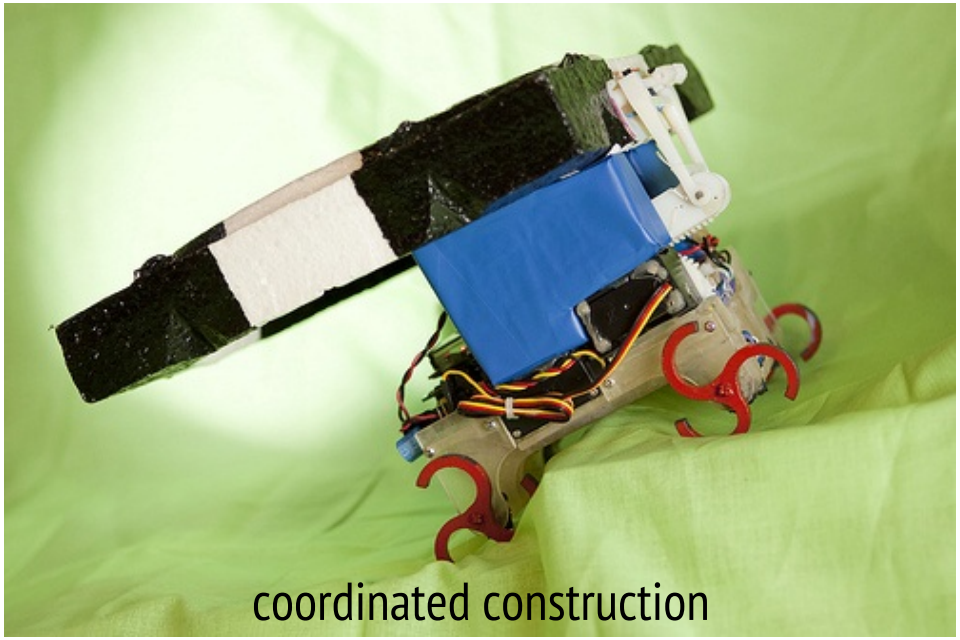
MAG-NEATO

a magnetic board cleaning robot



Raphael Cherney

INSPIRATION



coordinated construction

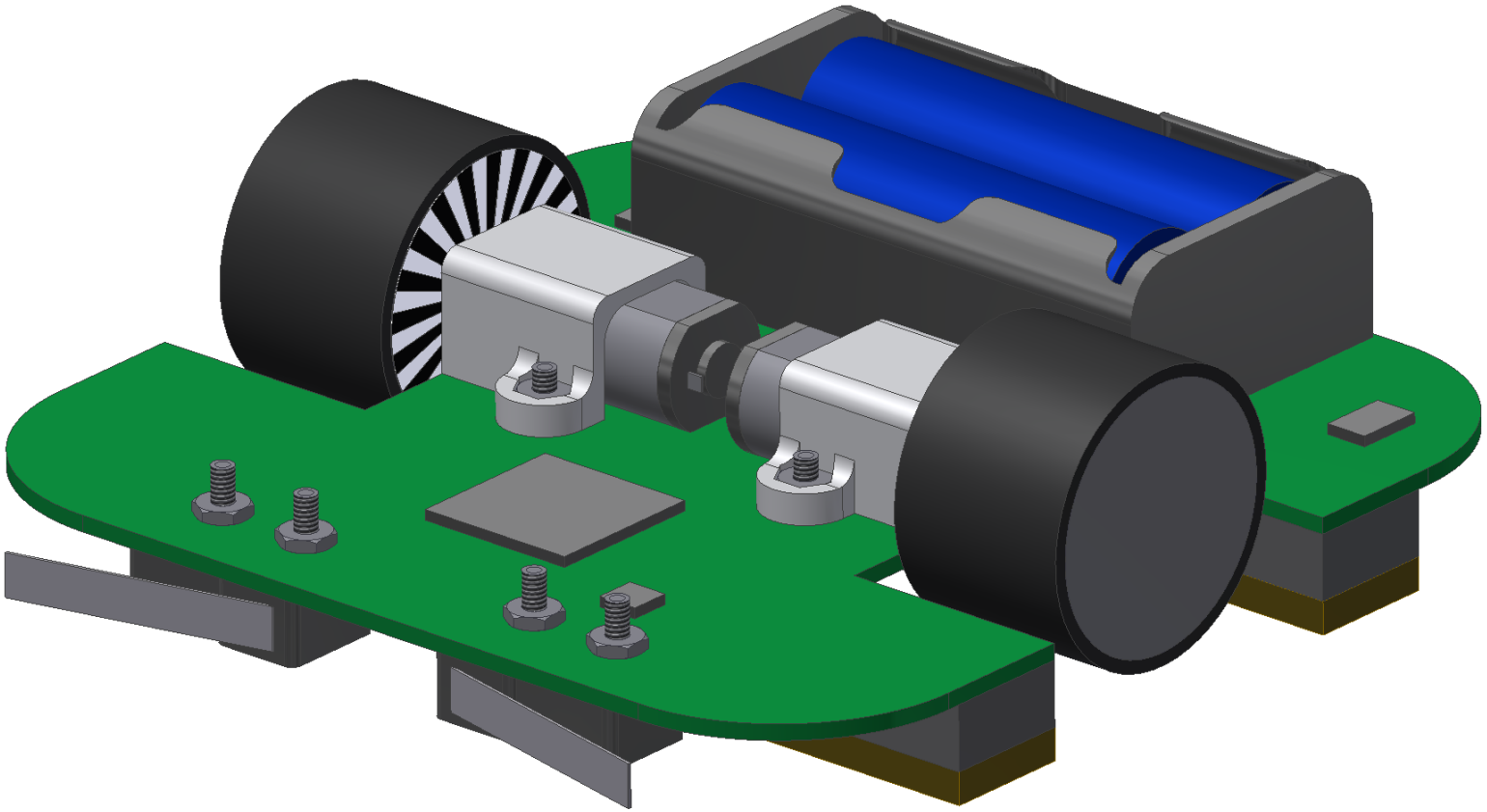
wall driving toys

GOALS

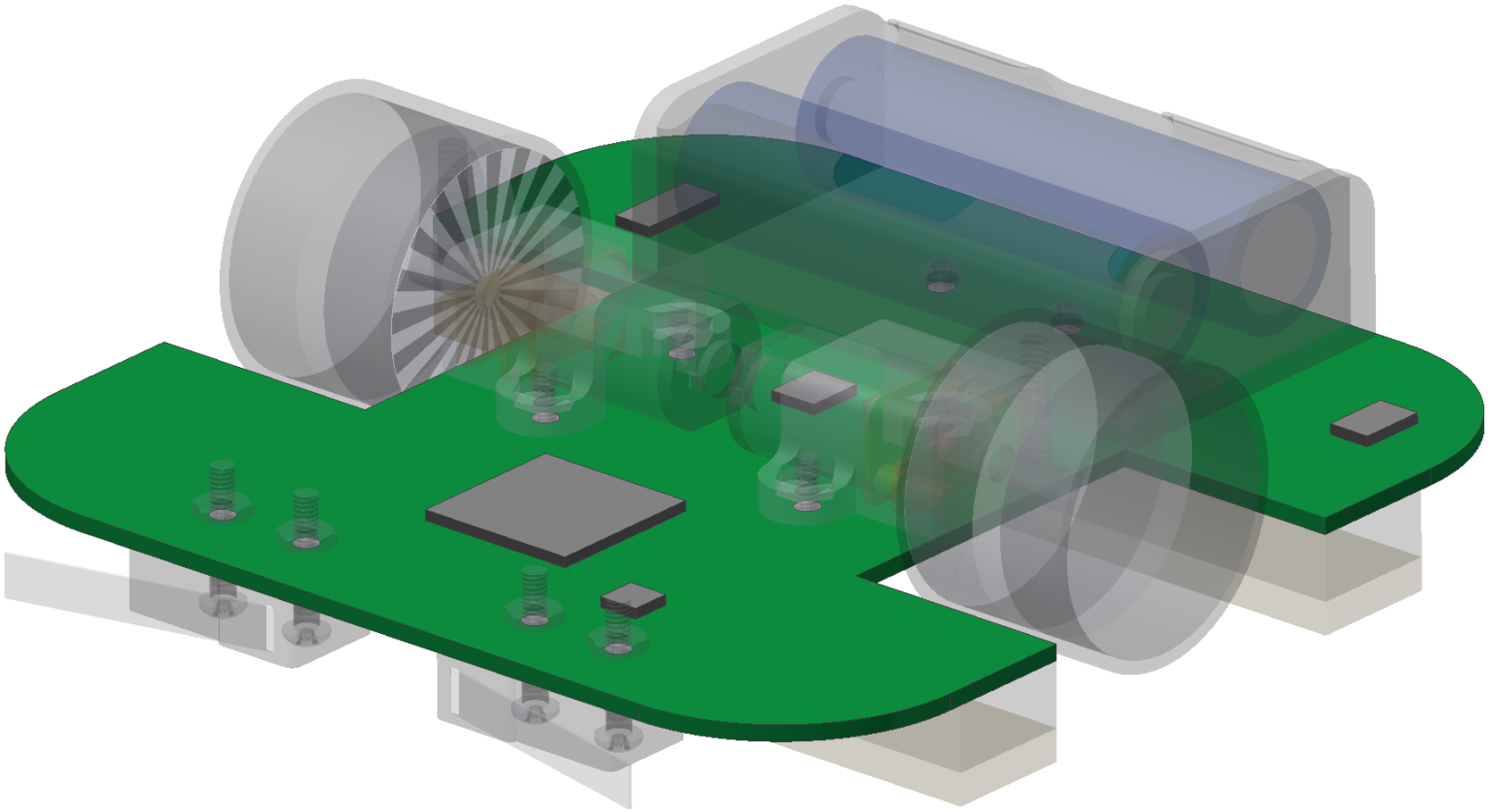
- Investigate magnetic climbing robots by building an autonomous robotic board cleaner
  - Reliable hardware
    - Low-cost
    - Easy to build
  - Documented codebase covering low-level controls
  - Demo behaviors

+

MECHANICAL DESIGN

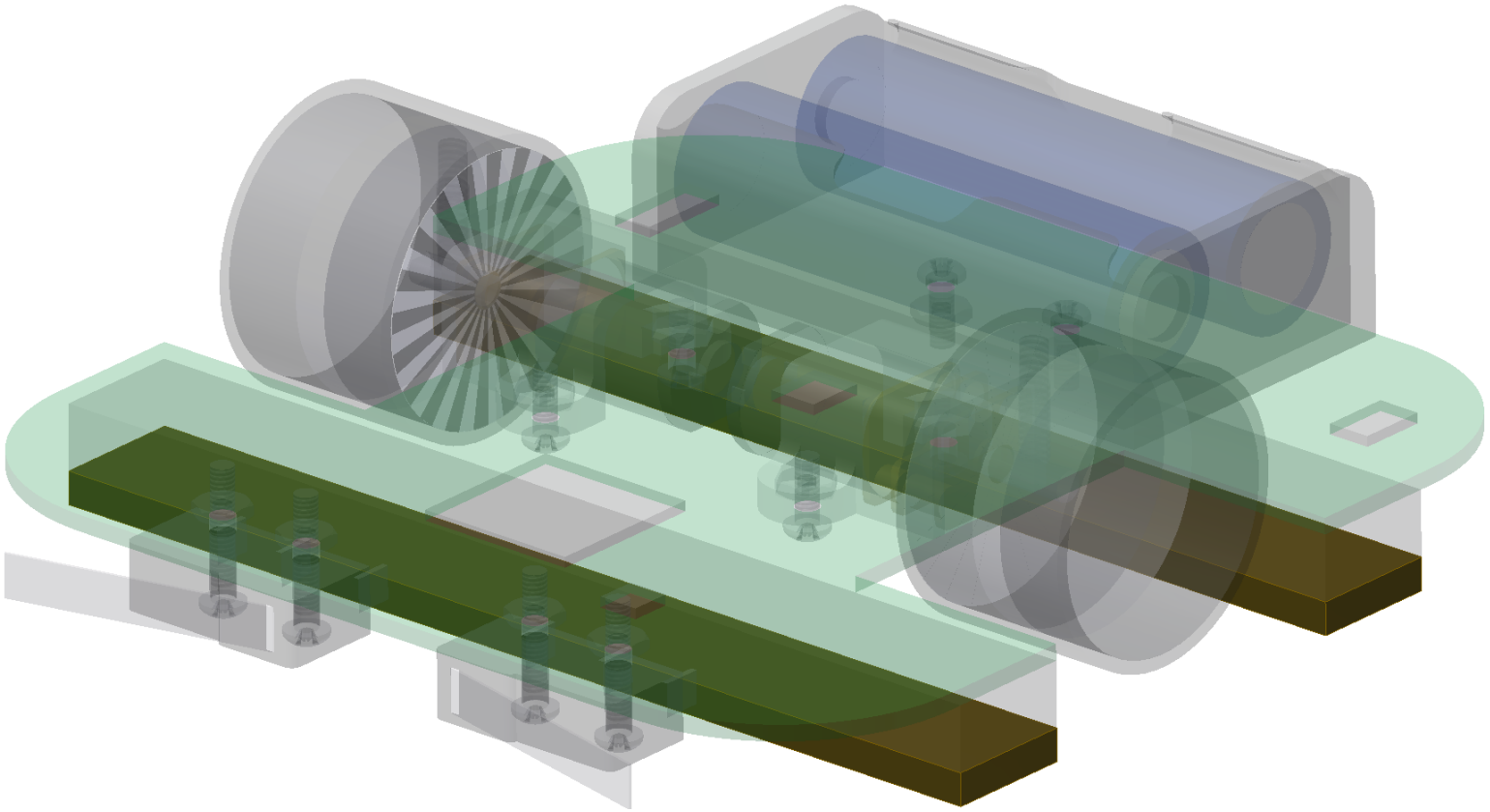


MECHANICAL DESIGN



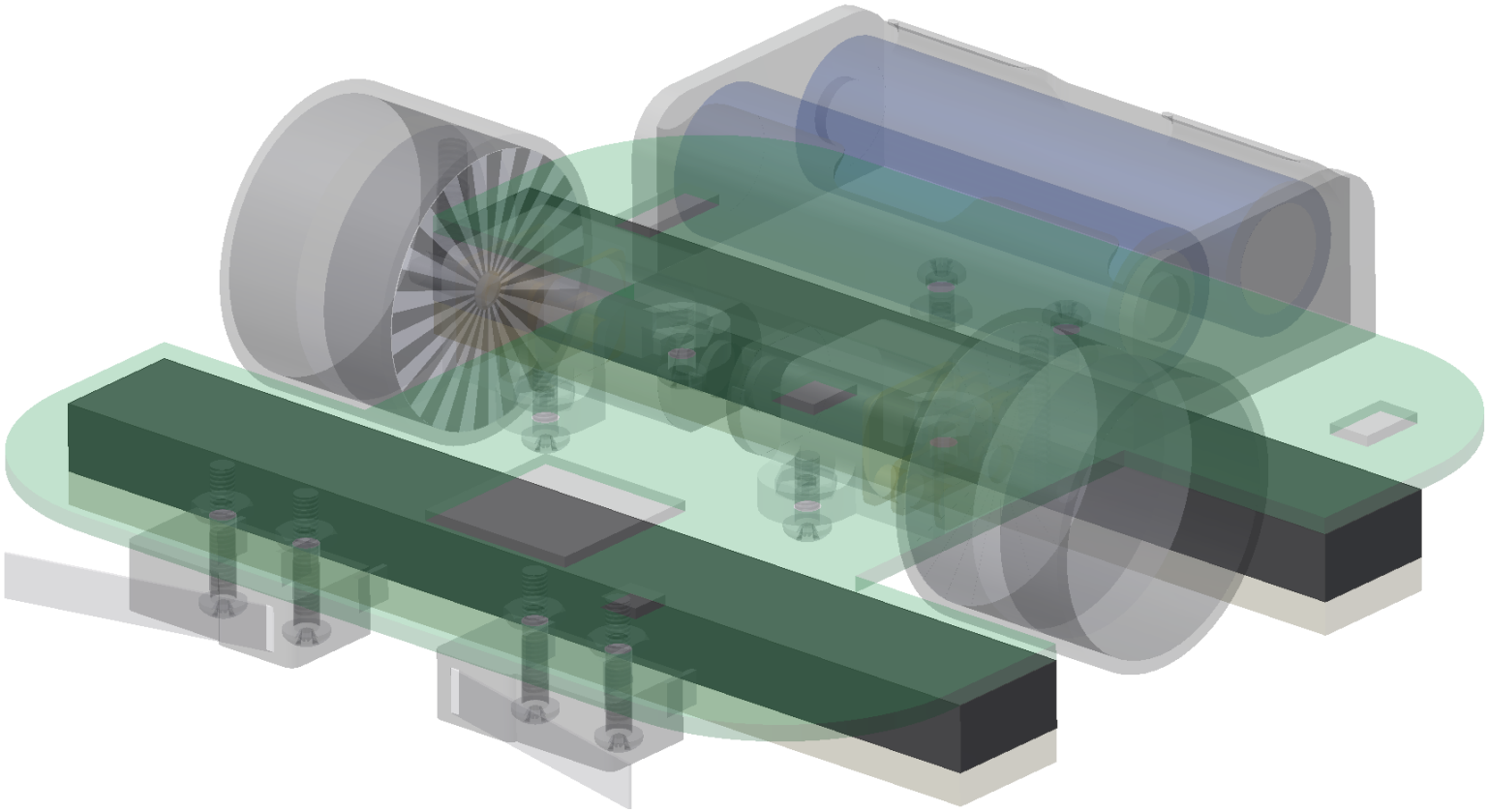
Custom two-layer printed circuit board

MECHANICAL DESIGN



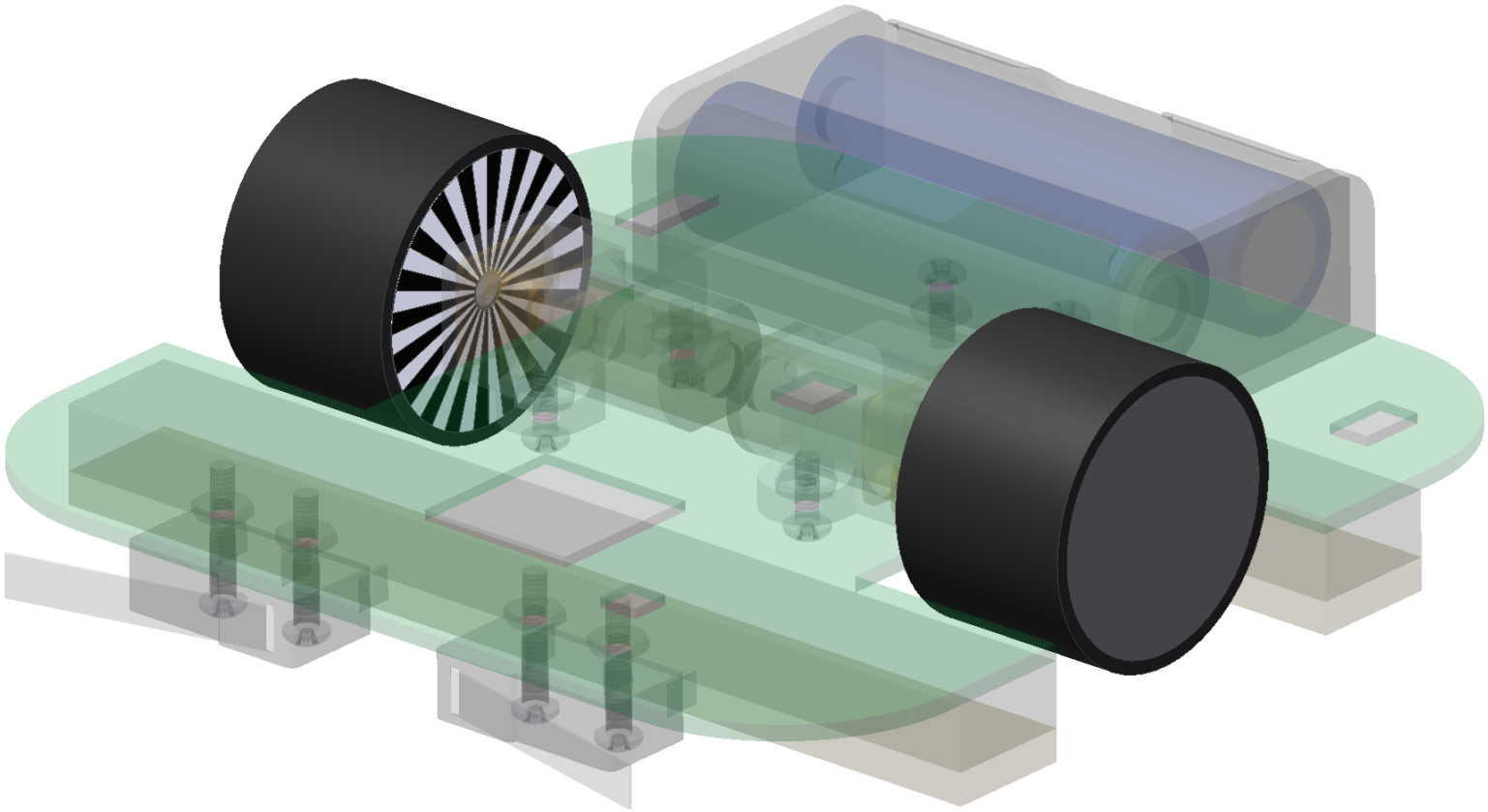
Felt erasing pads

MECHANICAL DESIGN



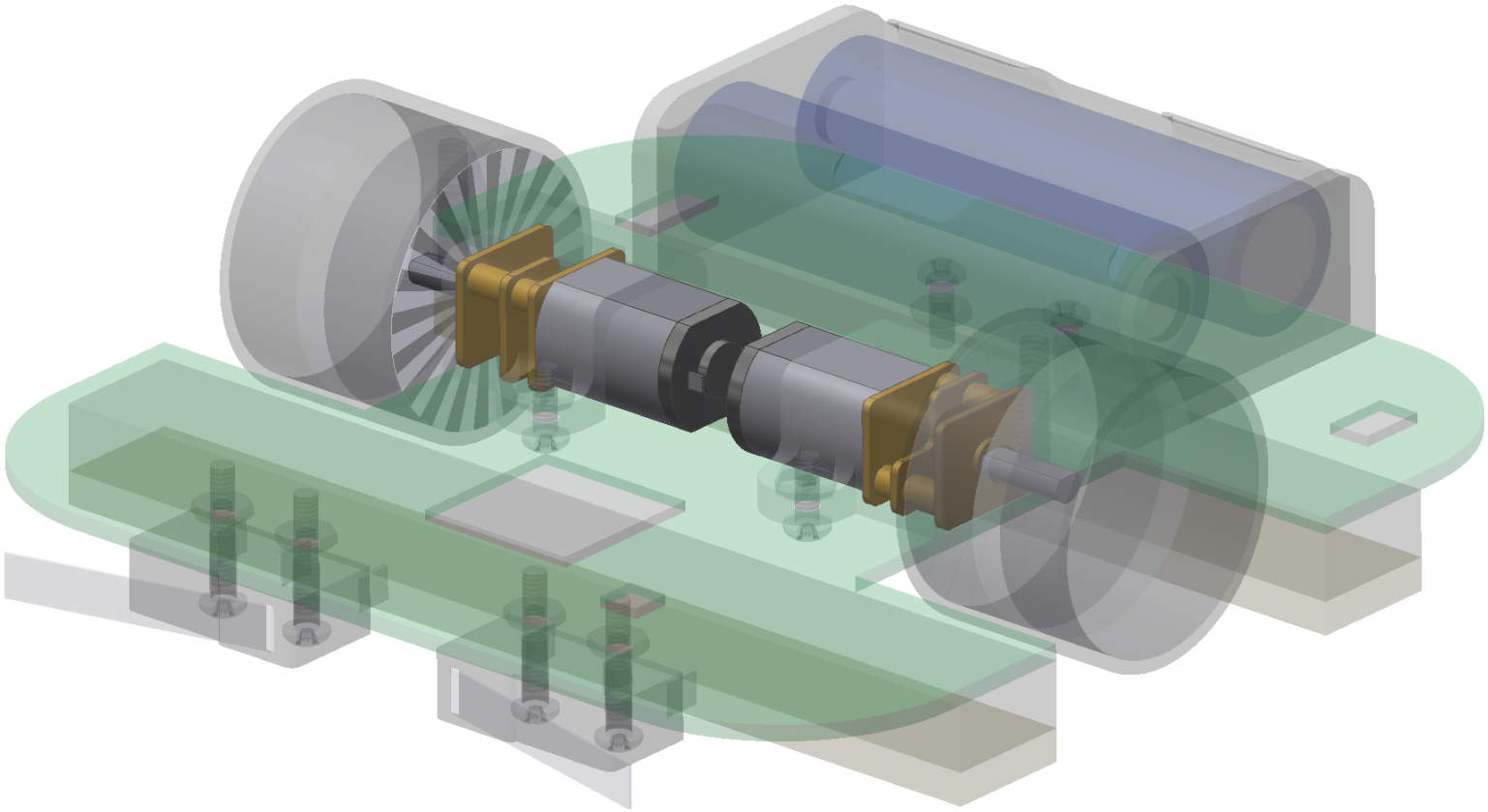
Compressive polyurethane foam

MECHANICAL DESIGN



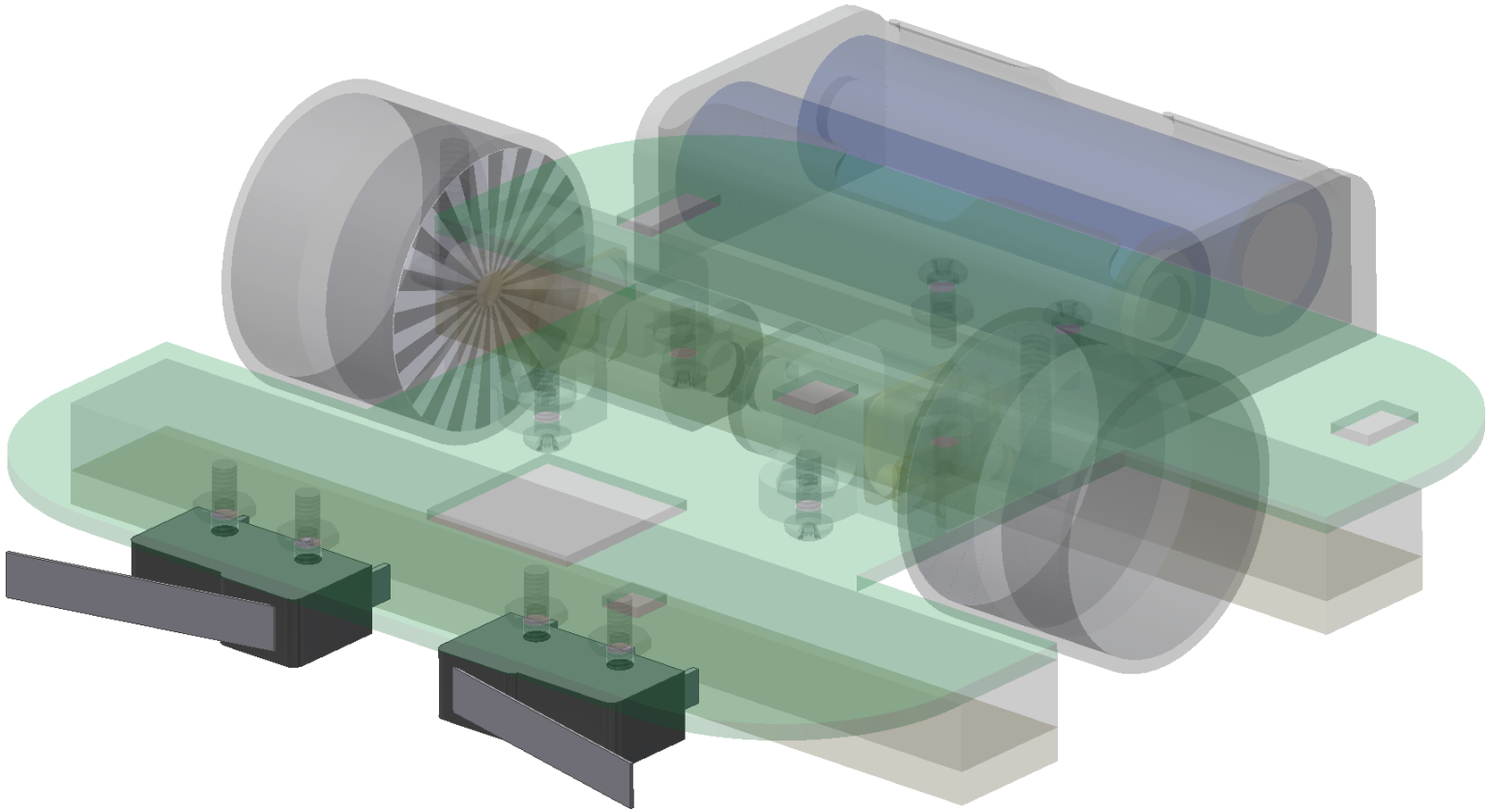
Custom magnetic wheels with encoders

MECHANICAL DESIGN



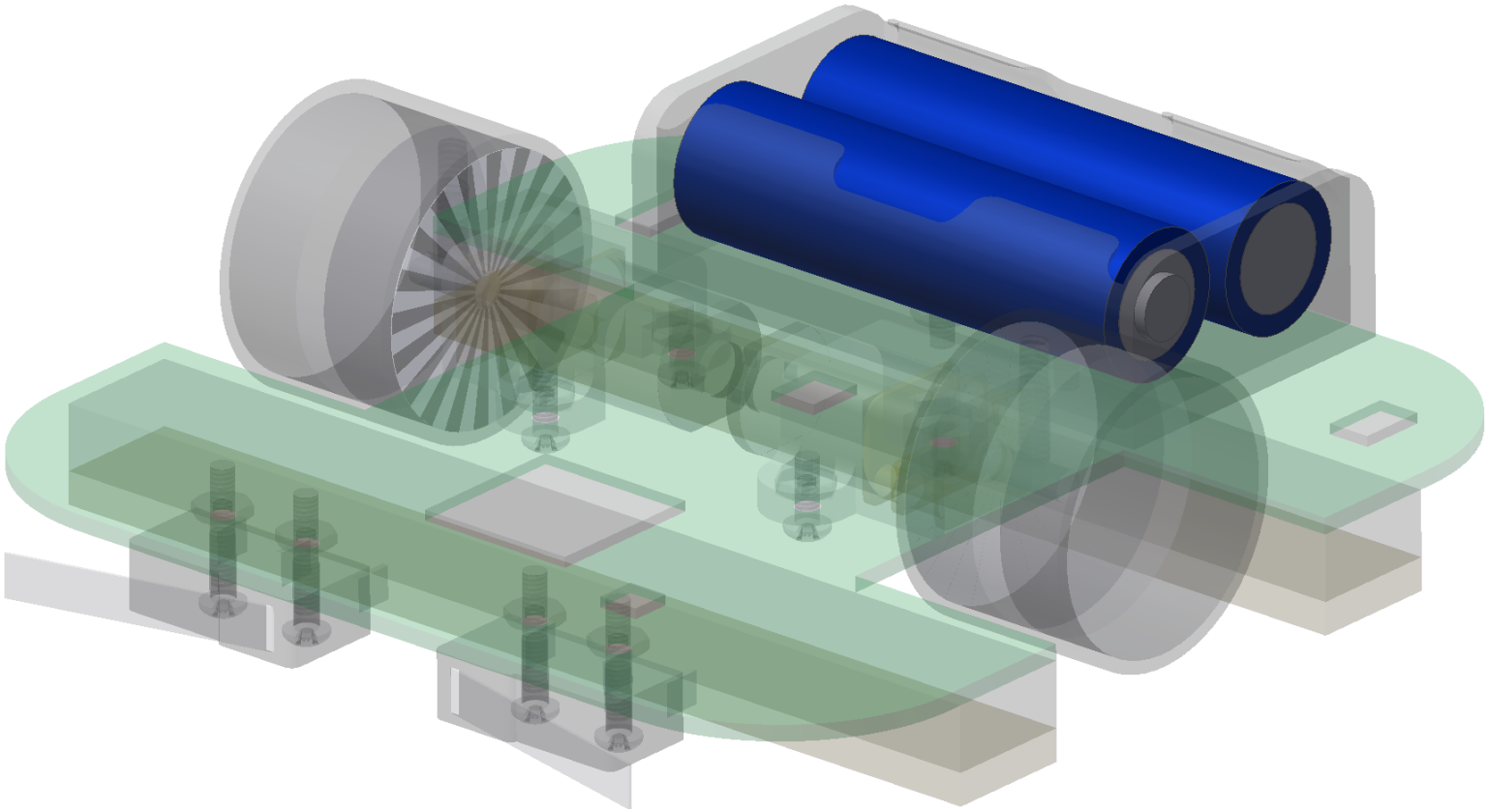
Two metal gearmotors

MECHANICAL DESIGN



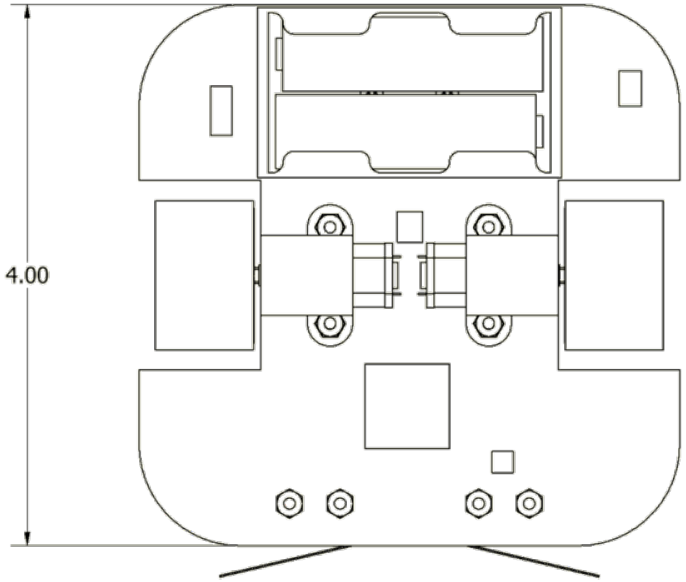
Two front bump sensors

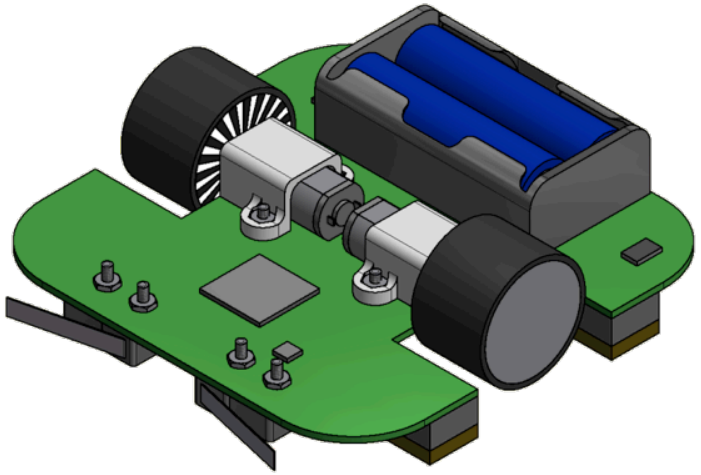
MECHANICAL DESIGN

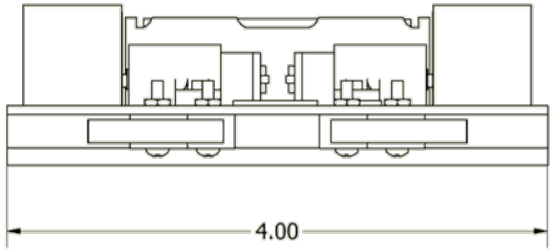


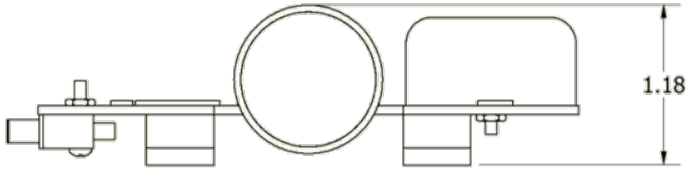
Rechargeable lithium-ion batteries

MECHANICAL DESIGN









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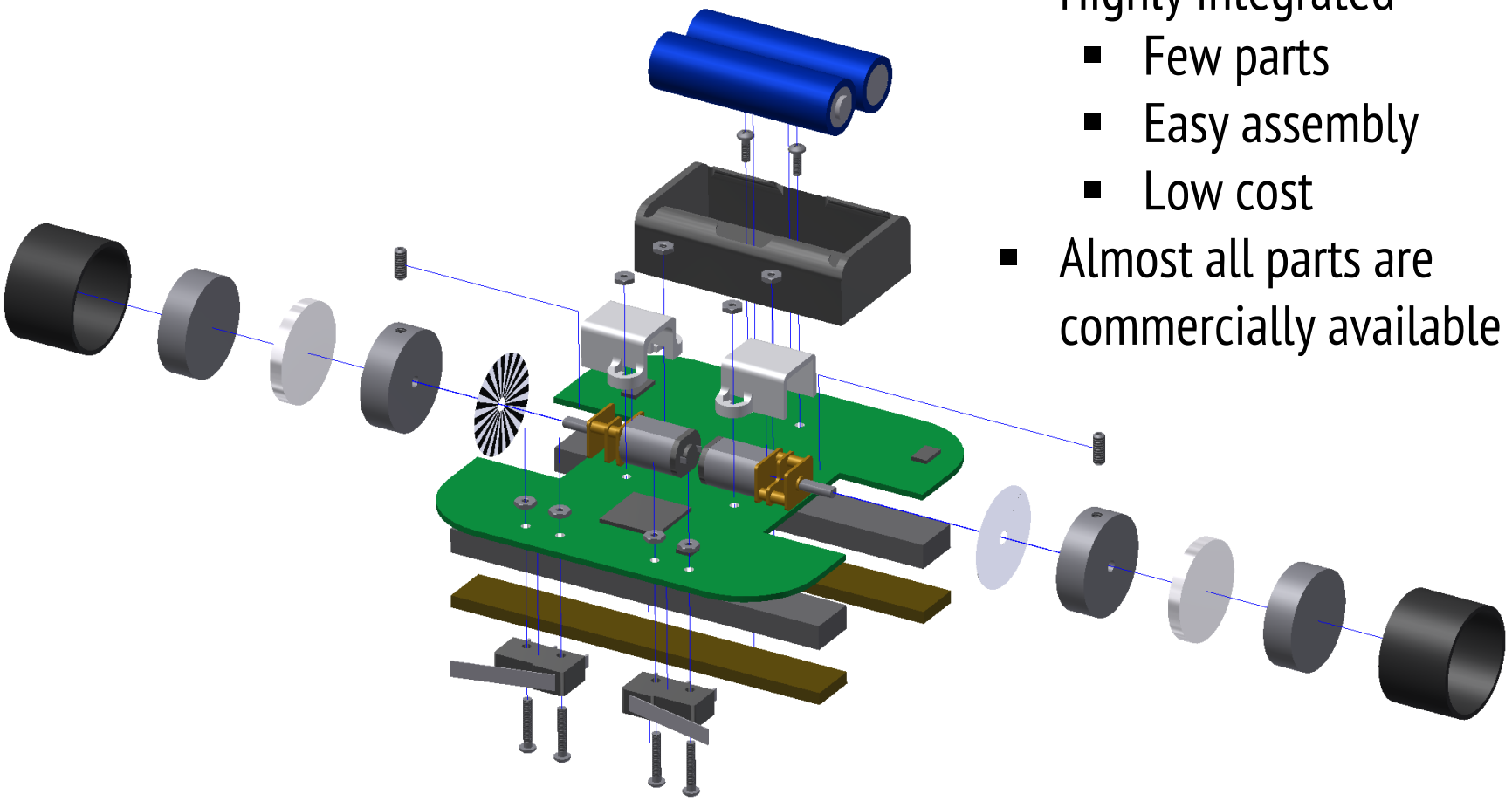
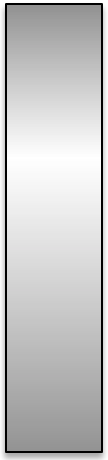


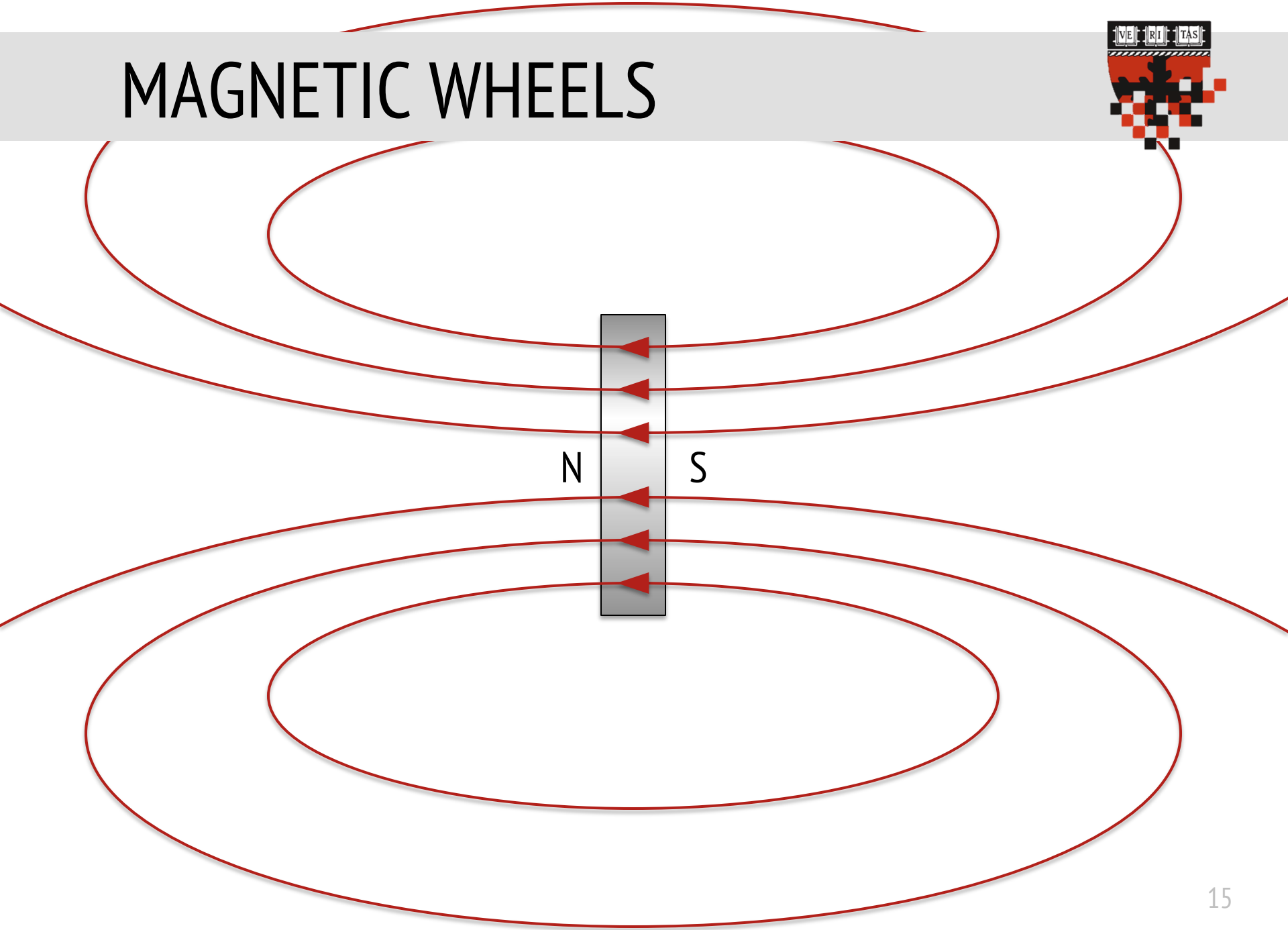
- Highly integrated
  - Few parts
  - Easy assembly
  - Low cost
- Almost all parts are commercially available

MAGNETIC WHEELS

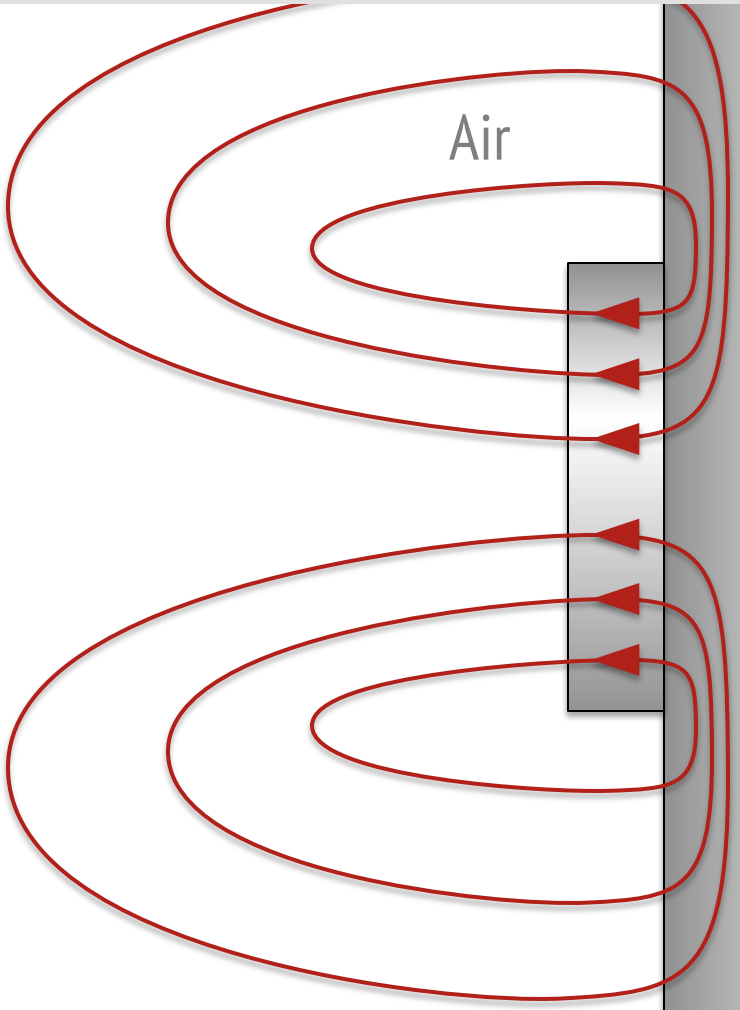


Neodymium rare earth magnet

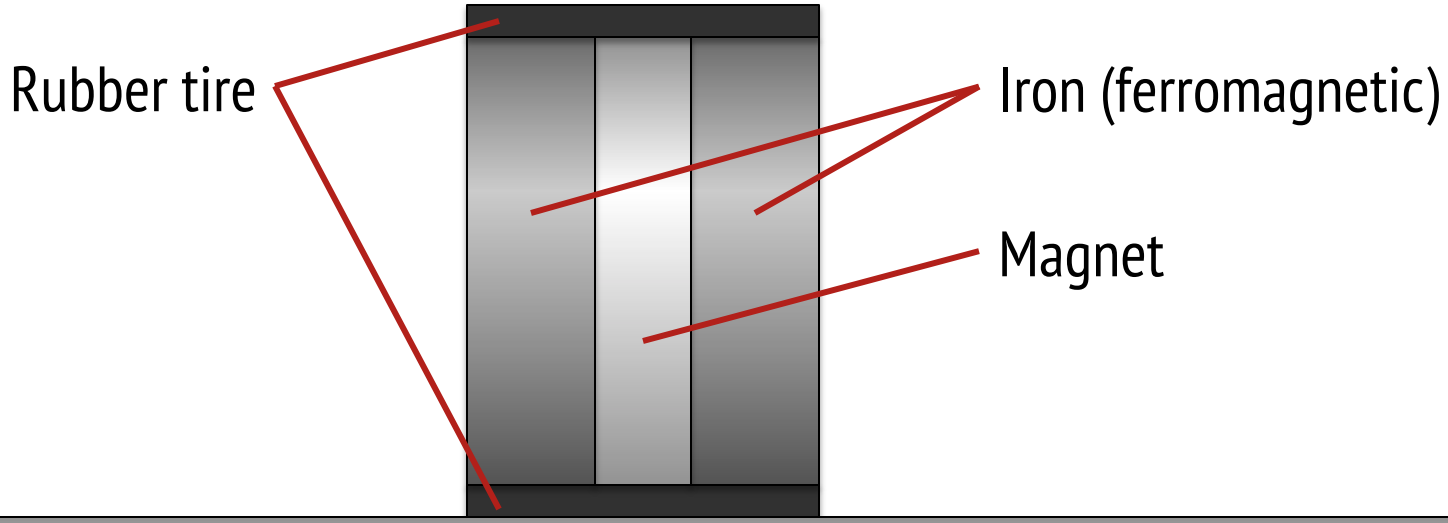
MAGNETIC WHEELS



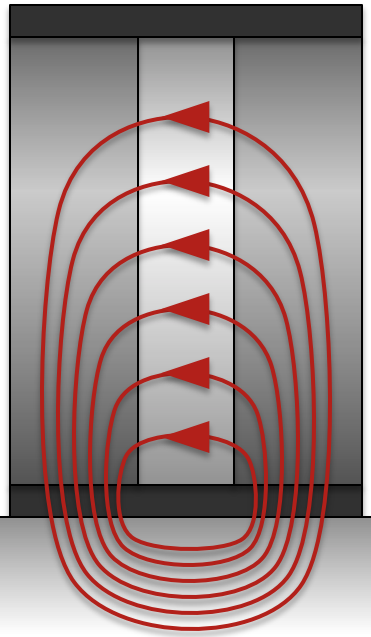
MAGNETIC WHEELS



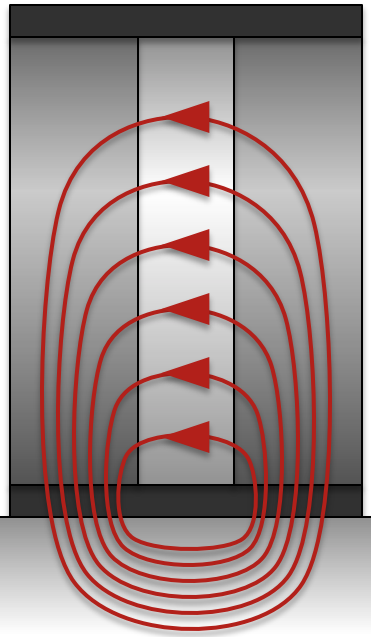
MAGNETIC WHEELS



MAGNETIC WHEELS

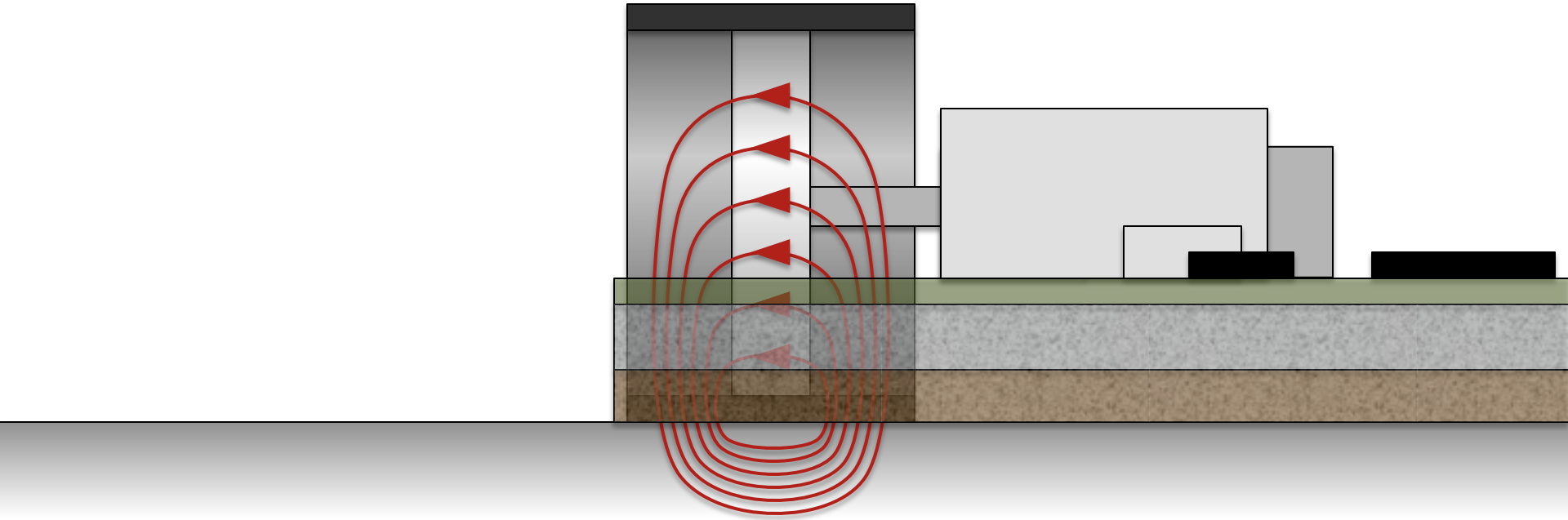


MAGNETIC WHEELS

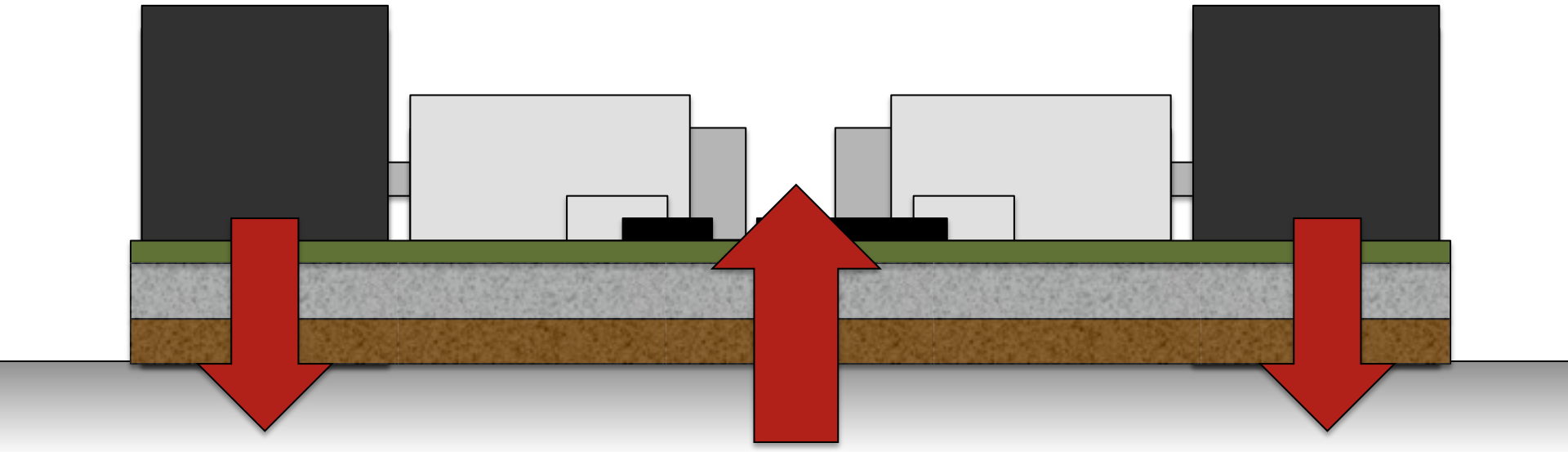


- Adjustable force
- Constant distance
- Robot cannot drive off the board

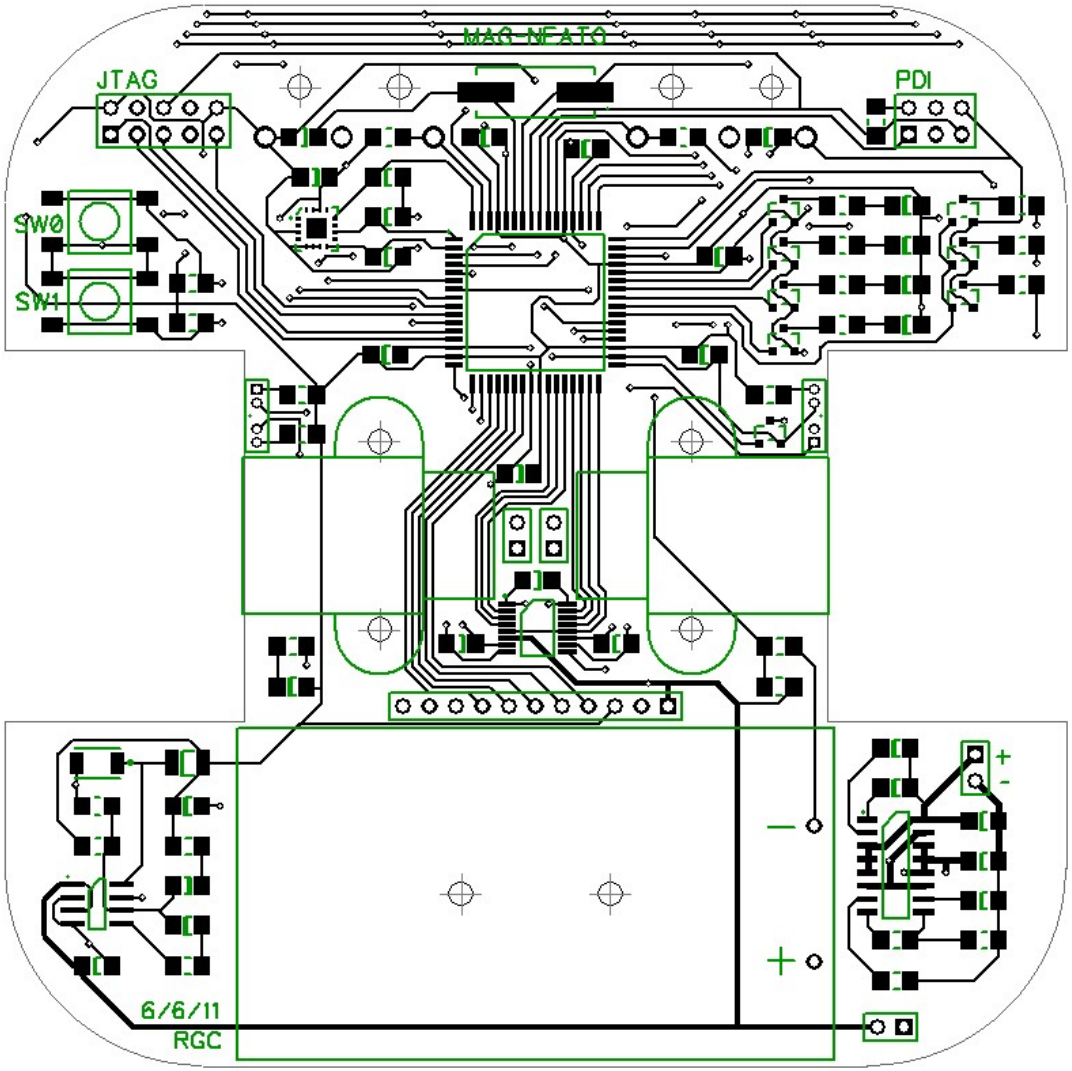
MAGNETIC WHEELS



MAGNETIC WHEELS



PRINTED CIRCUIT BOARD



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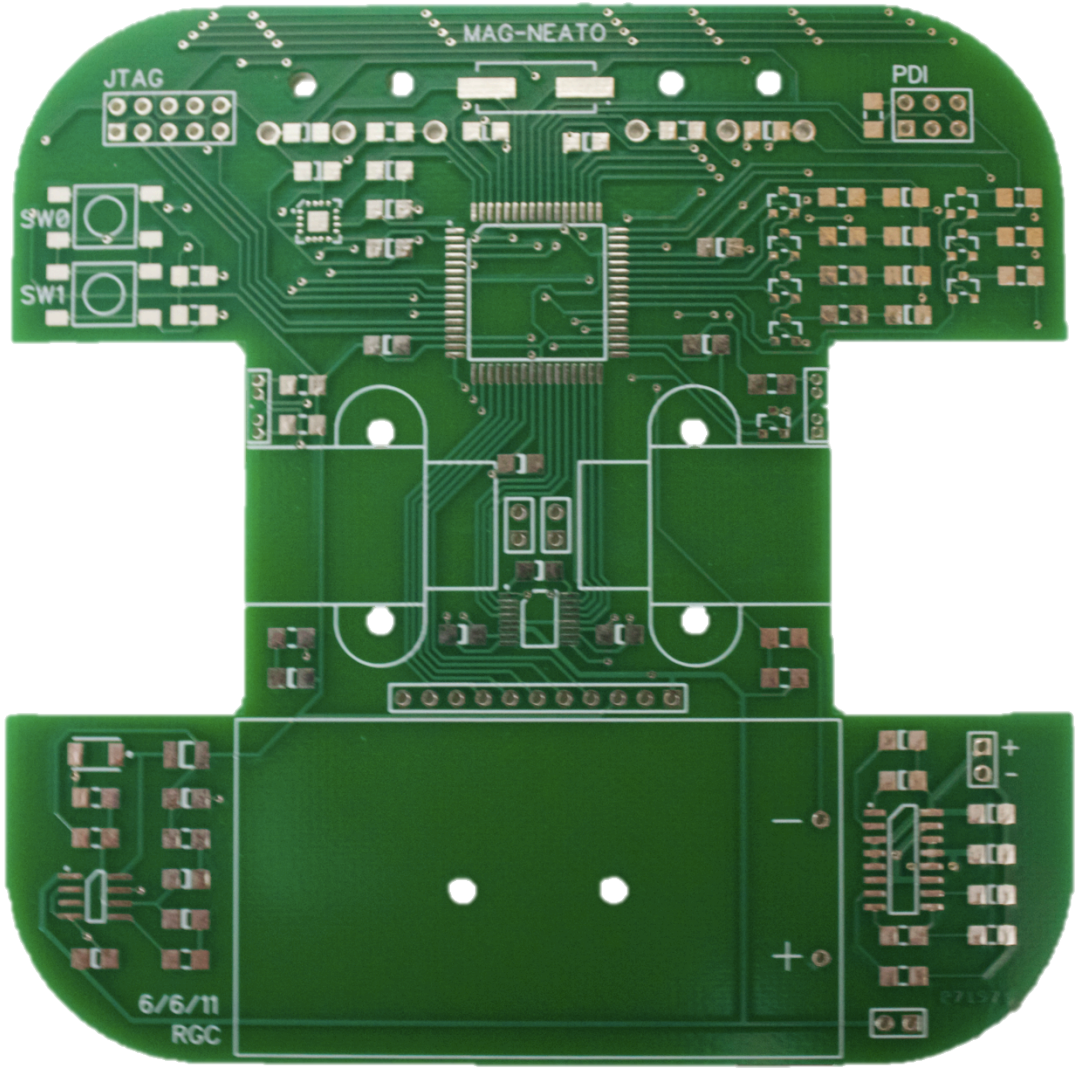

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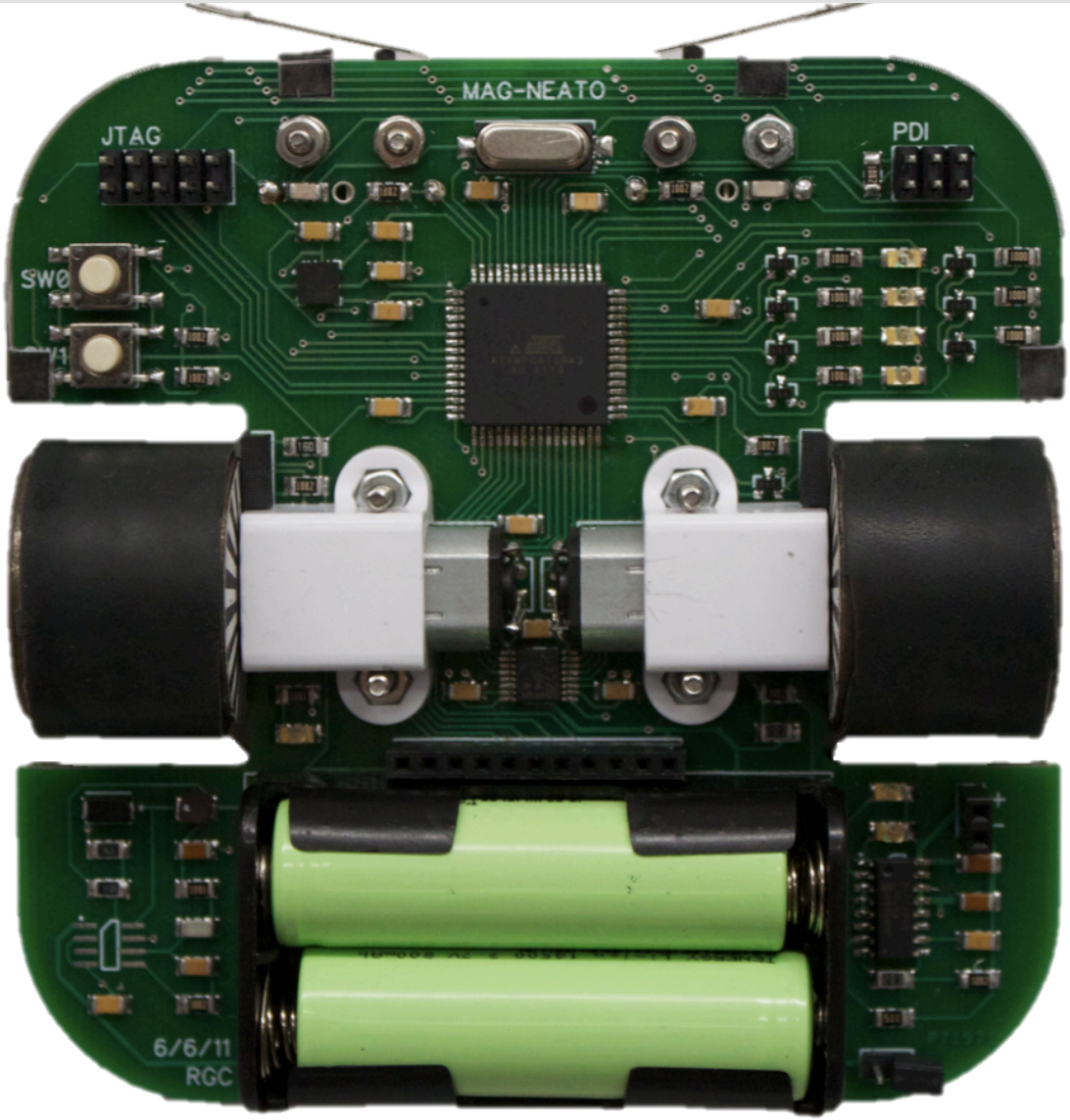

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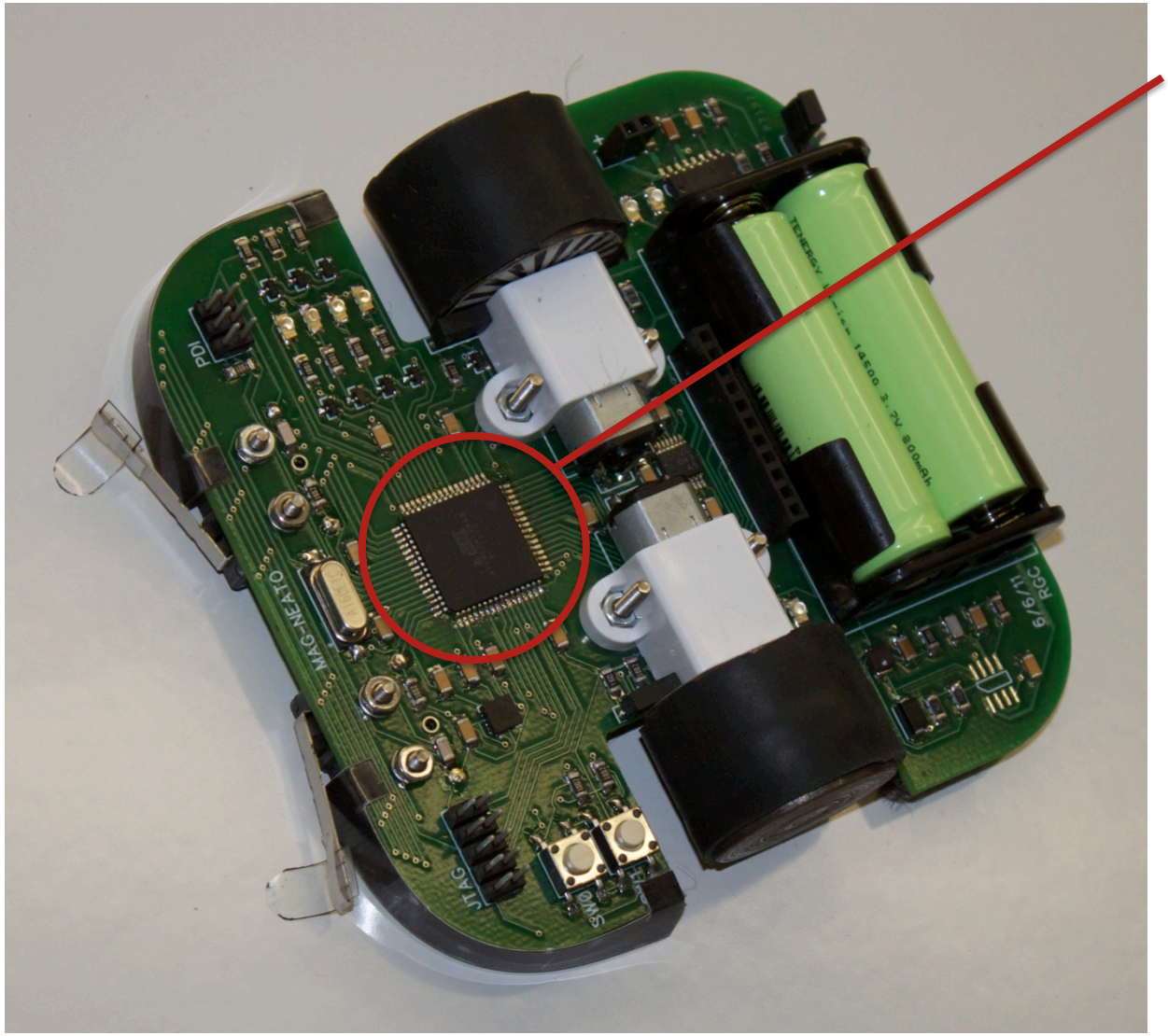
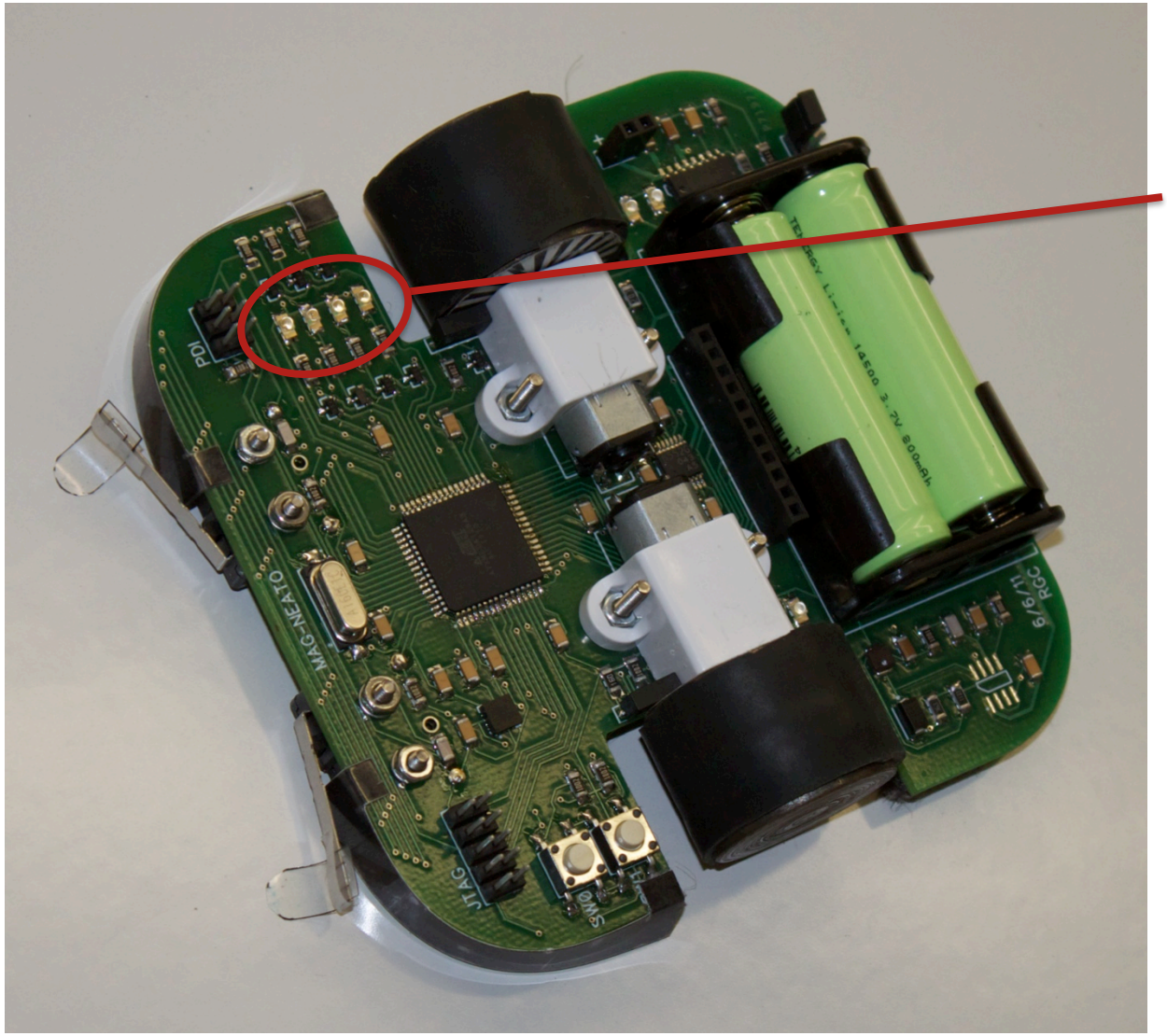


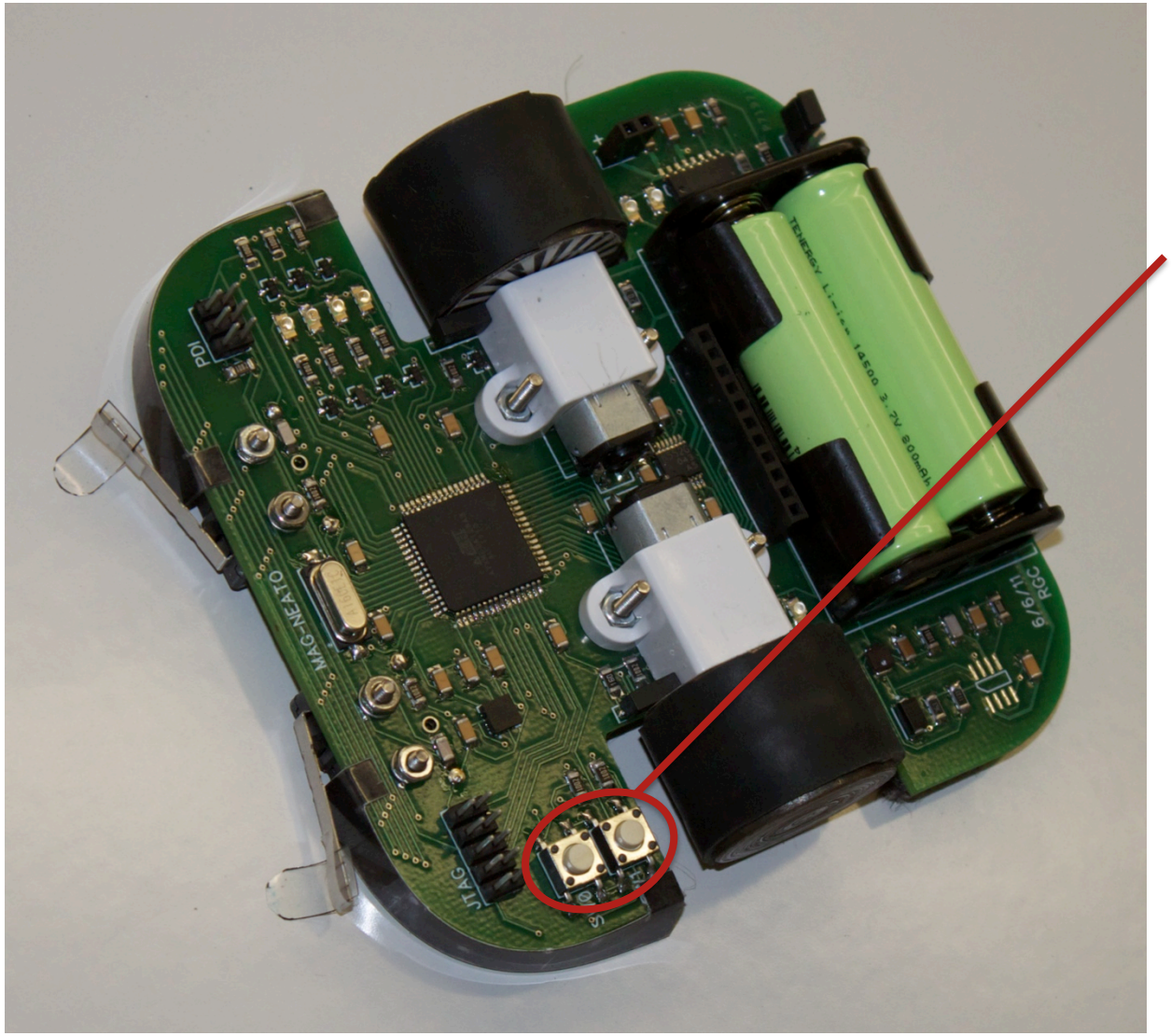
- 32 MHz AVR XMEGA microcontroller

PRINTED CIRCUIT BOARD



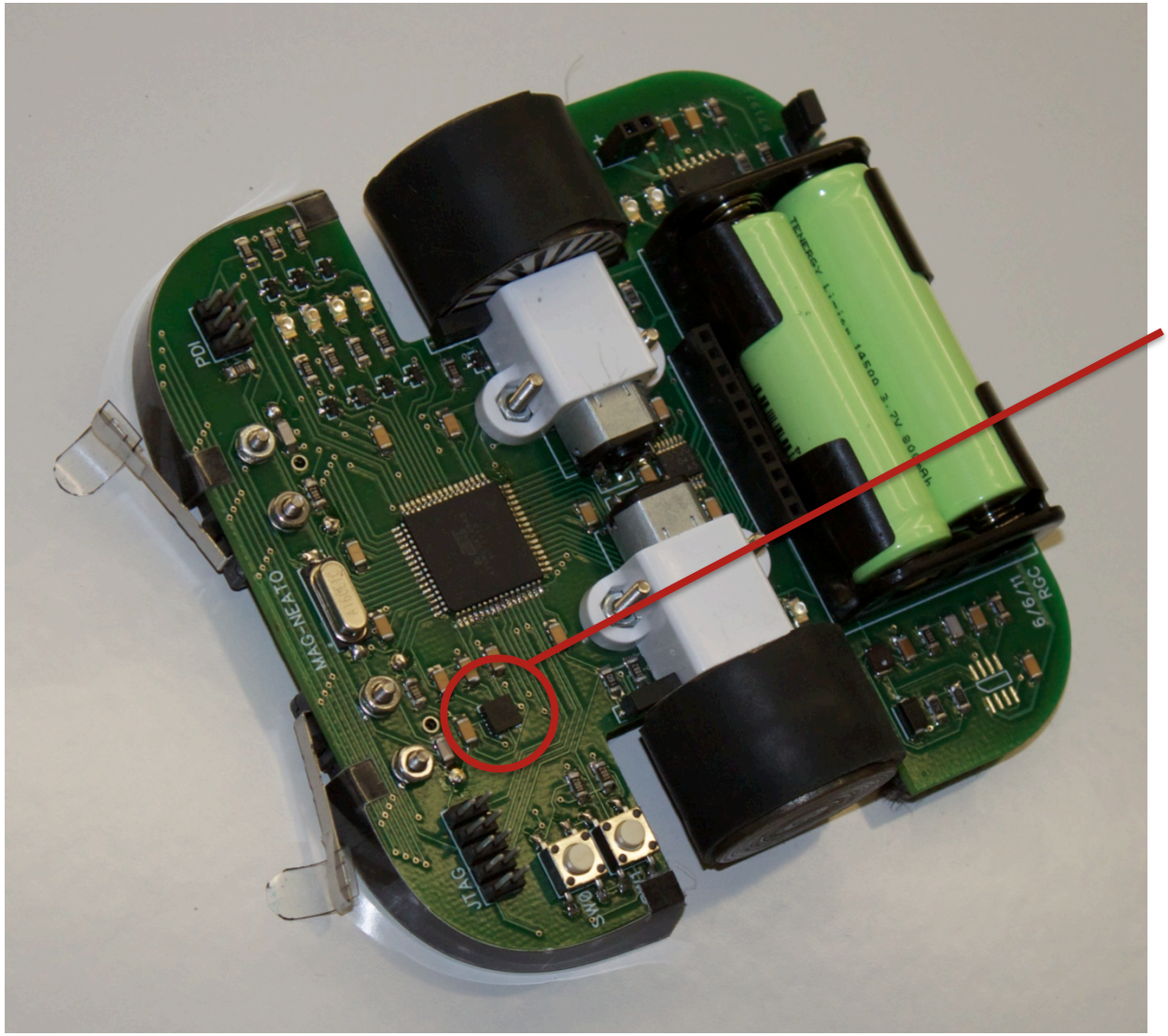
- 32 MHz AVR XMEGA microcontroller
- LED indicators

PRINTED CIRCUIT BOARD



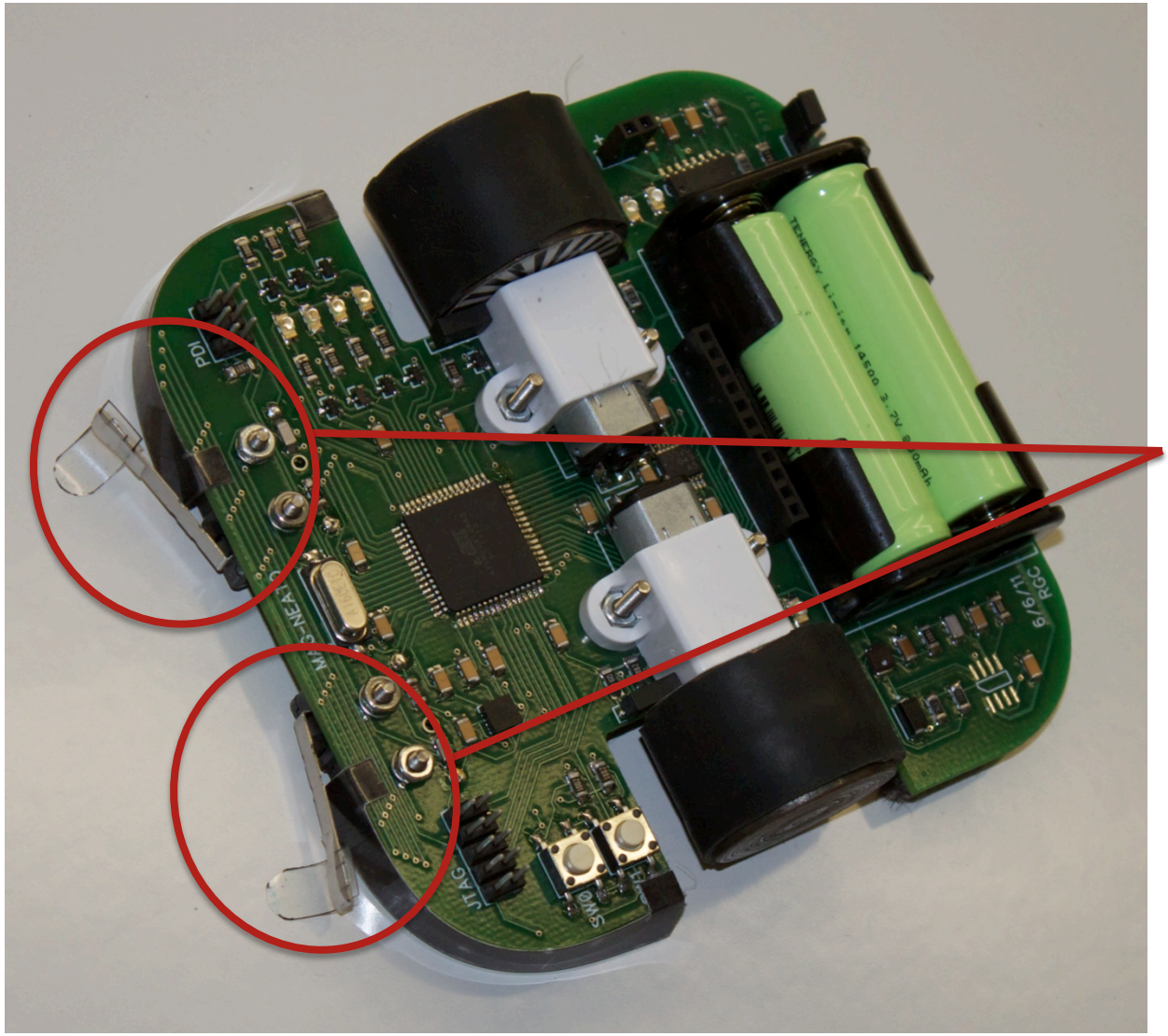
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons

PRINTED CIRCUIT BOARD



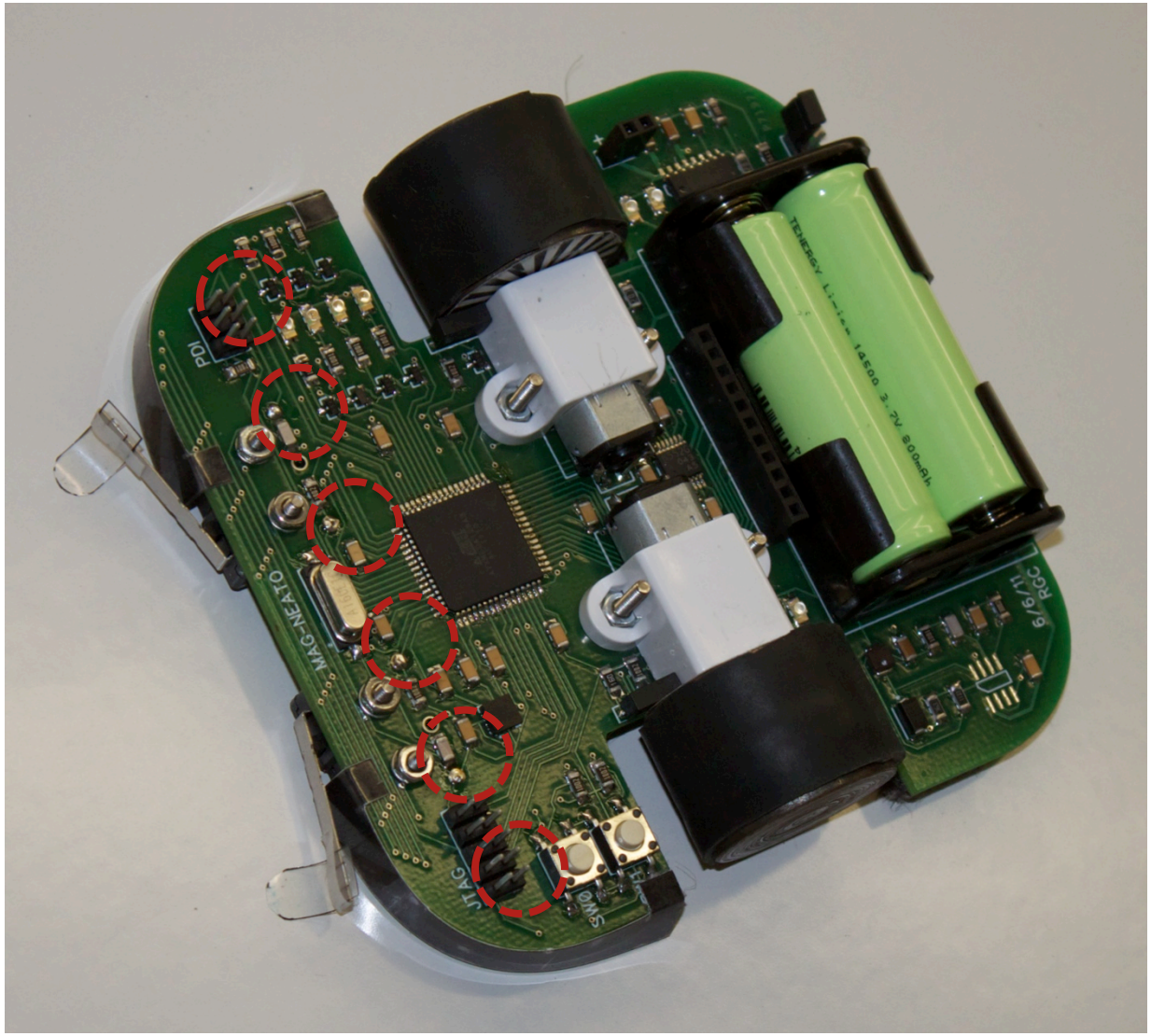
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor

PRINTED CIRCUIT BOARD



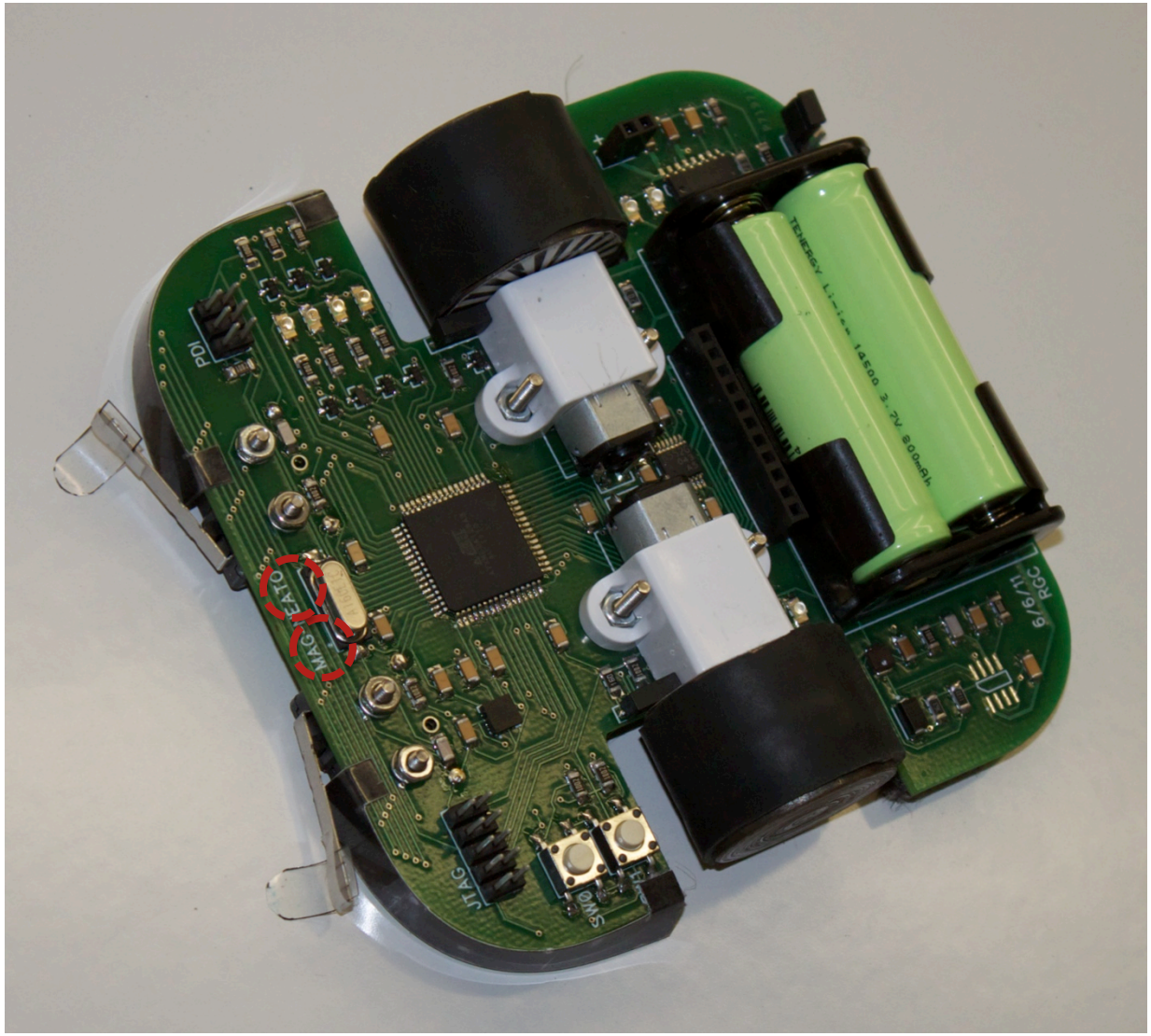
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor
- Two bump sensors

PRINTED CIRCUIT BOARD



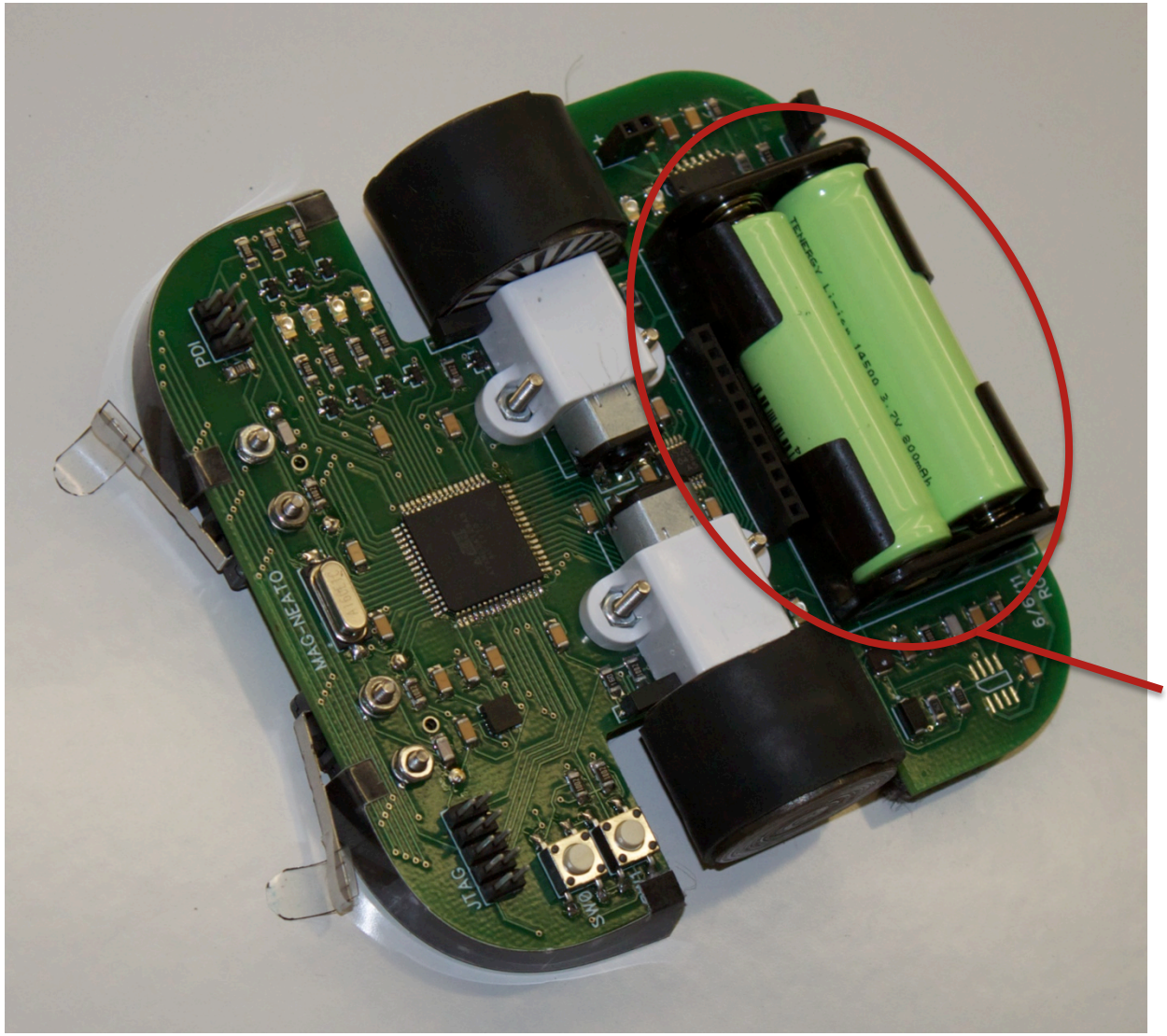
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor
- Two bump sensors
- Six color sensors

PRINTED CIRCUIT BOARD



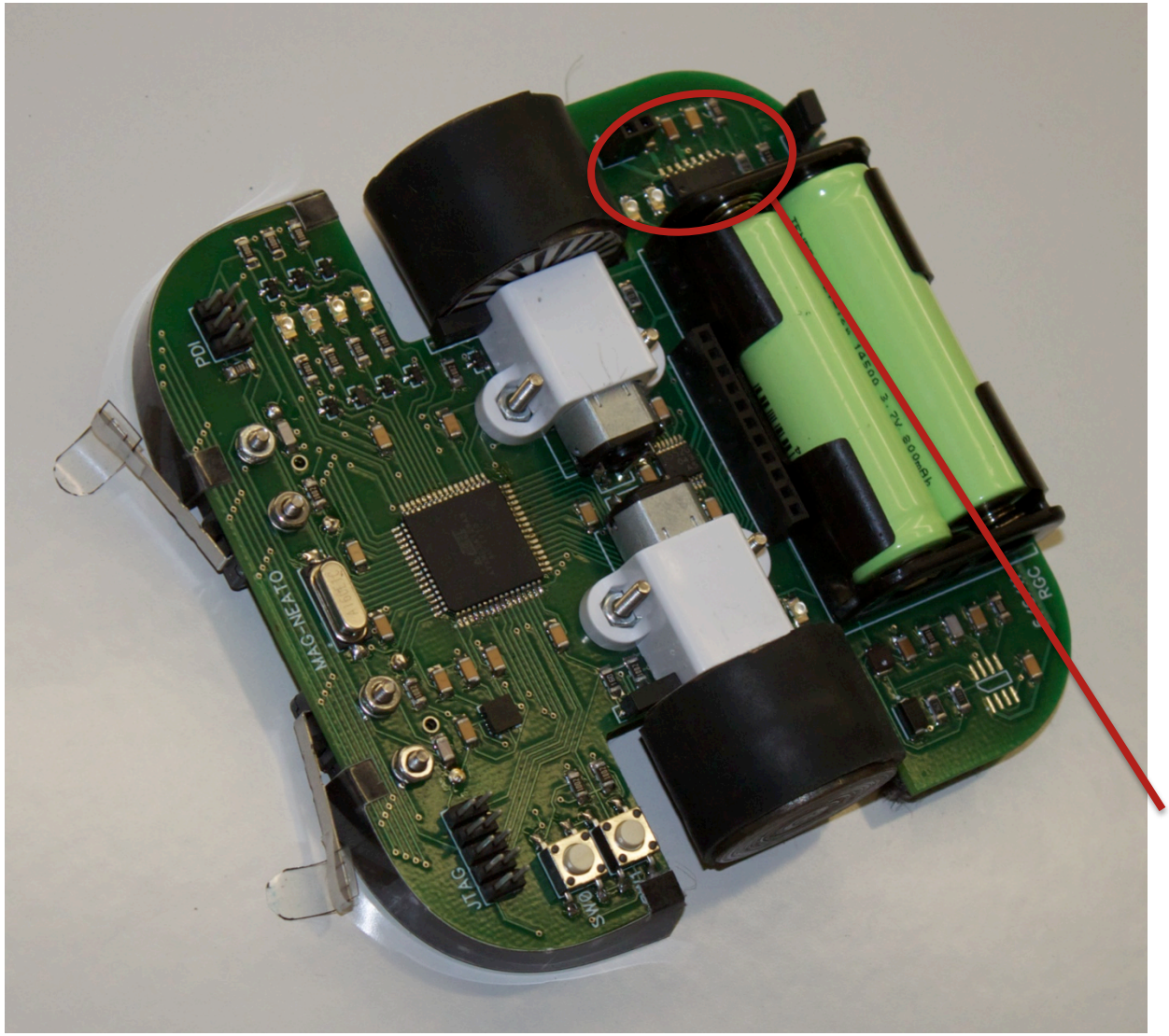
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor
- Two bump sensors
- Six color sensors
- Two reflective IR edge sensors

PRINTED CIRCUIT BOARD



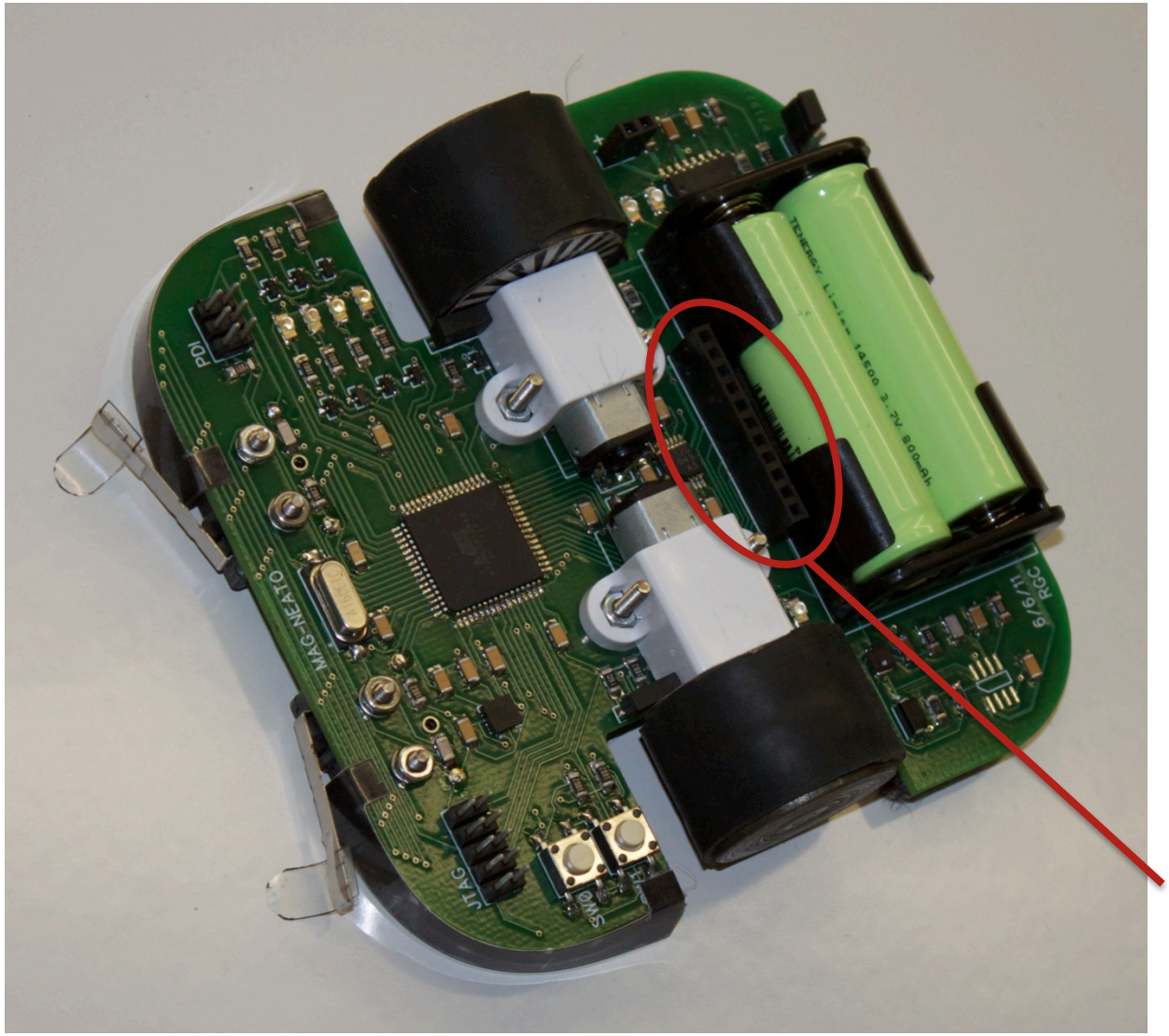
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor
- Two bump sensors
- Six color sensors
- Two reflective IR edge sensors
- Two 14500 lithium ion batteries

PRINTED CIRCUIT BOARD



- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor
- Two bump sensors
- Six color sensors
- Two reflective IR edge sensors
- Two 14500 lithium ion batteries
- Integrated battery charger

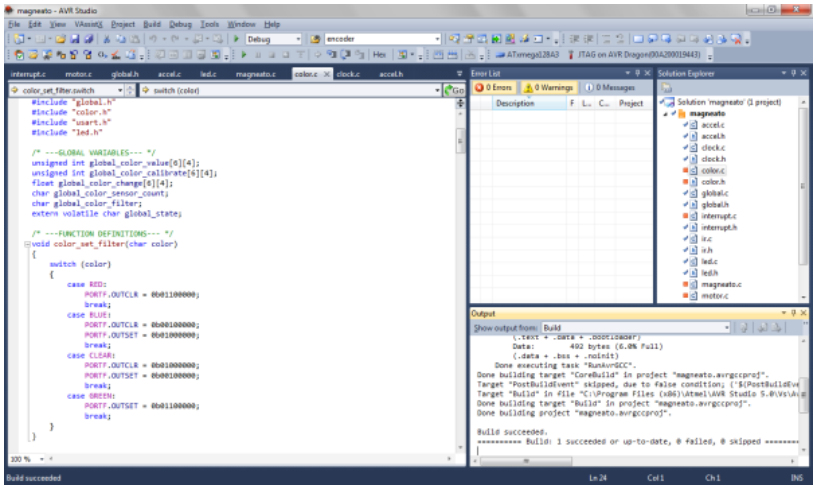
PRINTED CIRCUIT BOARD



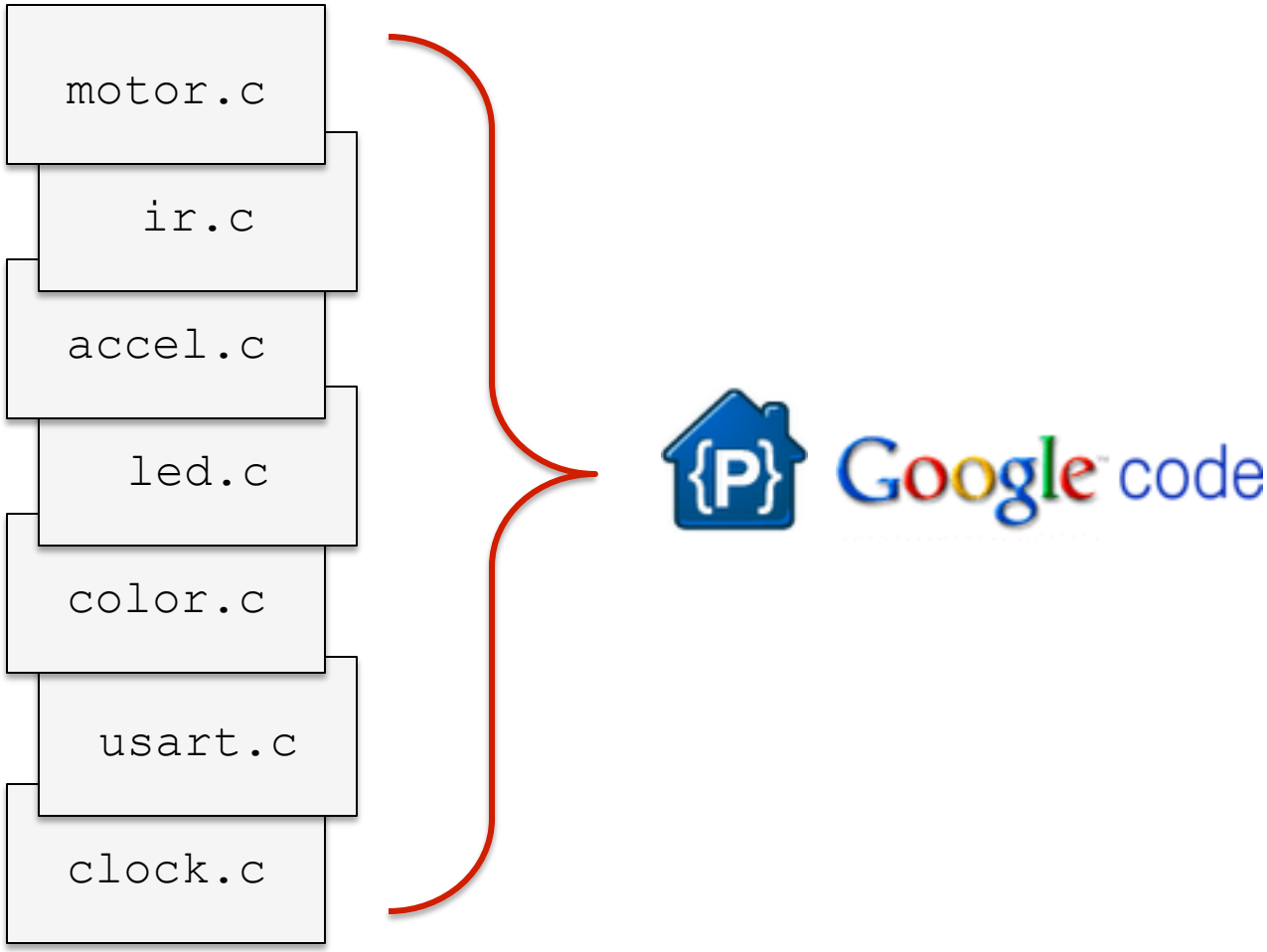
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor
- Two bump sensors
- Six color sensors
- Two reflective IR edge sensors
- Two 14500 lithium ion batteries
- Integrated battery charger
- Expansion port + serial communication

CODE

- Coded in C
- Can use any AVR programmer
- AVR Studio 5 IDE
  - Integrated compiler and debugger
  - Installs everything you need to get started

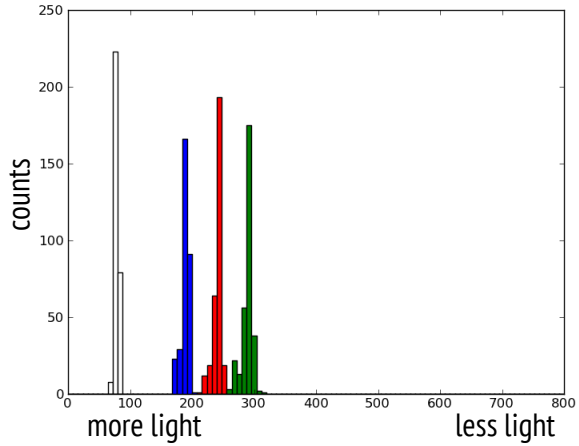


CODE

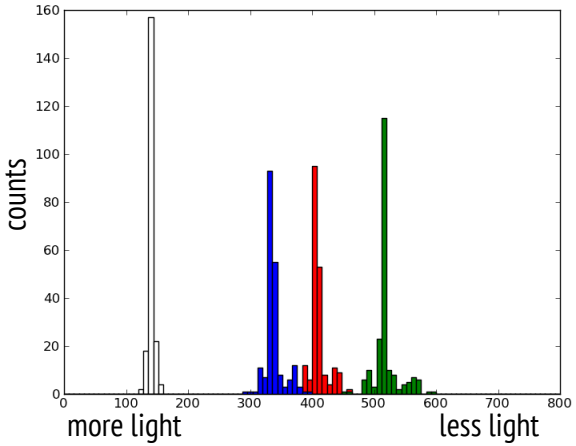


COLOR SENSING

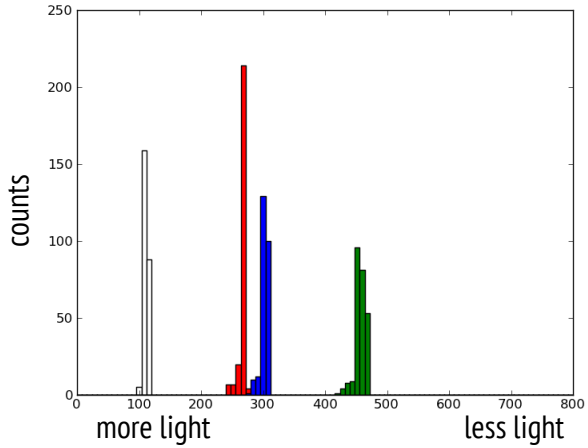
Background



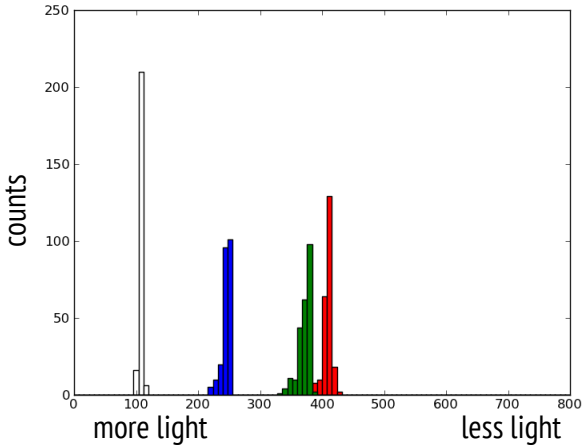
Black



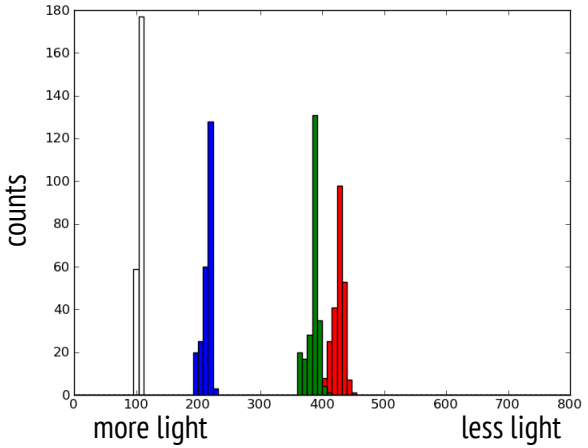
Red



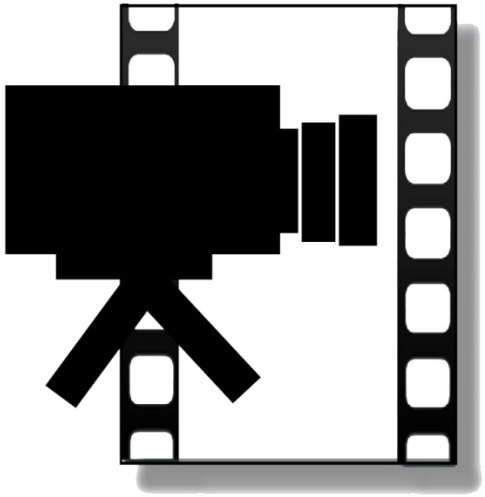
Green



Blue



DEMOS



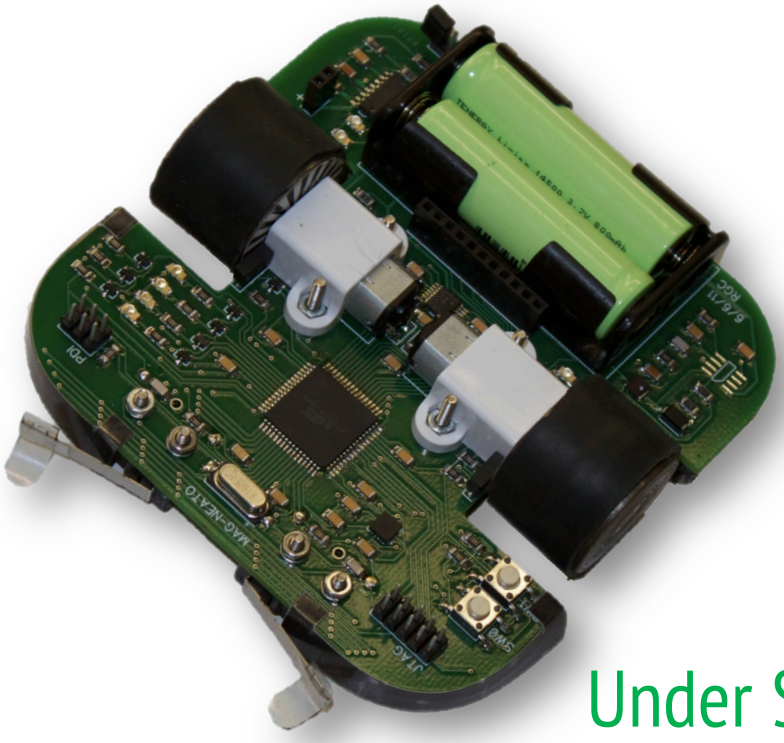
FUTURE WORK

- Rev 2 of boards correcting minor issues (in progress)
- Explore other surfaces
  - Blackboard
  - Windows
  - Metal siding
- Noise reduction
- New behaviors
- Expansion boards
  - Wireless communication
  - Remote control
  - Drawing
  - Sound processing

driving on window

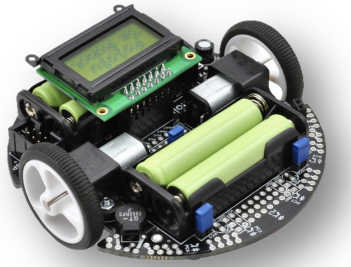
FUTURE WORK

Commercialize?



Under $100

EPFL e-puck
$1000

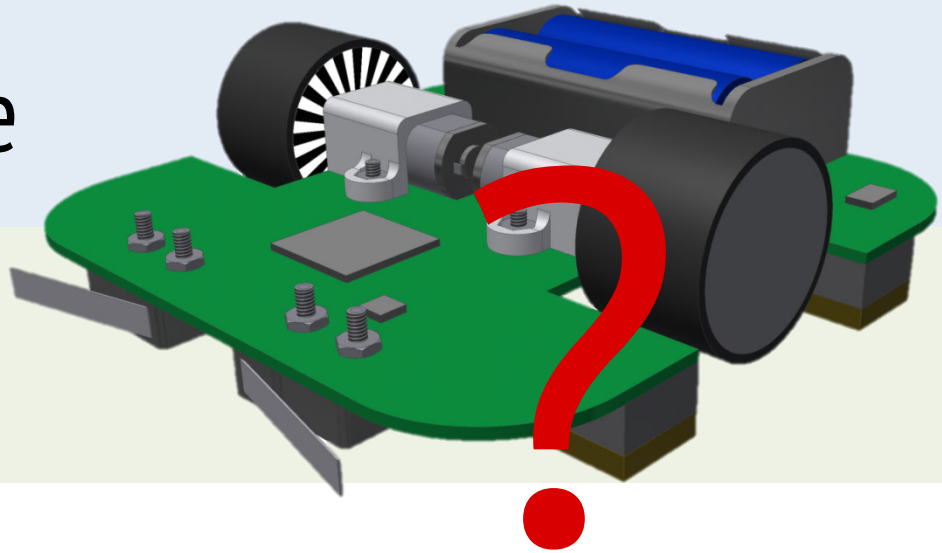


Pololu 3pi
$100

FUTURE WORK

Open Hardware

Open Source



THANKS

- Harvard University SEAS
- Self-Organizing Systems Research Group
- Franklin W. Olin College of Engineering
- Special thanks to:
  - Nils Napp
  - Radhika Nagpal
  - Michael Rubenstein

QUESTIONS