PRELIMINARY DESIGN REVIEW

AUBURN UNIVERSITY NASA LUNABOT TEAM

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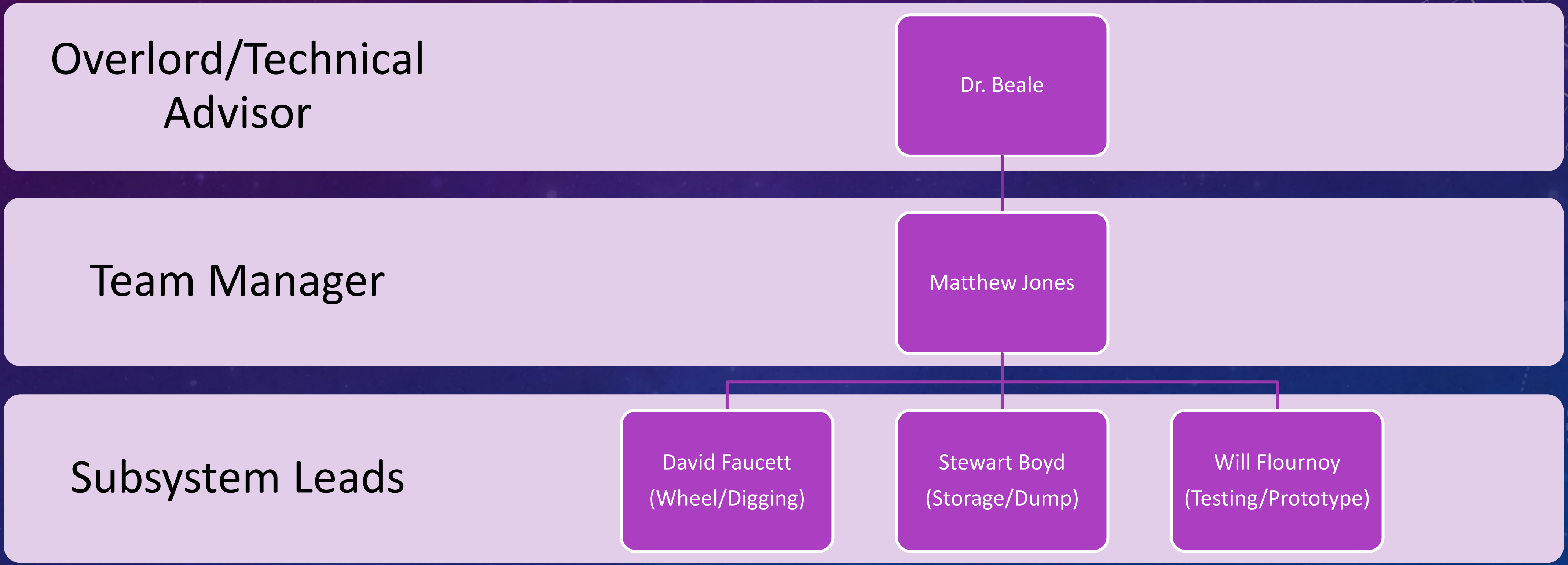
OVERVIEW

- Objective
- Team Structure
- Trade Studies
- System Architecture
- Testing
- Subsystem Design
- Estimated Points Per Run/Tech. Resource Budget Tracking
- Bill of Materials

MISSION STATEMENT

The objective of this project is to create the mechanical portion of an autonomous system weighing less than 80 kg capable of surviving/navigating terrain representative of the Martian surface in order to retrieve and deposit regolith. This system should be able to collect and deposit a minimum of 10 kg of regolith in 10 minutes. By the end of the summer, a non-autonomous version will be operational and tested. This prototype will then be handed off to the next group to be modified as needed to meet the 2015 NASA Robotic Mining Competition rules and participate in the 2015 competition.

TEAM STRUCTURE



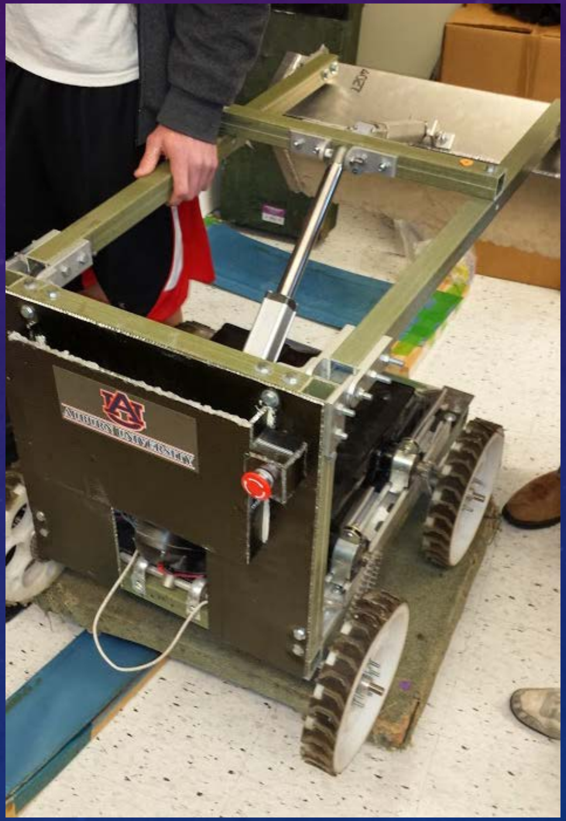
SUBSYSTEM COMPONENTS

- Digging/Drivetrain
  - Scooping
  - Depositing
  - Power Generation
  - Wheels
- Chassis
  - Location of “Fragile Components”
- Storage/Dumping
- Electrical

EXISTING DESIGN

Pros

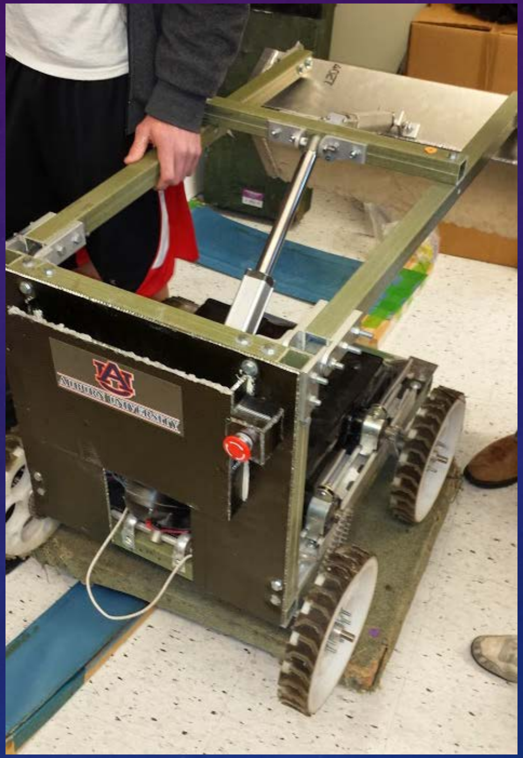
- Mechanically simple/robust
- Single digging/dumping mechanism
- Simple production



Cons

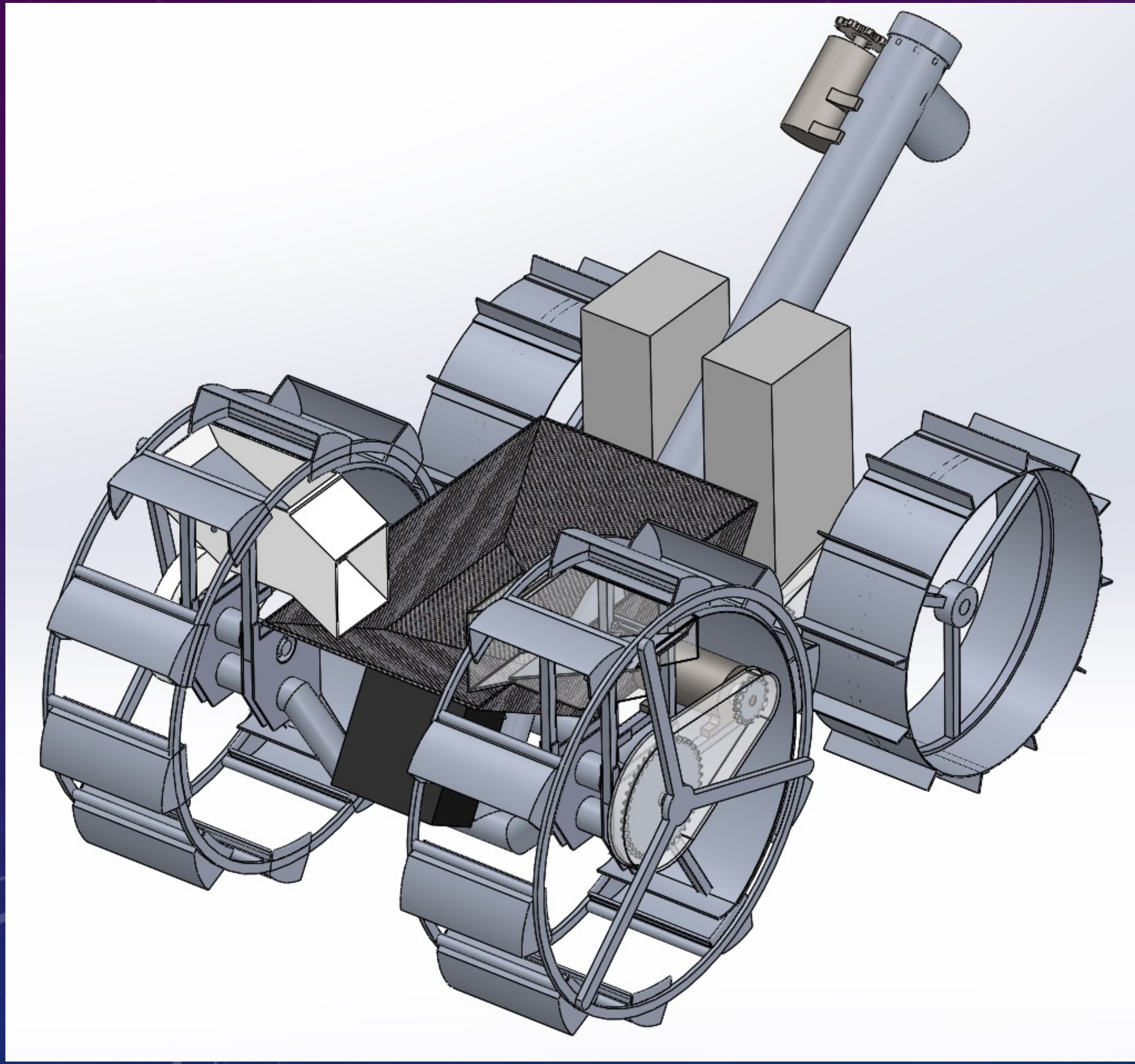
- Large/narrow wheels dig in decreasing maneuverability
- Bucket design changes weight balance
- No storage capacity (except digging bucket)
- Single dump requires accurate placement of bucket in relation to the bin

TRADE STUDIES



SYSTEM ARCHITECTURE

Final Concept



Final Concept

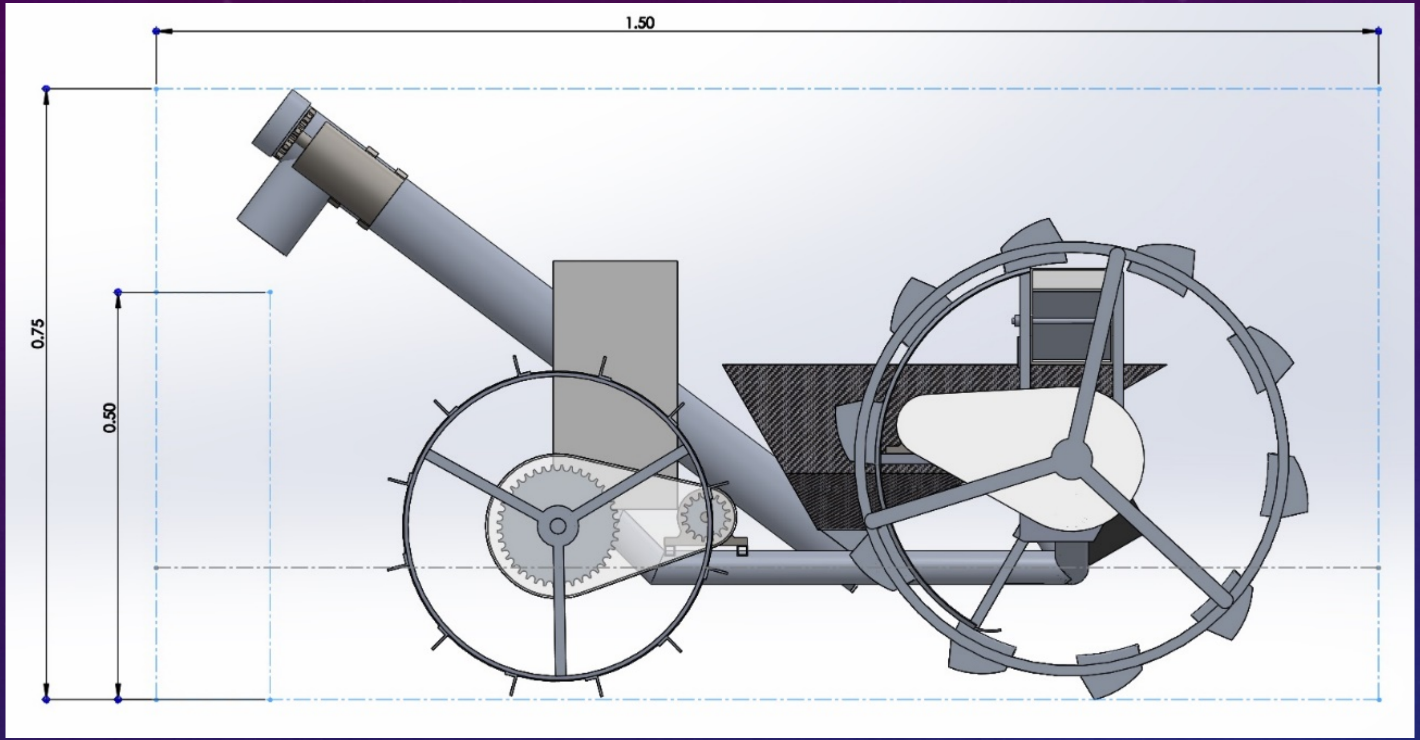
- 4 wheels
- 2 digging wheels for gathering BP-1
- Auger depositing
- Skid steering system
- Carbon fiber carrying bin

Pros

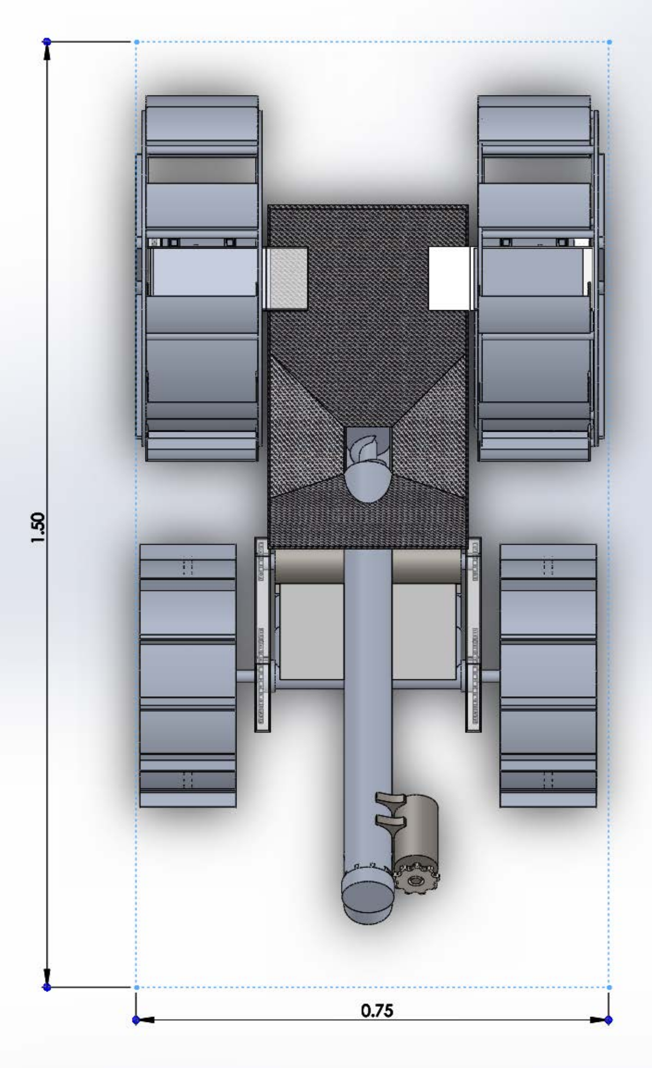
- Minimizes components that need to be controlled
    - Makes it easy to implement autonomy
- Lightweight 40kg

Design and NASA Size Specifications

Side View



Top View



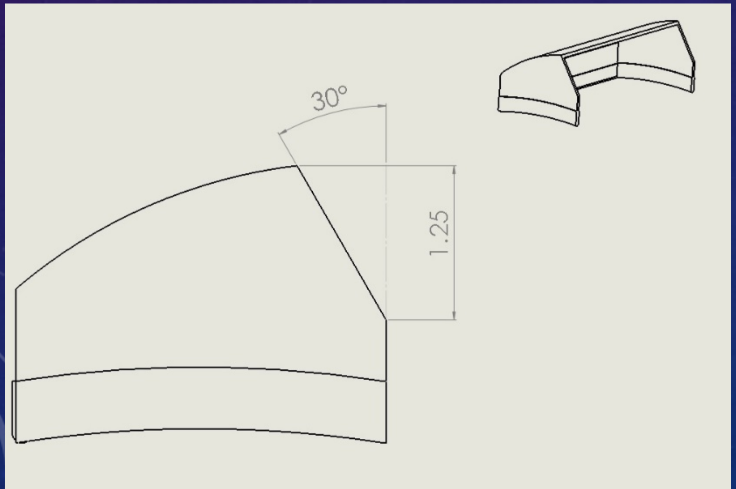
Overall dimensions of robot

- Fits within NASA requirements
- Provides clearance for auger to dump into depositing bin

WHEEL PROTOTYPE/SCOOP TESTING

Wheel Test Setup

Scoop Design Geometry



Reasons for test

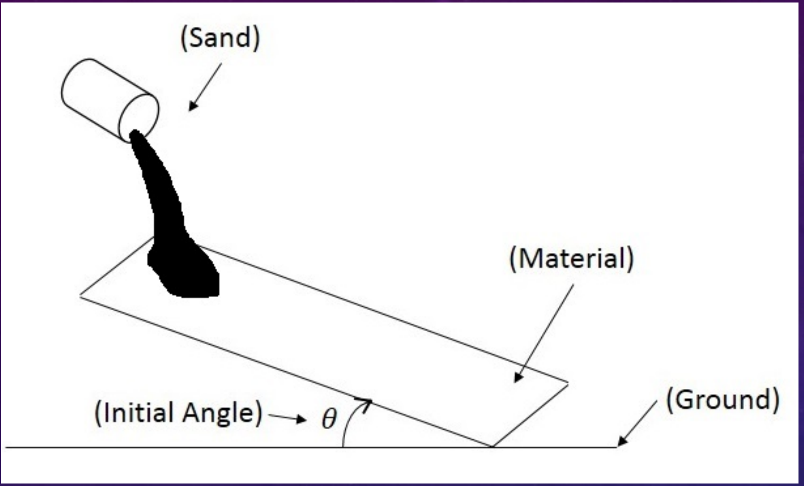
- Determine torque required to turn/dig
  - Sizing electric motor
  - Gearing
- Evaluate scoop design
  - Height of scoop
  - Entry angle
  - Number of scoops per wheel
- Determine if the concept would drive and dig

Conclusions from Test

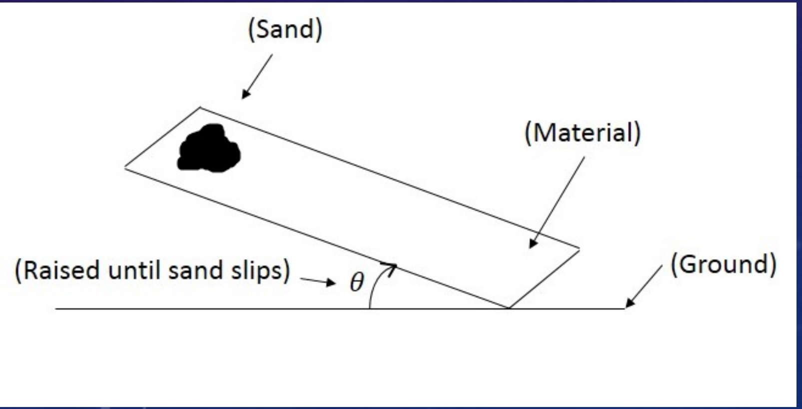
Scoop Height	1.25 in
Entry Angle	30 deg
Stationary Dig	10 ft lbs
Rolling Dig	5-8 ft lbs
Scoops per wheel	10

SLIP ANGLE TEST

1st Test Dropping Sand onto a Material



2nd Test Raising the Material until Sand Slipped



Reason for test

- Find minimum angle that regolith will slip at
  - When regolith is stationary
  - When regolith is dropped on surface

Test procedure

- 1st test dropping sand onto a material
- 2nd test raising the material until sand slipped

Conclusions from test

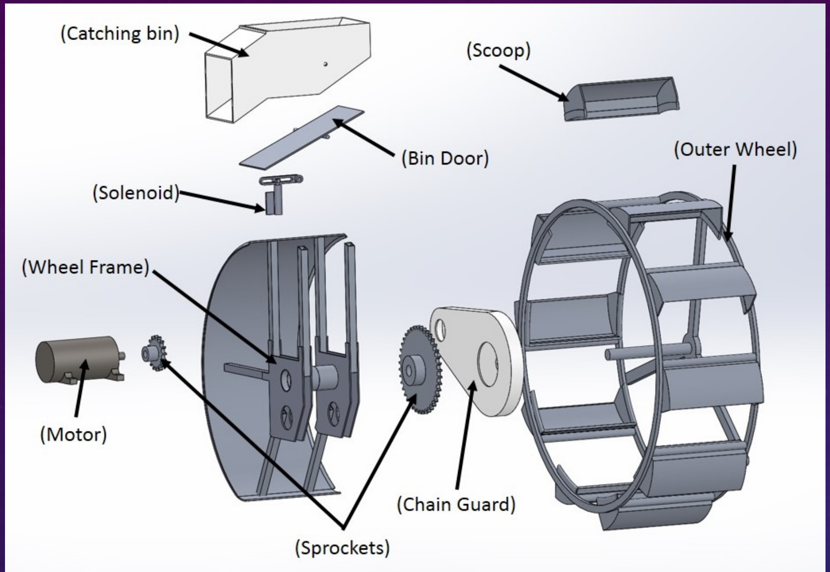
- Need a minimum angle of 30°
  - This ensures that regolith will side down

Results from Test

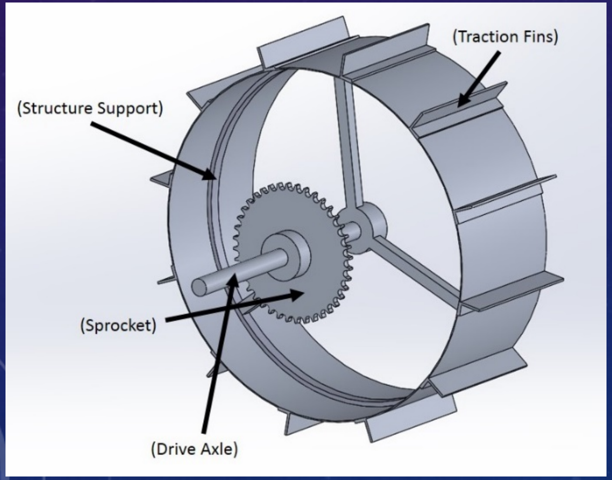
Test Type		Material				
		Carbon Fiber (Smooth)	Carbon Fiber (Rough)	Plastic	Steel	Aluminum
Static Sand Slip Angle (deg)	Damp	30	35	30	25	30
	Dry	25-30	35	30	25	30
Dynamic Sand Slip Angle (deg)	Dry	20	30	25	25	25

WHEEL SUBSYSTEMS

Exploded View of Digging Wheels Components



Driving Wheels Components



Digging wheel

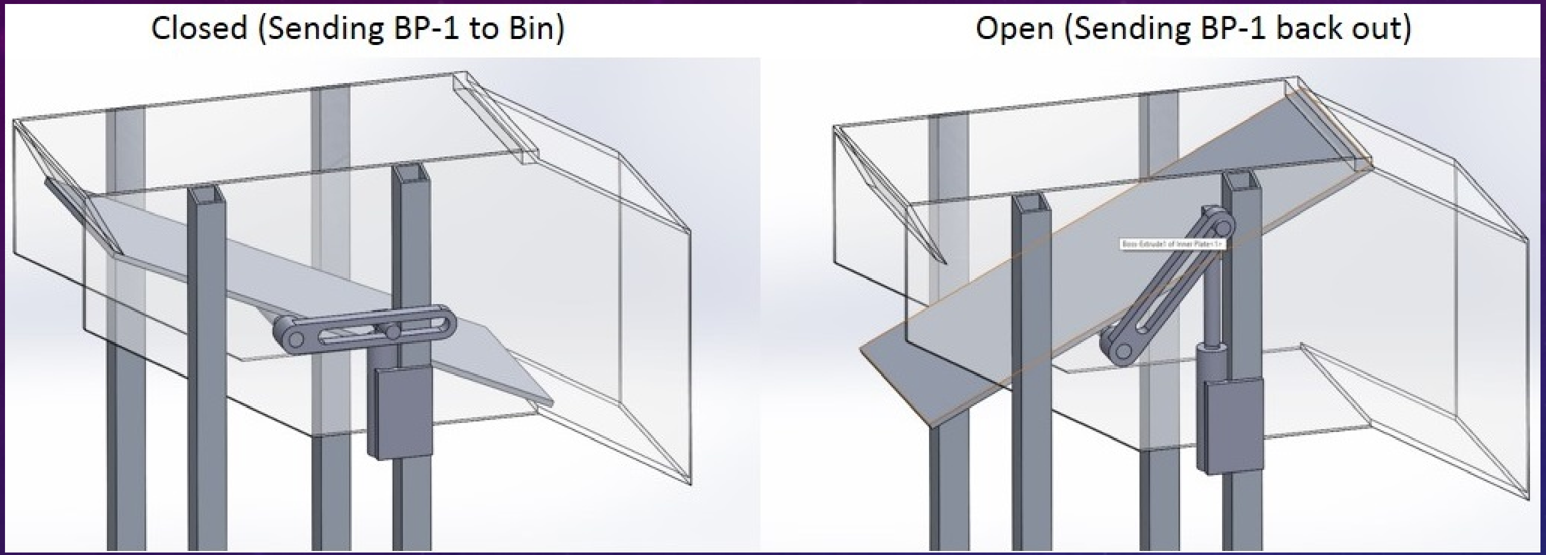
- Digging and drive system combined into one
    - Reduces systems that need to be controlled
- Driven by single motor
- Gathering controlled by solenoid simple on/off
- 1 DOF for digging and driving

Driving Wheel

- Traction fins for gripping surface
- Designed to be lightweight
- Wide footprint
    - Prevent wheel from digging down into the BP-1

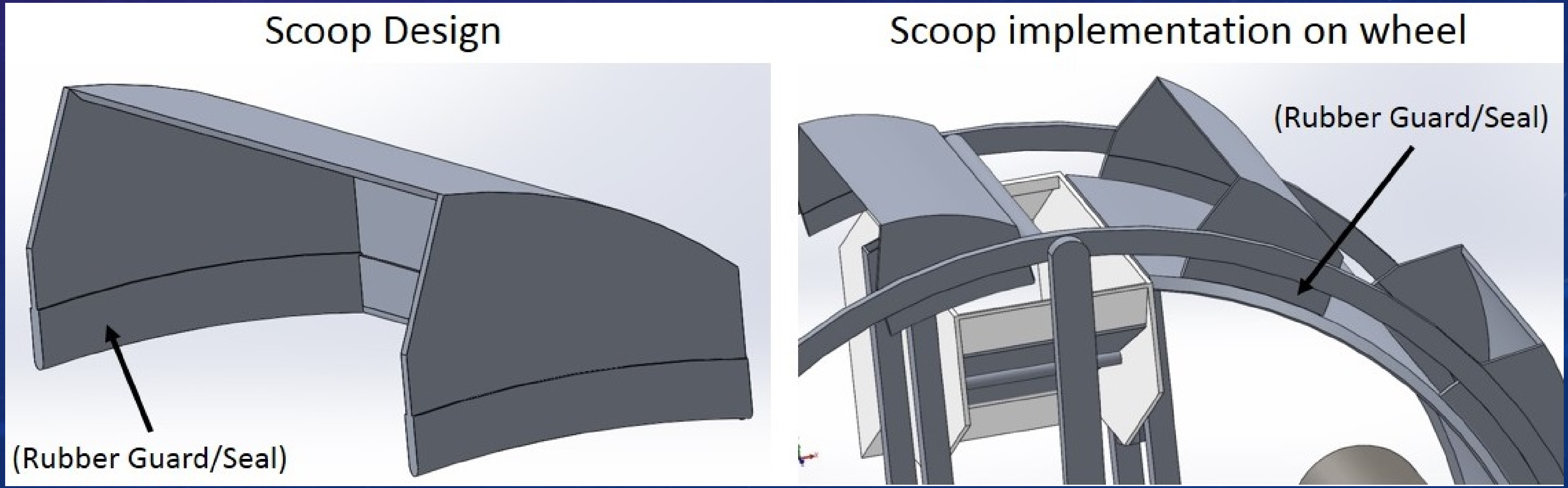
DIGGING WHEEL SUBSYSTEM

Solenoid Controlled Gathering Bin (On/Off)



- Simple operation
- Solenoid drives door from open to closed
- Open sending BP-1 to ground
- Closed sending BP-1 to bin

Scoop Design



- Rubber guard provides anti-jamming
- Entry angle of 30°

AUGER TEST

Auger Test Setup

Reason for test:

- Determine the validity of using an auger as a regolith deposition device

Results:

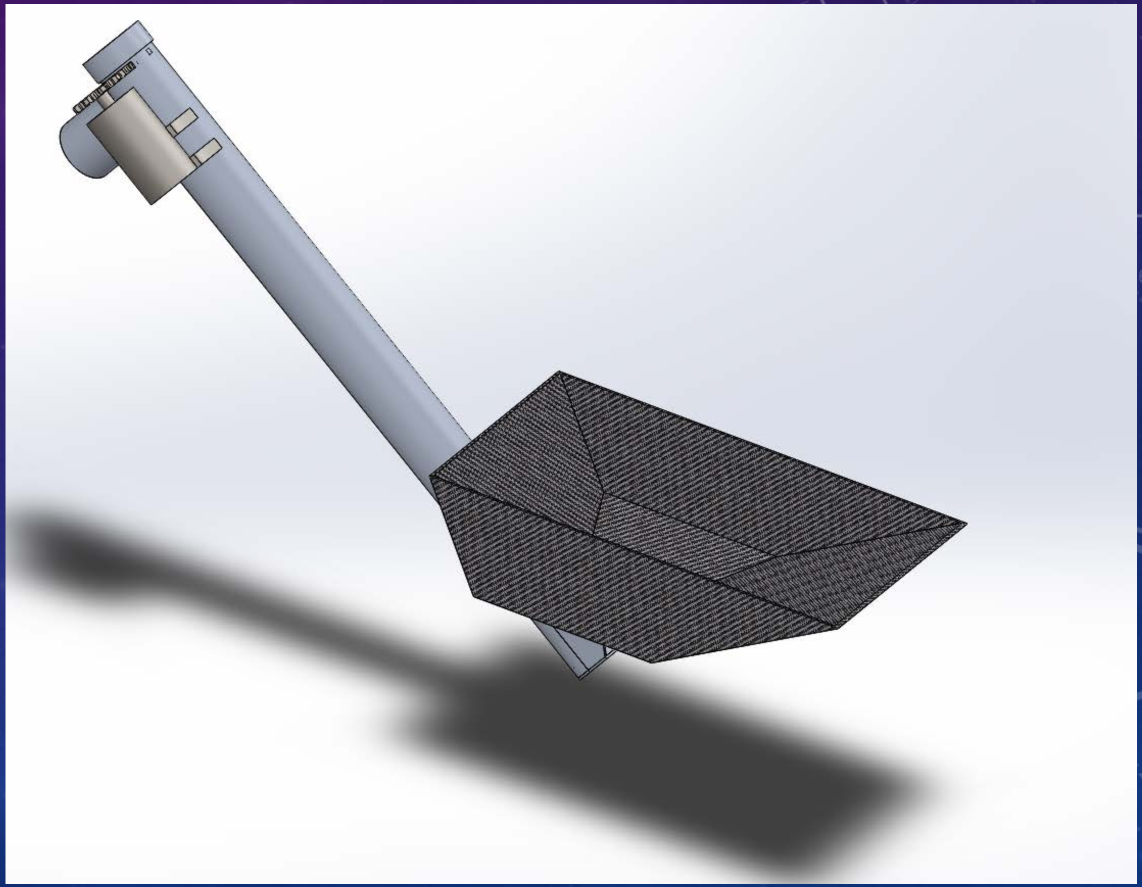
- Tested auger moved sand at a rate of 0.139 $\frac{kg}{s}$
  - The tested auger was the wrong type (hollow thread) and was tested with wet sand (harder to move)

Conclusions:

- The auger is a viable option for dumping regolith
  - When a proper auger (threaded shaft) the flow rate of regolith will be much higher than the rate found in the tests

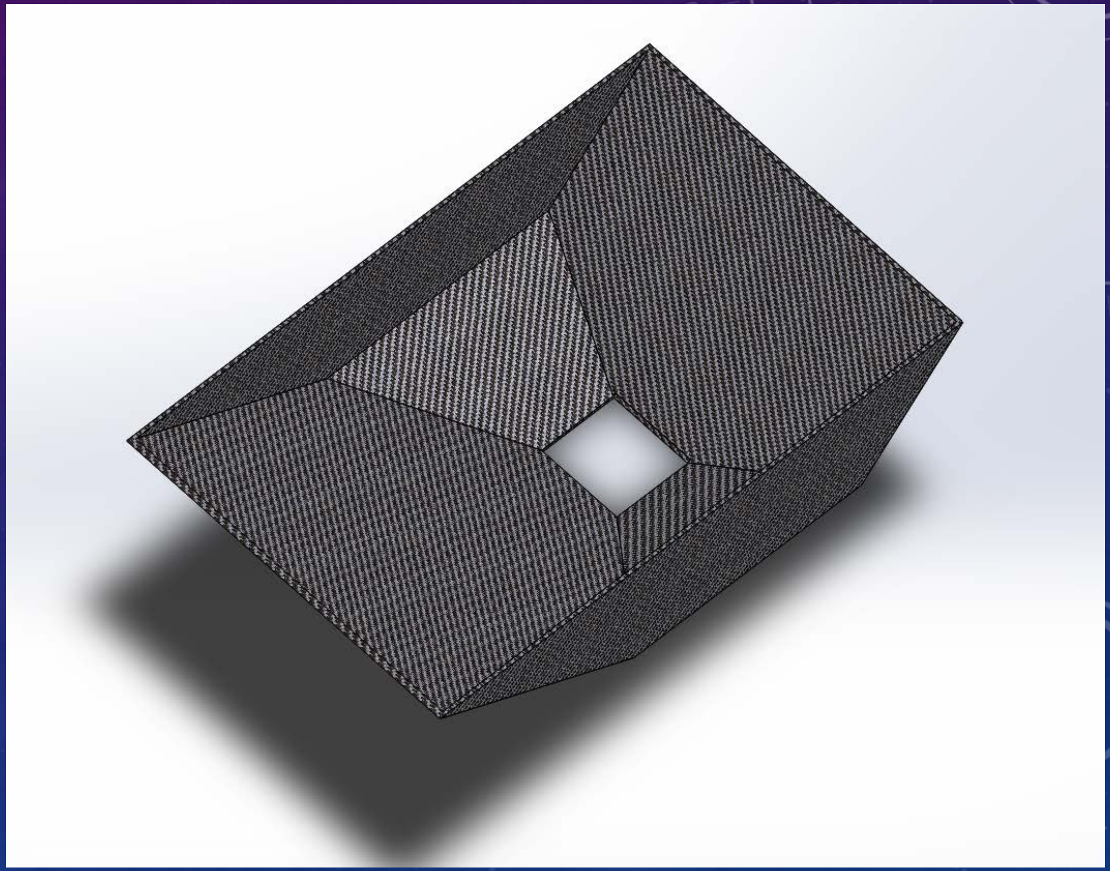
AUGER/BIN SUBSYSTEM

- 1 DOF
- Minimizes dust creation
- Minimizes spillage when dumping regolith
- Minimizes risk of tipping over when dumping regolith
- Easy to control



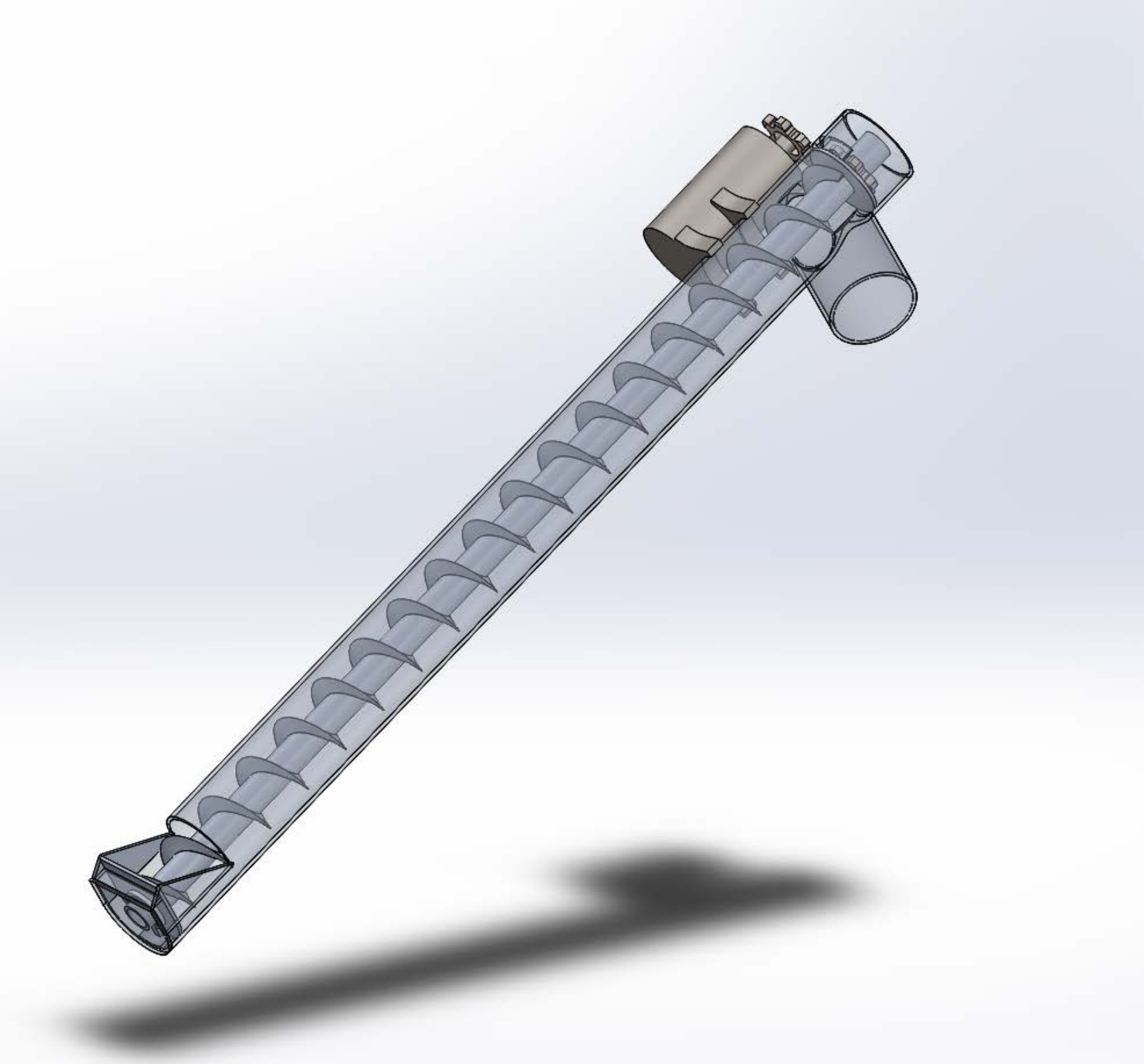
BIN

- All angles are >=30°
- Volume of 18000 cm^3, approximately 26 kg of regolith



AUGER CONVEYOR

- Requires only one motor
- Minimizes dust
- Maintains a steady center of gravity while dumping
- Harder to miss target bin



CONCEPT EVALUATION

Estimated Point

Category	Input
Saf/Comm	Yes
BP-1 Dug	22
Dry Weight	40
Engy Reported	Yes
Dust Features	50 (half)
Autonomy	Full 10 minutes
Total Points	**1276**

Weight Breakdown

Subsystem	Component	Weight per (kg)	QTY	Weight (kg)
Wheel	Motor	2.09	4	8.36
	Digging Wheel	6.00	2	12.00
	Rear Wheel	1.66	2	3.32
Chassis	Main Frame	1.87	1	1.87
Electrical	Battery	4.76	1	4.76
	Electronics	2.27	1	2.27
Auger	Motor	2.09	1	2.09
	Auger	2.96	1	2.96
	Bin	2.00	1	2.00
			Total	39.63

Overview of Cost

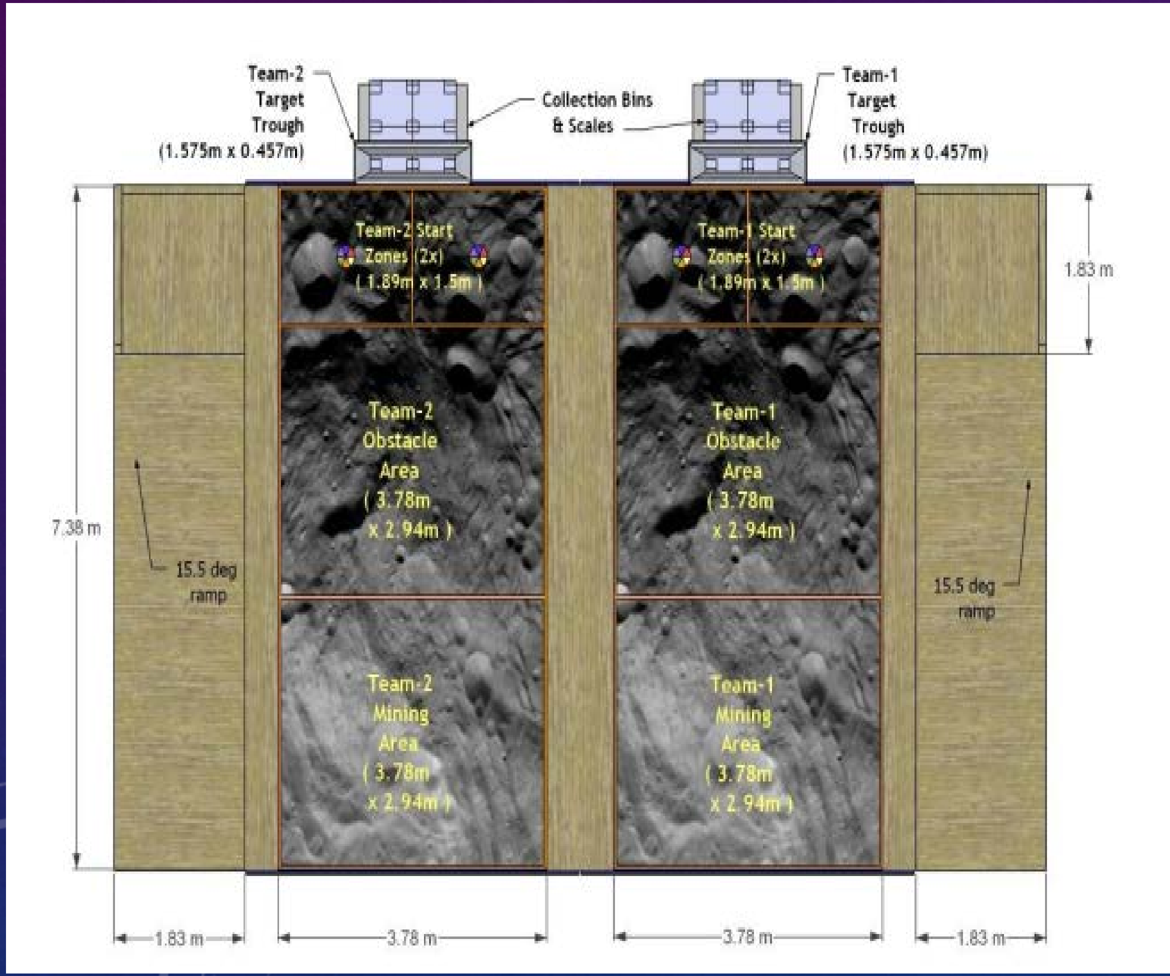
Bill of Material	
	Cost ($)
Driving System	1500
Auger/bin system	800
Chassis	100
Electronics	600
Total Cost	**3000**

Power Consumption

Power	Component	Watt-hr
24 V	Motor x 5	320
24 V	Auger Motor	80
	Total	**400**

QUESTIONS?

NASA ROBOTIC MINING COMPETITION



- Pass Safety and Comm Check
- Two 10 minute runs
- Minimum of 10 kg BP-1 to qualify
- Maximum 80 kg dry weight
- Can’t dig until inside mining area
- Randomly selected starting orientation

Element	Points
Pass Safety and Comm. Check	1000
BP-1 Excavated over 10kg	+3 per kg
Robot Weight	-8 per kg
Dust Tolerant Design	0-30 (Judge’s discretion)
Dust Free Operation	0-70 (Judge’s discretion)
Autonomous Operation	0, 50, 150, 250 or 500
Average Bandwidth	-1 per 50 kb/sec
Energy Consumption Reported	0 or 20

Bill of Materials

Bill of Materials

2 Digging Wheels and 2 Non Digging Wheels

Material	Amount	Cost per [$]	Total [$]
6061 Aluminum 24"x24" .05" thick	3	55.88	167.64
6061 Aluminum tube OD 1/2" ID 0.43" length 6'	2	25.15	50.3
6061 Aluminum Rect. Tube 1/2" x 1/2"	3	12.93	38.79
6061 Aluminum Bar Wd 1/4" Thick 1/4" length 6'	4	7.34	29.36
6061 Aluminum Sheet Thick 0.1" 24"x24"	1	32.77	32.77
Polycarbonate Plastic Thick 7/64" 24"x24"	1	21.43	21.43
6061 Aluminum Solid Bar D 3/4" length 6'	1	23.3	23.3
Steel Tapered-Roller Bearings Shaft Dia. 3/4" OD 1 25/32"	6	11.87	71.22
6061 Aluminum Solid Rod OD 2" Length 1'	1	24	24
6061 Aluminum Rect. Tube 3/4" x 3/4" Length 6'	1	15.56	15.56
IG52-04 24 VDC 10 RPM	4	155.08	620.32
Sprockets Chains sets	4	80	320
Continuous pull solenoid. Holding force 12.8 N, Voltage 24 VDC	2	20.42	40.84
Rubber Seal Wd. Inside (1/16" Ht 1/4") outside (3/16" Ht 5/16")	22	0.88	19.36
		Total (wheels)	1474.89

Auger/Bin/Chassis

Material	Amount	Cost per [$]	Total [$]
IG52-04 24 VDC 10 RPM	1	155.08	155.08
Sprockets Chains sets	1	80	80
Bearings	2	9	18
Screw	1	275	275
Aluminum Cap	1	8	8
Solid Carbon Fiber Sheet ~ 1/8" x 24" x 24" w/ gloss finish	1	236.5	236.5
4' 3" OD Aluminum Tube	1	70.76	70.76
1'x1' 1.25" aluminum plate	1	15.03	15.03
2' .5" Square Aluminum Tube	1	2.34	2.34
12' 1-1/8" Aluminum Tube	1	36	36
		Total Auger/Bin/Chassis	896.71

Electronics

Material	Amount	Cost per [$]	Total [$]
ACDelco ATX14BS (14-BS) Powersport Battery	1	69.7	69.7
NI myRio Enclosed Device	1	500	500
		Total (Electronics)	569.7

Total (Overall) 2941.3

FUNCTIONAL REQUIREMENTS

- Dig at least 10 kg of BP1 in 10 minutes
- Must be contained originally in 1.50 m (length) x 0.75 m (width) x 0.75 m (height)
- Height must never go above 1.50 m
- Must navigate over/around or move obstacles with:
  - Mass of up to 10 kg
  - Diameter of 10-30 cm
- Must avoid/survive craters with the following dimensions
  - Diameter 10 - 30 cm
  - Width 10 - 30 cm
- Weight must be less than 80 kg unloaded
- Deposit dirt in competition bin 0.50 m above surface
- Must be able to be controlled from separate area wirelessly and/or run autonomously
- Must be capable of being run with a wired remote control.
- Must be able to operate in a semi dust free manner

Functional Decomposition

Carry Dirt

- Can’t tip
- Support dirt weight
- No spillage/low dust generation

Dig Dirt

- Target time for digging
- Repeatability
- Low dust generation
- Placing dirt in carrying receptacle

Mobility

- Motion in cardinal direction (forward/reverse, left right)
- Obstacle avoidance/survivability
- Carry dirt load
- Low dust generation

Dump dirt

- Hit target receptacle
- Low dust

Structural Support

- Hold everything together
- House “fragile” components
  - Prevent dust penetration
- Lightweight
- Robust