The ARTEMIS Project

Lunar Regolith Excavator Student Competition

ME Team #8 / ECE Team #1

James Dickson
Jeremy Nagorka
Anthony Gantt
Jennifer Schrage
Christopher Loftis
Nick Stroupe
Alan Williams

Outline

- **The Lunabotics Competition**
- **System Overview**
- **Test Bed construction**
- **Excavation Subsystem Design**
- **Locomotion Subsystem Design**
- **Power Subsystem Design**
- **Microcontroller and Communications Design**
- **Budget**
- **Schedule**

The Lunabotics Mining Competition

Lunabotics Mining Competition

- Designed to engage and retain students in STEM disciplines
- Provide a competitive environment in which may result innovative ideas and solutions that could be applied to actual lunar excavation

Max Weight	80 kg
Min Excavation Material	10 kg
Max width	1.5 m
Max length	0.75 m
Max height	2 m
Max setup time	10 minutes
Operation time	15 minutes
Max take down time	5 minutes

Table 1. Competition Specifications

Figure 1. Artist's rendering of lunar excavation, taken from Lunabotics Mining Competition announcement

Needs Analysis Flow Diagram

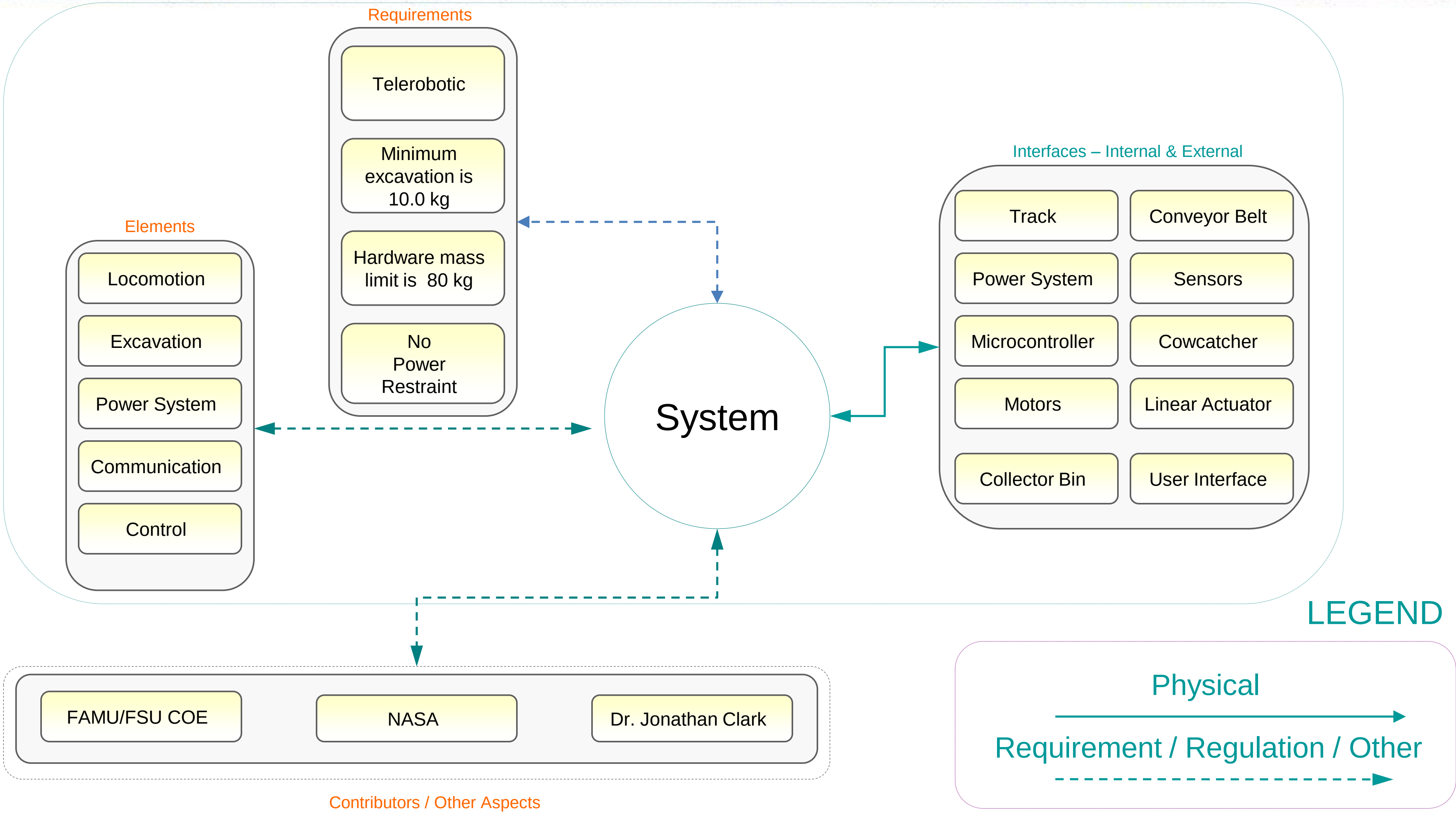


Figure 2. Needs analysis flow diagram for ARTEMIS Project

Robotic Platform Design

Figure 3. Robot design schematic

Circuit Block Diagram

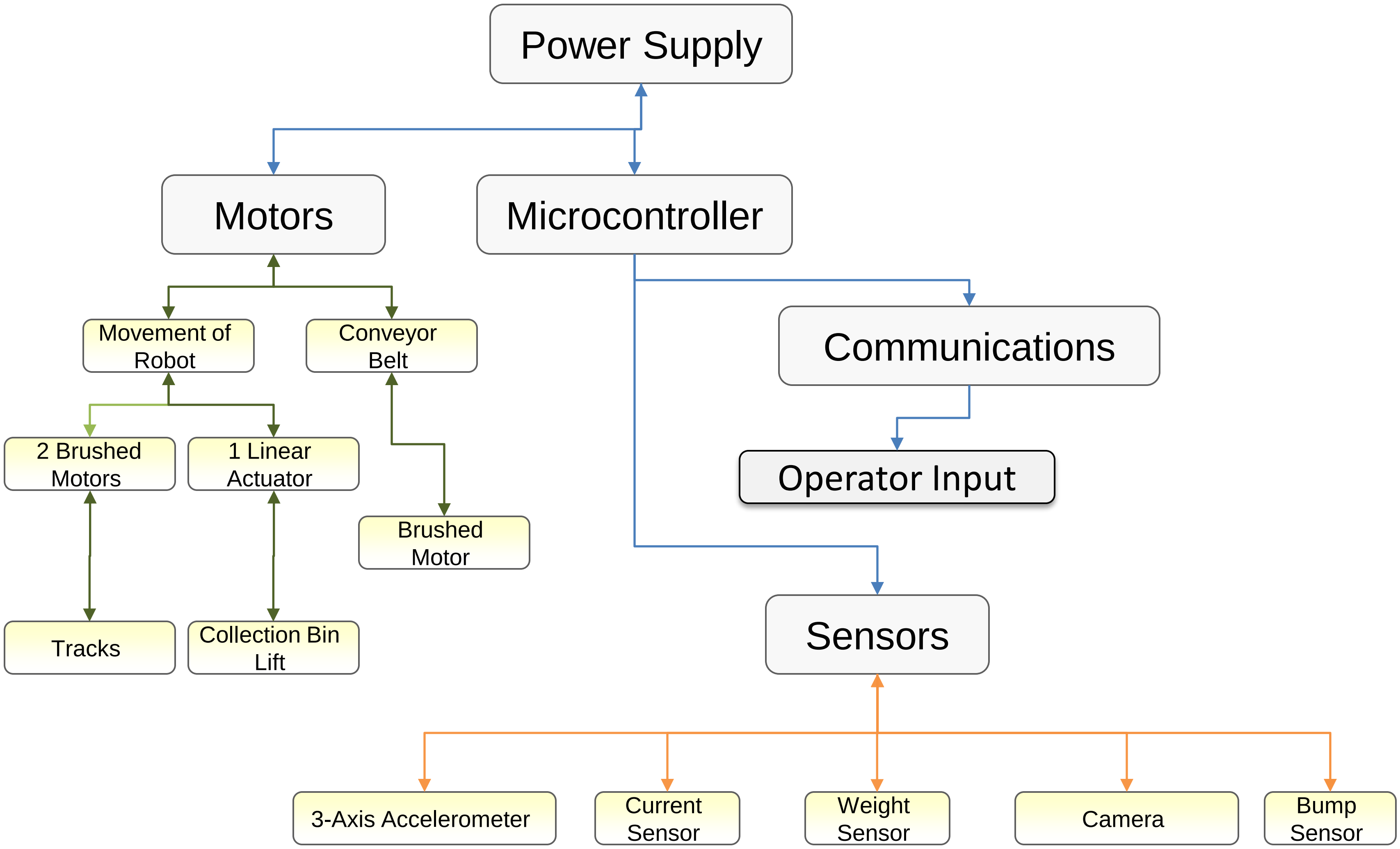


Figure 4. Circuit block diagram

System Breakdown

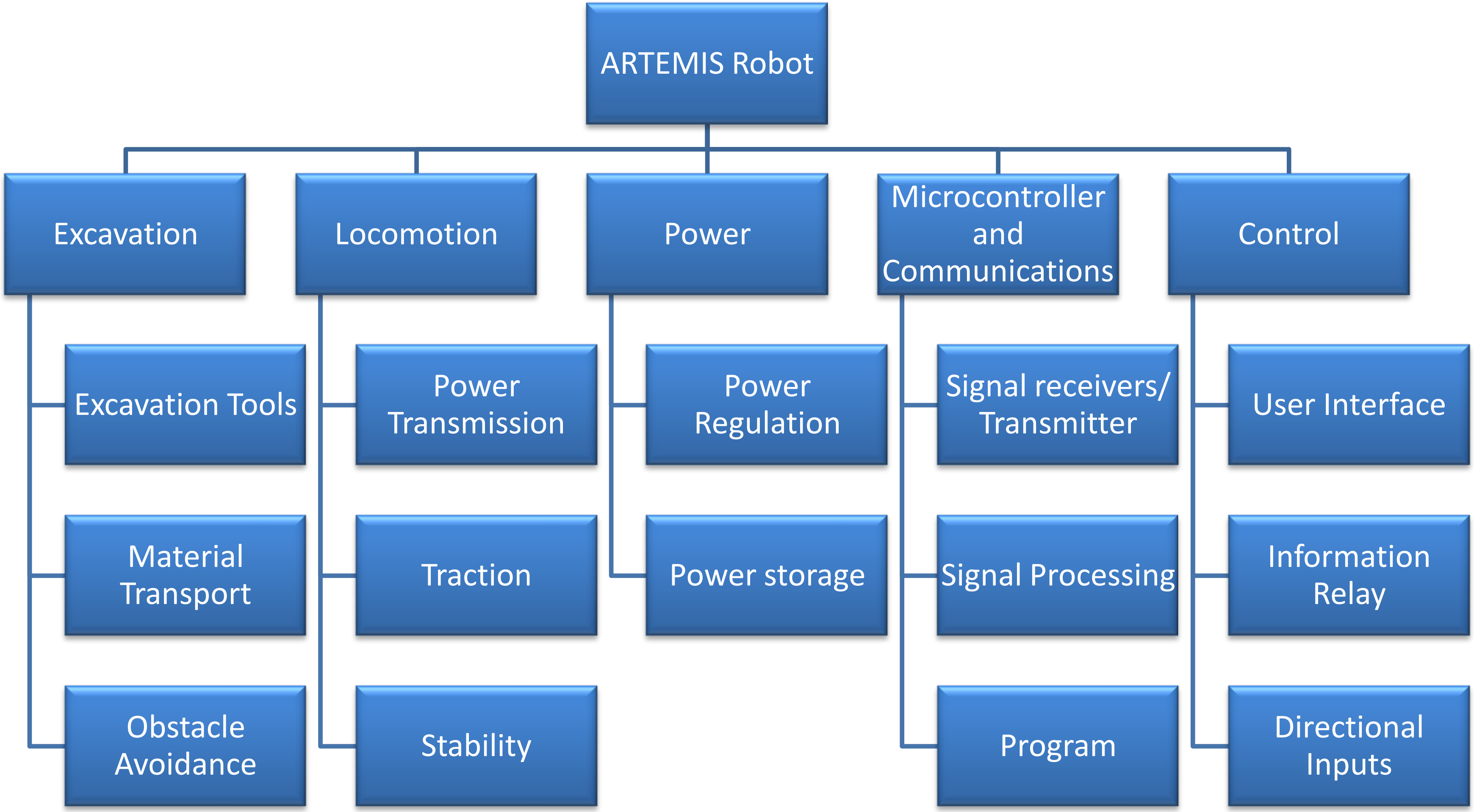


Figure 5. System breakdown structure

Building the Testing Bed

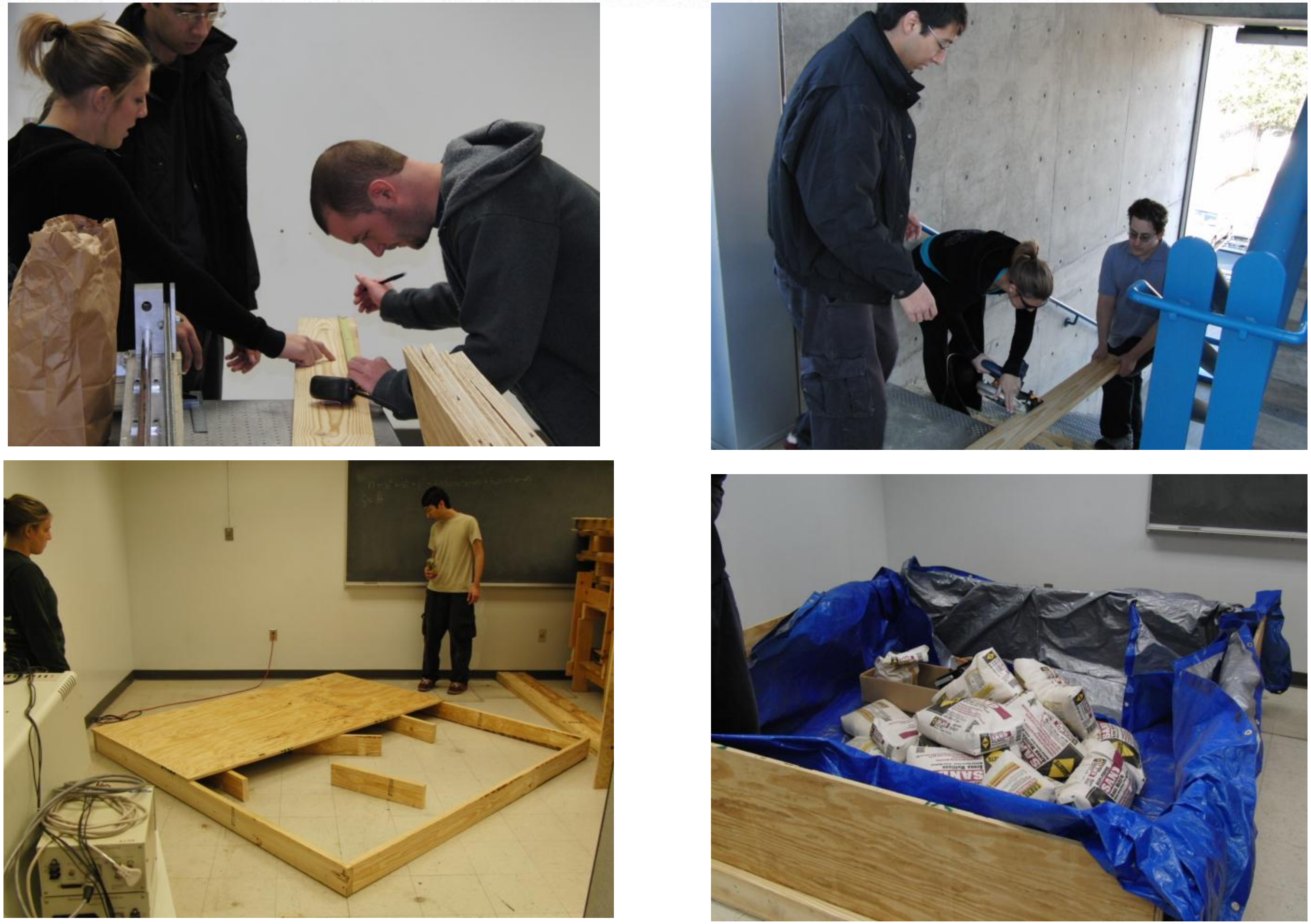


Figure 6. Construction of test bed

Completed Test Bed

Figure 7. Completed Test Bed

System Overview

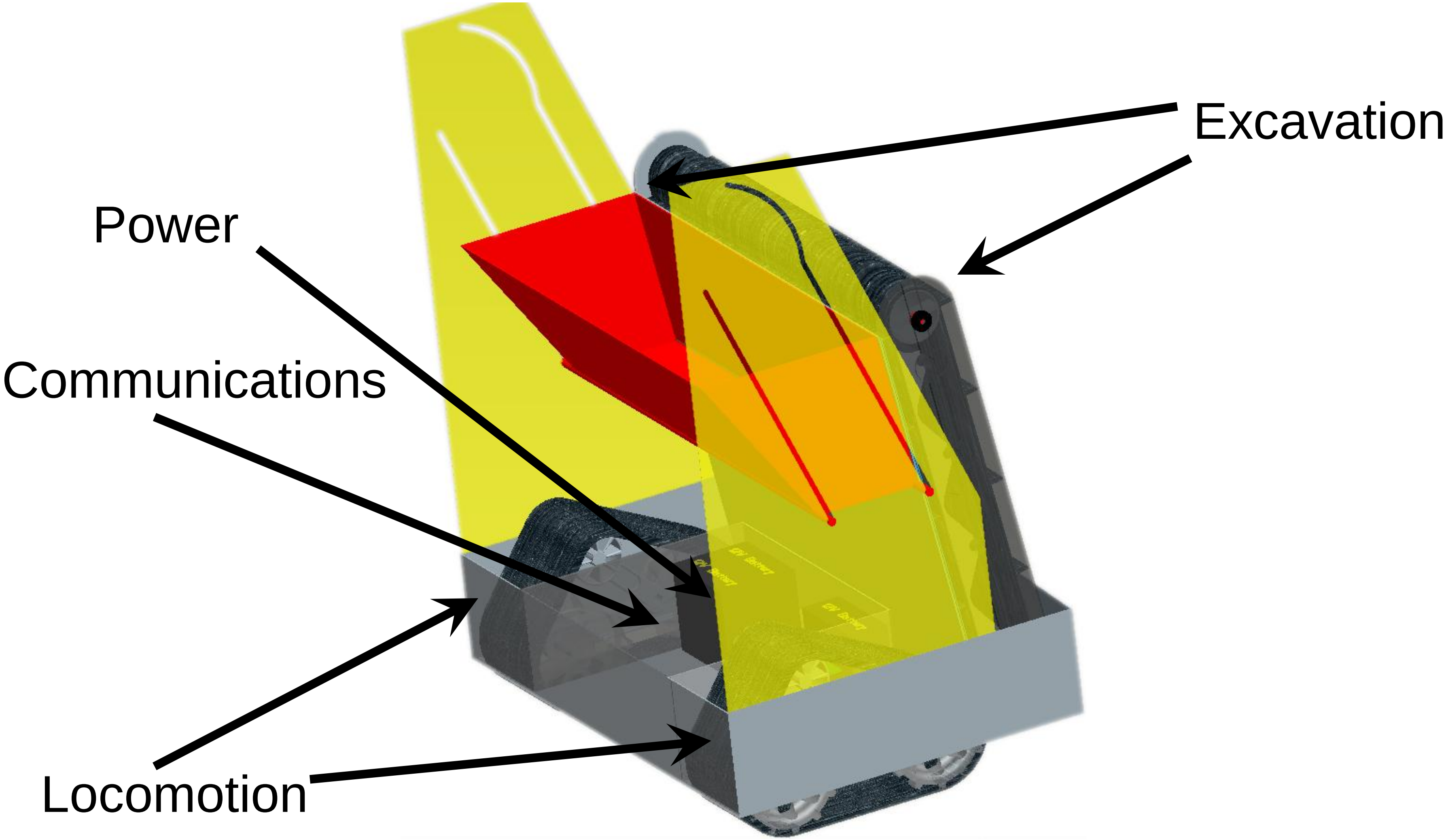


Figure 8. Overall platform design with subsystems

Excavation Subsystem Design

- Excavation Subsystem Components:
  1. Cleated belt – cleats excavate regolith into trough
  2. Conveyor – transports regolith up trough to be deposited into bucket
  3. Bucket – holds regolith until delivery to holding bin

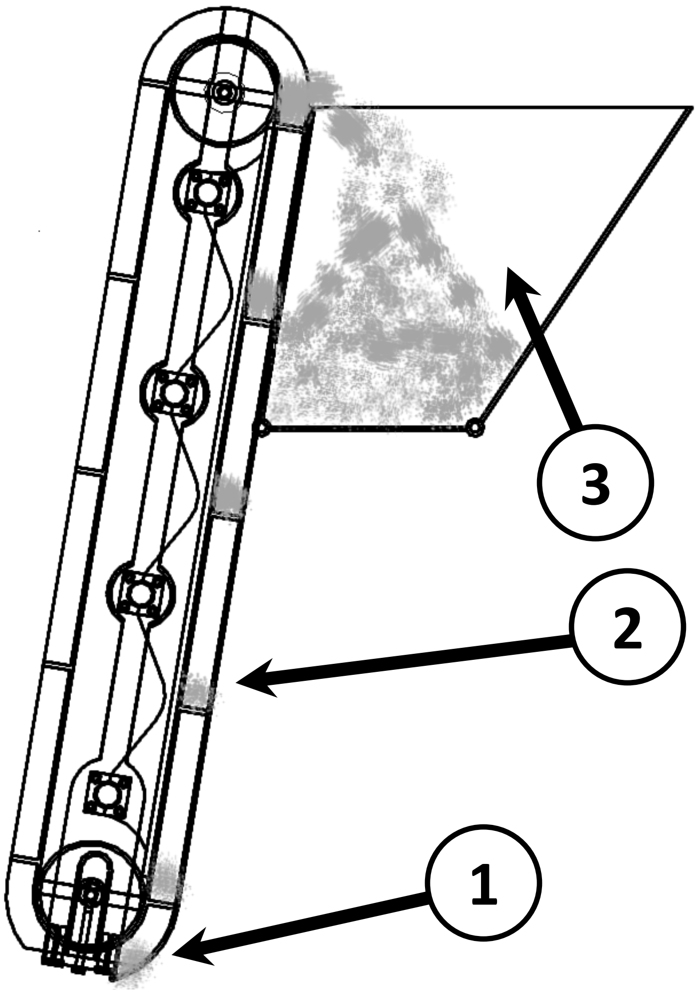


Figure 9. Excavation subsystem components and flow of regolith

EXCAVATION

CLEATED CONVEYOR REVISION

- Overall width reduced from 94 to 81 cm
- Weight savings through use of thinner material
- Easier machining
- Estimated excavation rate of 0.5 kg/s

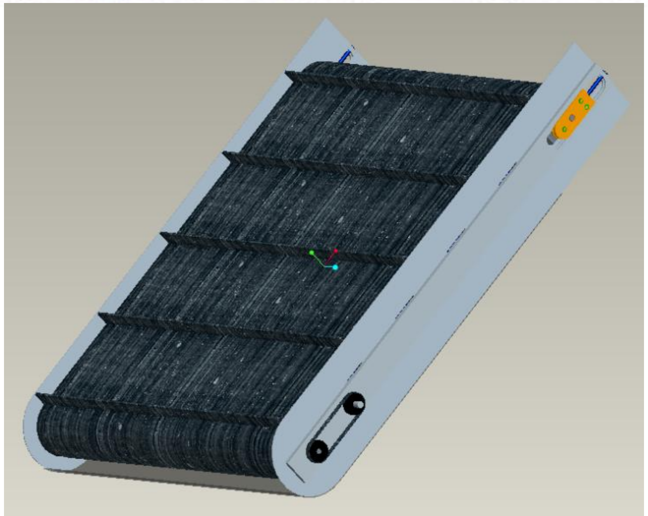


Figure 10. Conveyor Isometric View

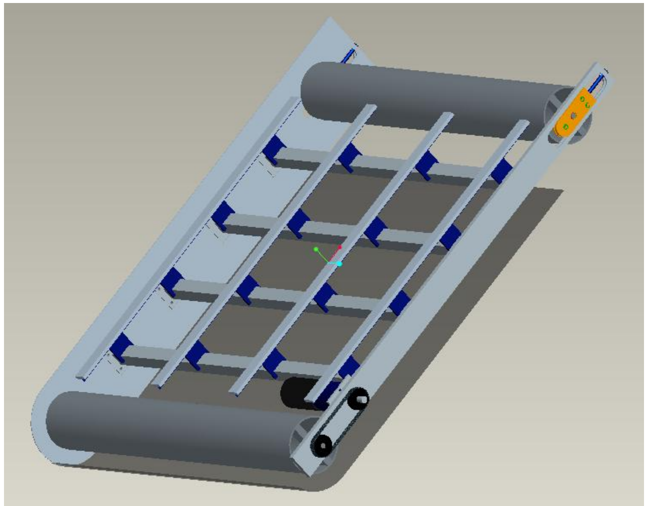


Figure 11. Conveyor Isometric view with Belt and right shield removed

CLEATED CONVEYOR REVISION

- Motor assembly mounted on the inside of the frame
- Belt drive coupling between motor shaft and driven roller
- Two piece belt tensioning mechanism
- Two bolt tension adjustment

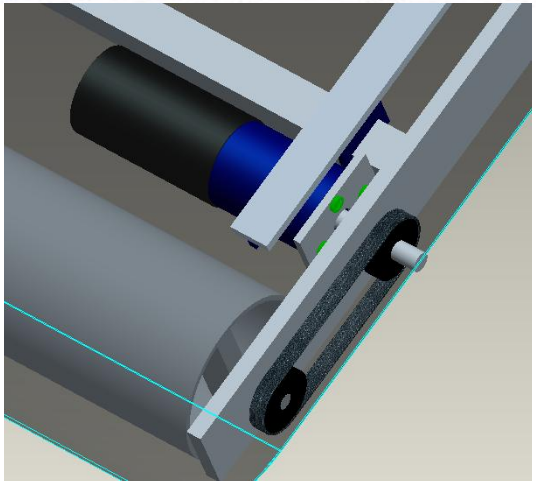


Figure 12. Detail View of Motor Mounting and Belt Drive

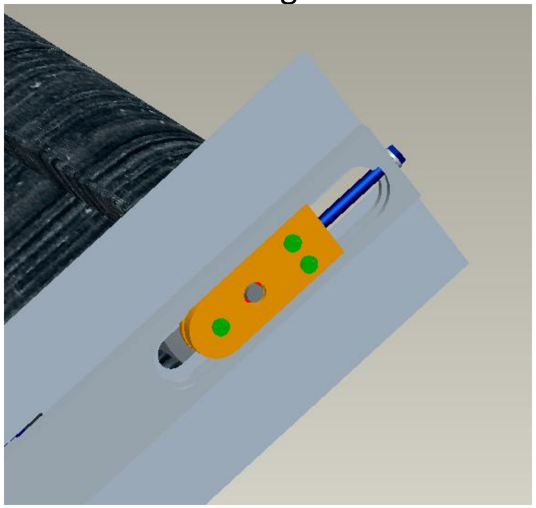


Figure 13. Conveyor Belt Tensioning Mechanism

EXCAVATION

CONVEYOR MOTOR

- 24 Volt DC motor with 12:1 gear reduction drive

- Motor Ratings:
  - 285 RPM
  - Current rating of 2850 mA
  - Torque rating of 1.1 Nm
  - Stall torque of 29 Nm

- Weight
  - 1.58 kg

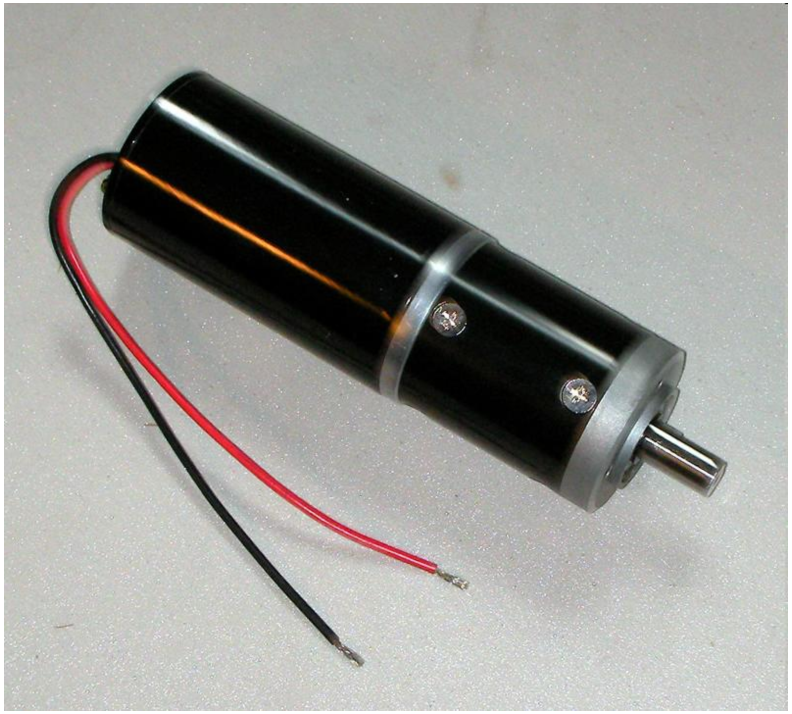


Figure 14. High Torque 24V Electric Motor with 12:1 Gear Reduction

EXCAVATION

WHATS NEXT?

- Source cleated conveyor belt
- Fabricate frame and rollers
- Purchase sealed bearings
- Purchase gears and belt drive
- Test

Bucket Design

- Density of Regolith - 1.5 g/cm^3
- Desired Capacity - 100 kg
- Required Volume - 0.066 m^3
- Time to Reach Desired Capacity - 200 s
- Our Bucket
  - Volume - 0.0675 m^3
  - Material AL 6061
  - 4.23 kg

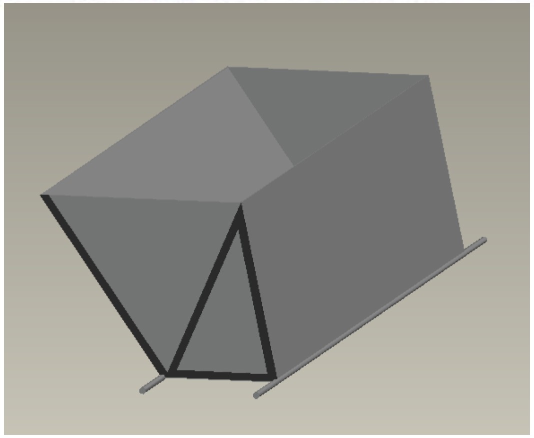


Figure 16. Isometric view of bucket design

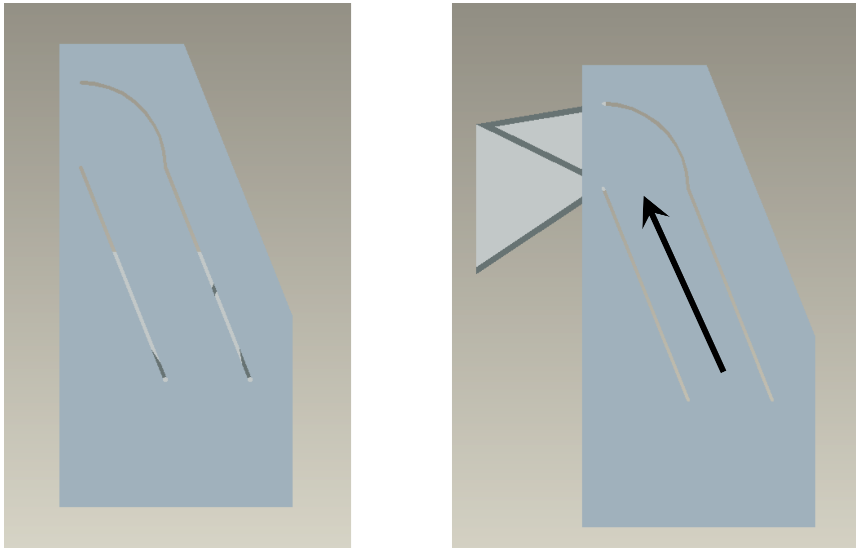


Figure 17. Example of bucket dumping from side view

Locomotion Subsystem

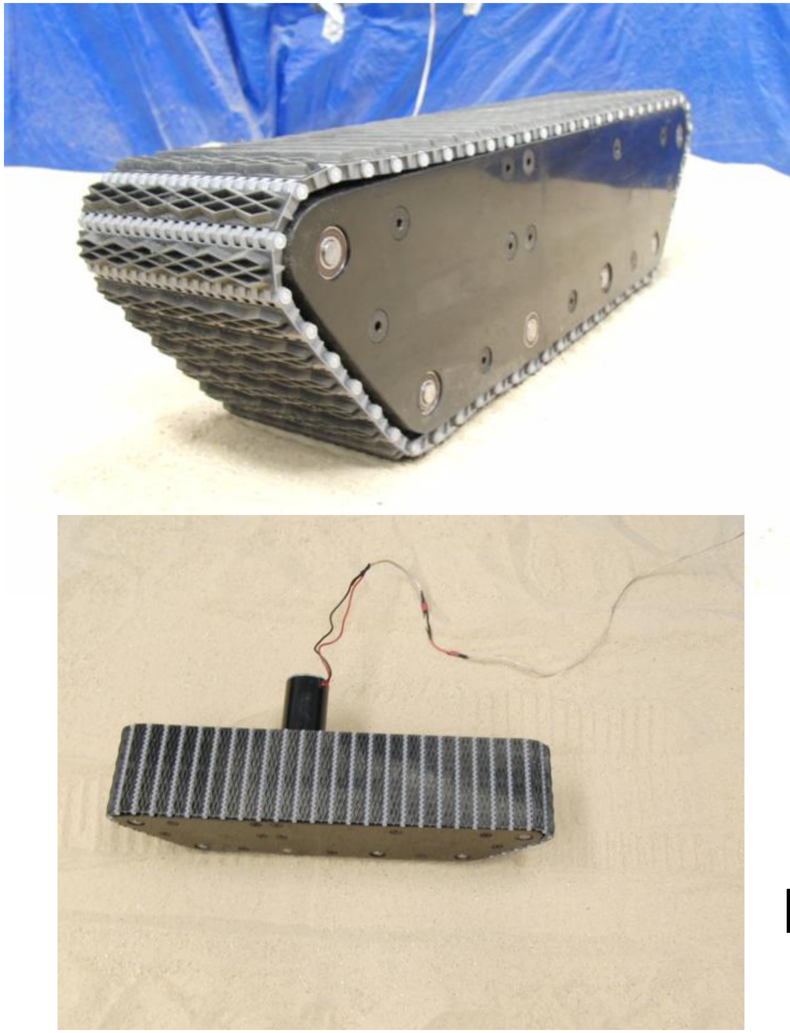


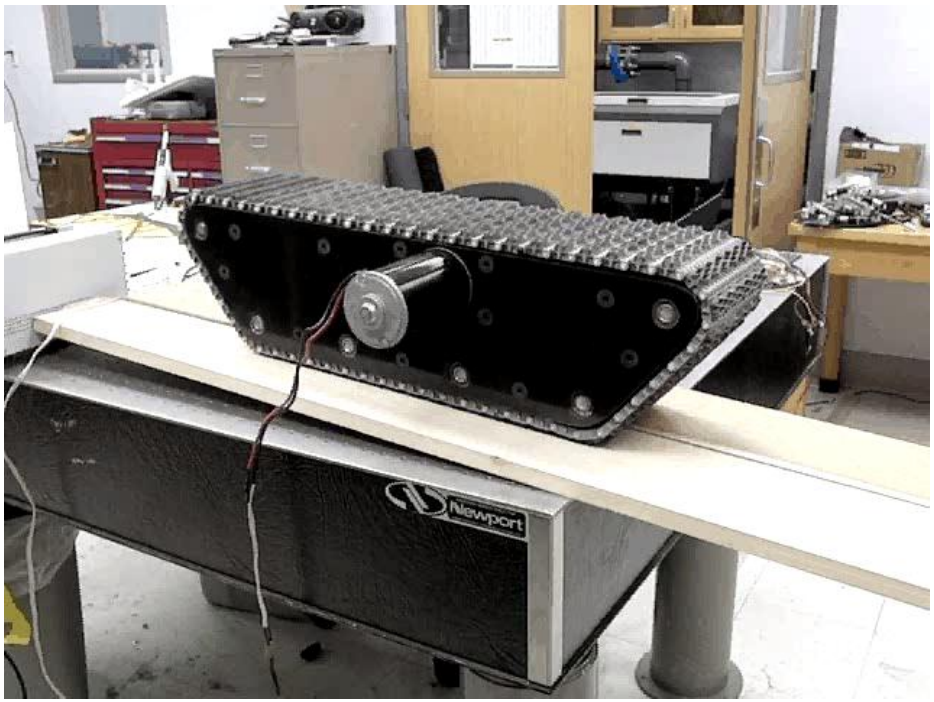
Figure 18. Track design

Track Specifications:

- 10 kg weight / track
- 70.5 x 16 x 20.4 cm
- 24 V / 30 A motor
- 4:1 Primary gear reduction with a 1.5:1 gear reduction at chain

Initial design ~13 kg at a cost of $1654.00 per track. Sponsorship by E.M.T. Robotics placed final tracks at cost of $638.00 and weight of 10 kg.

Locomotion Subsystem



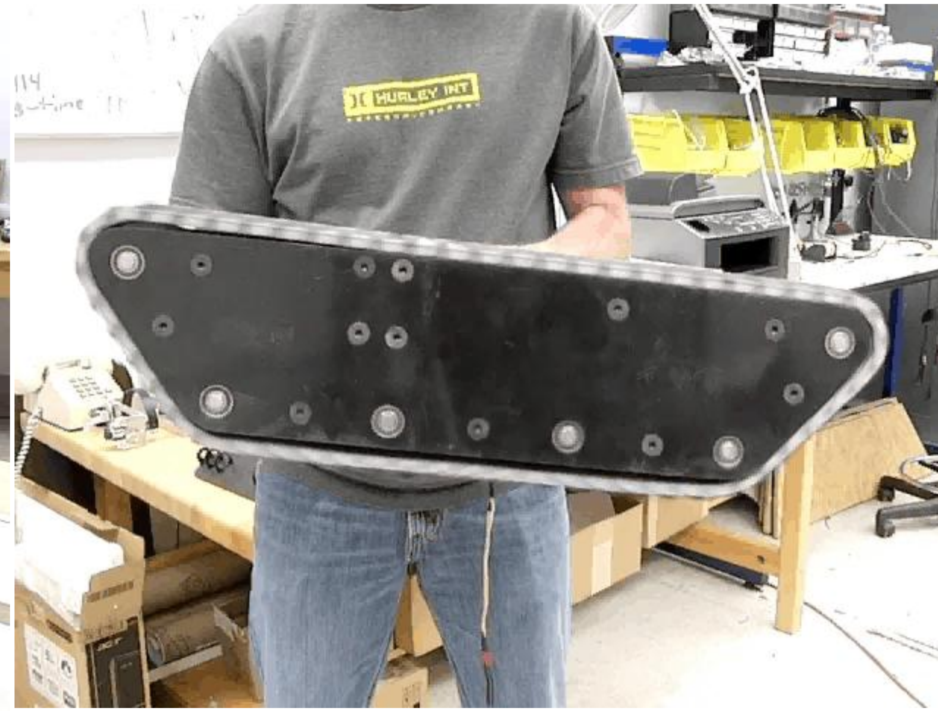


Figure 19. Tracks run at 9 V and 6.0 A for example test runs

System Power Circuit

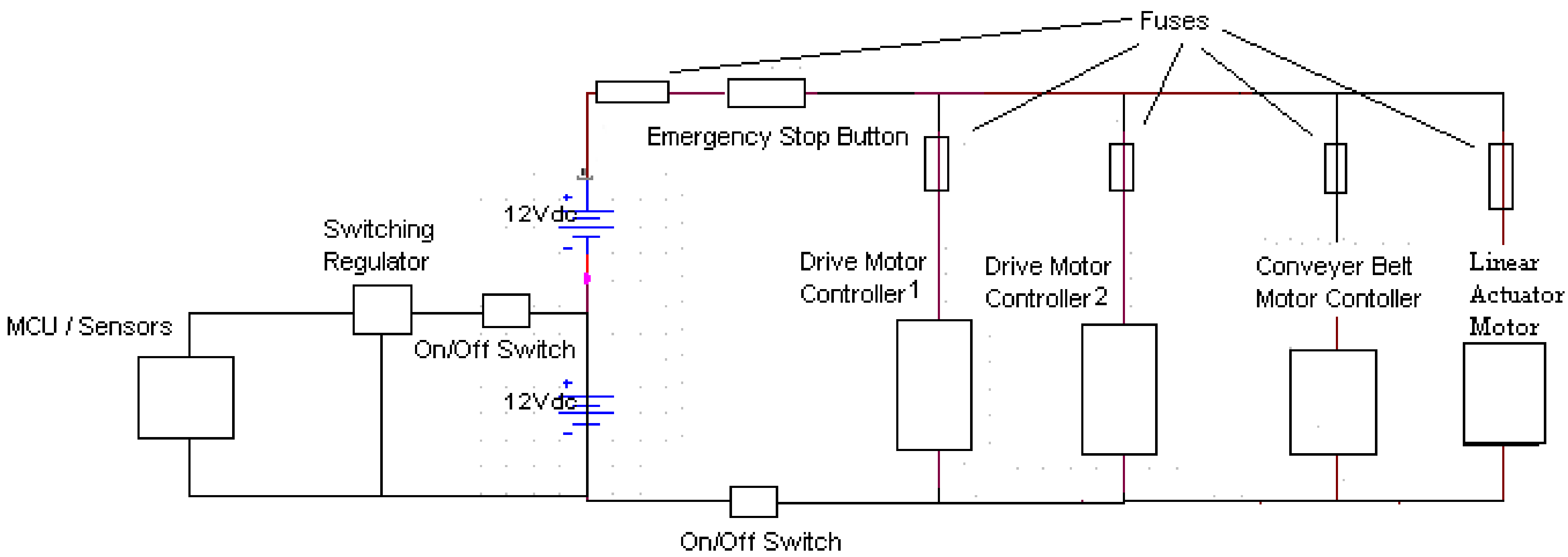


Figure 20. System Power circuit including fuses, motors, and power supplies

Wiring Diagram

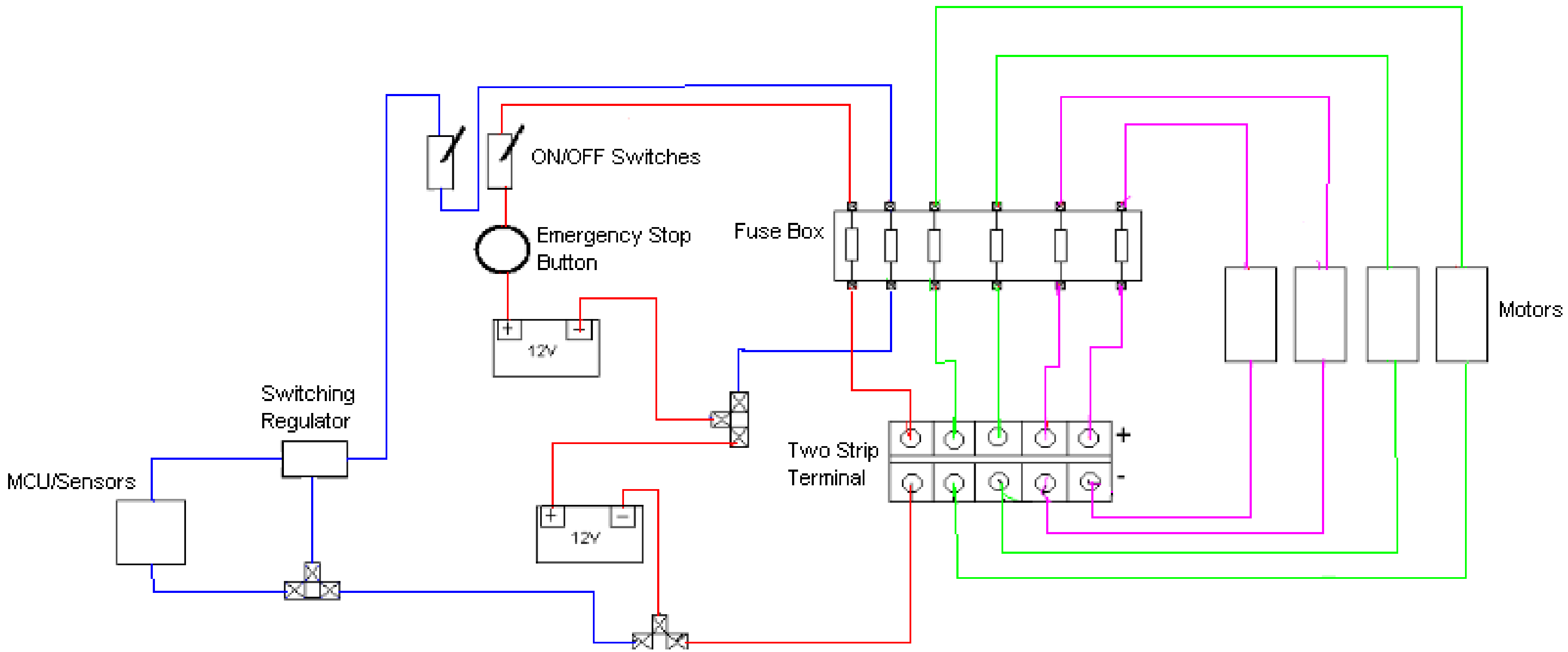


Figure 21. Wiring diagram for ARTEMIS

Red – 10AWG

Green – 16 AWG

Purple – 18 AWG

Blue – 28 AWG

Battery Type

LiFeP04

"Lithium Iron Phosphate"

- 12V
- 55A Maximum Discharge Rate
- 19.8 Ah

- Weight: 2.45 Kg each
- Cost: $289.00 each

Figure 22. Example of a LiFeP04 battery

Next Steps

- Test batteries upon arrival.

- Test and verify current draw of motors.

- Purchase remaining electrical components (wires, switches, fuses, terminals) from local electronics store.

- Assemble and continue testing.

Telerobotic Interface

- Network provided has no extra delay
  - Control robot directly with remote commands, non-autonomous

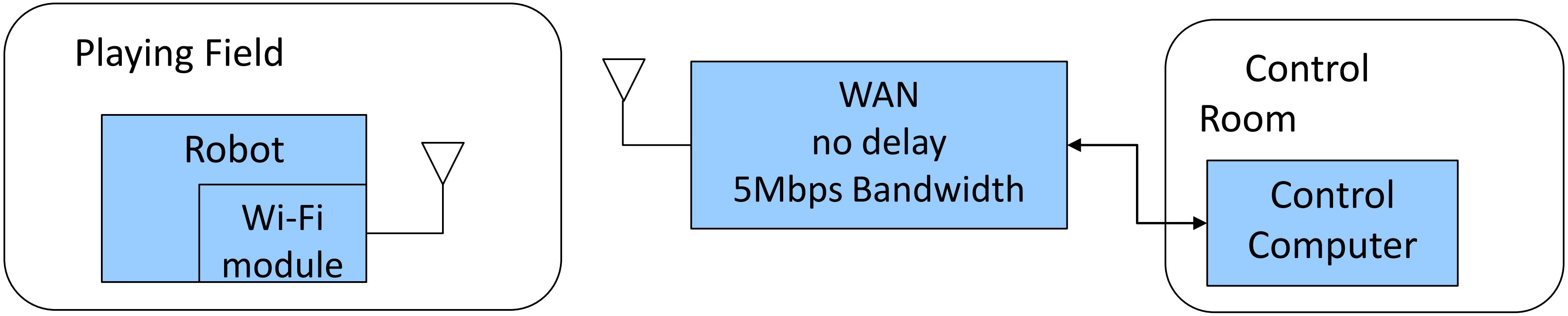


Figure 23. Diagram of communications during competition

- Link Robot to WAN Wirelessly
  - WiFi access point to WAN provided
  - Using Wifly serial to WiFi module on robot
- So far the whole link is setup in lab
  - All but Wifly setup and working

Microcontroller Side

Programming tasks required for microcontroller

Read in data from sensors

Send gathered data through comm link

Receive commands through comm link

Drive motors from commands

Interpret sensor inputs into useful data

Limited autonomy

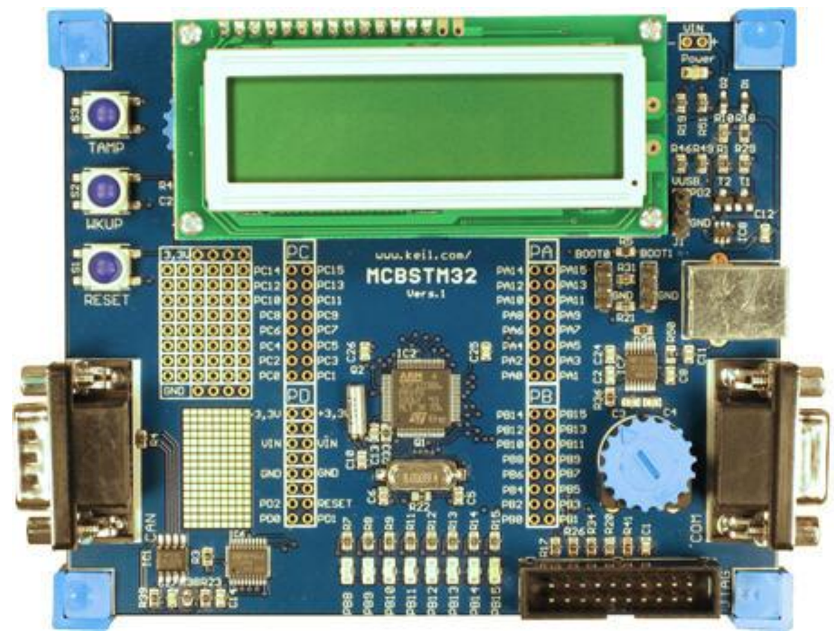
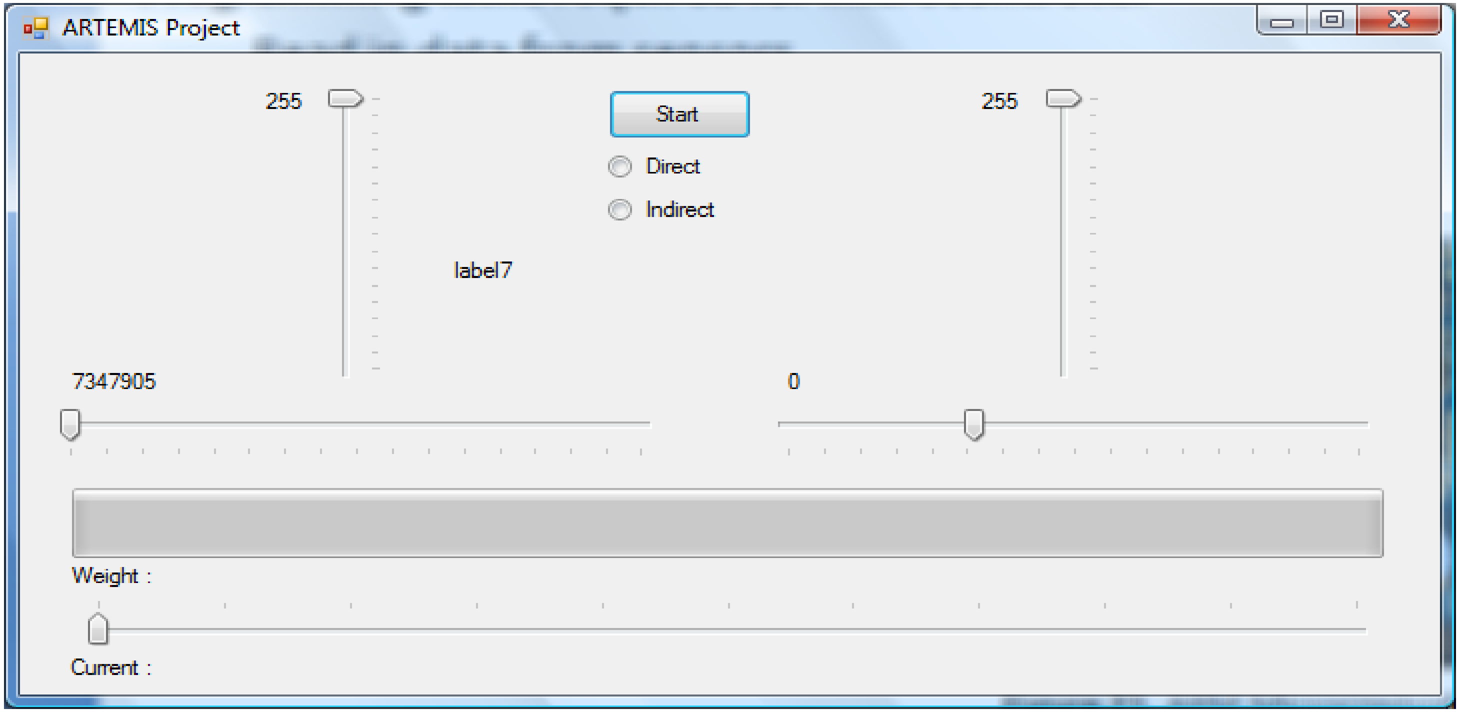


Figure 24. ARM Microcontroller

Control Computer Side

- Programming tasks required for control computer
  - Read in and interpret input from a joystick – PS2 controller
  - Send commands over comm link
  - Receive and display data from comm link
- User interface so far



Controller

The standard PS2 controller has 15 buttons; all of them, except for start and select, which are analog. They include:

- Four buttons arranged as a directional pad on the top left
- Analog, Start and Select buttons in the top middle
- Four action buttons on the top right
- Two action buttons on the front left
- Two action buttons on the front right
- One analog joystick on the top left
- One analog joystick on the top right

Figure 25. Example of controller inputs

Figure 26. Internal circuitry of controller

Sensors

Gyroscope

Accelerometer

Current Sensor

IR Sensor

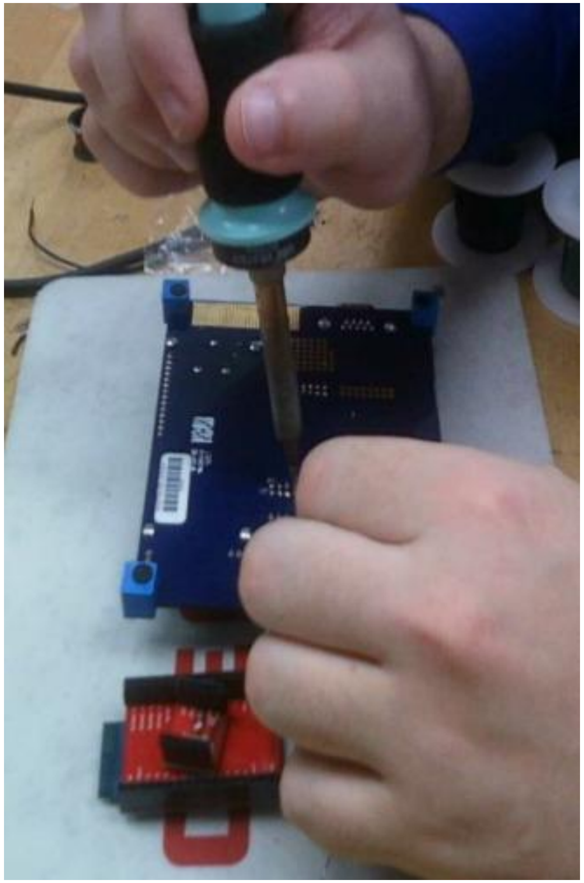


Figure 27. Testing of sensors and microcontroller

Sensors

- Weight Sensor

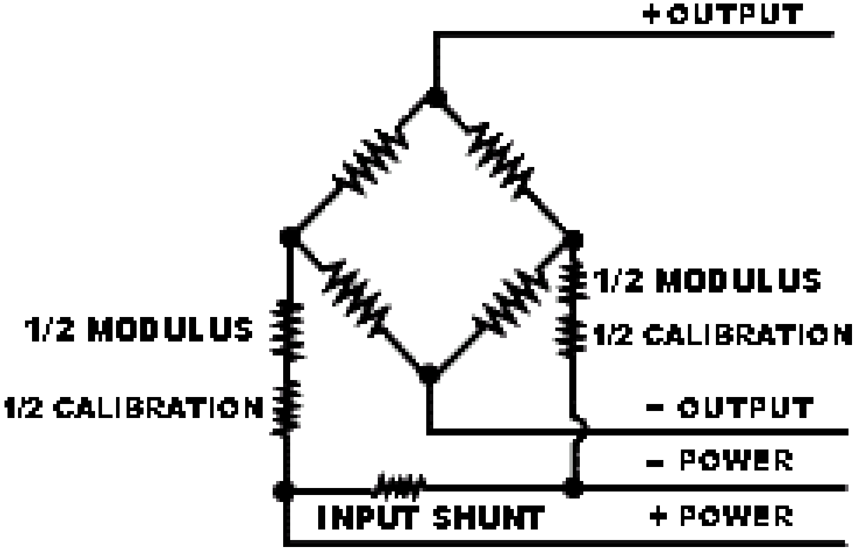


Figure 28. Weight sensor and circuit

- Bump Sensor

Figure 29. Bumper sensor

Cost Analysis of System

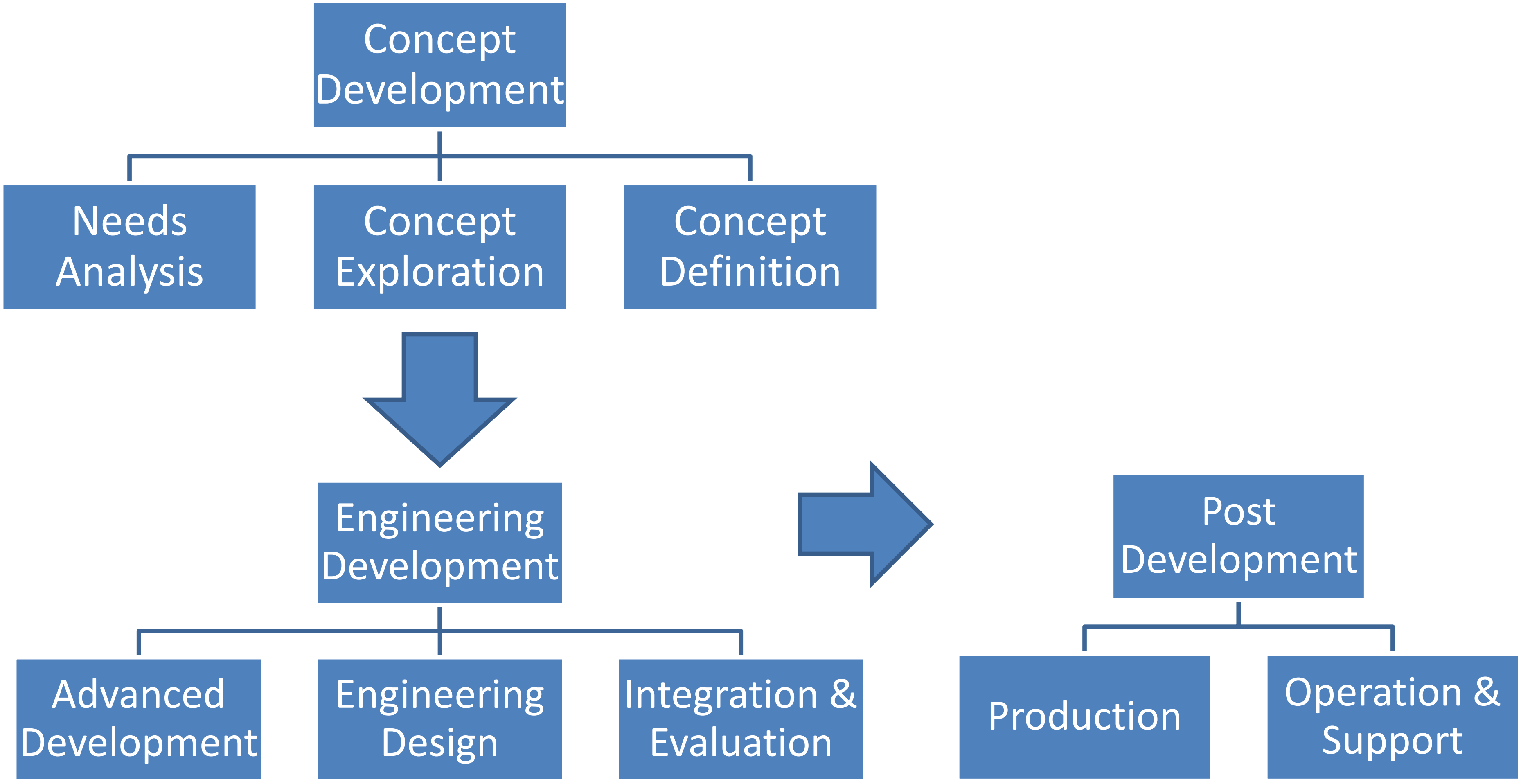
Items Bought			
	QTY	Price	Total
Batteries	4	$300.00	$1,200.00
Battery Charger	1	$50.00	$50.00
Tracks	2	$637.34	$1,274.68
Triple Axis Accelerometer Breakout ADXL335	1	$24.95	$24.95
Gyro Breakout Board - LPR530AL Dual 300%	1	$29.95	$29.95
AttoPilot Current Sense Breakout	1	$19.95	$19.95
2.4 GHz Duck Antenna RP-SMA- Large	1	$9.95	$9.95
Scale	1	$32.12	$32.12
Raw Aluminum	1	$651.75	$651.75
Sandbox Frame	1	$166.47	$166.47
Sand	1	$87.00	$87.00
Conveyor Motor	1	$131.83	$131.83
Miscellaneous (Shipping, etc)	1	$39.10	$39.10
Total			**$3,717.75**

Items Donated
MCBSTM32 Microcontroller
Wifly Wi-Fi Module

Items Still Needed			
	QTY	Price	Total
Interface Cable SMA to U.FL	1	$4.95	$4.95
Motor Controllers	4	$100.00	$400.00
Linear Actuator	1	$809.00	$809.00
Switching Regulator	2	$12.00	$24.00
Regolith Simulant	1	$500.00	$500.00
Bearings	4	$8.95	$35.80
Small Drive Belt	1	$5.33	$5.33
Small Timing Pulleys	2	$22.79	$45.58
Cleated Belt	1	$63.24	$63.24
Miscellaneous (Shipping, Wires, etc)	1	$150.00	$150.00
Total			**$2,037.90**

Grand Total	**$5,755.65**
Budget	**$6,500.00**
Travel Allowance	**$744.35**

Lifecycle



Concept Development
Needs Analysis
Concept Exploration
Concept Definition
Engineering Development
Advanced Development
Engineering Design
Integration & Evaluation
Post Development
Production
Operation & Support

Projected Schedule

- **Assemble chassis and tracks together (completed by 3/1)**
- **Assemble electrical components in chassis (completed by 3/5)**
- **Assemble conveyor excavator and bucket (completed by 3/13)**
- **Finish acquiring building materials, circuitry, motors, and batteries (3/5)**
- **Re-design as needed**

Conclusions

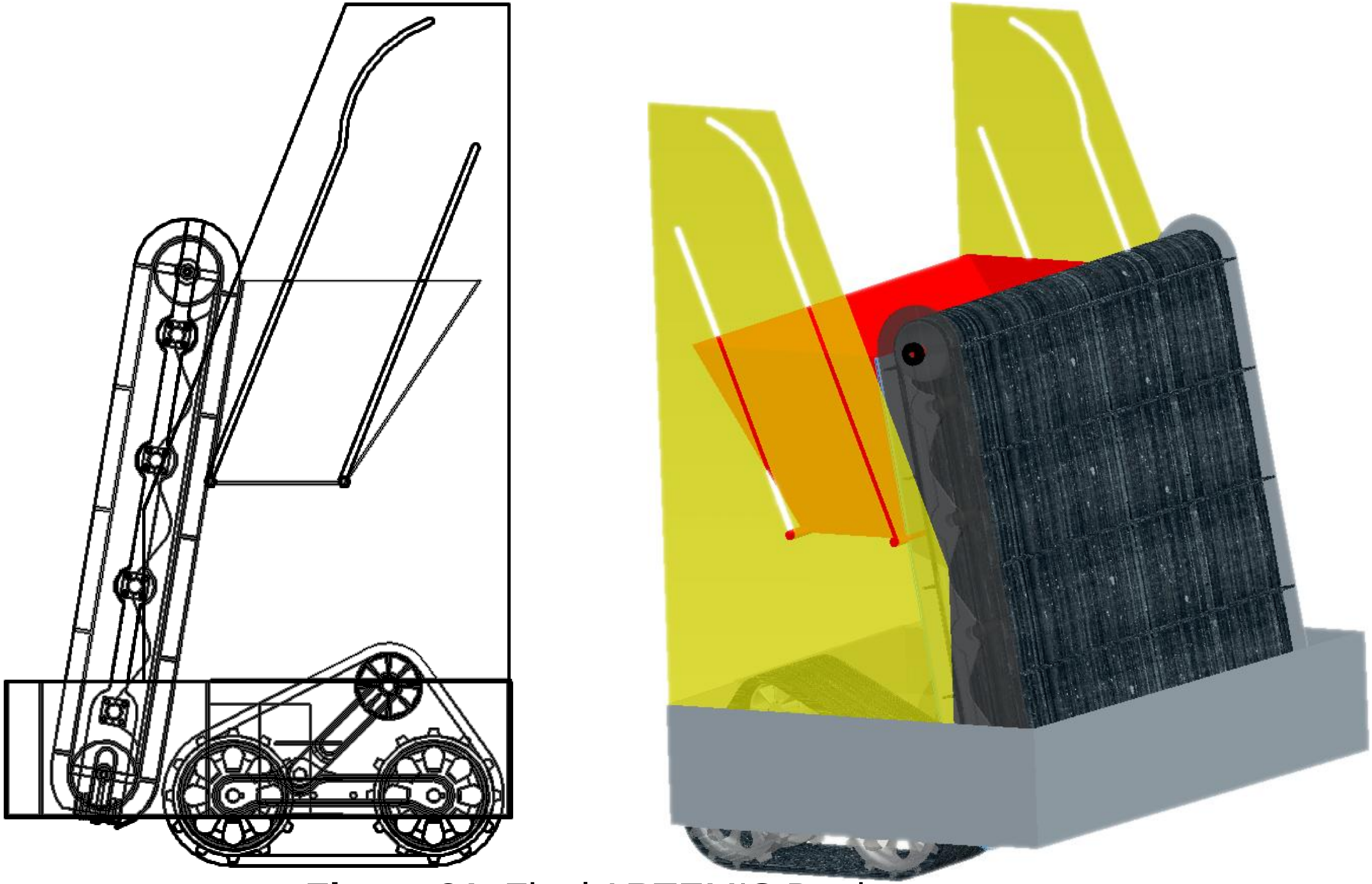


Figure 31. Final ARTEMIS Design

Acknowledgements

STRIDE Laboratory — Scansorial and Terrestrial Robotics and Integrated Design

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Florida A&M University 1982 Florida State University — College of Engineering

ARM

Evolution Model Technology — EMT Robotics

Questions and Comments

The ARTEMIS Project

Prototyping Belt Design

Figure 32. Testing of the belt prototype design