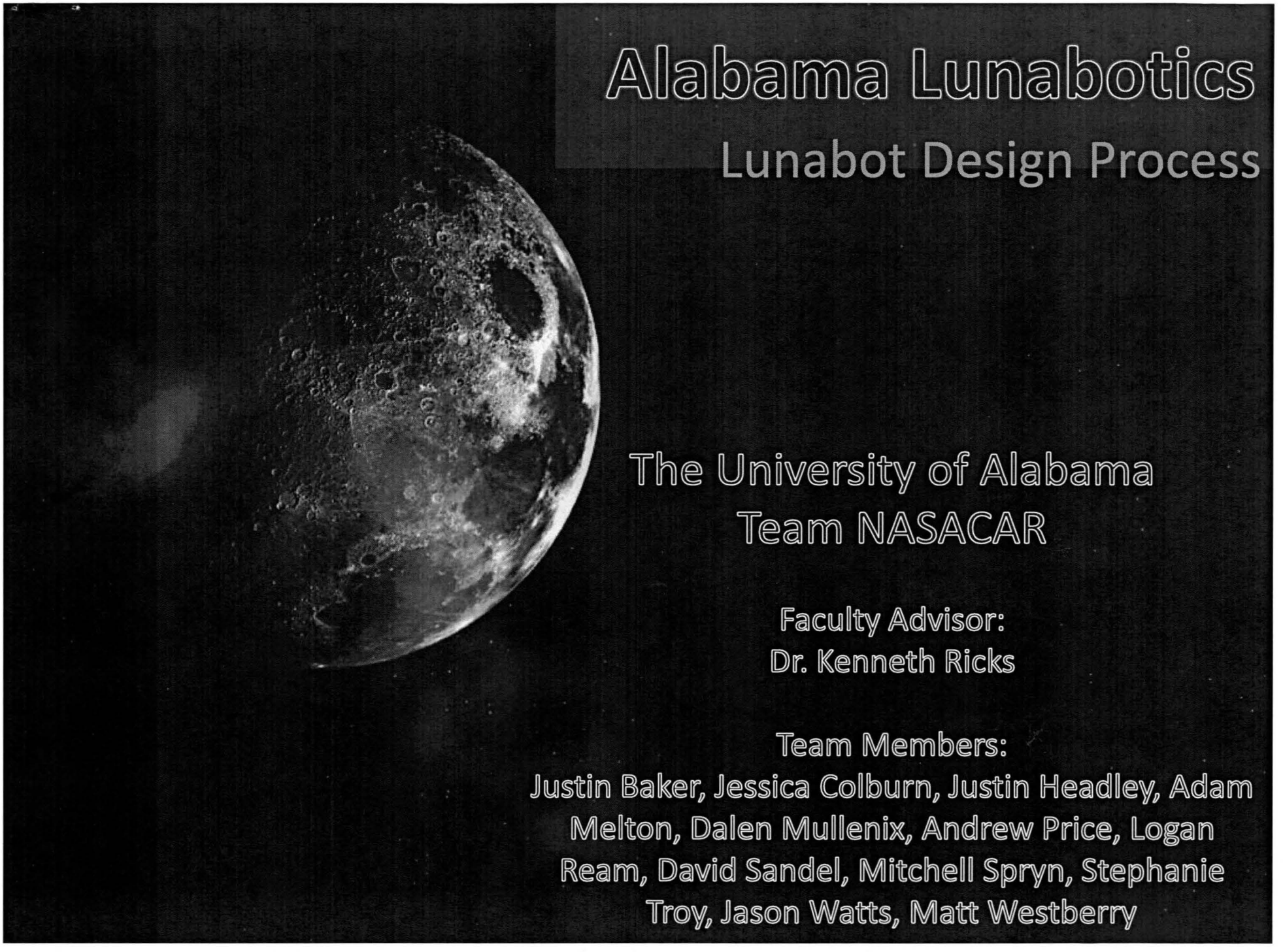

Alabama Lunabotics
Lunabot Design Process
The University of Alabama
Team NASACAR
Faculty Advisor:
Dr. Kenneth Ricks
Team Members:
Justin Baker, Jessica Colburn, Justin Headley, Adam Melton, Dalen Mullenix, Andrew Price, Logan Ream, David Sandel, Mitchell Spryn, Stephanie Troy, Jason Watts, Matt Westberry

Introduction

The University of Alabama

- Tuscaloosa, AL
- 31,747 students
- Pretty decent football team

Team NASACAR

- 3rd year in Lunabotics competition
- 12 team members
- 5 disciplines
- 5 grad, 7 undergrad

Sponsors:

WALTER ENERGY
JIM WALTER RESOURCES

I.E.C.S Inc.
Advanced Controls for Industry

ZOËS KITCHEN

SOLIDWORKS

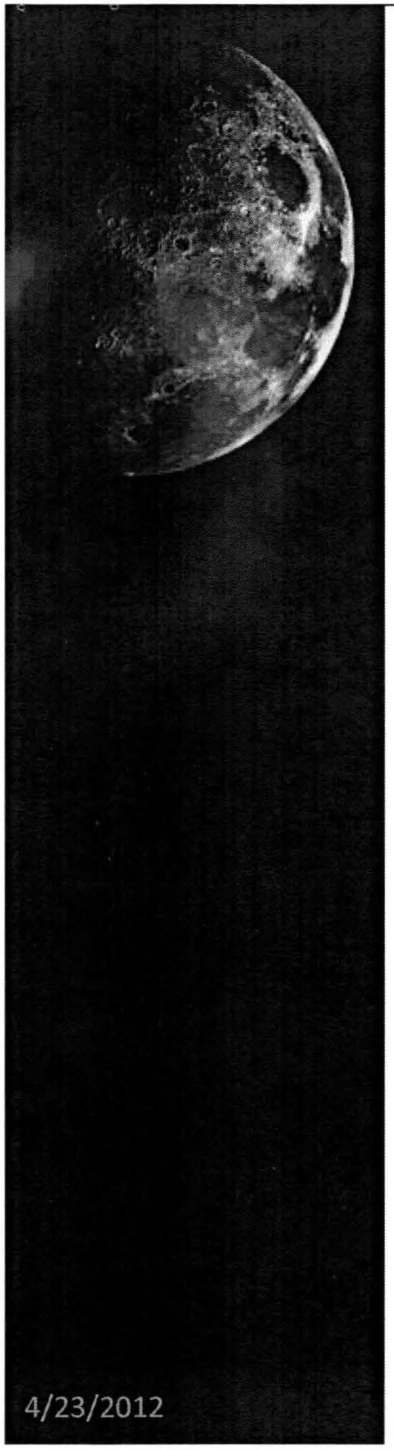
JOY MINING MACHINERY
A Joy Global Inc. Company

Purpose

- Explore design process and decisions
- Highlight design alternatives considered
- Showcase testing procedures and results
- Answer questions about any other areas of interest to the audience

Agenda

- Final Design
- Base Evolution
- Module Experimentation
- Software Evolution
- Operational Overview
- Testing Overview
- Conclusions

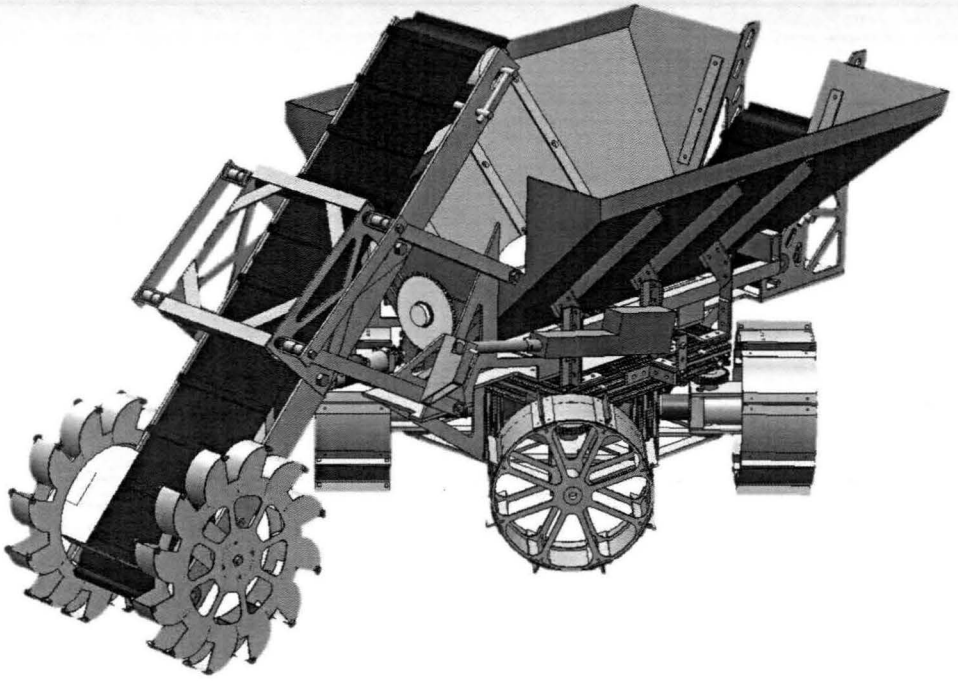


FINAL DESIGN

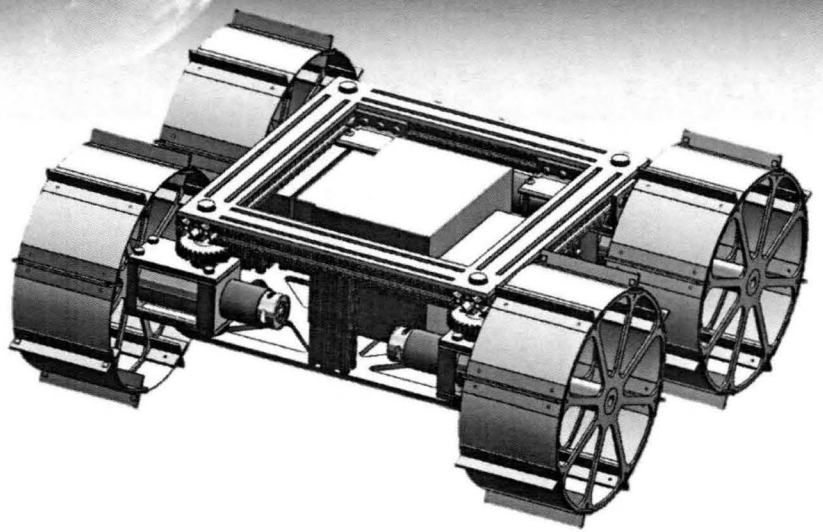
Beginning at the End

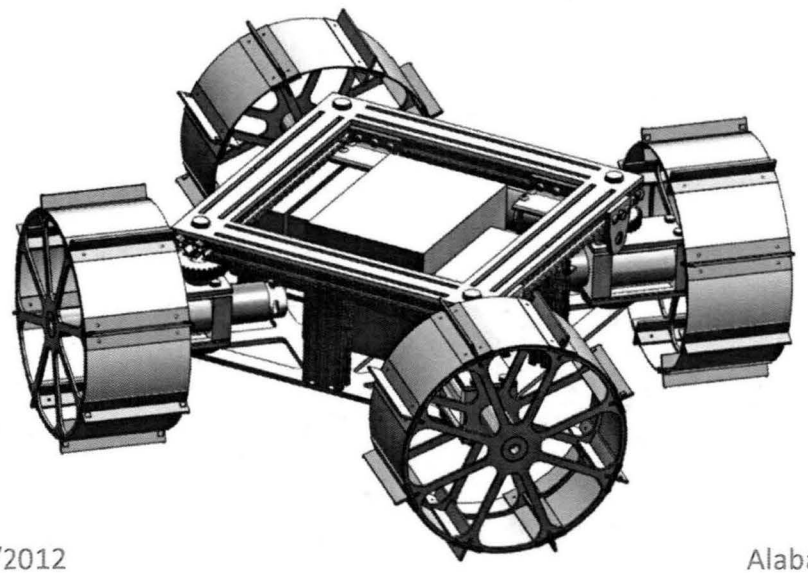
Complete System

- Bucket wheel excavator mounted on multi-purpose base
- 125kg onboard regolith storage
- On- and Off-loading conveyors
- Evolved successful design components while reengineering remainder



Multi-Purpose Base

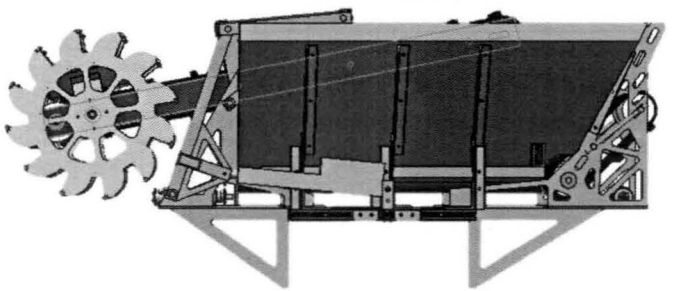


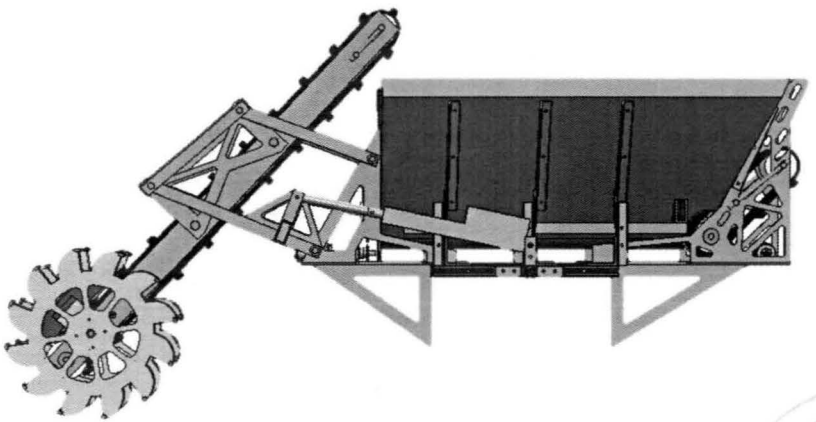


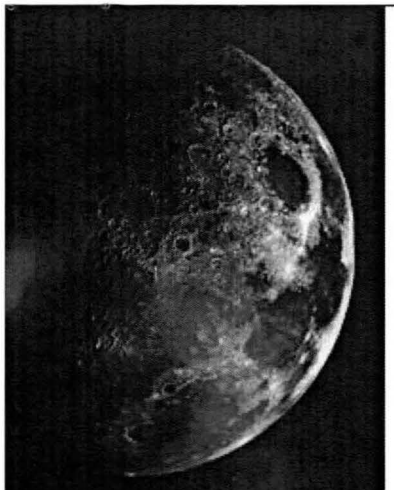
- Omni-directional wheel system allows travel in any direction over rough terrain
- Contains common power and control electronics
- Common interface provided for modules

Primary Digging Module

- Retractable digging arm keeps loading angle manageable while maintaining size constraint
- Designed for side to side cutting pattern



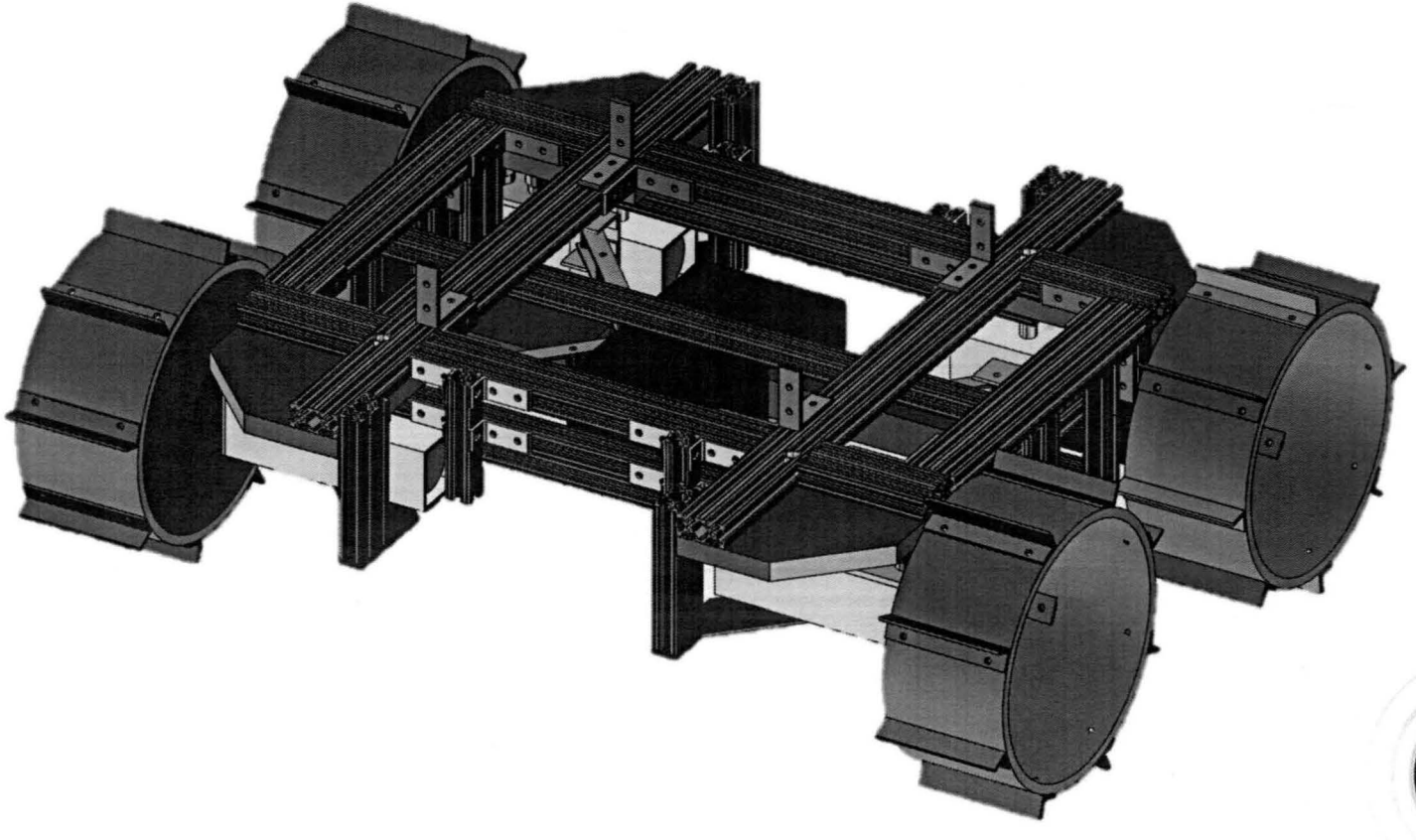




BASE DESIGN EVOLUTION

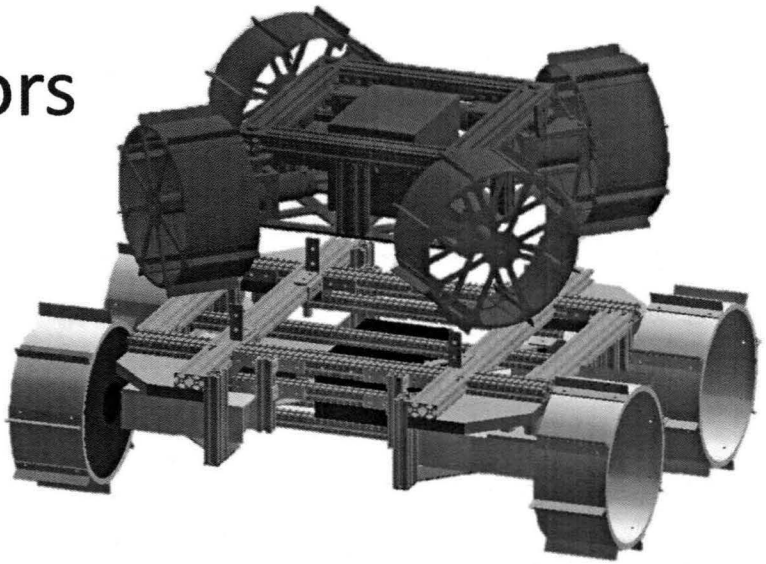
If it ain't broke...

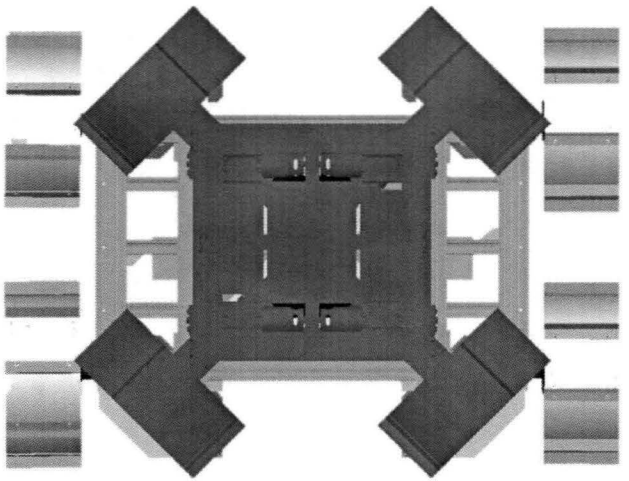
2011 Base



Size Adaptation

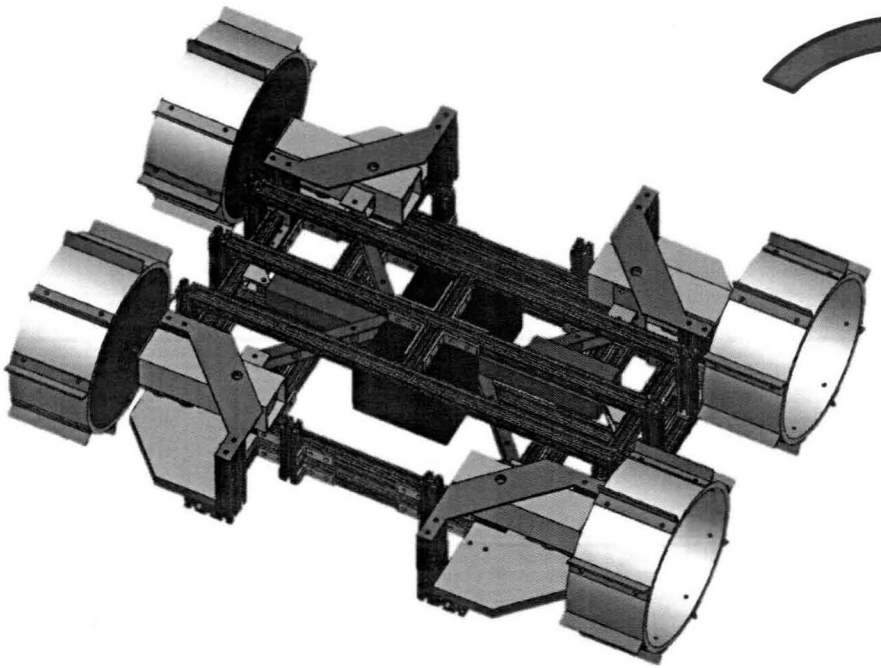
- New size constraints necessitated a much smaller base than last year
- Smaller size still uses more powerful batteries and motors

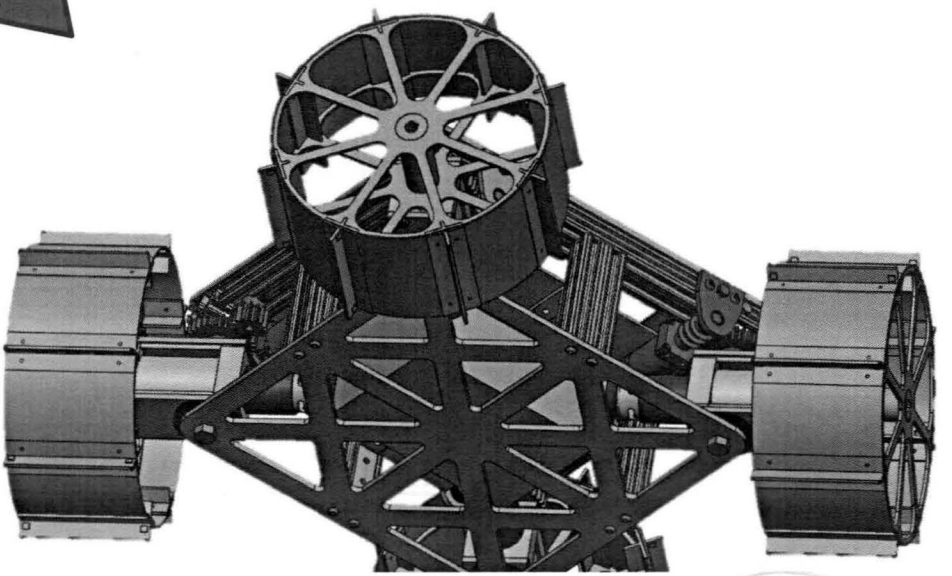




Worm/Gear Revision

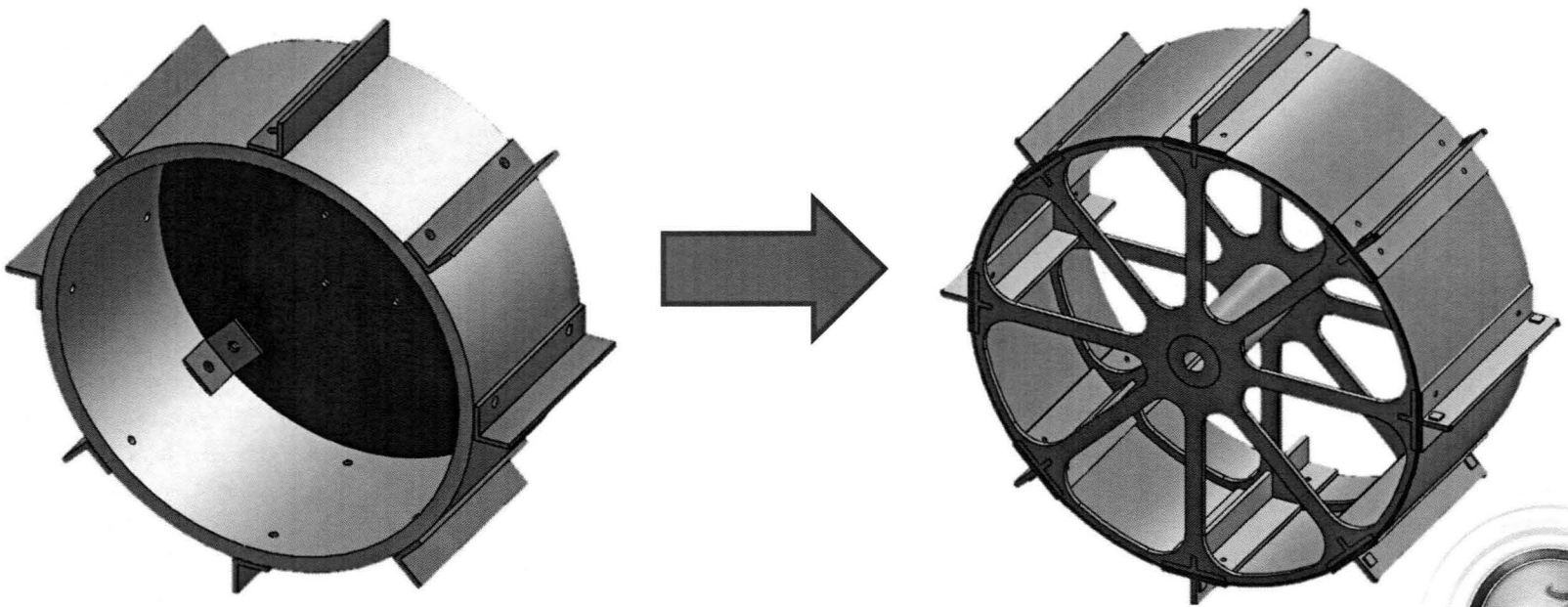
- Replaced linear actuators with independent worm gear actuators

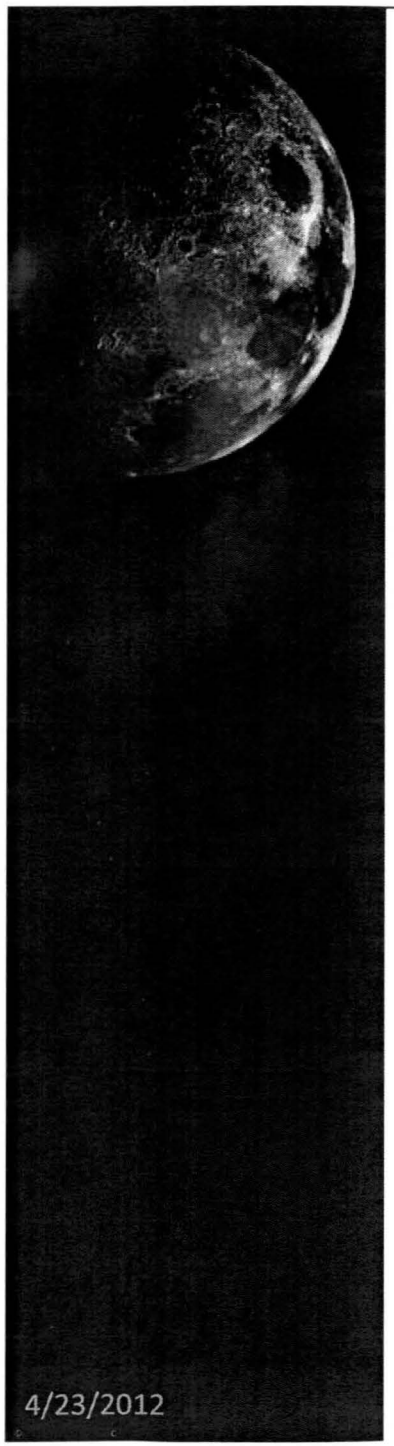




Wheel Design

- Upgraded from solid aluminum and PVC to CNC aluminum and fiberglass
- New wheels are ~75% lighter



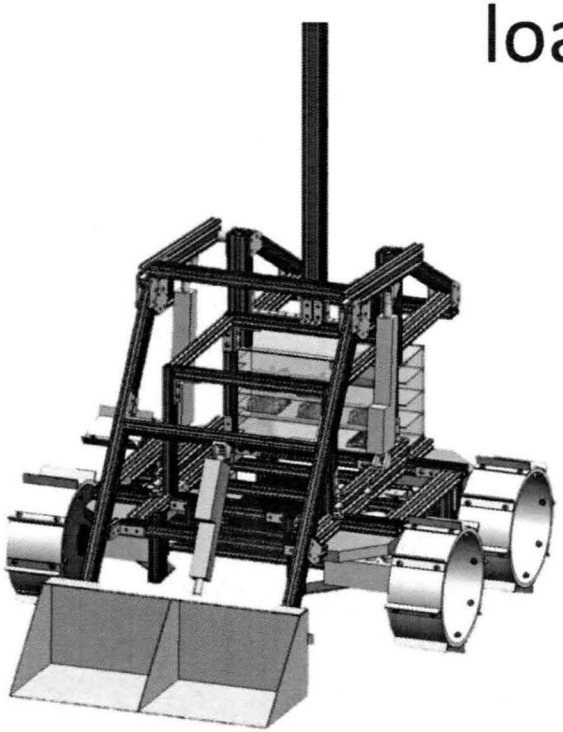


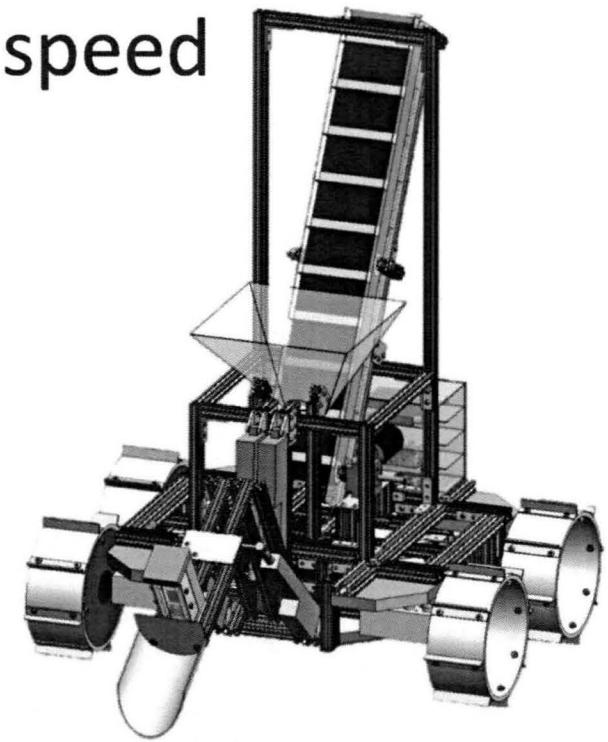
MODULE DESIGN

If it is broke, on the other hand...

2011 Modules

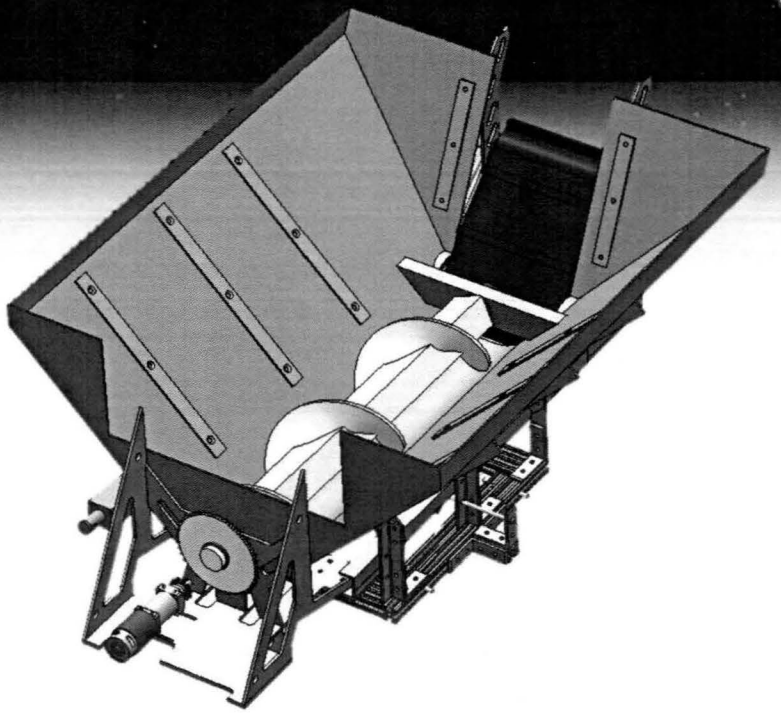
- Last year featured front end loading and percussive digging modules
- Decided to add onboard storage and increase loading speed

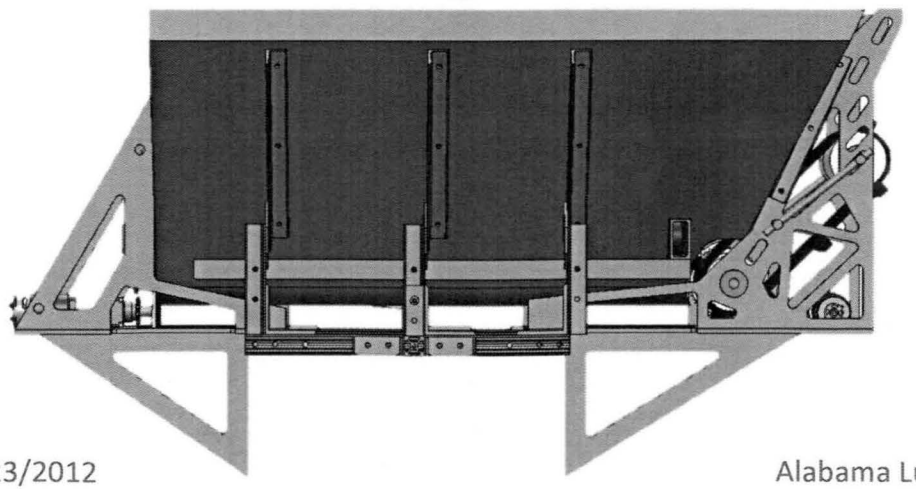


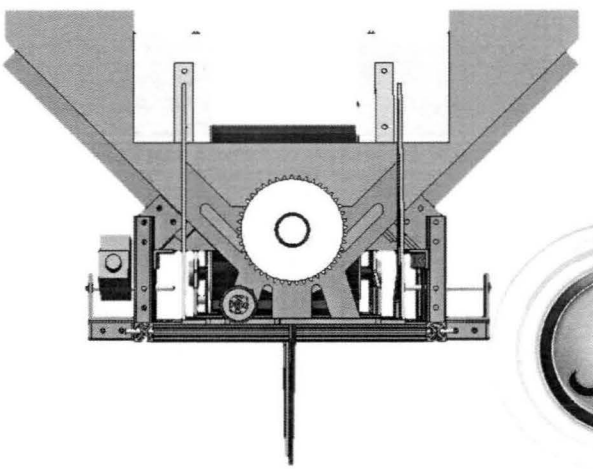


Onboard Storage

- Storage was decided relatively early in the process
- Screw conveyor and rear belt facilitate offloading

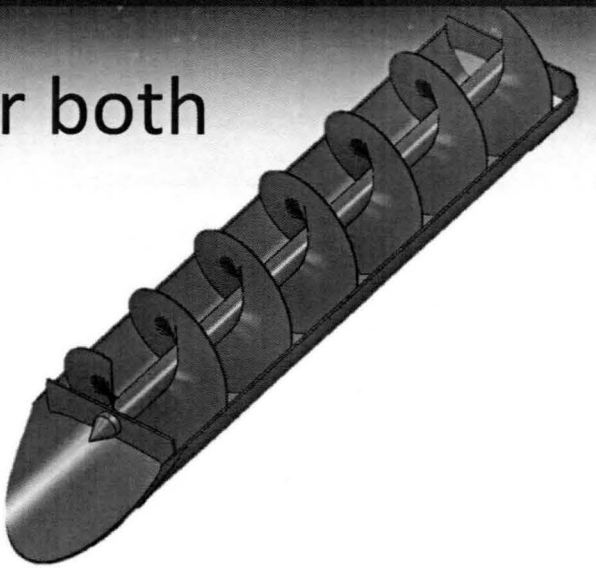


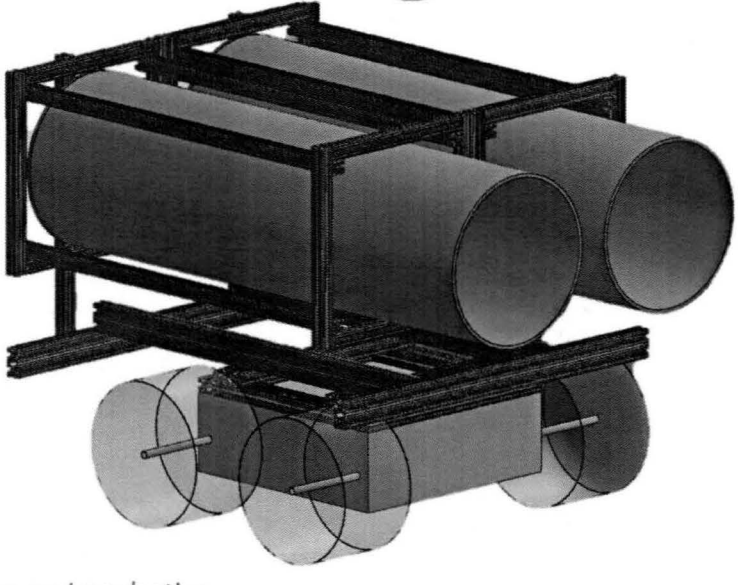




Auger Variations

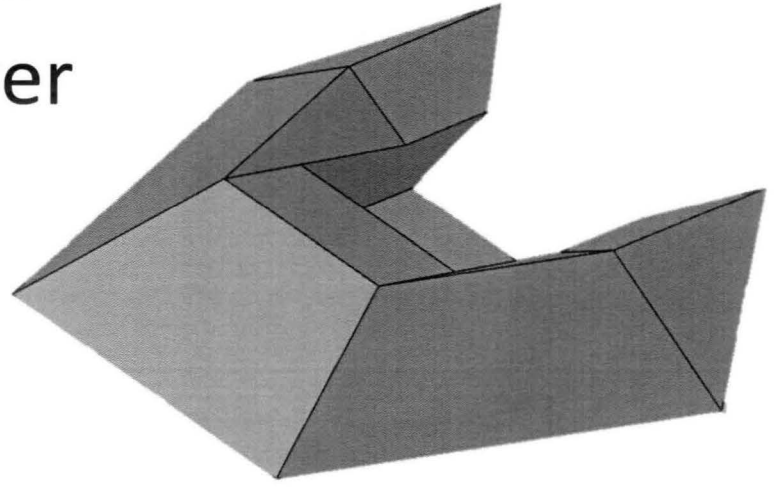
- Provided single moving part for both digging and storage
- Metal augers proved both expensive and heavy





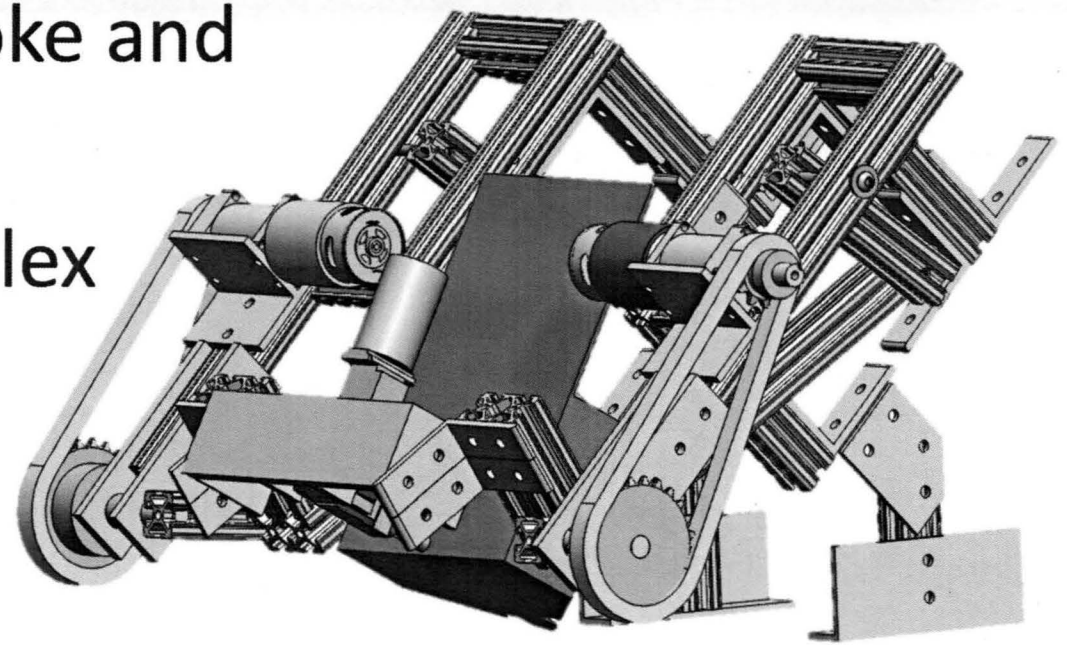
Cutting Diggers

- Cutting heads were designed to slice or vibrate into compacted regolith
- Rate of collection was lower than competing designs



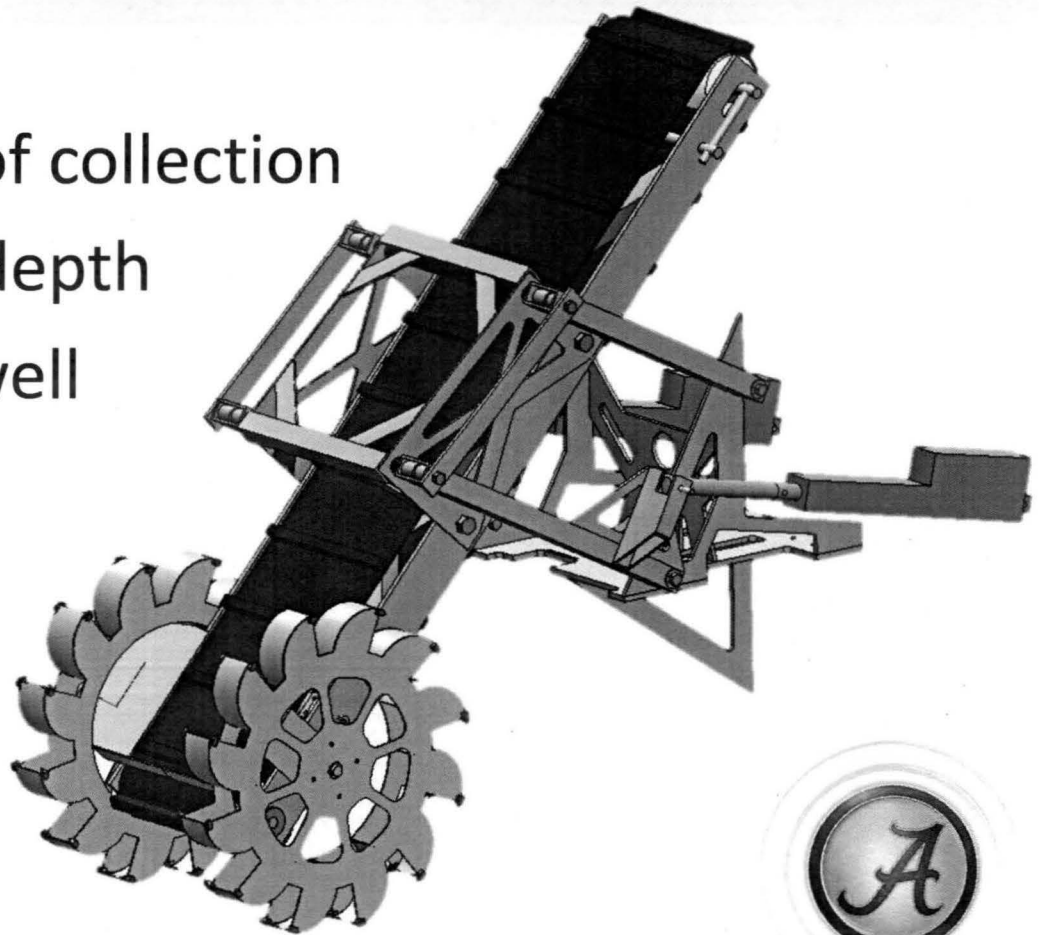
Percussive Oscillator

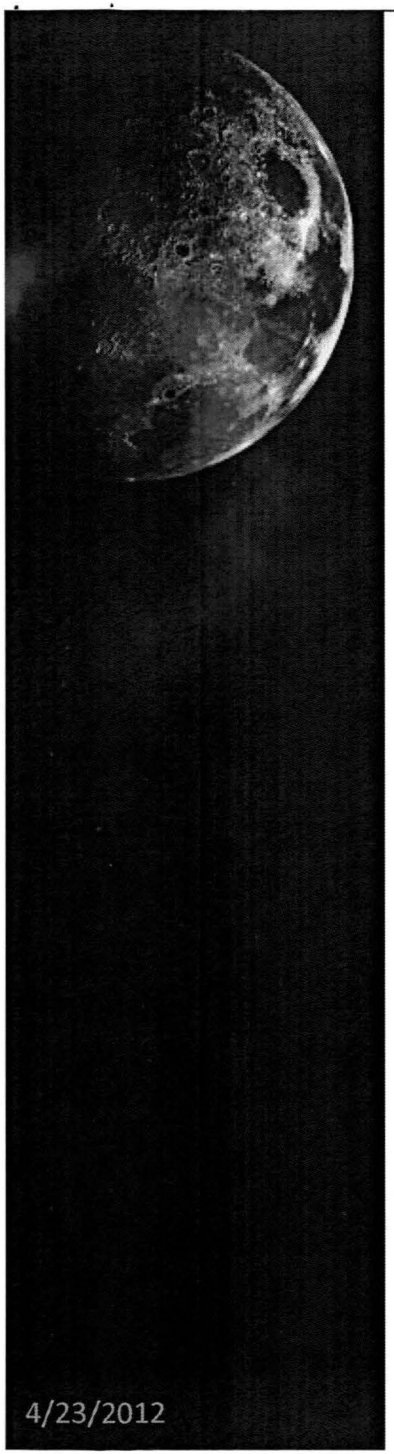
- Combined last year's percussive digger with a shorter digging stroke and conveyor belt
- Mechanically complex



Bucket Wheel Excavator

- Settled on four-bar linkage with bucket wheel and conveyor belt
  - Provided high rate of collection
  - Adjustable digging depth
  - Cutting pattern fit well with swept wheel capabilities

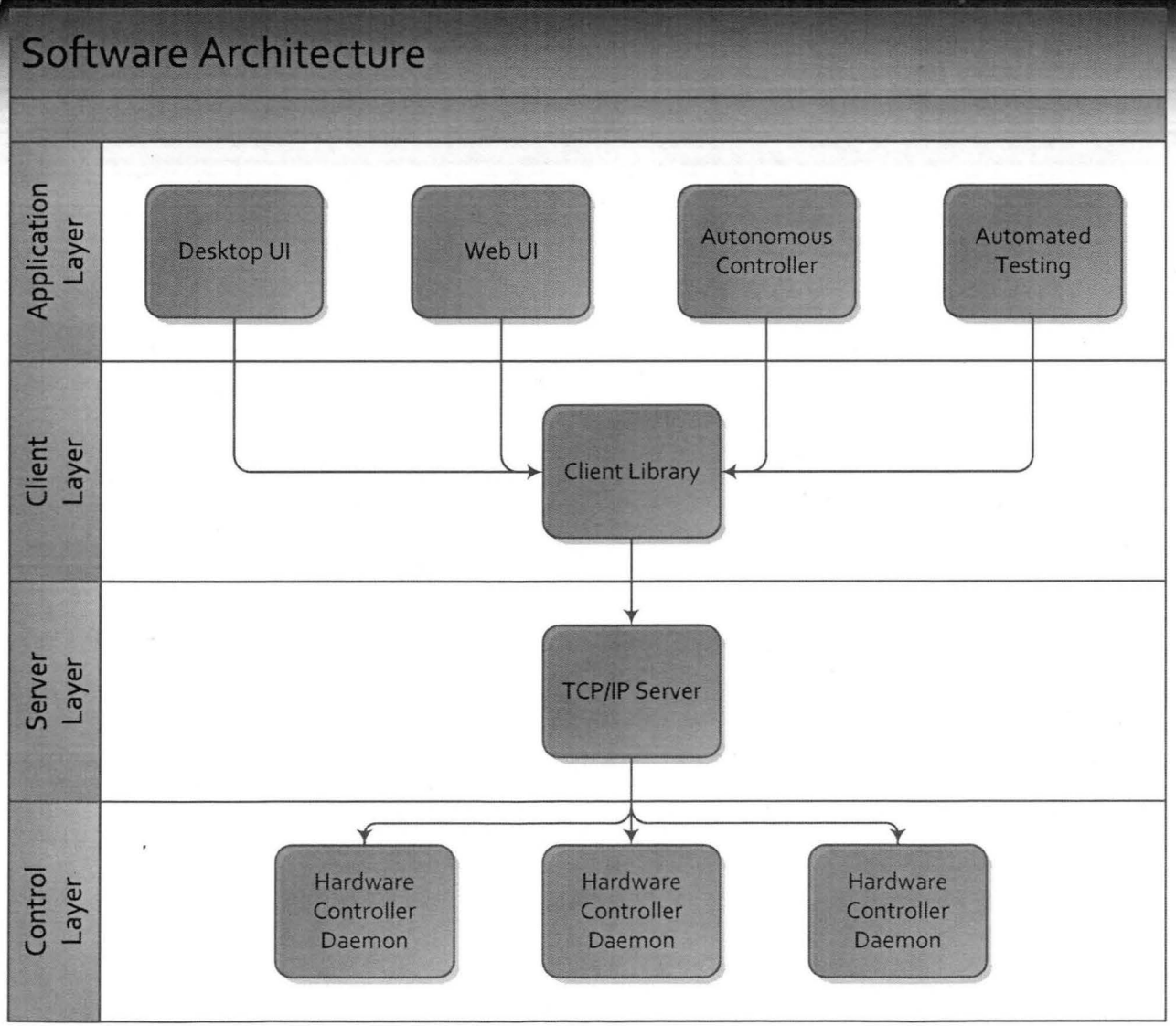




SOFTWARE DESIGN EVOLUTION

Inheritance and Selection

General Architecture



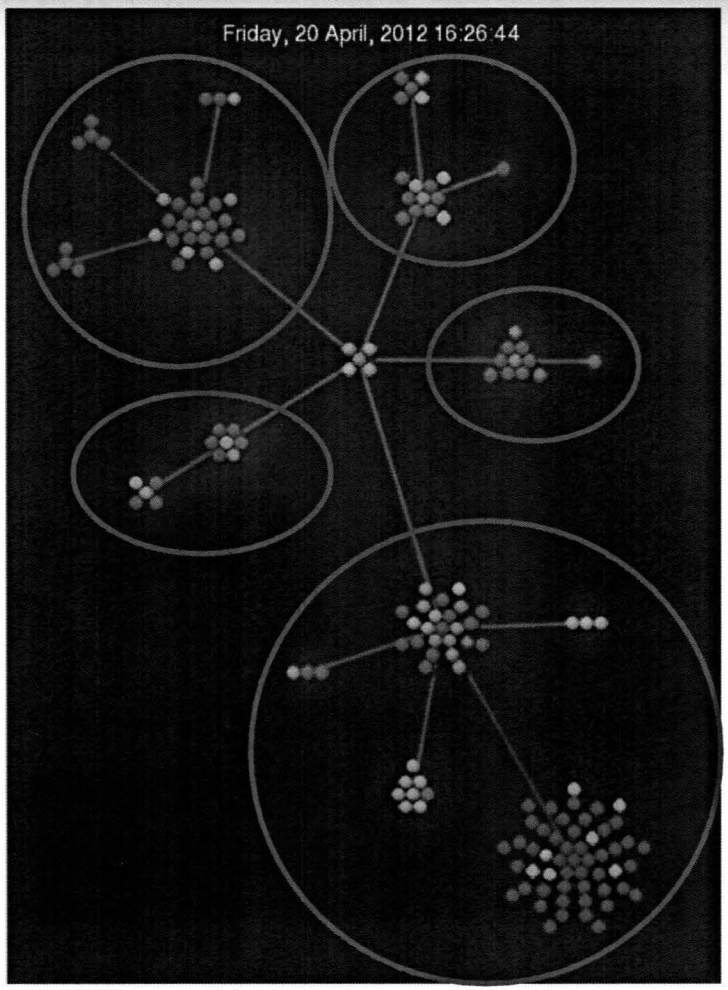
Client Software Growth

SVN Repository Structure

cs	66
png	39
jpg	7
js	7
gif	6
resx	6
csproj	5
css	5
aspx	4
config	4
settings	4
htm	2
testsettin...	2
xsl	2
Master	1
asax	1
design	1
dgml	1
htc	1
sln	1
uitest	1
vsmdi	1
webtest	1
xml	1

Core DLL

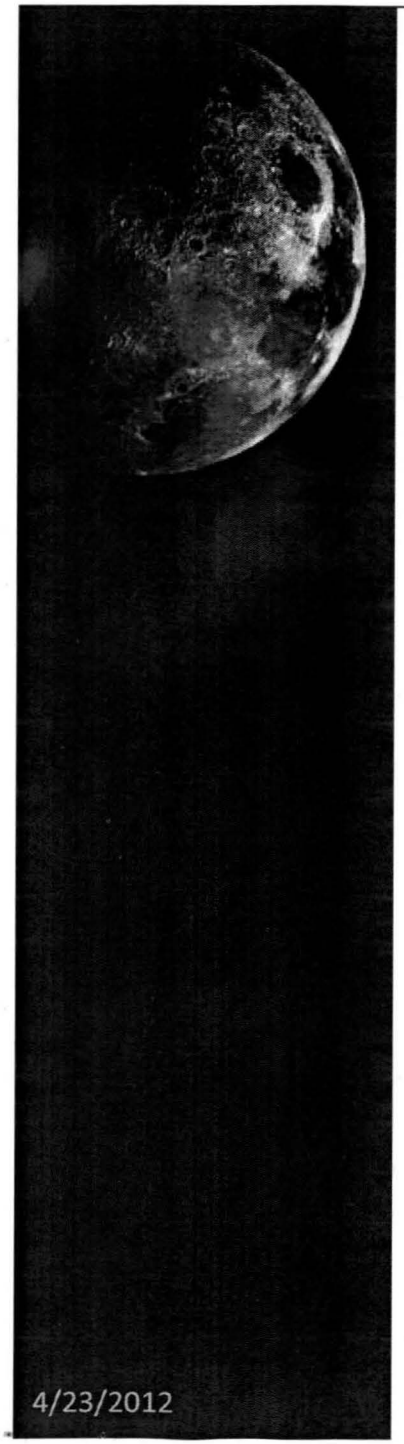
Automation



Desktop UI

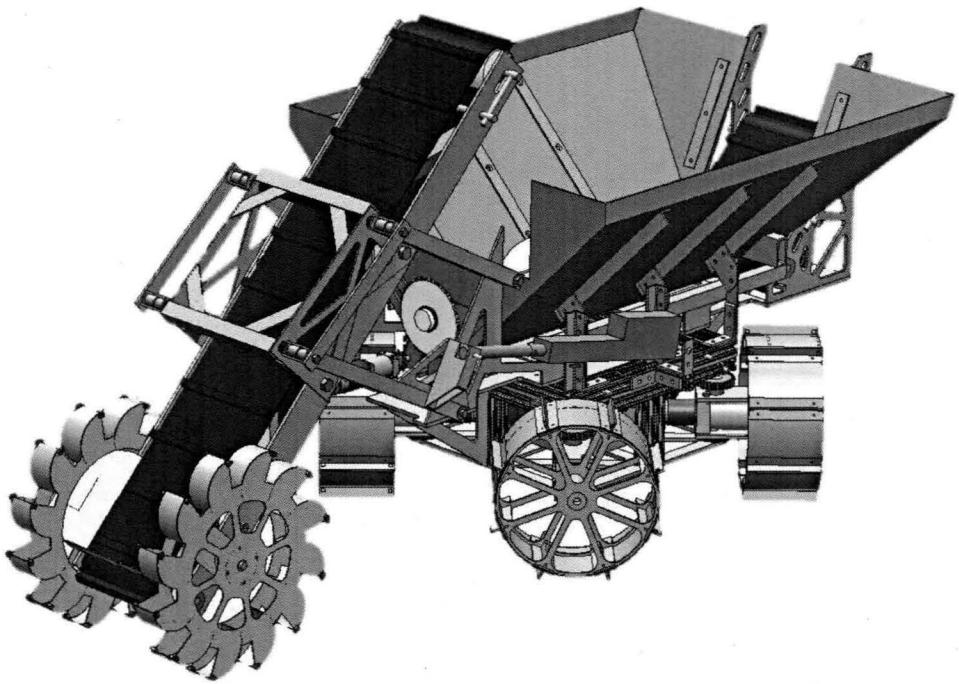
Testing

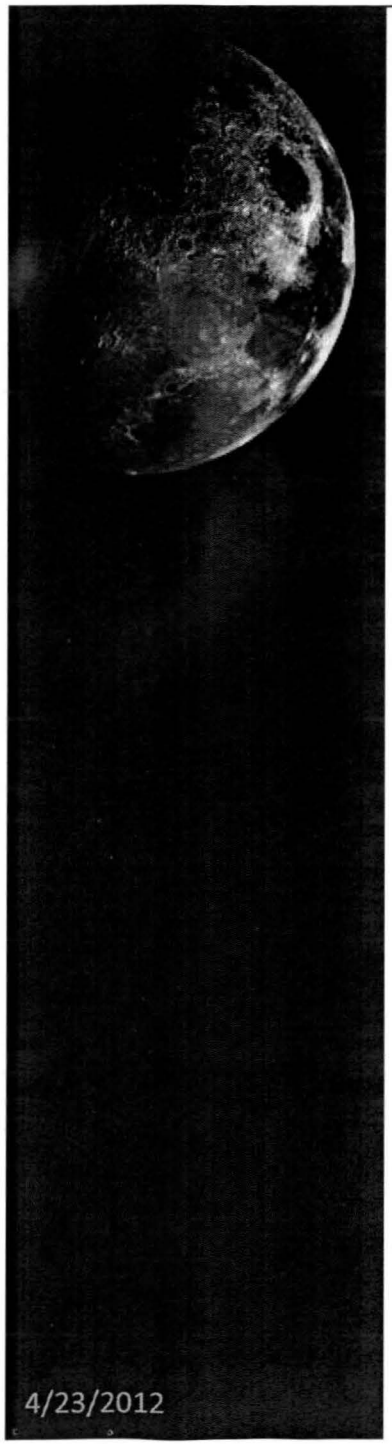
Web UI



OPERATIONAL OVERVIEW

Operational Demonstration



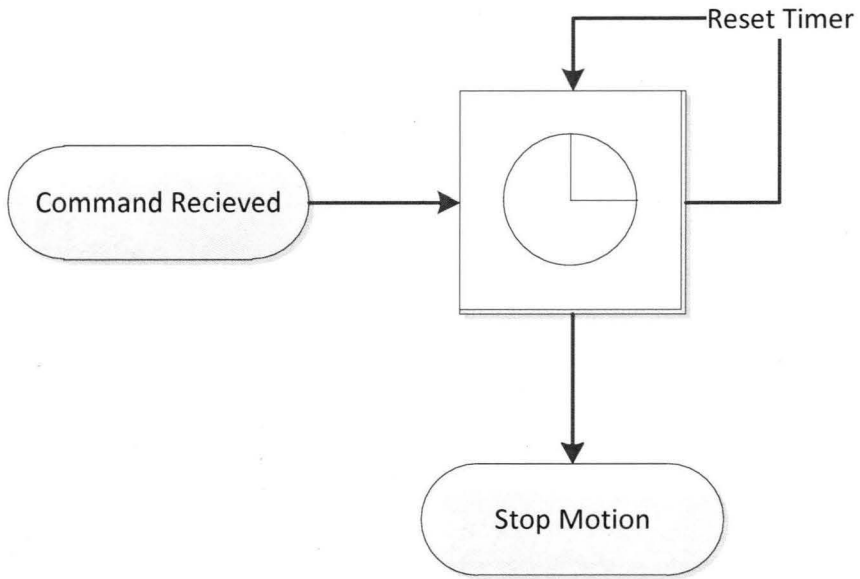


SAFETY FEATURES

It's first, after all.

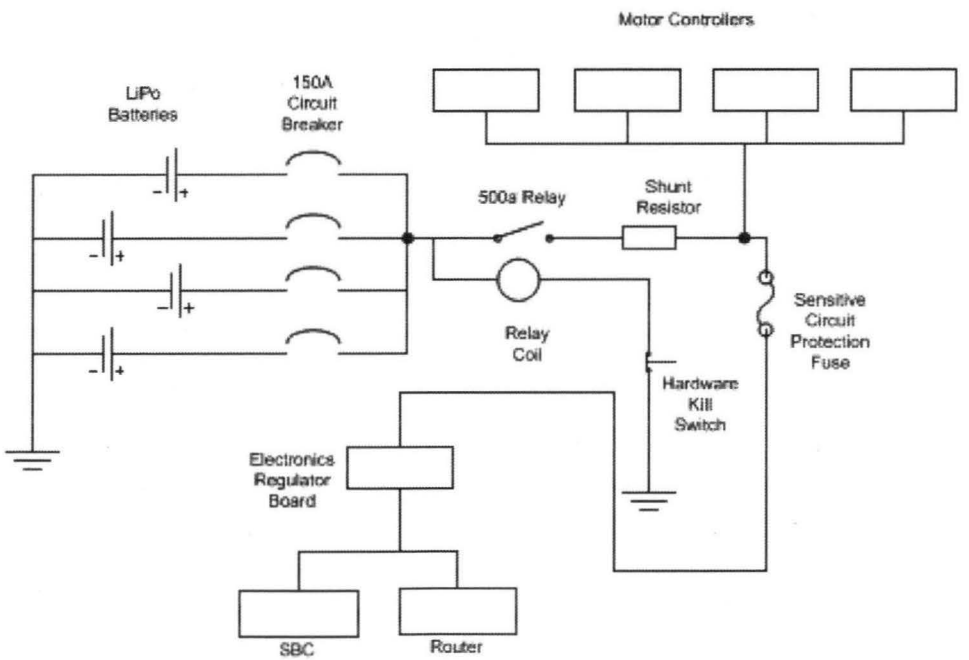
Software Watchdog

- Previous experience highlighted the importance of a watchdog timer
- Provides graceful degradation in event of communication failure



Battery Protection

- Independent battery circuit breakers
- Logic-level electronics protected by fuses



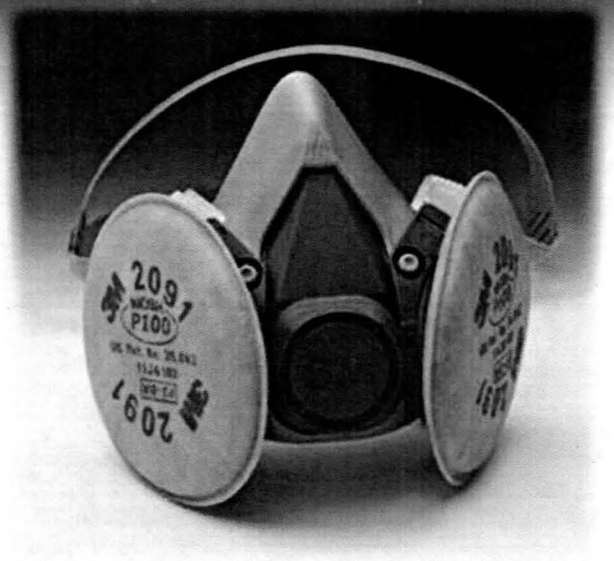
Single Line Electronics Block Diagram

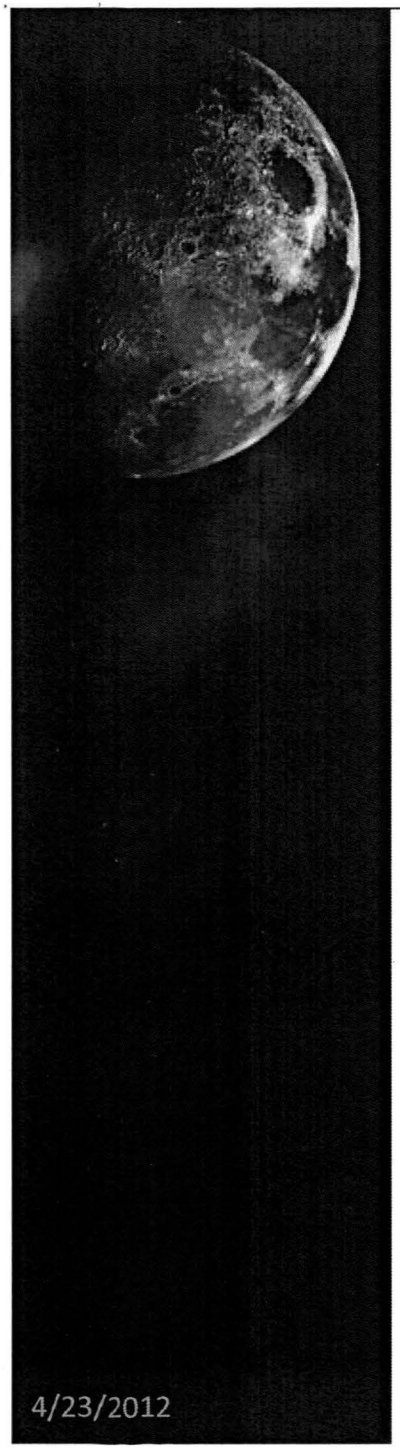
Other Safety Features

- E-STOP kill switch disables all electronics and motors
- Polarized connections prevent incorrect wiring and short circuits
- Large gauge wire, heat sinks, and automatic thermal protection shutoff minimize risk of overheating drive electronics

Personal Protective Equipment

- Respirators and Tyvek suits provided by UA Environmental Health and Safety
- Used during all sandbox and BP-1 testing

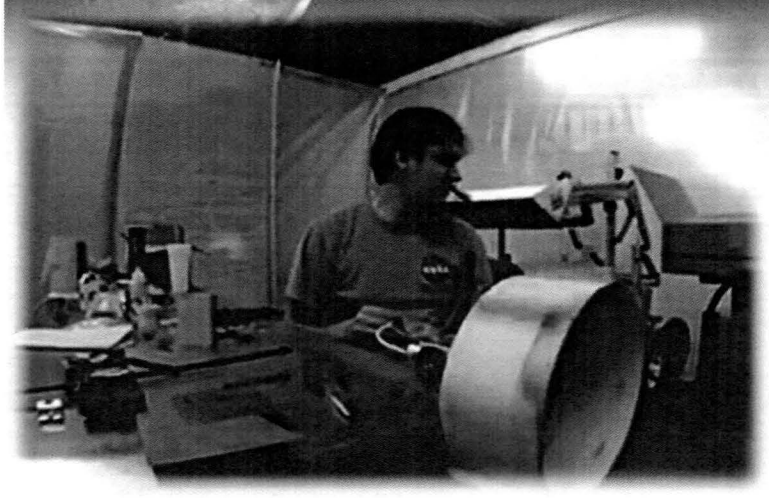


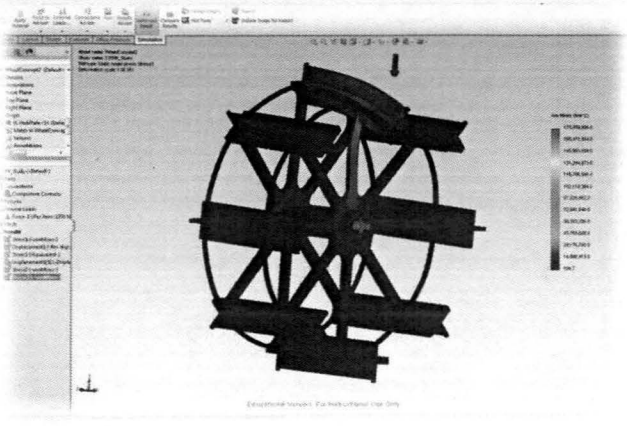


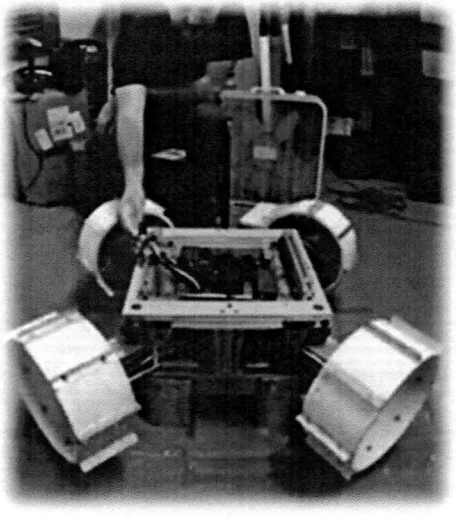
TESTING

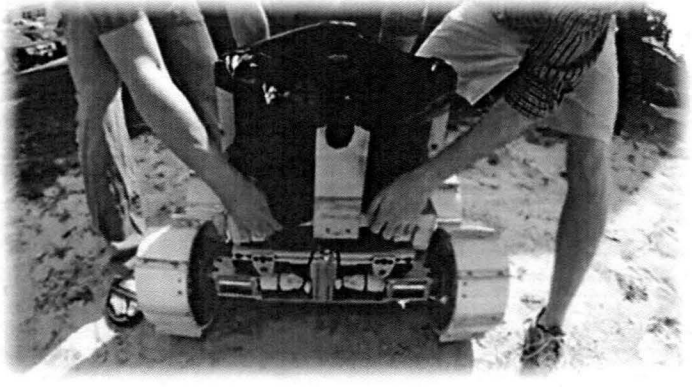
1,2,3…

Subsystem Testing

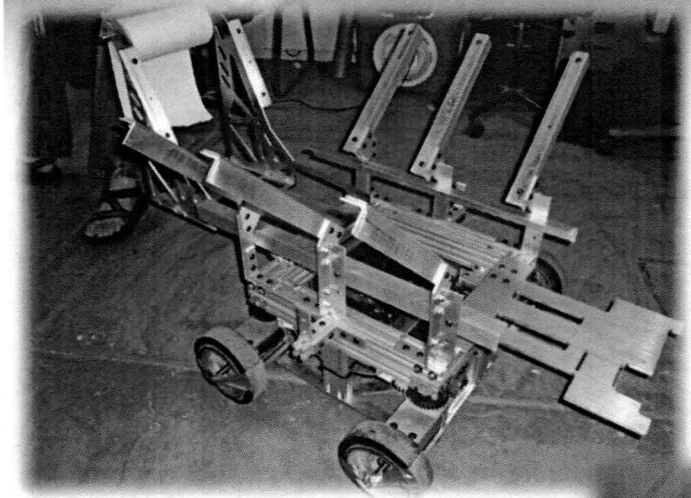


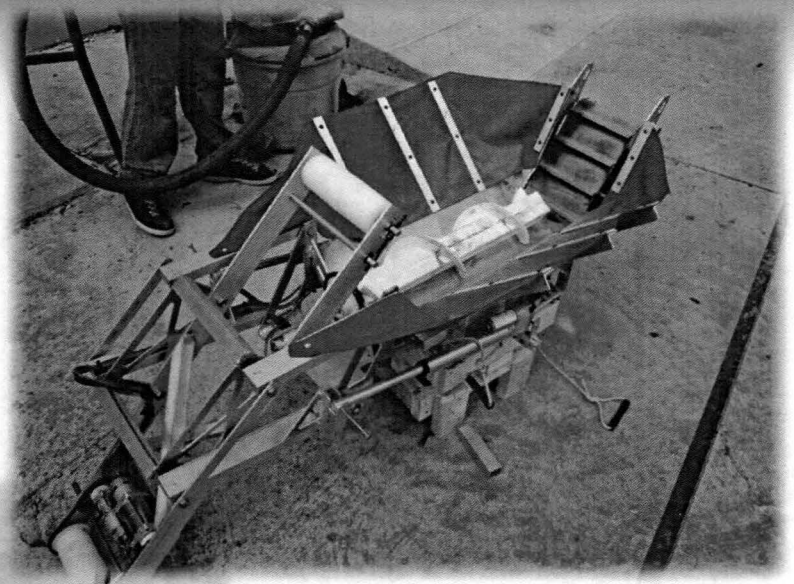


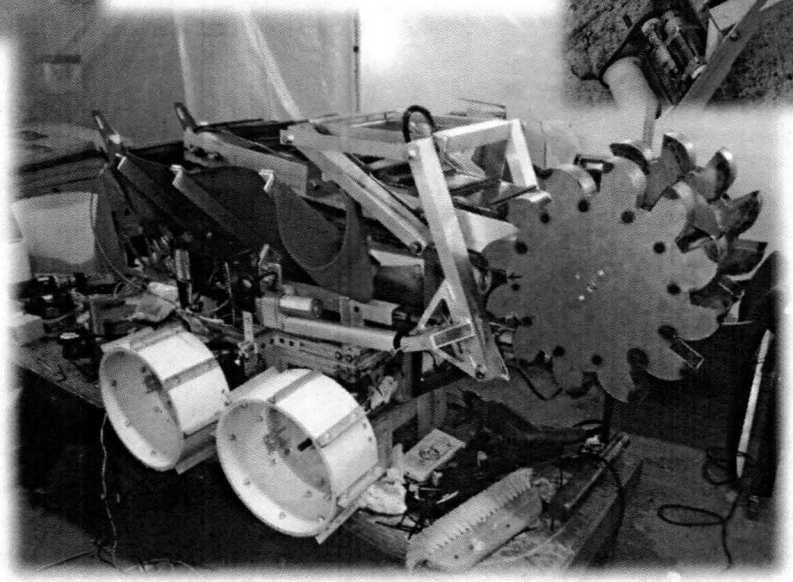




System Testing



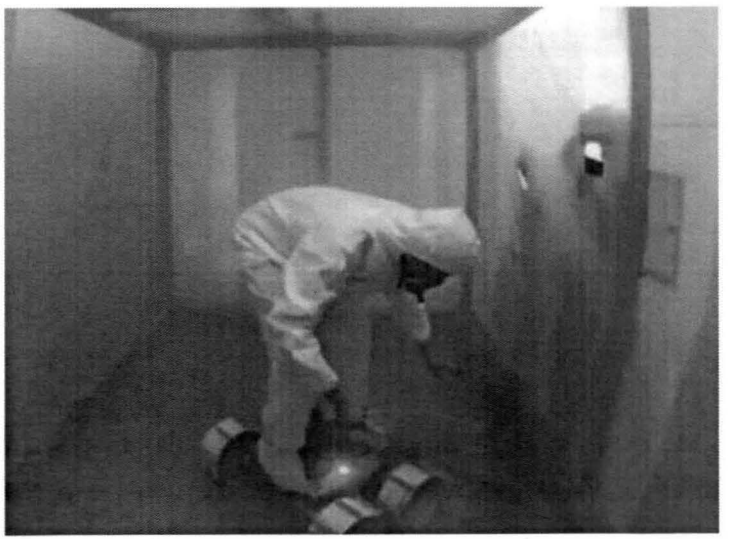




Testing Facilities

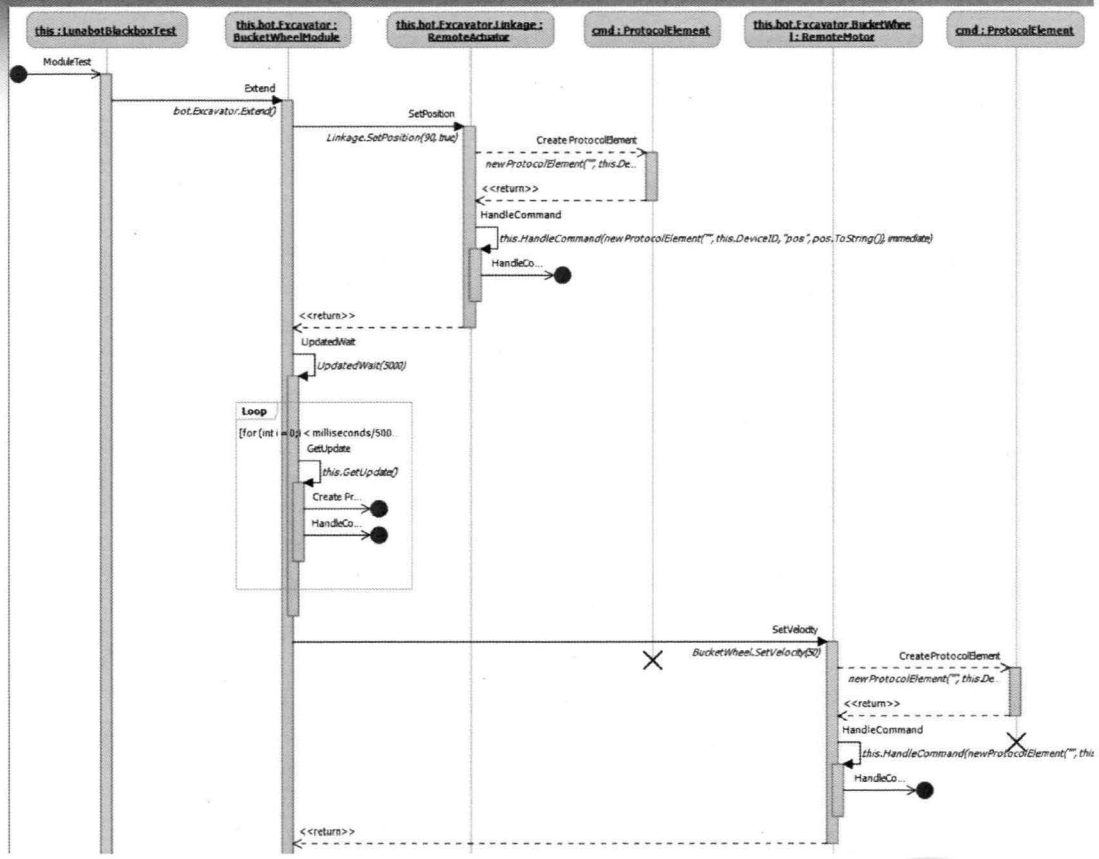
Outdoor Sandpit

Indoor Arena

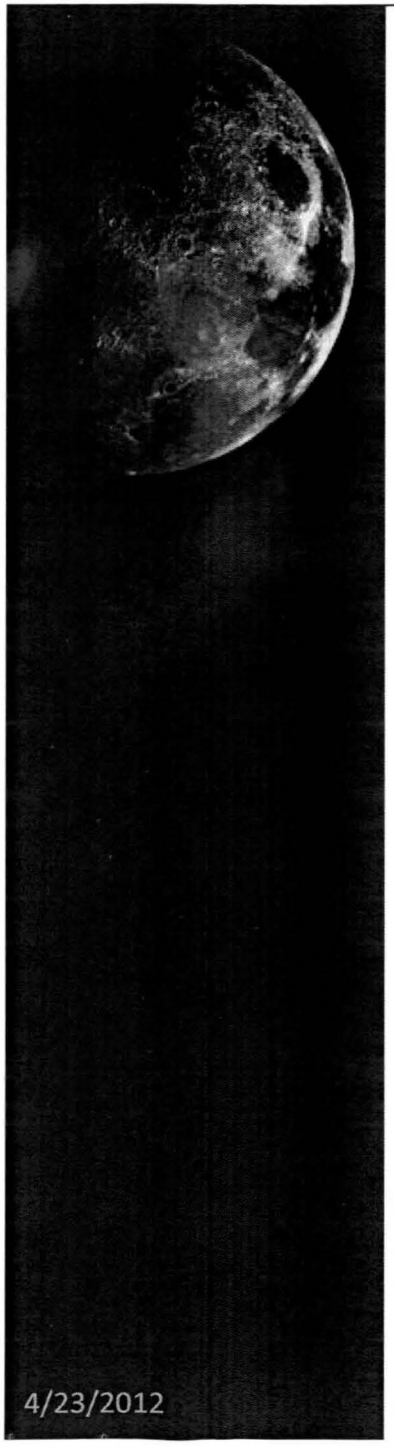


Automated Testing

- Used Visual Studio to generate:
  - Unit tests for components
  - System tests for the integrated robot
  - UI tests for web and desktop



Partial Sequence Diagram for System Test

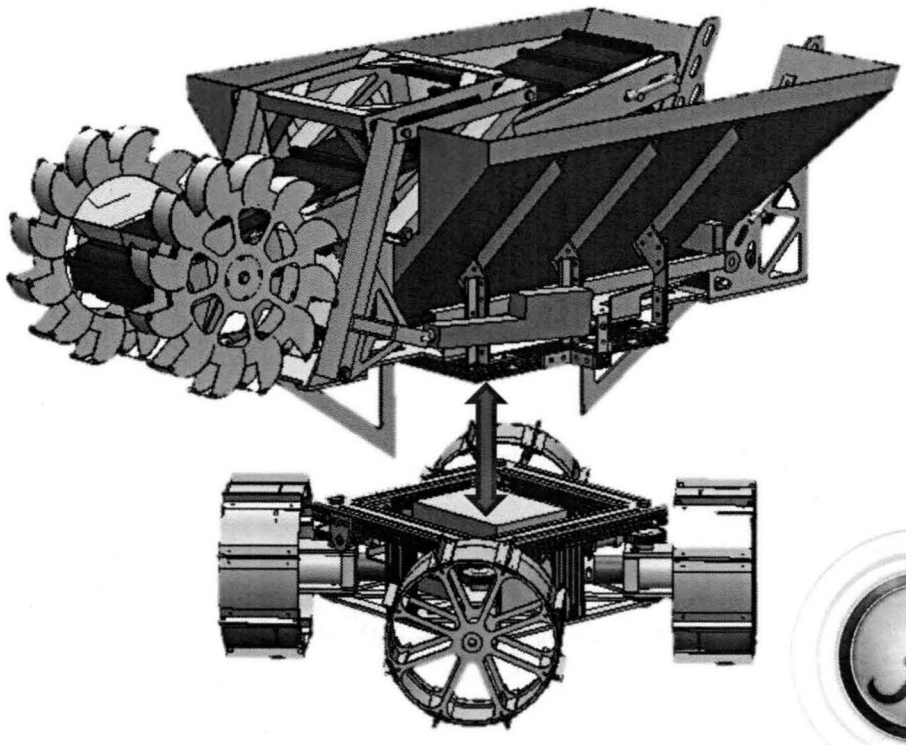


HIGHLIGHTED FEATURES

Yellow is Preferred

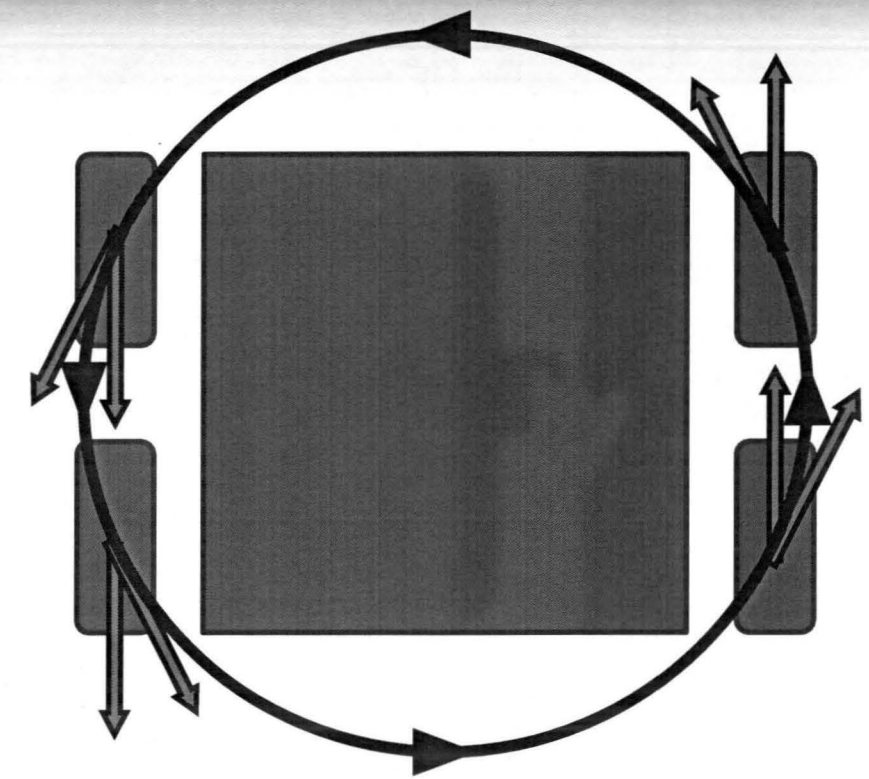
Modular Construction

- Mechanical, electrical, and software interfaces allow for modular reconfiguration
- Base framework could be used for variety of missions
- Adapted last year's front end loader for the new base interface



Omni-Directional Drive

- Direction of Rotation
- Force Applied by Wheel
- Direction of Travel of Wheel



Omni-Directional Drive

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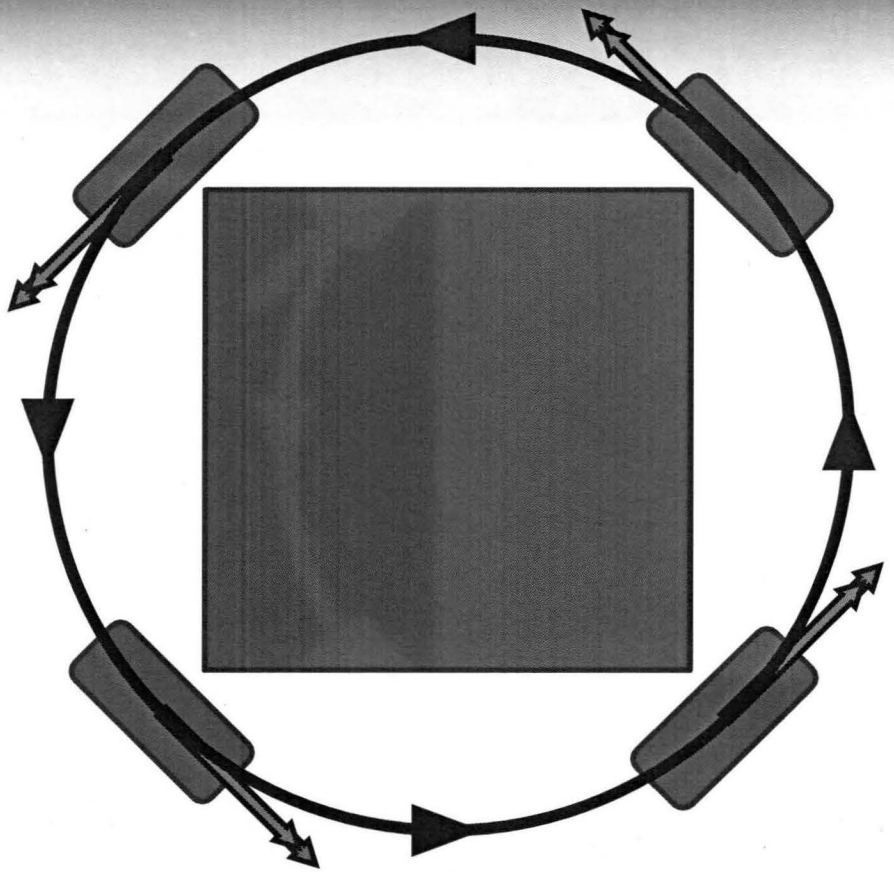
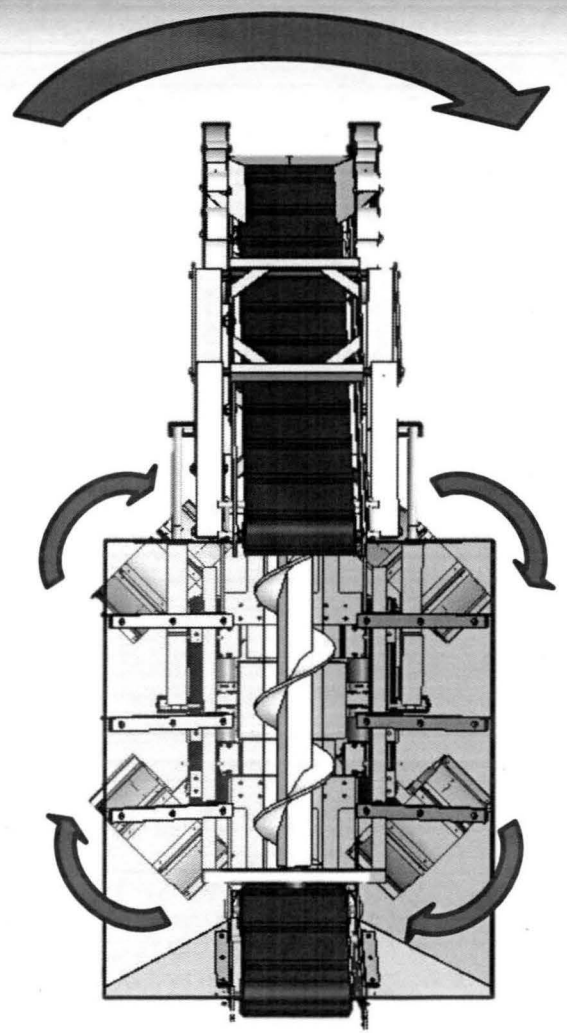
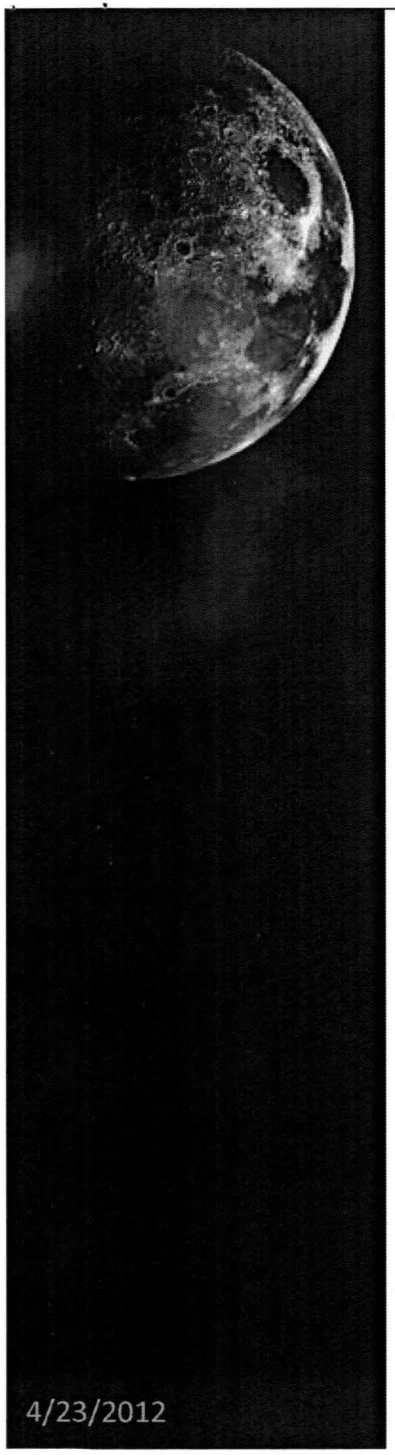
- Direction of Travel of Wheel



Cutting Pattern

- 45° and 90° wheel positions mimic industry bucket wheel excavator usage by allowing transverse or circular cutting pattern





CONCLUSIONS

Now all has been heard

Conclusions

- Modular Construction
- Omni-Directional Wheel System
- Industry Inspired Bucket Wheel Excavator
- Object Oriented Software Design
- Automated System Testing

Credits

- http://code.google.com/p/gource/
- http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSu7zK1fslxtUO8_ePvTSevVSeChshvTSevTSeSSSSSS--&width=310
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- http://bama.ua.edu/~ehs/

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Questions

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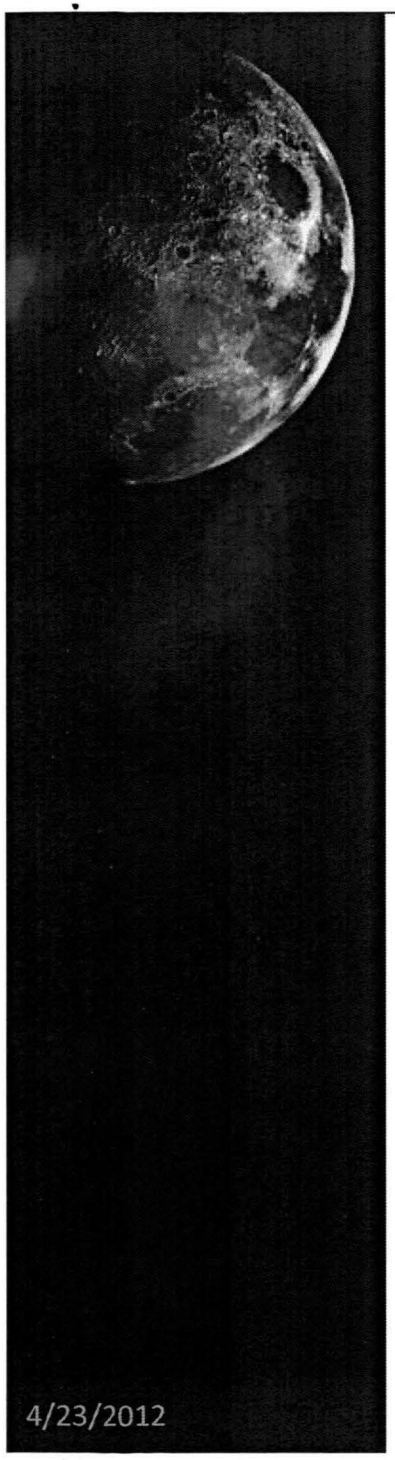

SUPPLEMENTAL INFORMATION

BP-1

- Donated by Anderson and Anderson Resources
- Required sealed enclosure and respirator use.
- Planned research into percussion and vibration technologies
- Future applications for digging efficiency and dust control