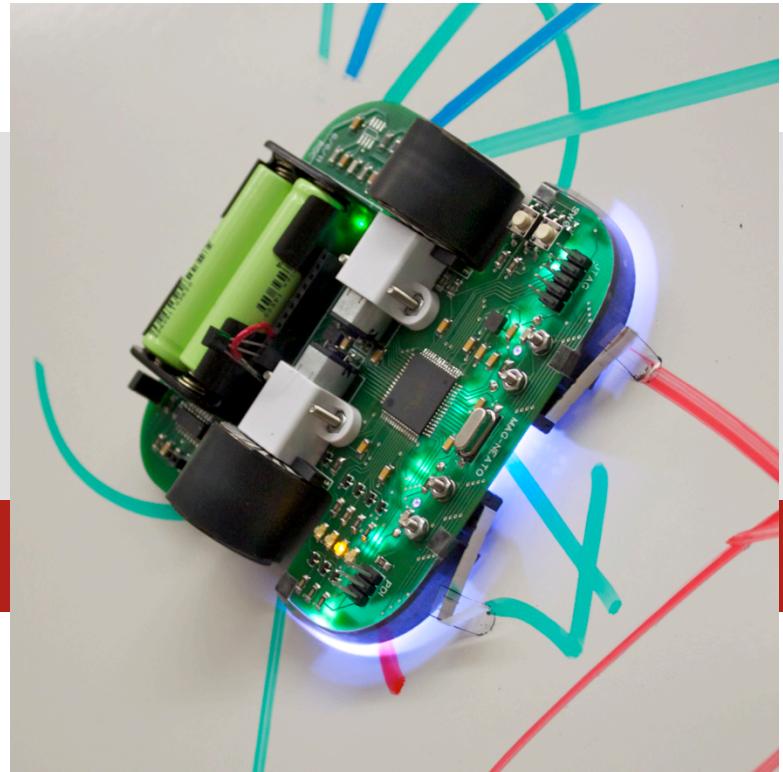


# MAG-NEATO

a magnetic board cleaning robot

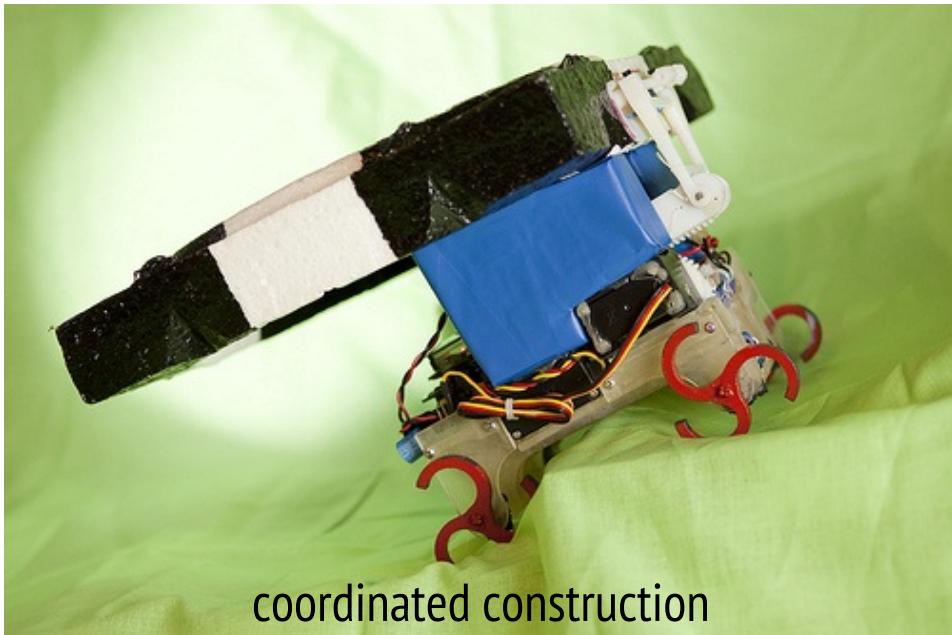
HARVARD UNIVERSITY  
Self-Organizing Systems Research Group



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

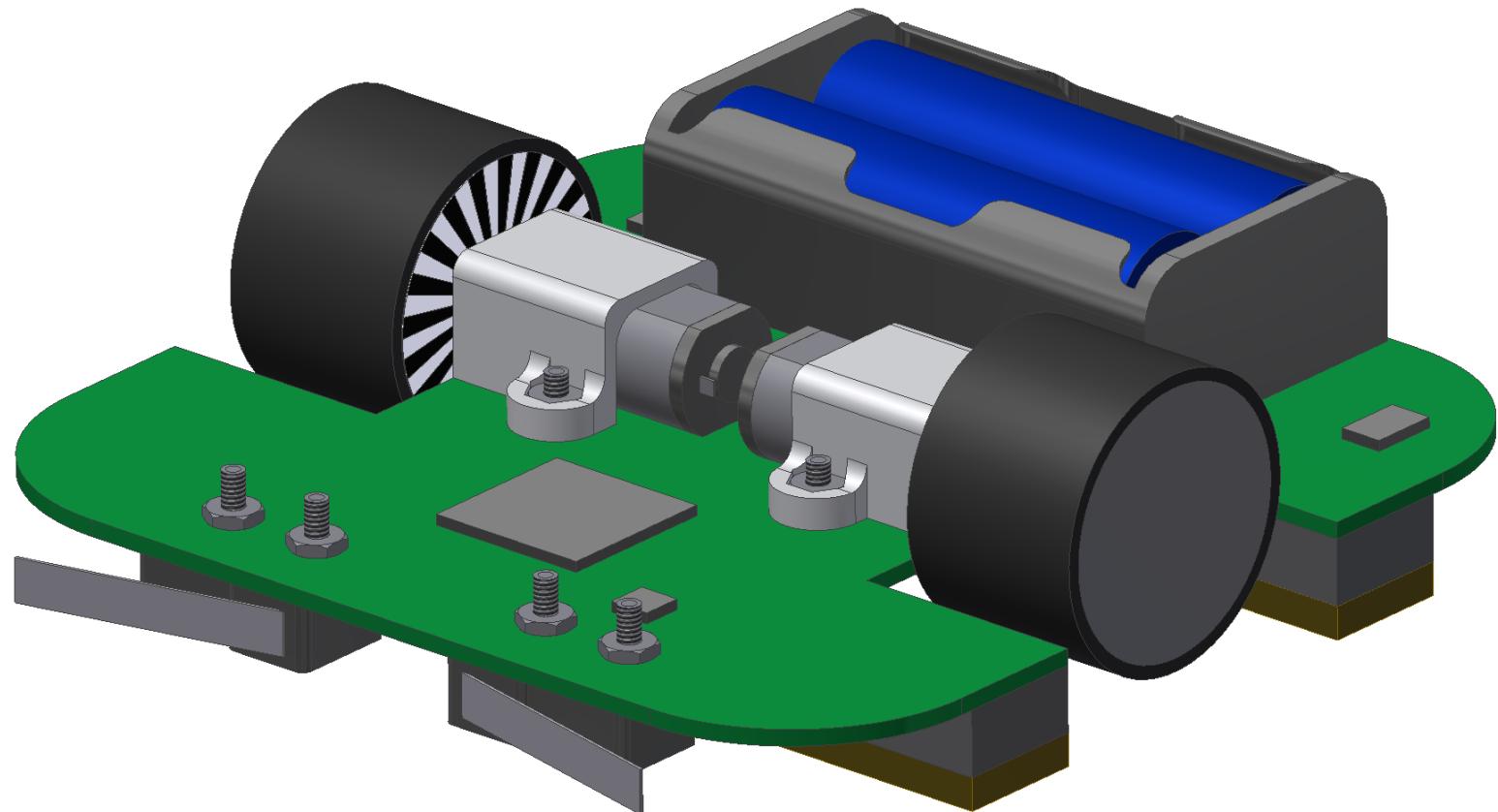


+



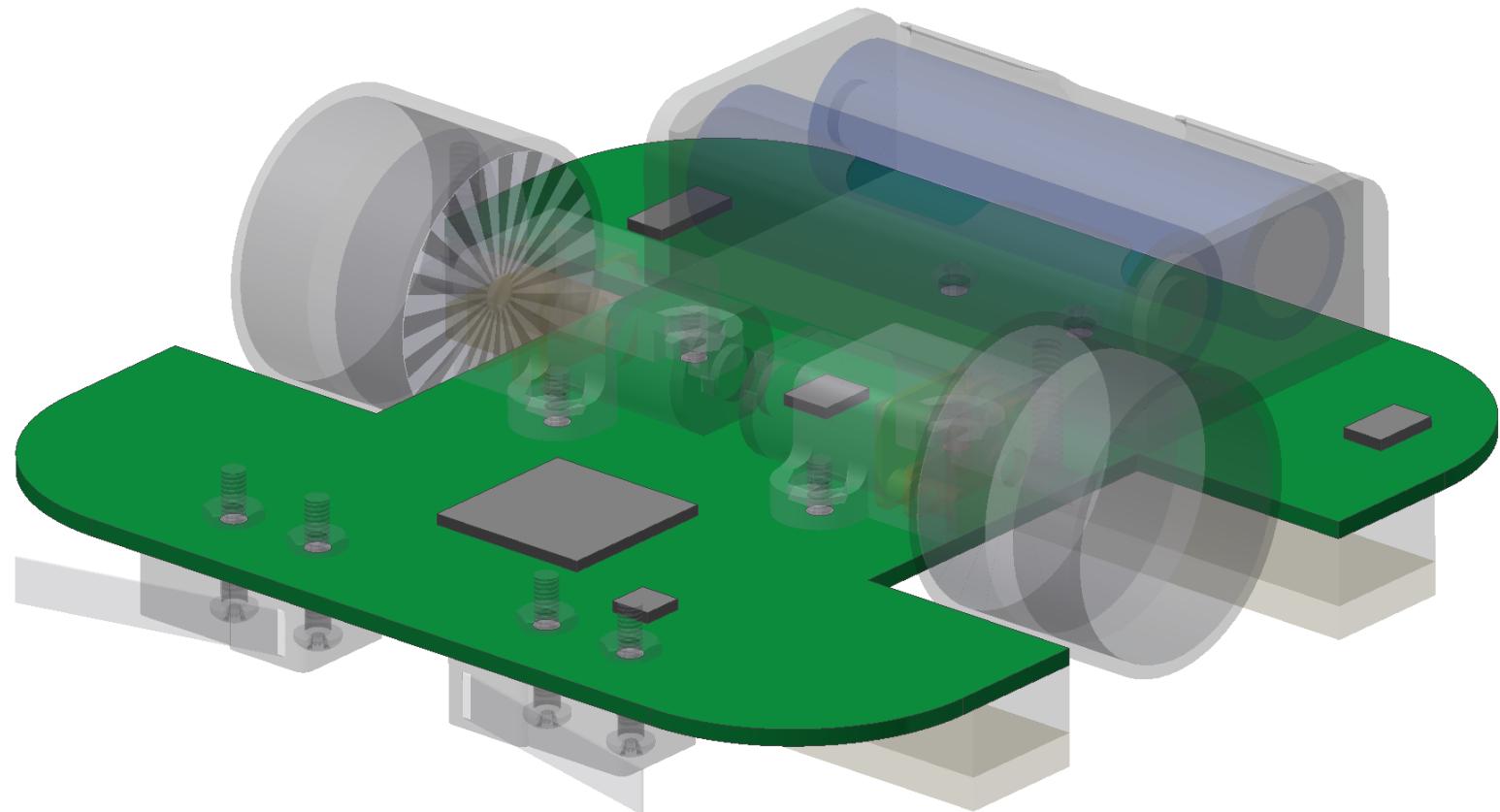


# MECHANICAL DESIGN



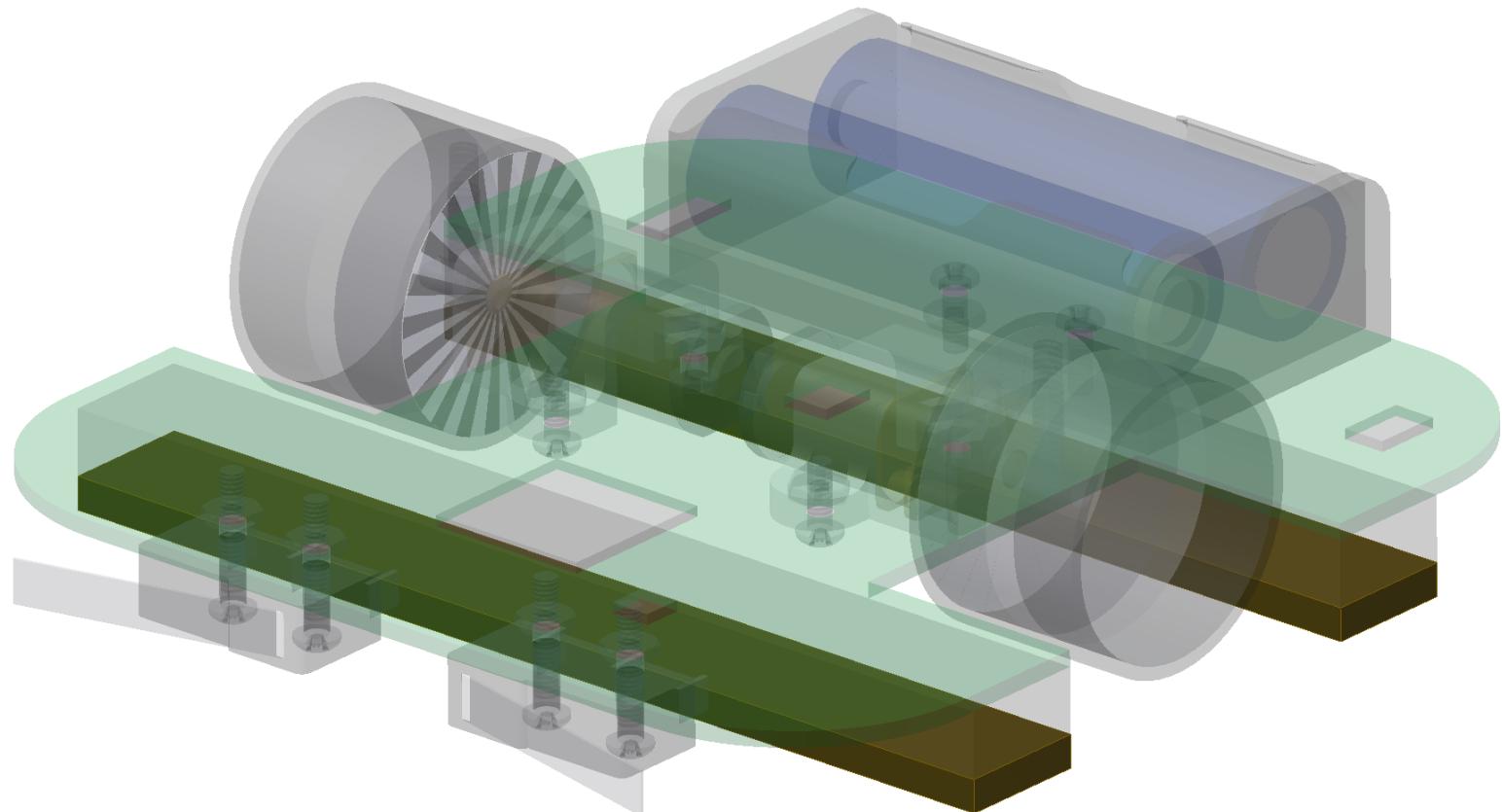


# MECHANICAL DESIGN



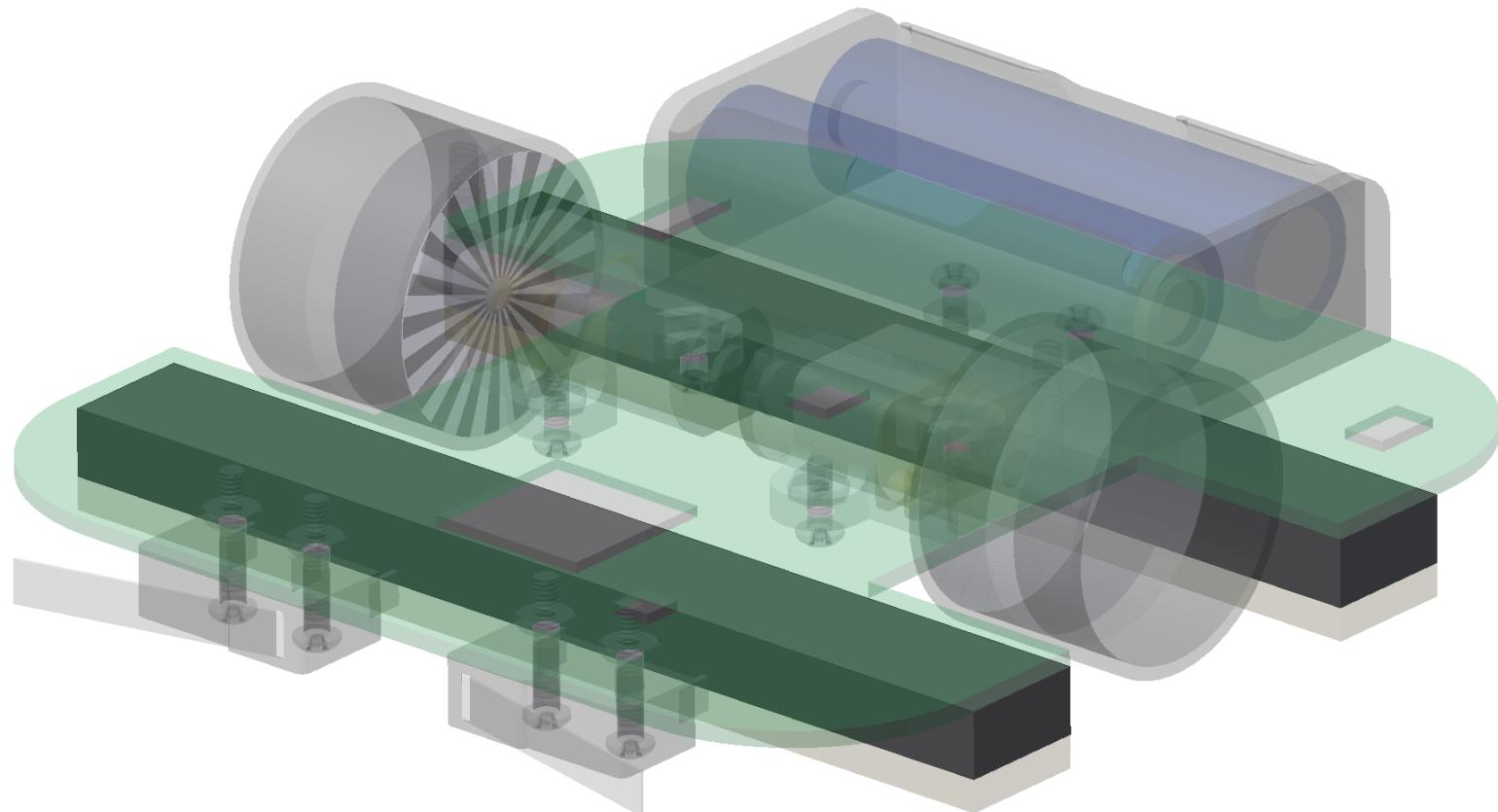
Custom two-layer printed circuit board

# MECHANICAL DESIGN



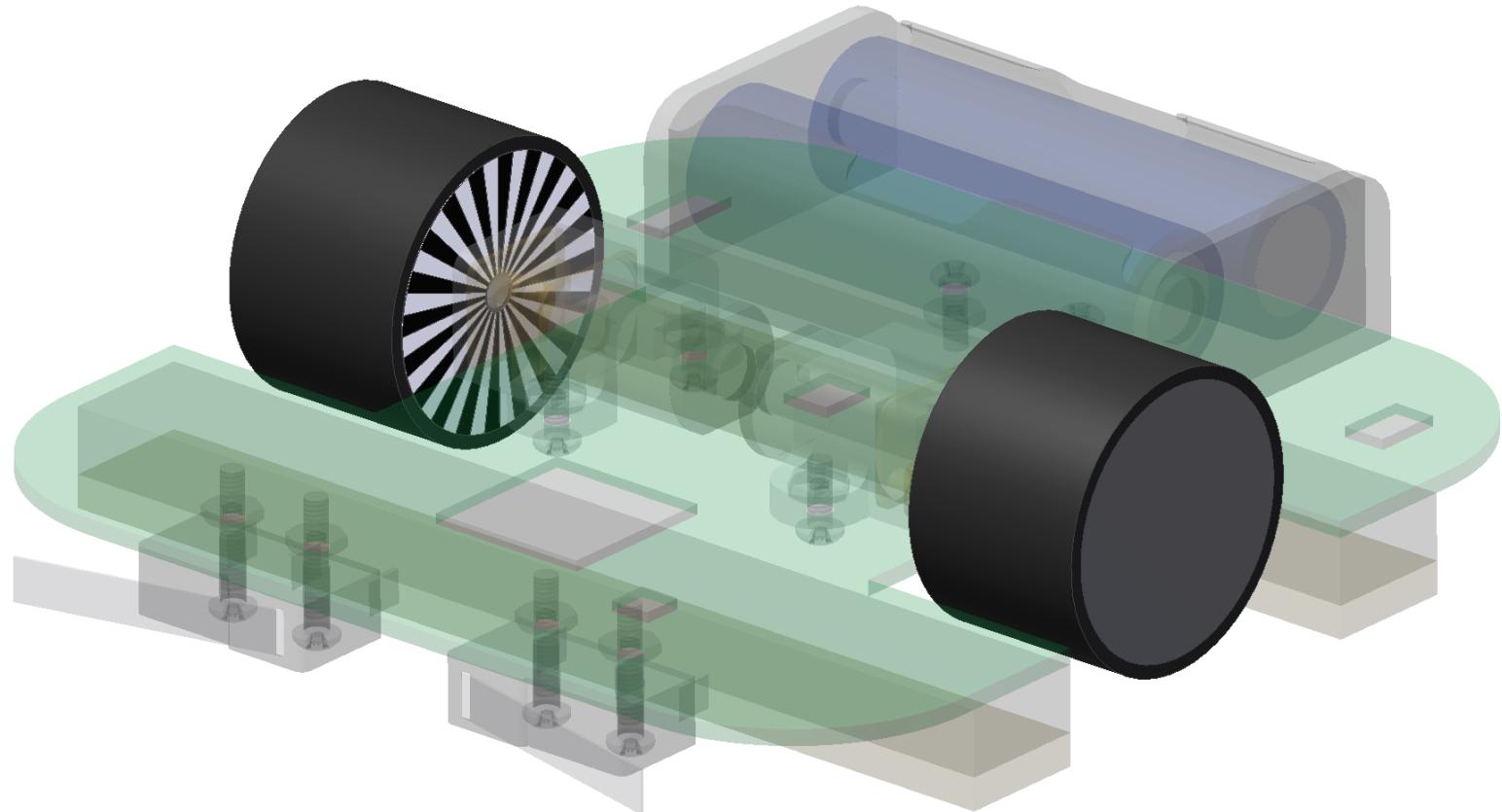
Felt erasing pads

# MECHANICAL DESIGN



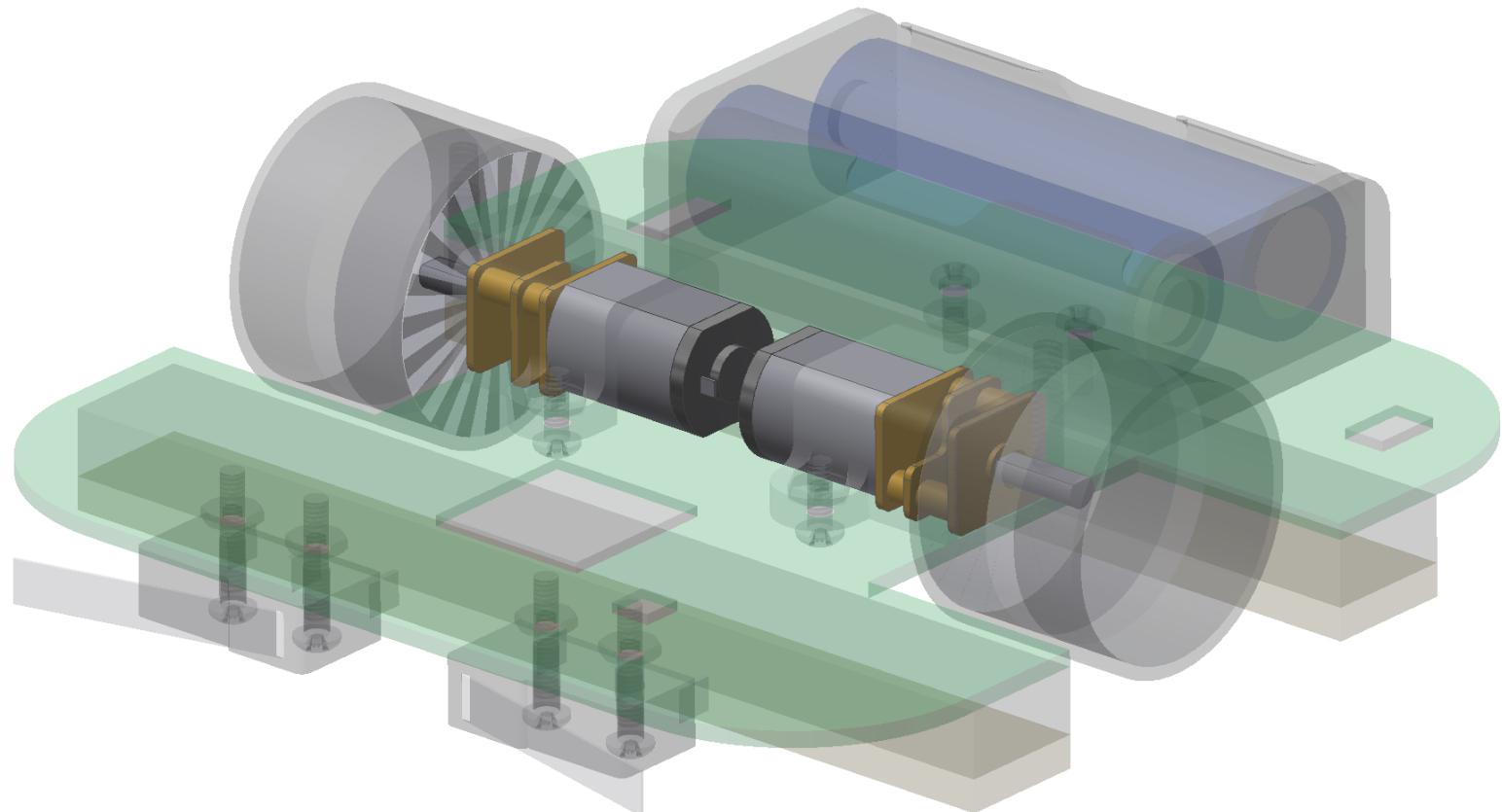
# Compressive polyurethane foam

# MECHANICAL DESIGN



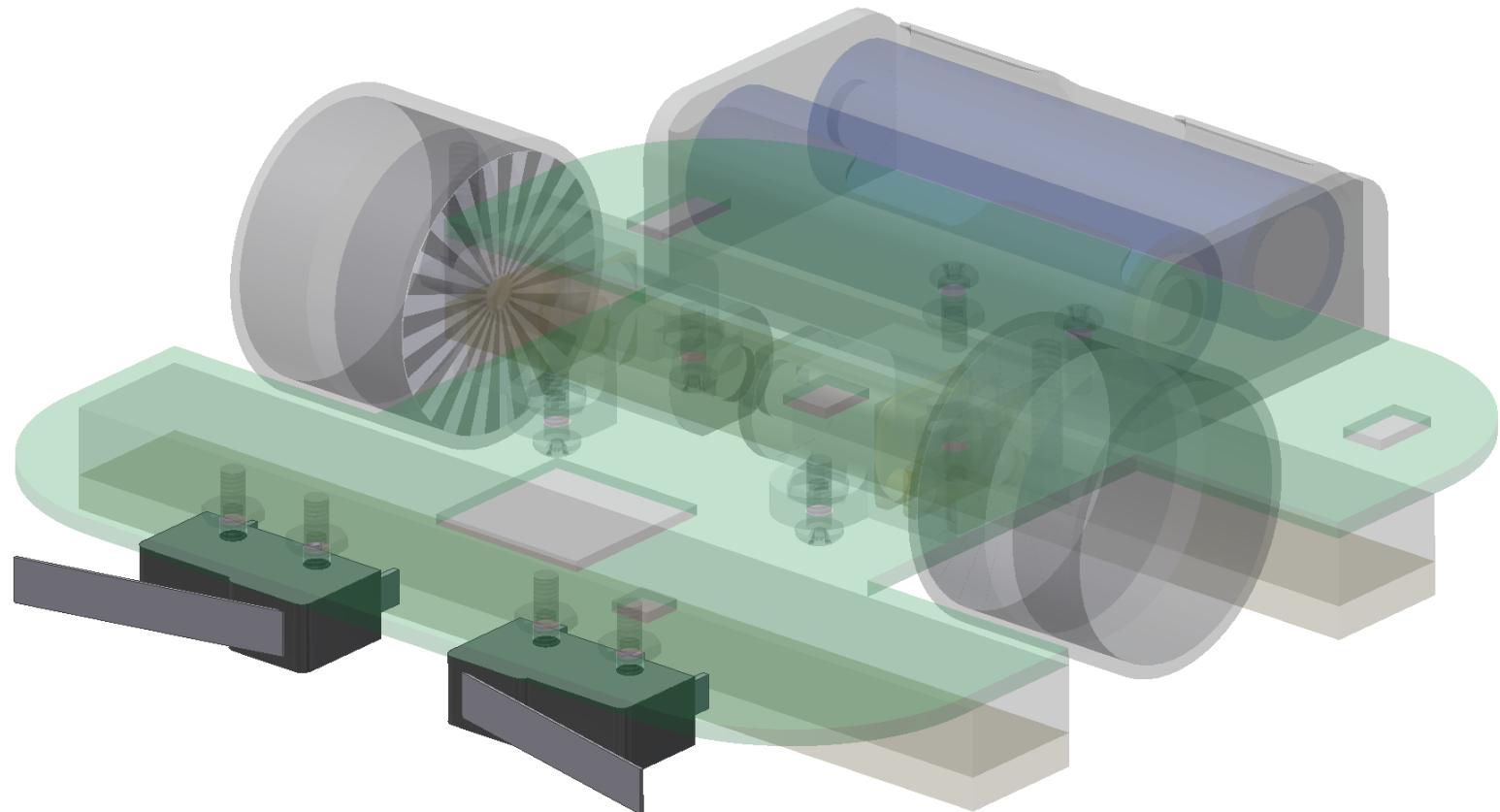
Custom magnetic wheels with encoders

# MECHANICAL DESIGN



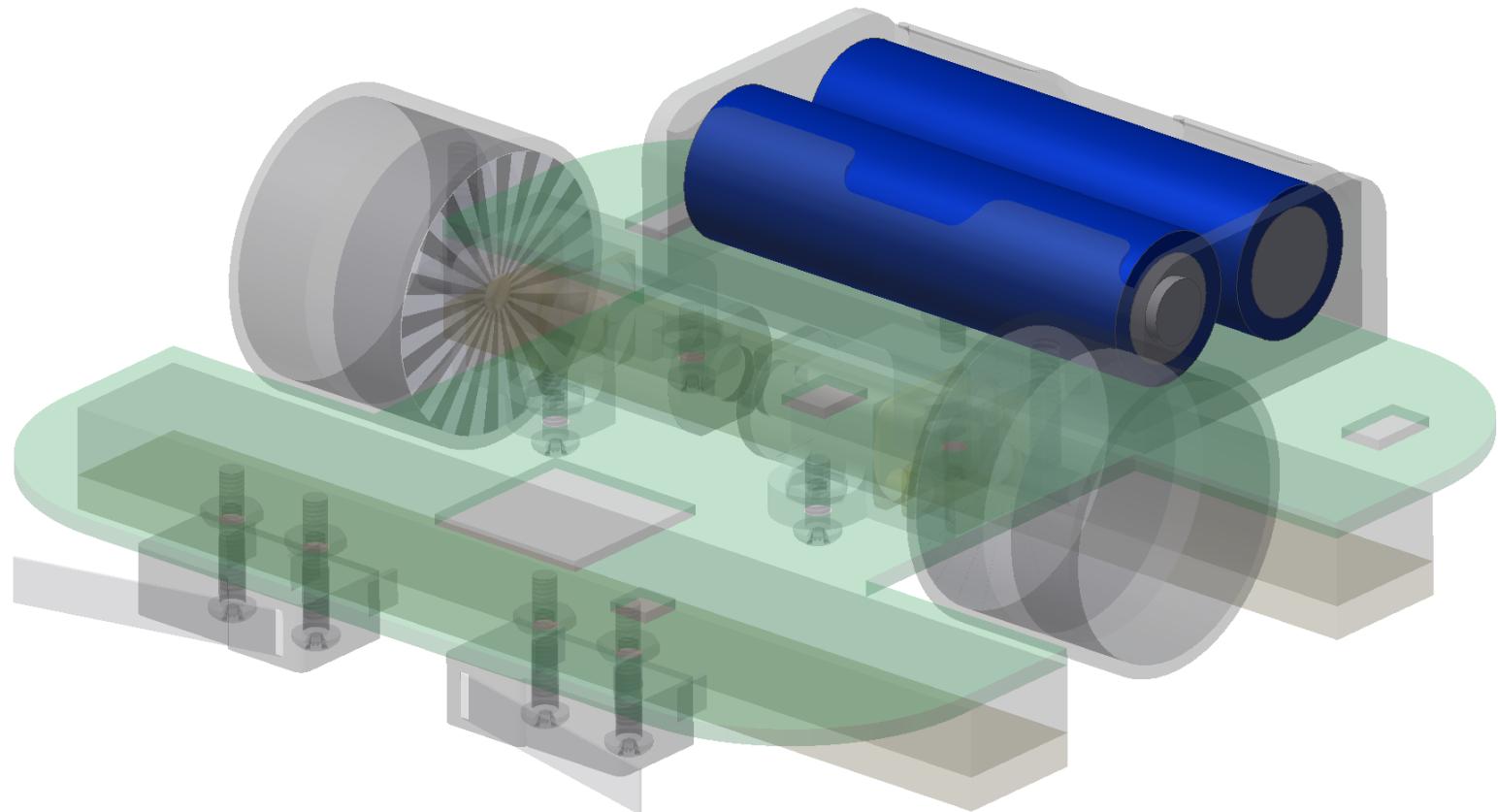
Two metal gearmotors

# MECHANICAL DESIGN



Two front bump sensors

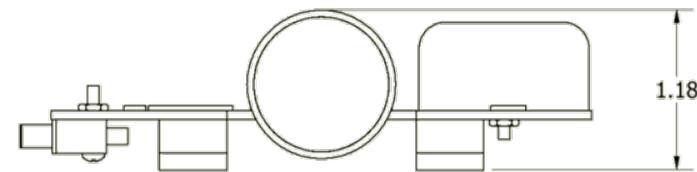
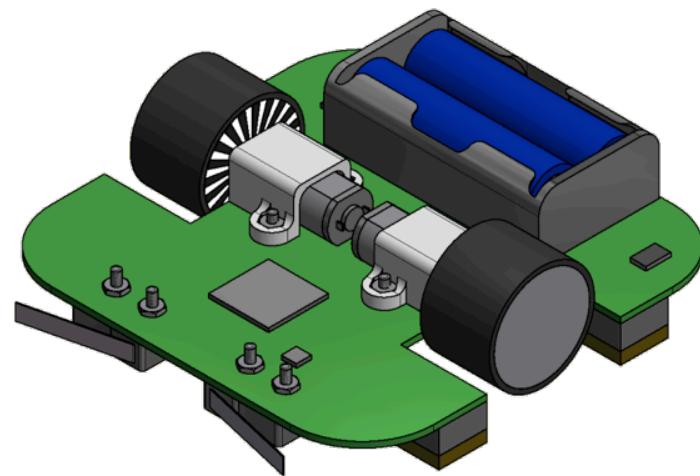
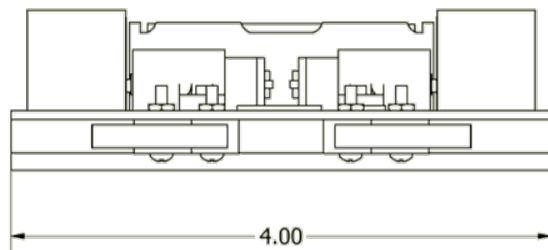
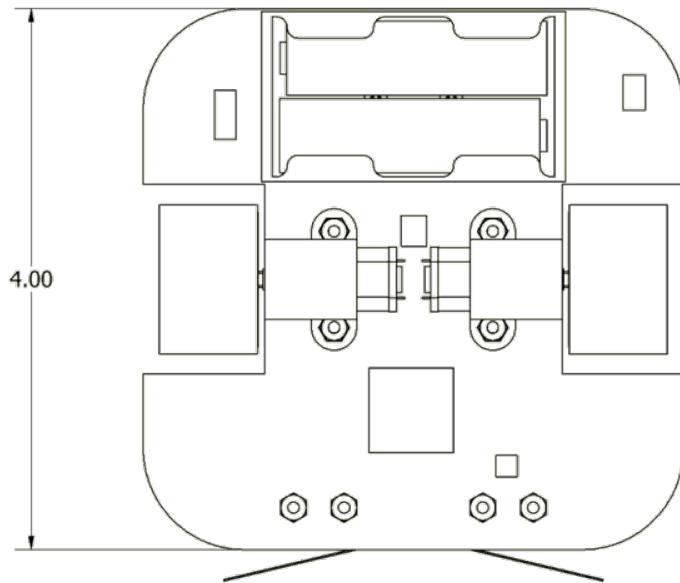
# MECHANICAL DESIGN



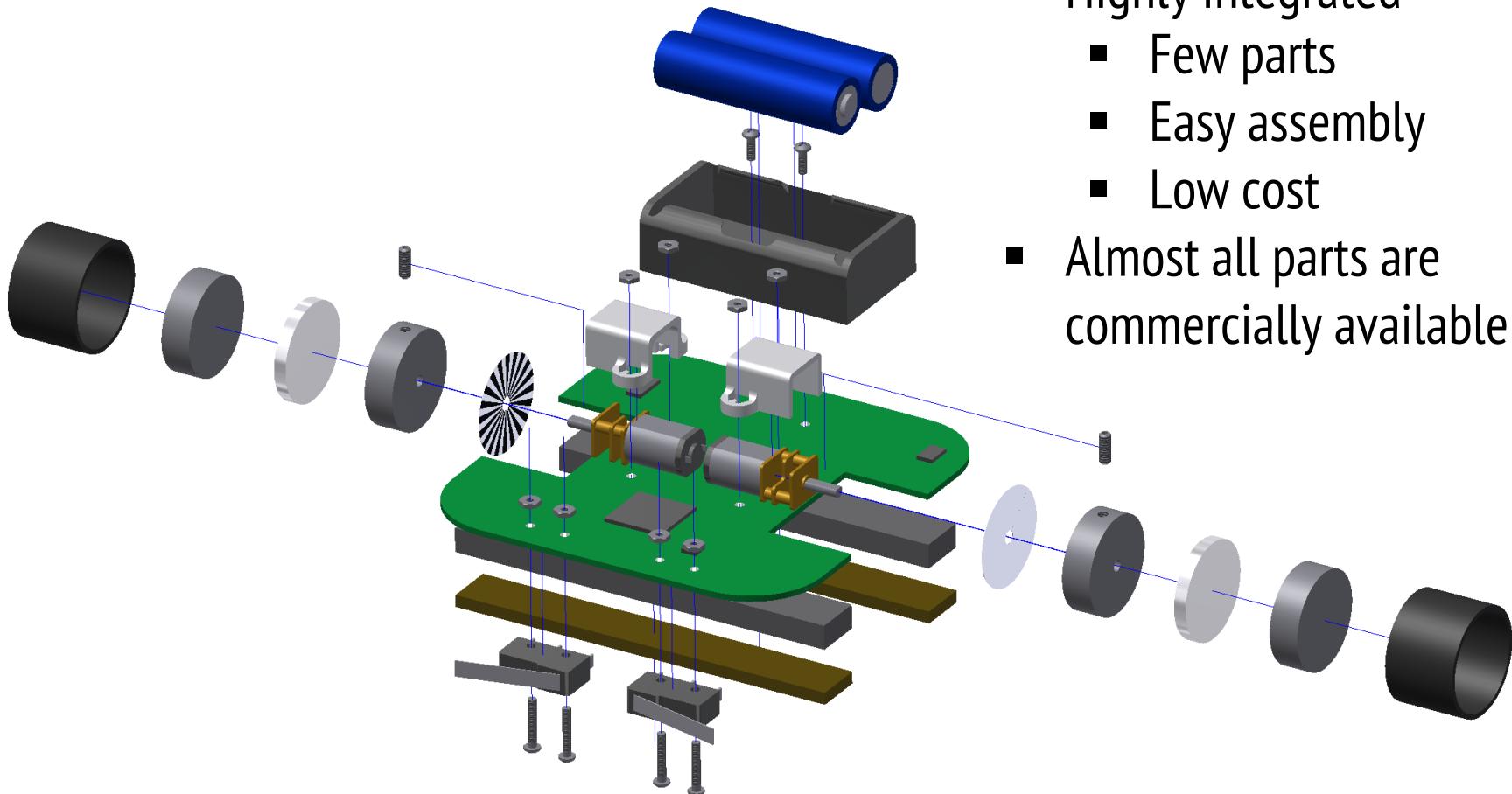
Rechargeable lithium-ion batteries



# MECHANICAL DESIGN



# MECHANICAL DESIGN



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



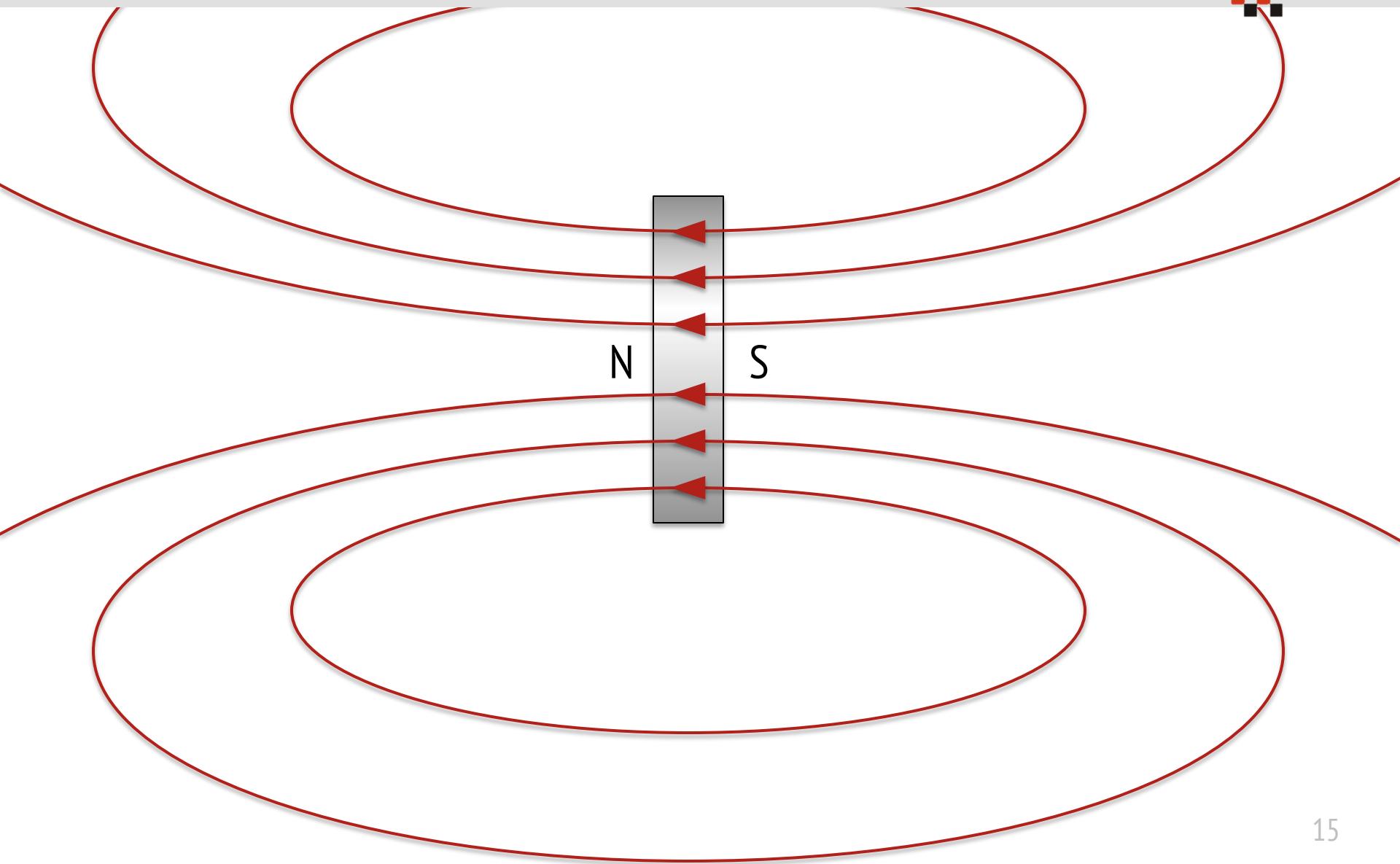
# MAGNETIC WHEELS



Neodymium rare earth magnet

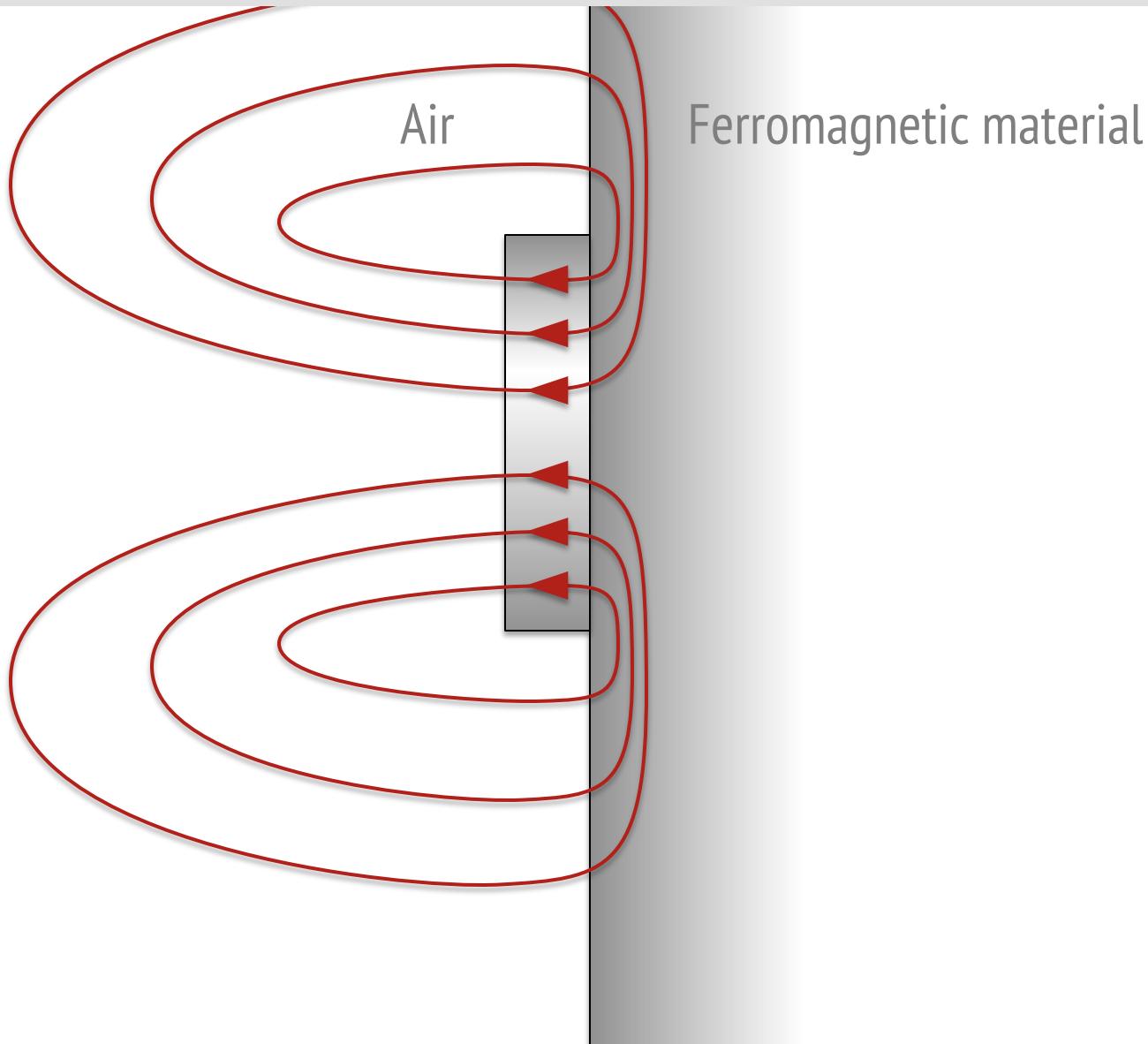


# MAGNETIC WHEELS



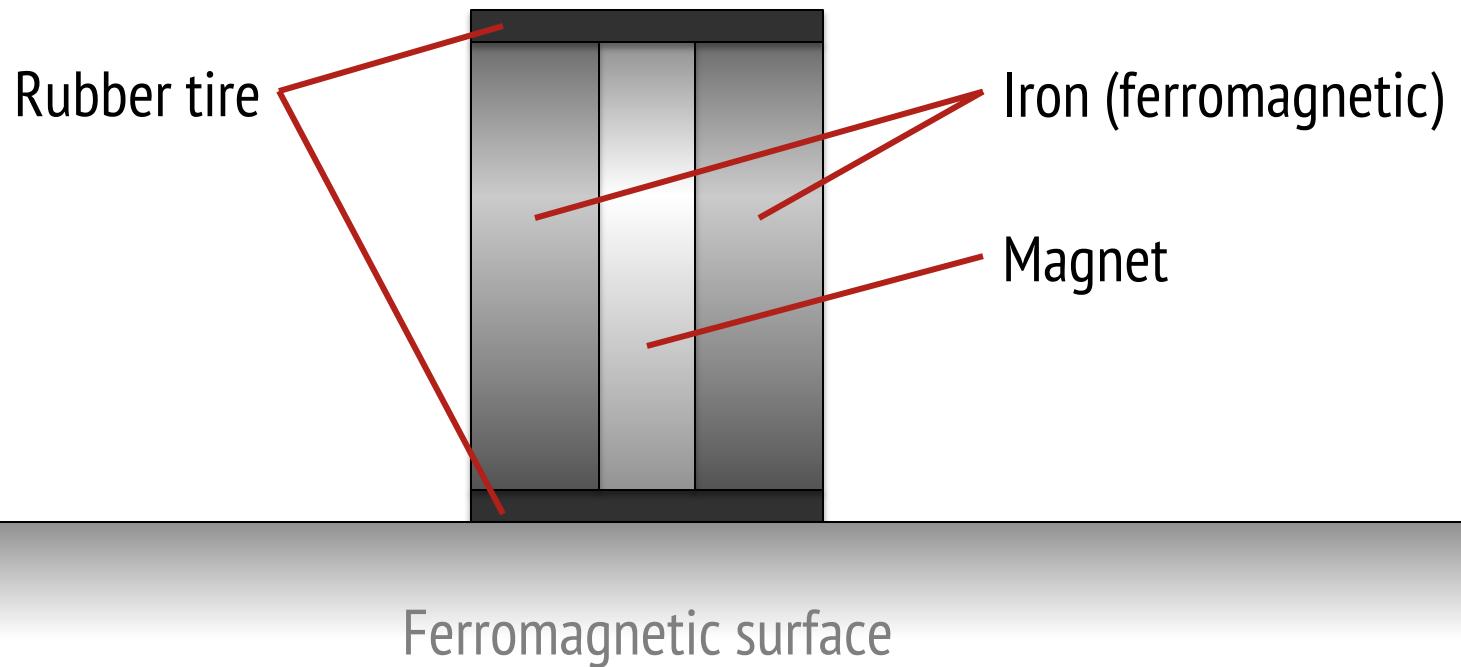


# MAGNETIC WHEELS



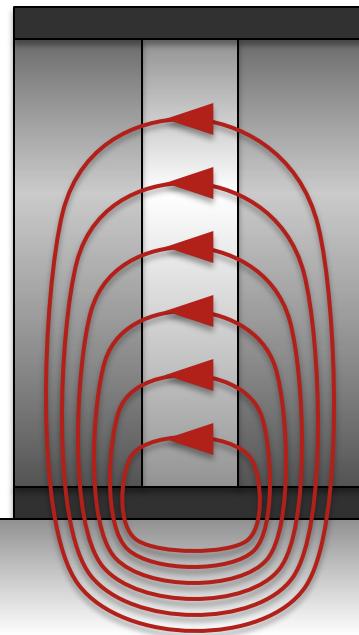


# MAGNETIC WHEELS

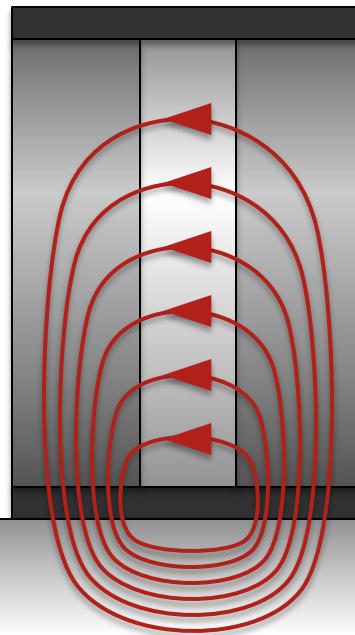




# MAGNETIC WHEELS



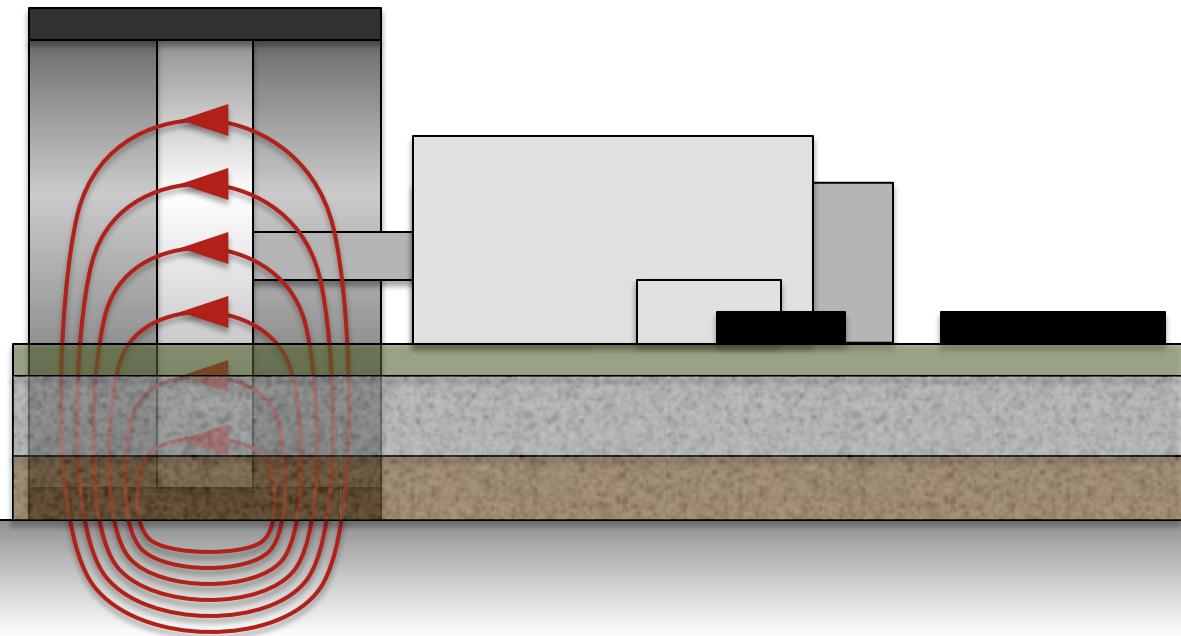
# MAGNETIC WHEELS



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

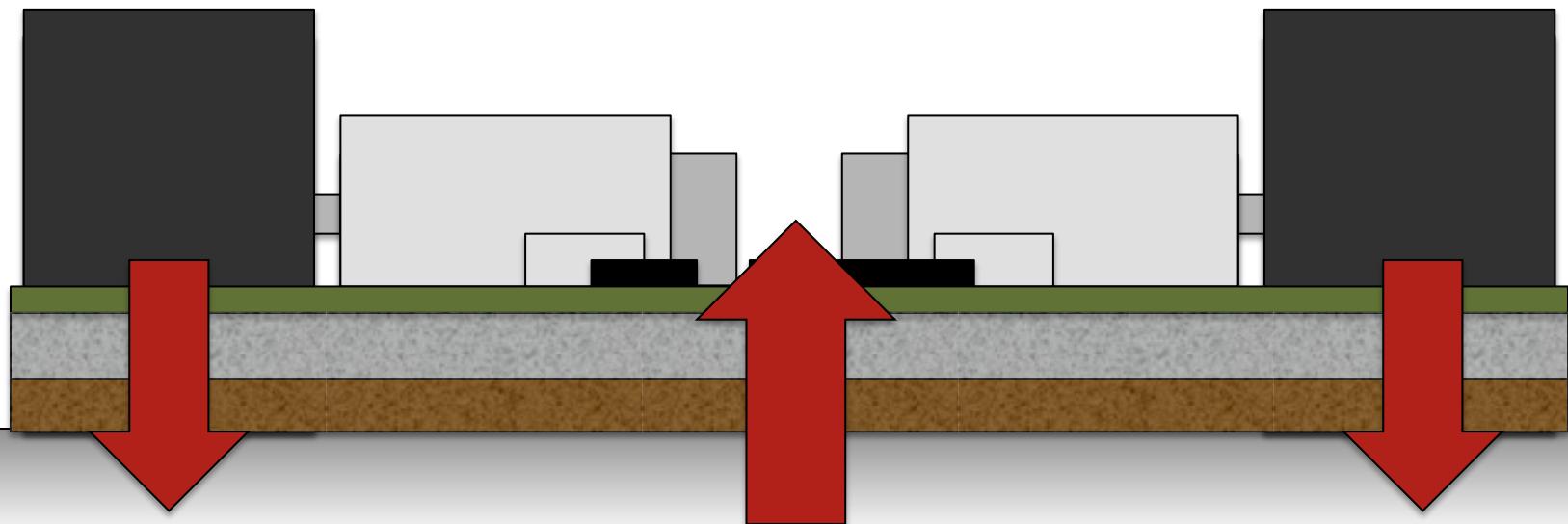


# MAGNETIC WHEELS



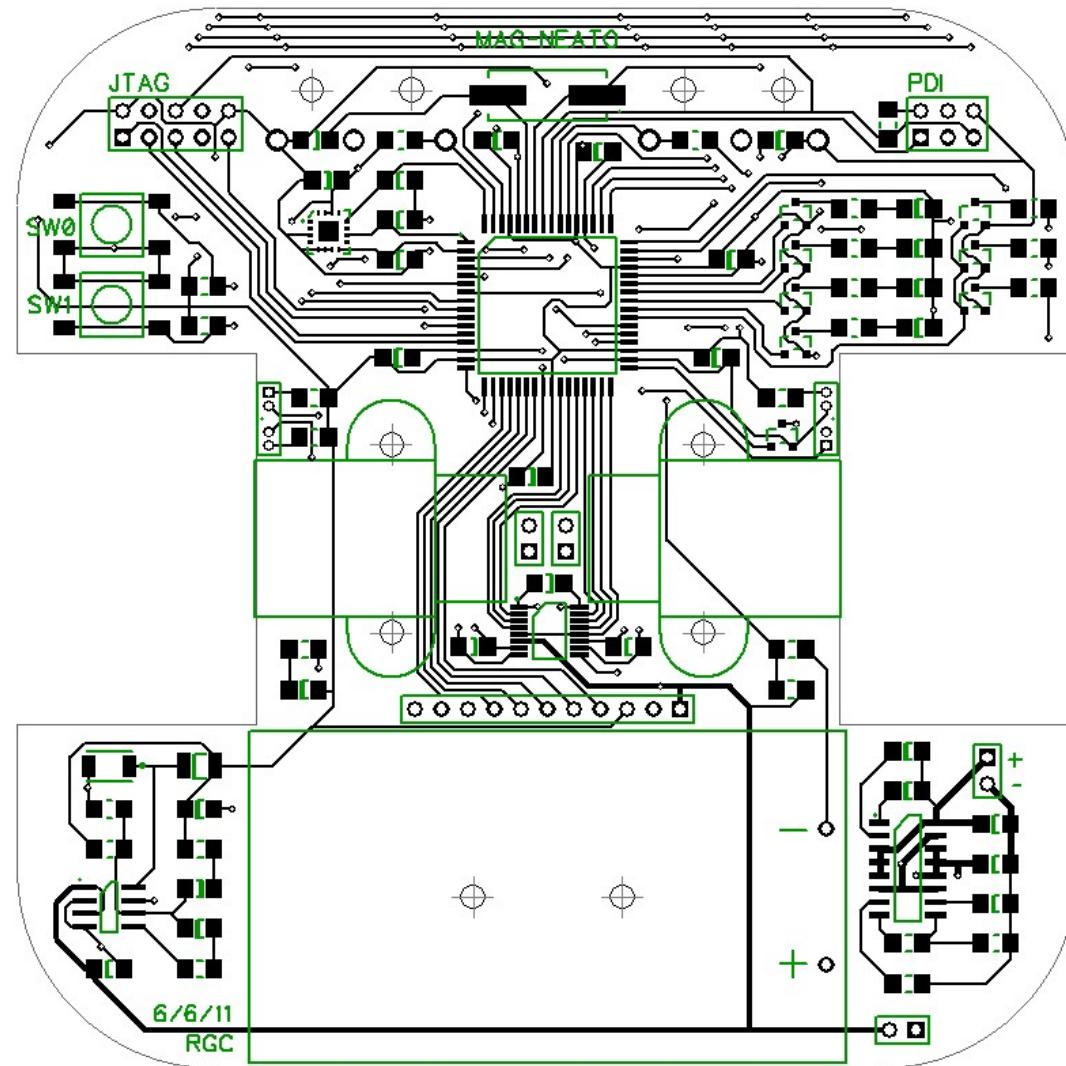


# MAGNETIC WHEELS



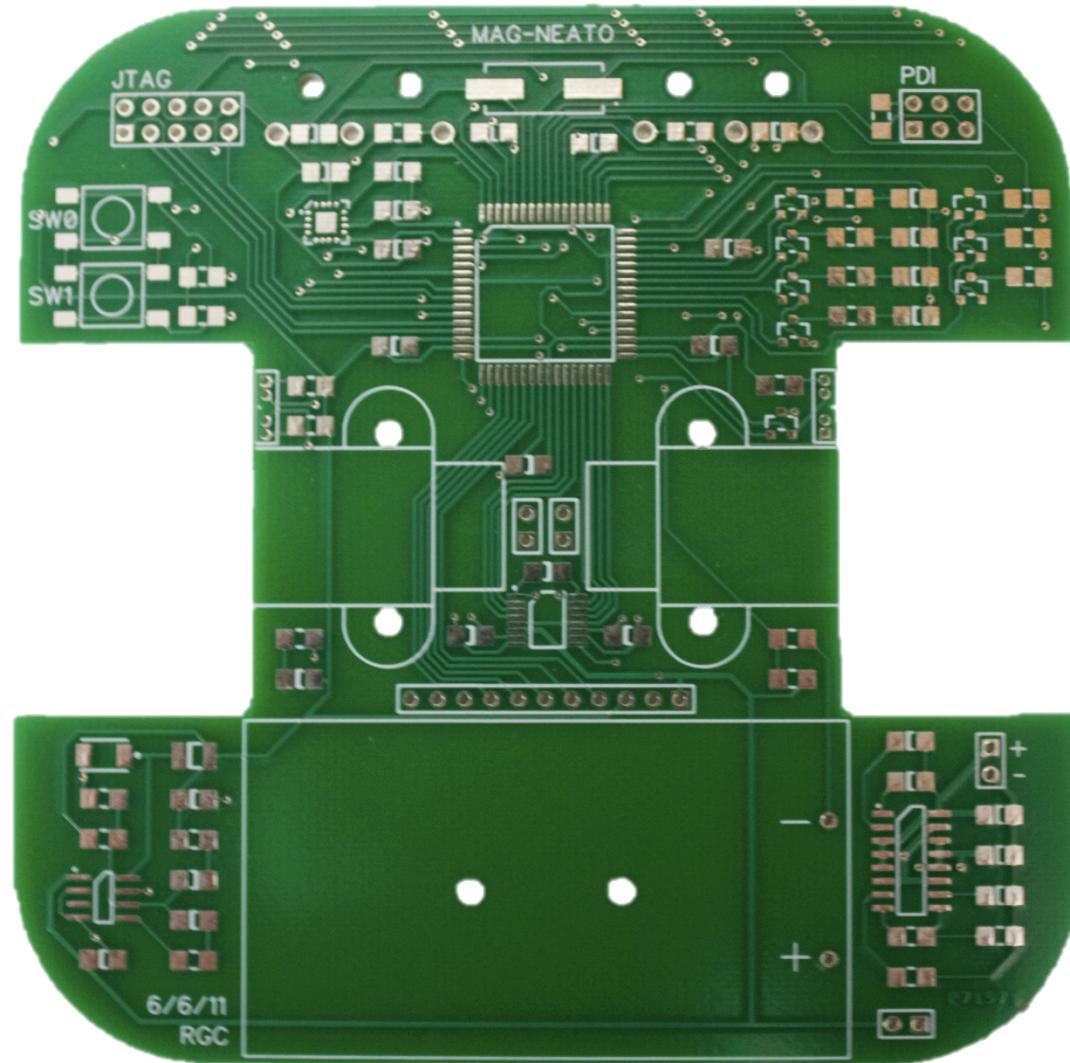


# PRINTED CIRCUIT BOARD



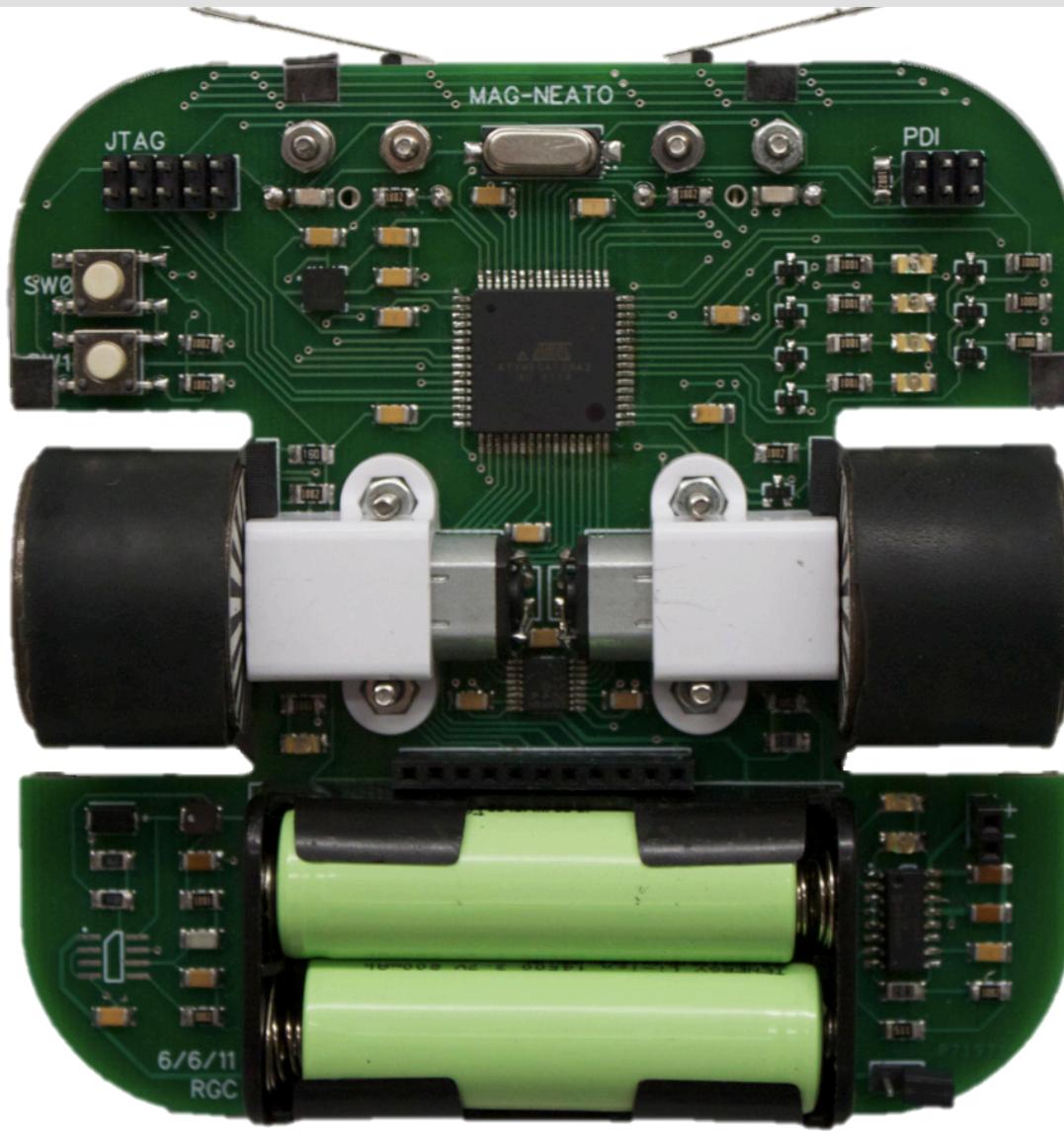


# PRINTED CIRCUIT BOARD



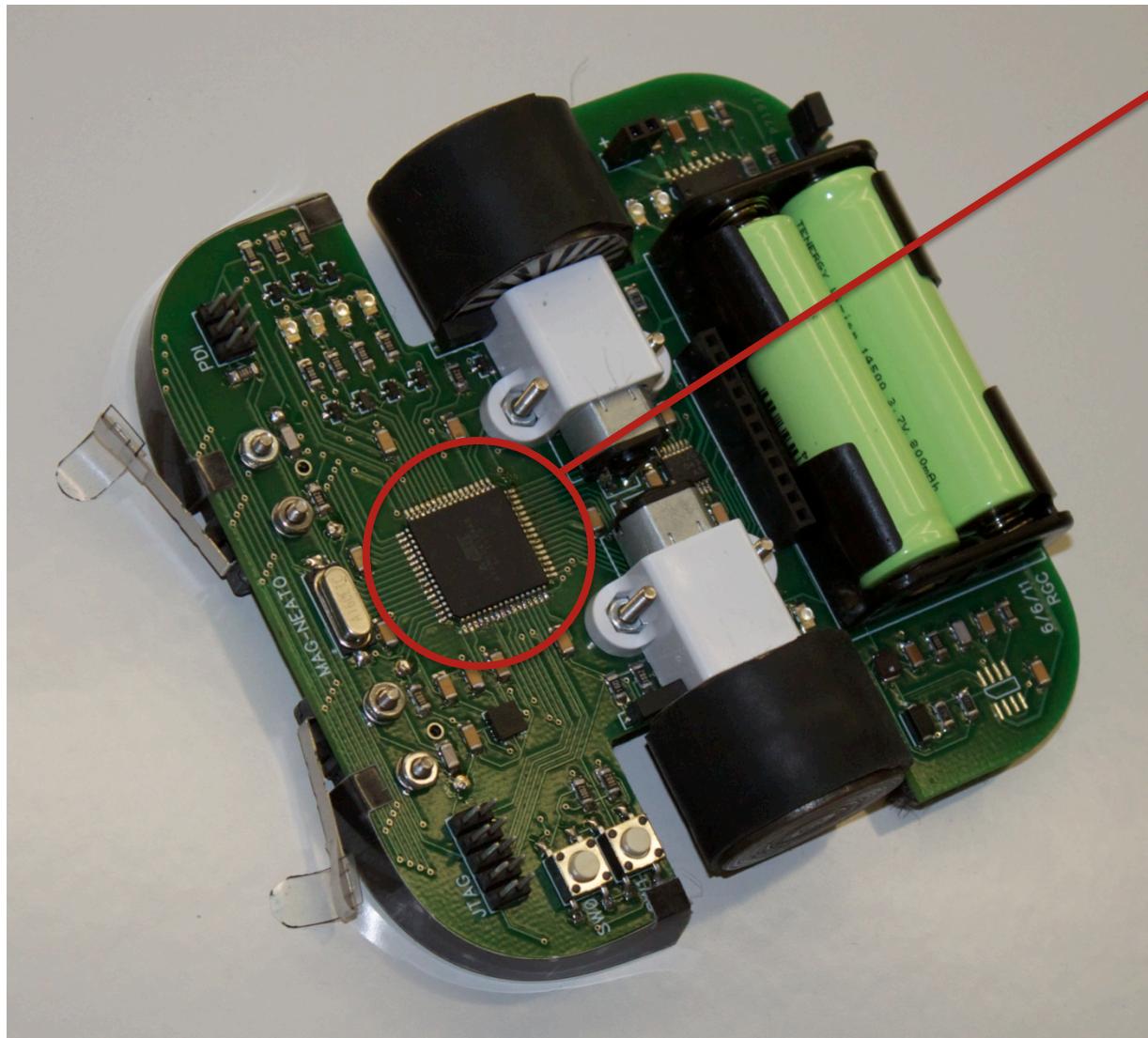


# PRINTED CIRCUIT BOARD





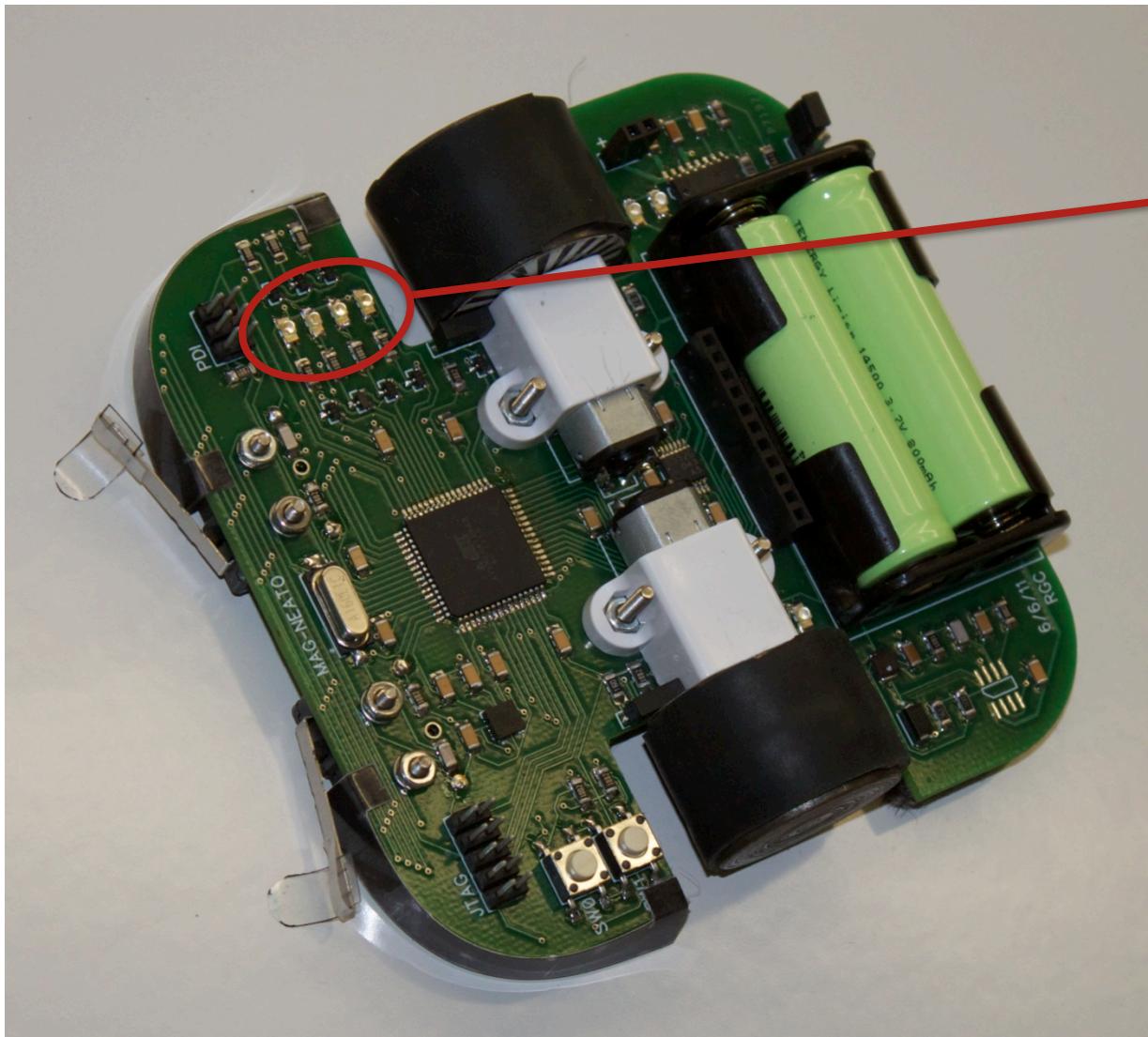
# PRINTED CIRCUIT BOARD



- 32 MHz AVR XMEGA microcontroller

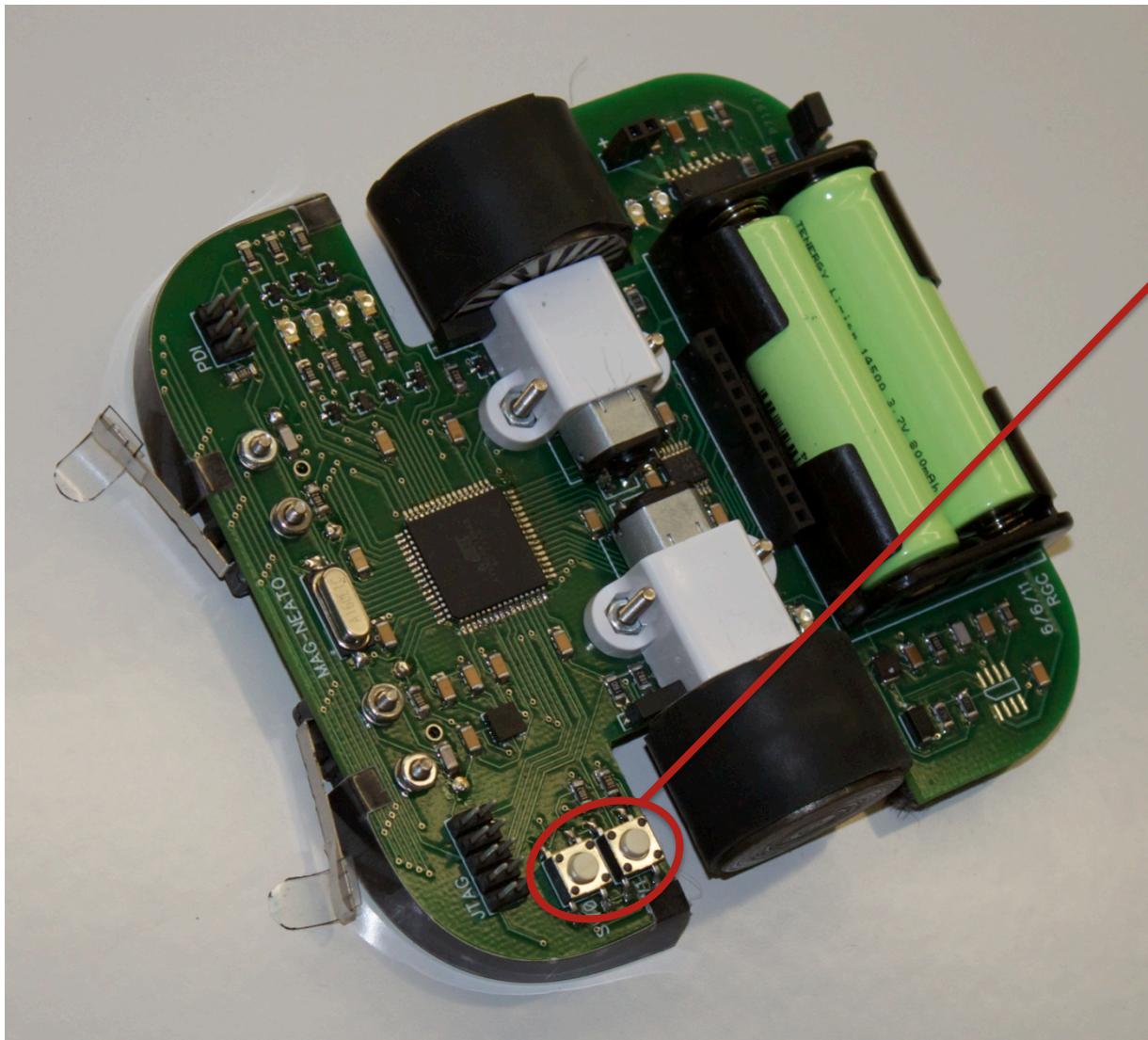


# PRINTED CIRCUIT BOARD



- 32 MHz AVR XMEGA microcontroller
- LED indicators

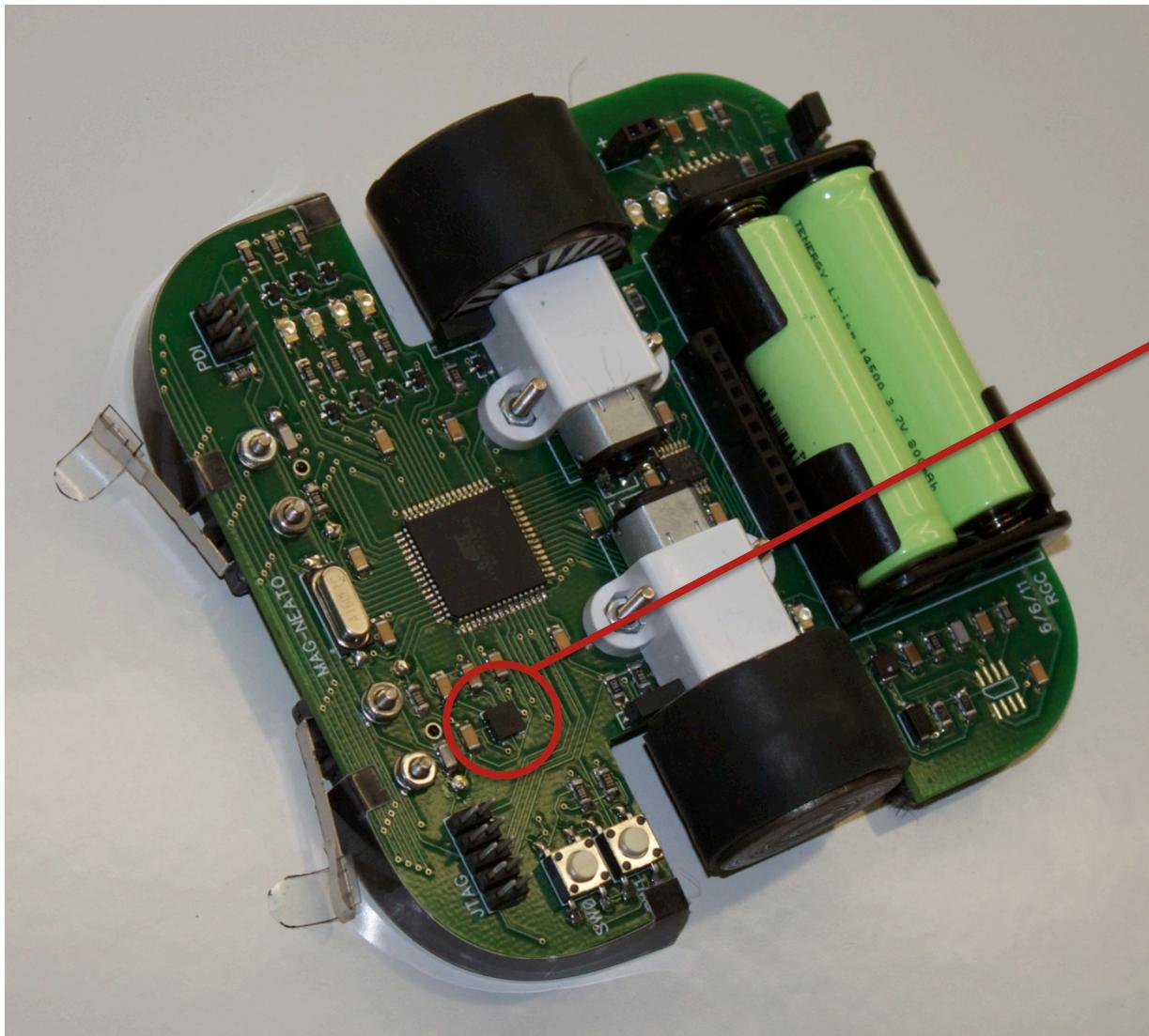
# PRINTED CIRCUIT BOARD



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

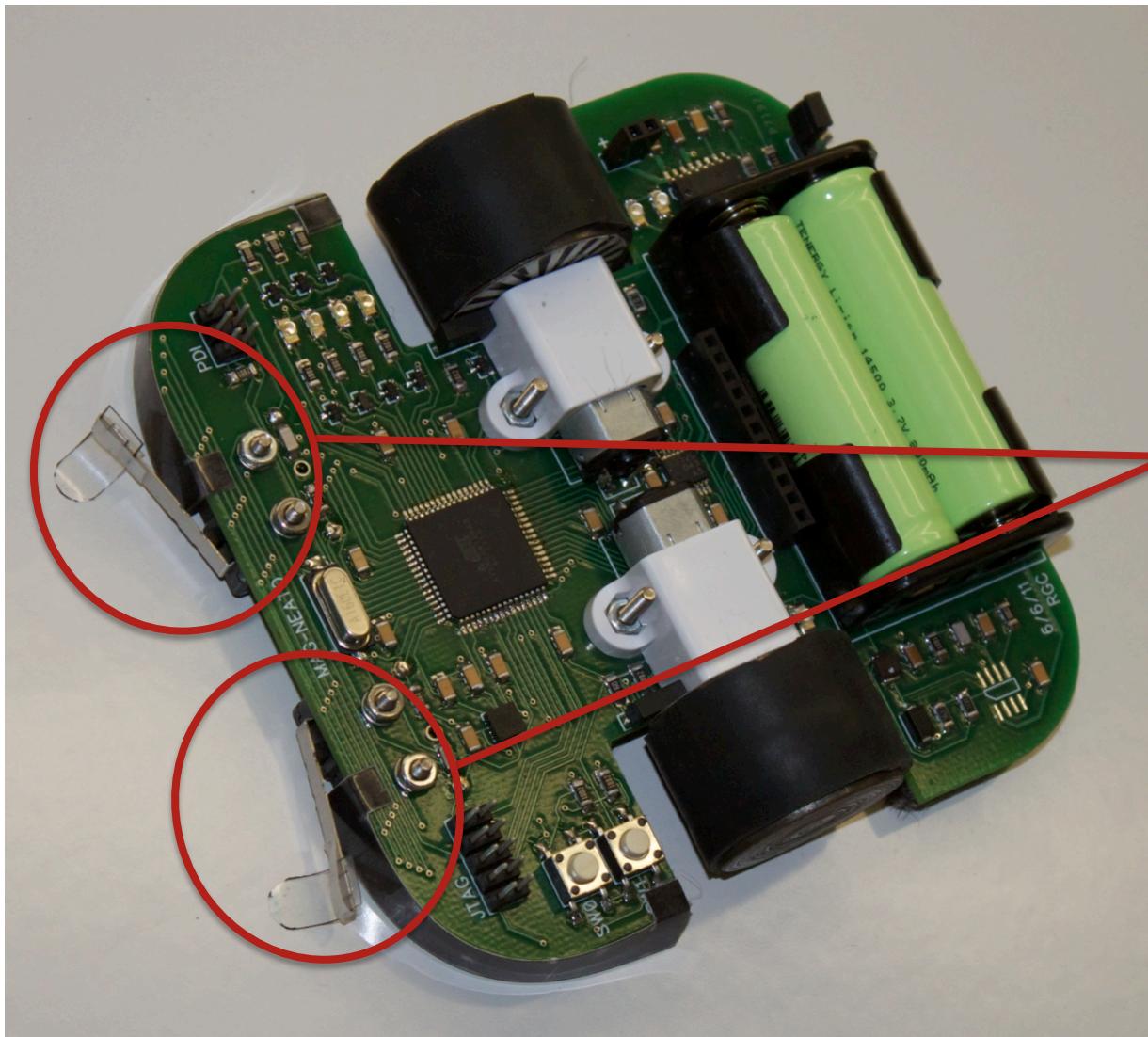


# PRINTED CIRCUIT BOARD



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

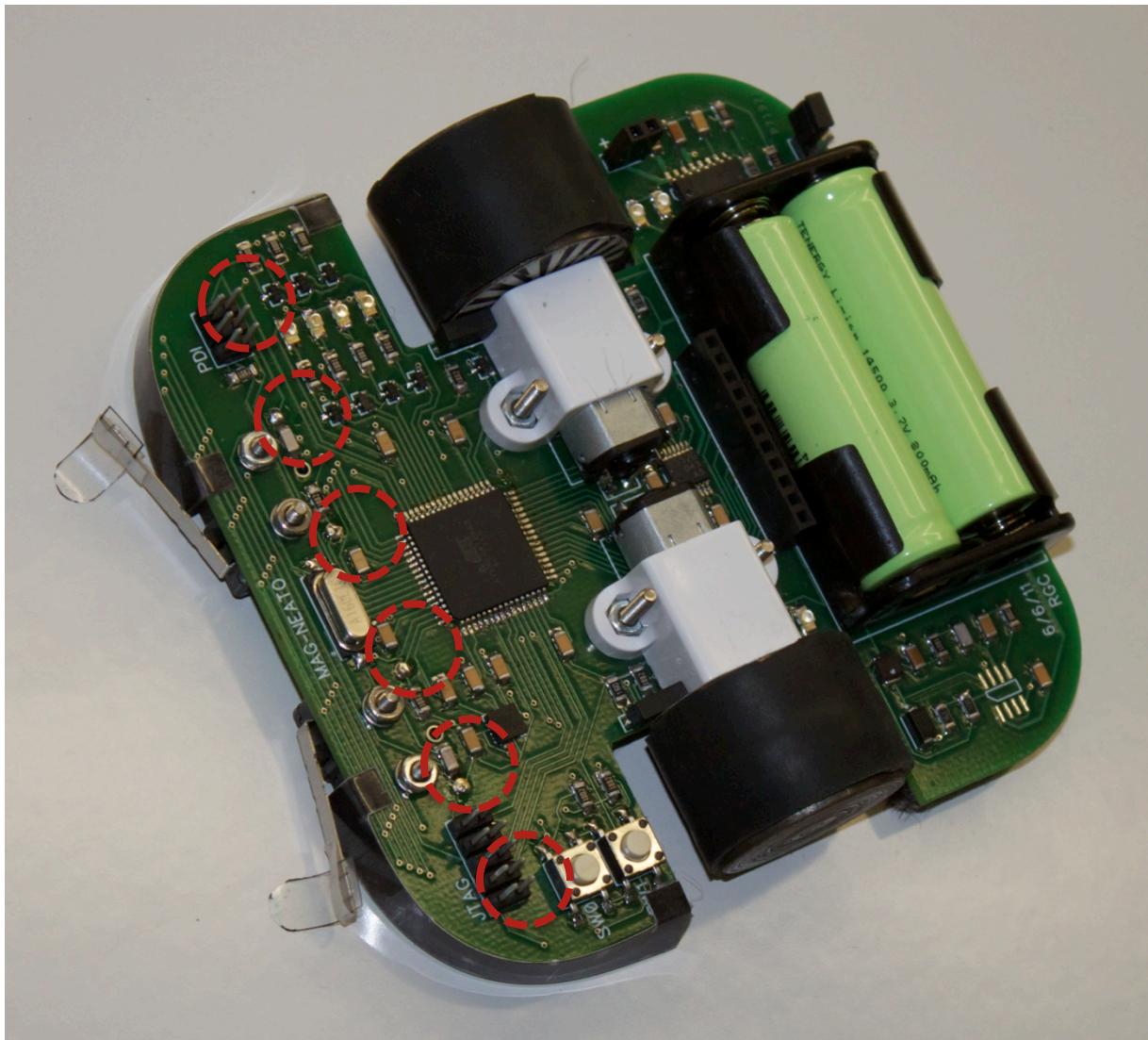
# PRINTED CIRCUIT BOARD



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

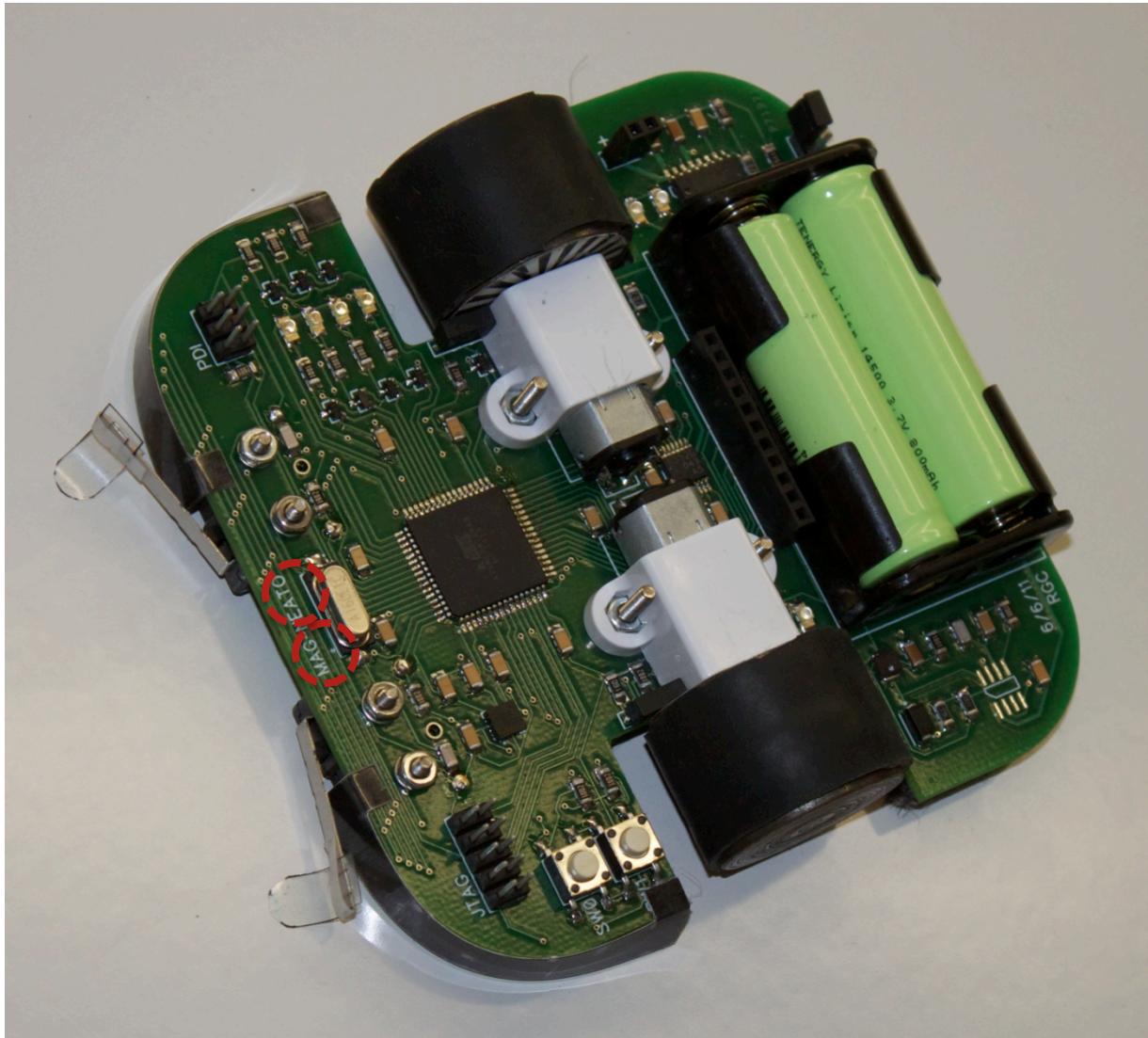


# PRINTED CIRCUIT BOARD



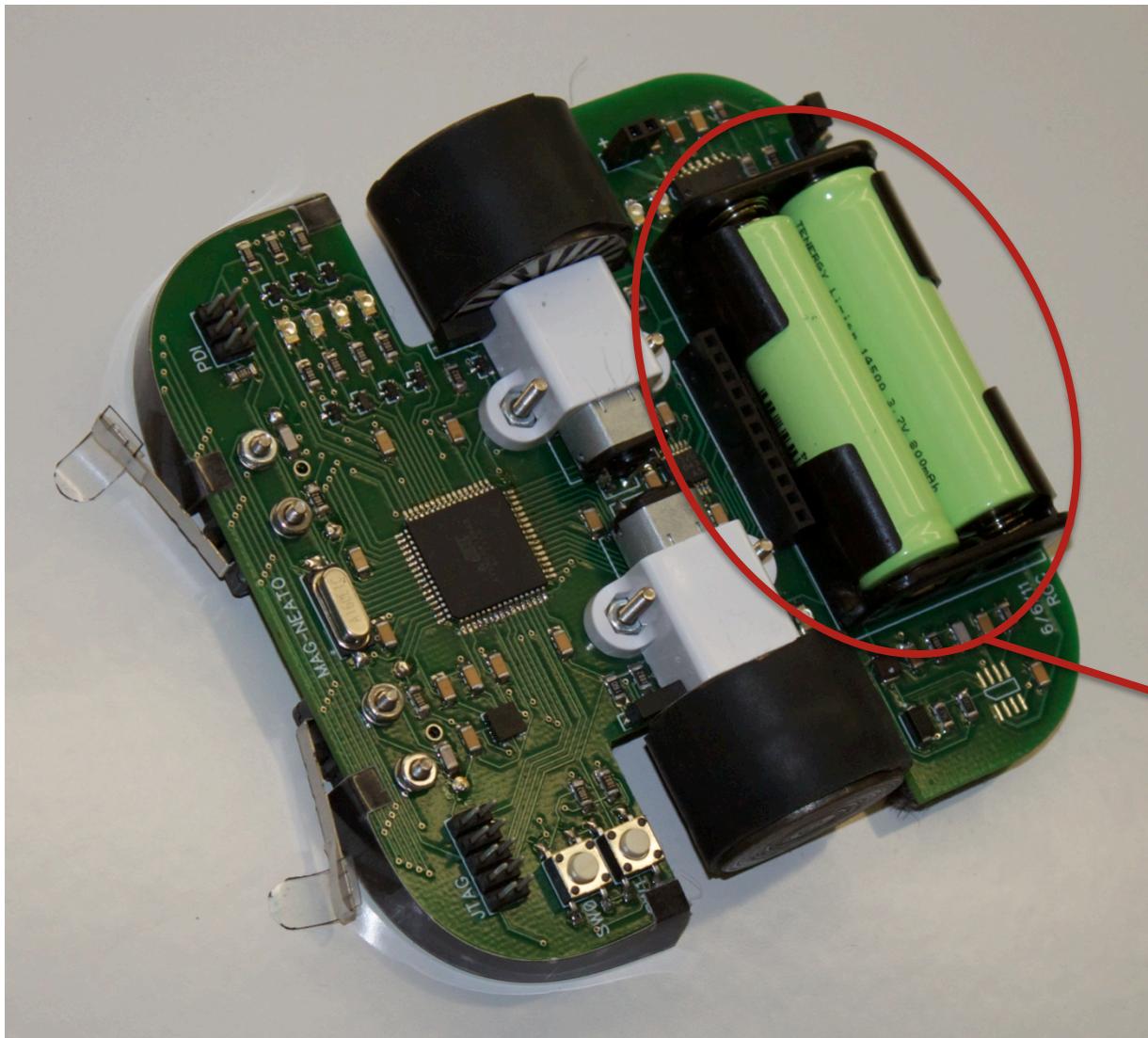
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor
- Two bump sensors
- Six color sensors

# PRINTED CIRCUIT BOARD



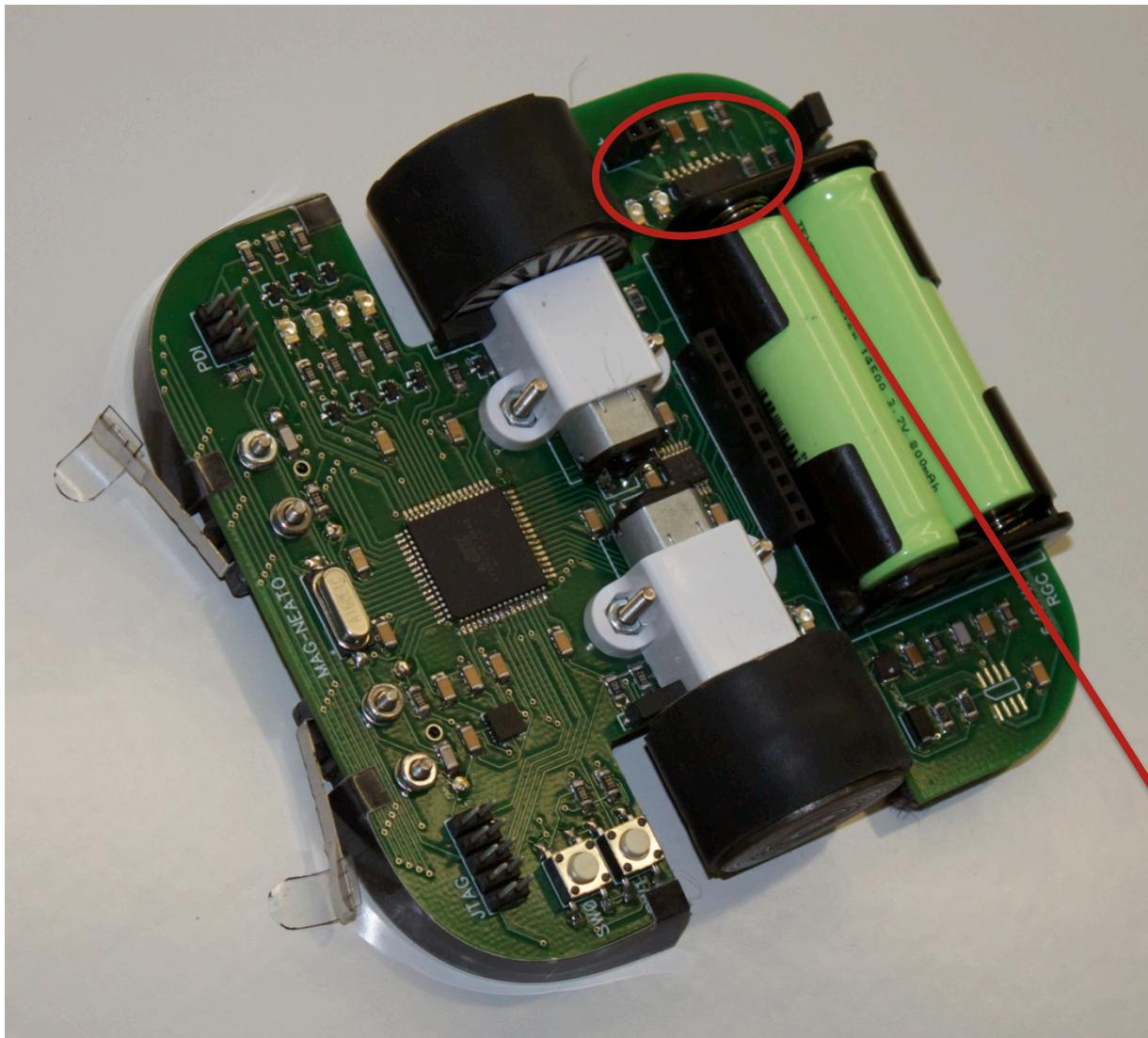
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor
- Two bump sensors
- Six color sensors
- Two reflective IR edge sensors

# PRINTED CIRCUIT BOARD



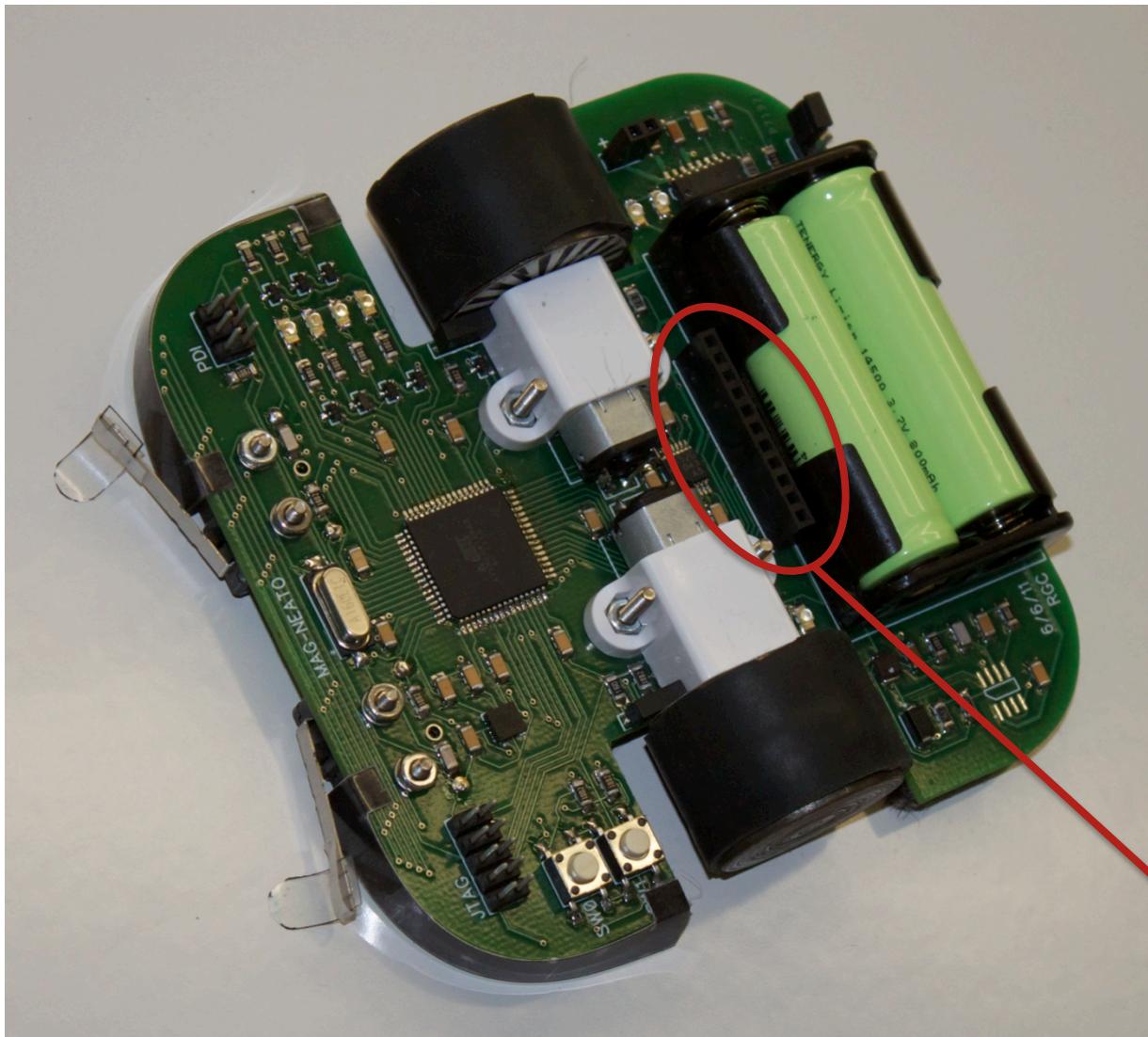
- 32 MHz AVR XMEGA microcontroller
- LED indicators
- Two user input buttons
- 3-axis accelerometer tilt sensor
- Two bump sensors
- Six color sensors
- Two reflective IR edge sensors
- Two 14500 lithium ion batteries

# 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



Powered by Visual Studio

The screenshot shows the AVR Studio 5 IDE interface. The code editor displays C code for a project named 'magneto'. The code includes header files like 'color.h', 'global.h', and 'motor.c', and defines variables such as 'global\_color\_value' and 'global\_color\_change'. It also contains function definitions for 'color\_set\_filter' and 'color\_set\_filter'. The Solution Explorer on the right lists all files in the project, including 'magneto', 'accelc', 'clockc', 'colorc', 'globalc', 'interrupc', 'ledc', 'magnecto', and 'motorc'. The Output window at the bottom shows the build log, indicating a successful build.

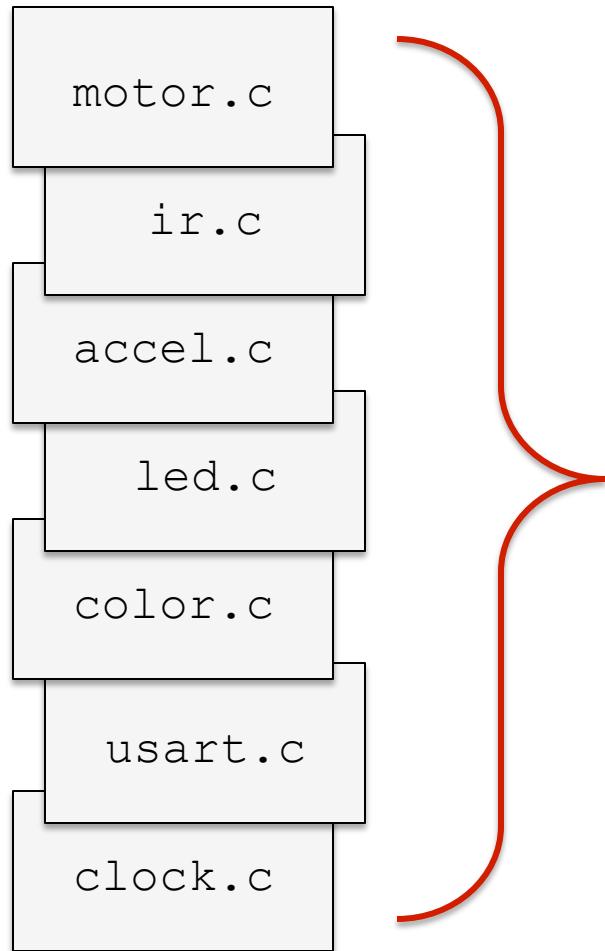
```
/* ---GLOBAL VARIABLES--- */
unsigned int global_color_value[6][4];
unsigned int global_color_change[6][4];
char global_color_sensor_count;
char global_color_filter;
extern volatile char global_state;

/* ---FUNCTION DEFINITIONS--- */
void color_set_filter(char color)
{
    switch (color)
    {
        case RED:
            PORTF_OUTCLR = ~0x01100000;
            break;
        case BLUE:
            PORTF_OUTCLR = ~0x00100000;
            PORTF_OUTSET = 0x00100000;
            break;
        case GREEN:
            PORTF_OUTCLR = ~0x00100000;
            PORTF_OUTSET = 0x00110000;
            break;
        case ORANGE:
            PORTF_OUTCLR = ~0x00110000;
            break;
    }
}
```

Build succeeded.  
\*\*\*\*\* Build: 1 succeeded or up-to-date, 0 failed, 0 skipped \*\*\*\*\*



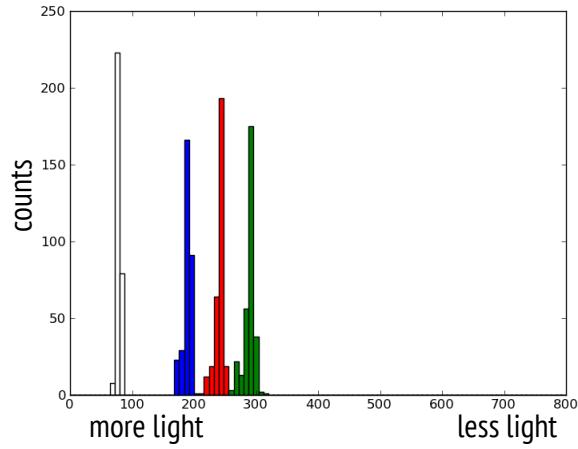
# CODE



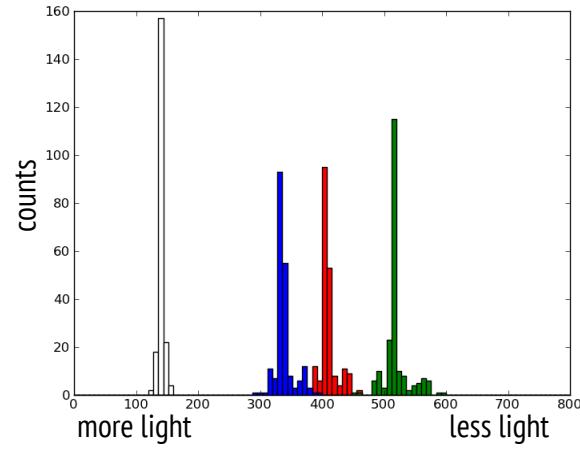


# COLOR SENSING

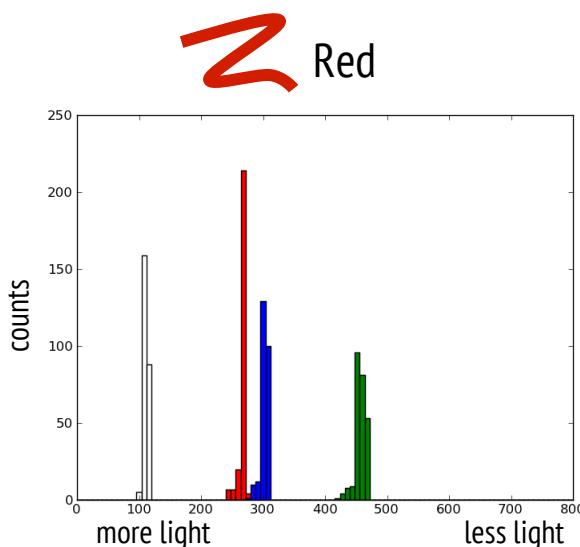
Background



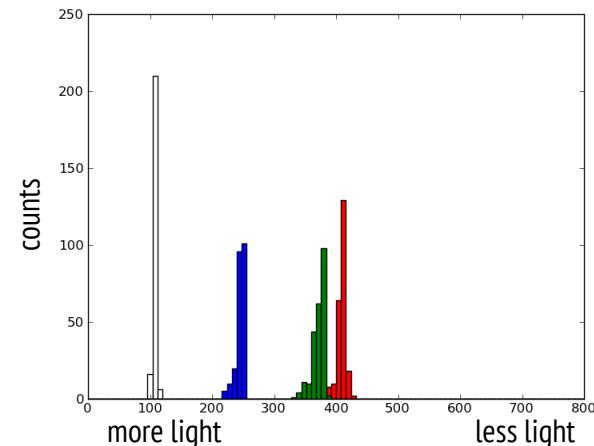
Ζ Black



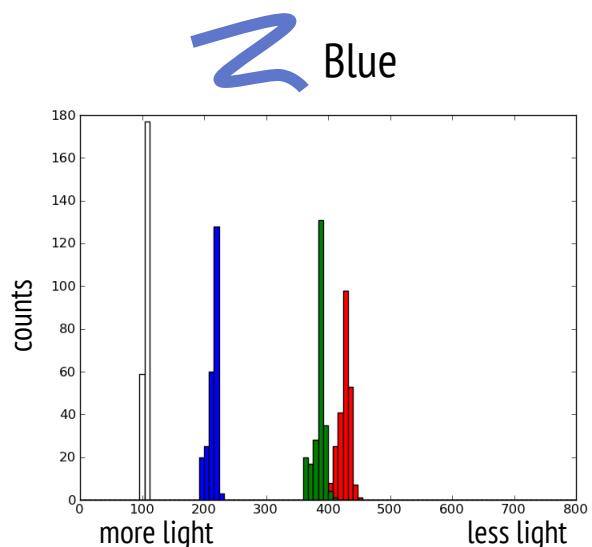
Ζ Red



Ζ Green

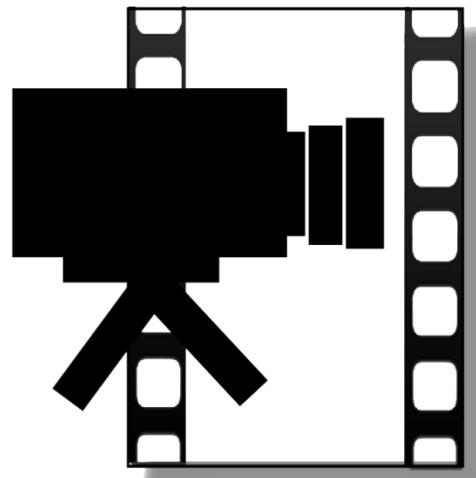


Ζ Blue





# 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

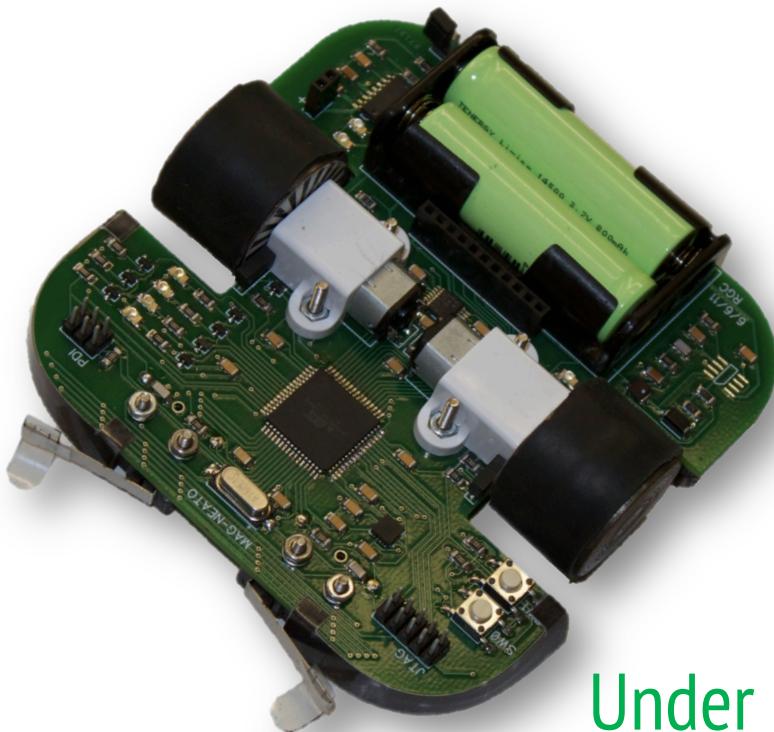


driving on window



# FUTURE WORK

Commercialize?



Under \$100



EPFL e-puck  
\$1000



Pololu 3pi  
\$100



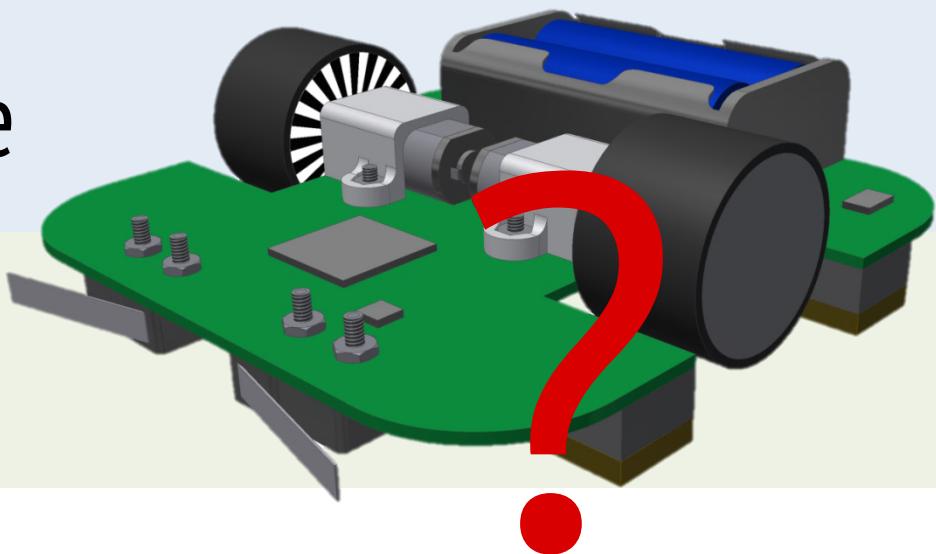
# FUTURE WORK



Open Hardware



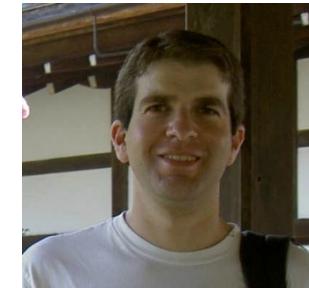
Open Source





# 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

