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:
• 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
• 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
• 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...
• 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
- 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...
• Last year featured front end loading and percussive digging modules
• Decided to add onboard storage and increase loading speed
• Storage was decided relatively early in the process
• Screw conveyor and rear belt facilitate offloading
• Provided single moving part for both digging and storage
• Metal augers proved both expensive and heavy
• Cutting heads were designed to slice or vibrate into compacted regolith
• Rate of collection was lower than competing designs
• 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
SVN Repository Structure
OPERATIONAL OVERVIEW
SAFETY FEATURES

It’s first, after all.
• Previous experience highlighted the importance of a watchdog timer
• Provides graceful degradation in event of communication failure
• 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
Outdoor Sandpit  Indoor Arena
• 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
• 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

- Direction of Rotation
- Force Applied by Wheel
- Direction of Travel of Wheel
• 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
• http://code.google.com/p/gource/
• http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSu7zK1fslxtUO8_ePvTSevVSeChshvTSevTSeSSSSSS--&width=310
• http://www.safespec.dupont.com/safespec/media/images/products/main/TY127S_WH_01.jpg
• http://bama.ua.edu/~ehs/
SUPPLEMENTAL INFORMATION
• 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