

The background image depicts a lunar mining competition. In the foreground, a white lunar rover with a NASA logo and an American flag is shown. A person in a white spacesuit and helmet is standing on the rover. In the background, a lunar lander is visible on the surface, and a large, futuristic lunar base structure is situated on a hill. The scene is set on a reddish-brown lunar surface with craters and rocks.

LUNABOTICS MINING COMPETITION May 27-28, 2010 Astronaut Hall of Fame

Space Resources Roundtable / PTMSS, June 2010

**Rob Mueller, Chief, NASA KSC, Surface Systems Office, NE-S
Gloria Murphy, NASA KSC, Education Project Manager, XA-D
Presented by Paul van Susante, NASA Fellow,
Colorado School of Mines**



What is a Lunabot?

- Robot Controlled Remotely or Autonomously
- Visual and Auditory Isolation from Operator
- Excavates Black Point 1 (BP-1) Aggregate
- Weight Limit - 80 kg
- Dimension Limits - 1.5m width x .75m length x 2m height
- Designed, Built and Tested by University Student Teams





Background/History

The Competition is linked to a Senior Design Class and Systems Engineering Curriculum

ESMD Senior Design Project
KSC1-05-SD
Lunar Regolith Excavation O2
Prod/Outpost Emplace
posted in 2007 on the ESMD Space
Grant Education Project website:
<http://education.ksc.nasa.gov/esmdspacegrant/>

**Lunar Regolith Excavator
Senior Design Course
incorporating NASA Systems
Engineering Process**
Curriculum developed and pilot
tested by Auburn University
during 2008-09 and posted at:
<http://education.ksc.nasa.gov/esmdspacegrant/LunarRegolithExcavator.htm>

**Lunar Regolith Excavator
Senior Design Course
Faculty Workshop**
Held at KSC on May 27, 2009
with 43 faculty from around the
country participating of which
37% were from minority
serving institutions.





Competition Categories

- On-site Mining
 - 1st, 2nd & 3rd Place for most lunar simulant deposited in collector within 15 minutes
 - Minimum of 10 kg required to place
- Systems Engineering Paper (mandatory)
- Outreach Project (mandatory)
- Slide Presentation (optional)
- Team Spirit (optional)



Benefits

- Prepare Students for Future Workforce
- Soil Containment Structure for New Technologies Development (ISRU)
- New Concepts for Excavation Technologies
- Community Awareness of Future KSC Activities
- Outreach to local middle schools, FIRST Robotics, Girl Scouts and Boys & Girls Club



Partnerships

- Technical Expertise - KSC Engineering
- Project Management - KSC Education
- Funding - ESMD Education
- Host – Delaware North
- Collaboration with Exploration Technology Development Program (ETDP)
- Involvement - JPL, JSC, LaRC, MSFC



Sponsors

- Caterpillar, inc
- Newmont Mining Company
- Honeybee Robotics Spacecraft Mechanisms Corporation
- Reynolds, Smith & Hills (RS&H) Consulting Engineers
- AIAA Space Resources Technical Committee (TC)
- ASCE Regolith Operations, Mobility & Robotics TC

Thank you to our sponsors!



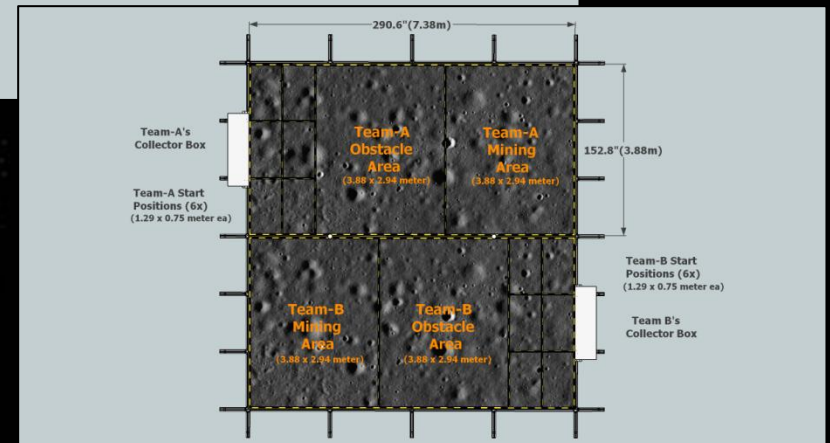
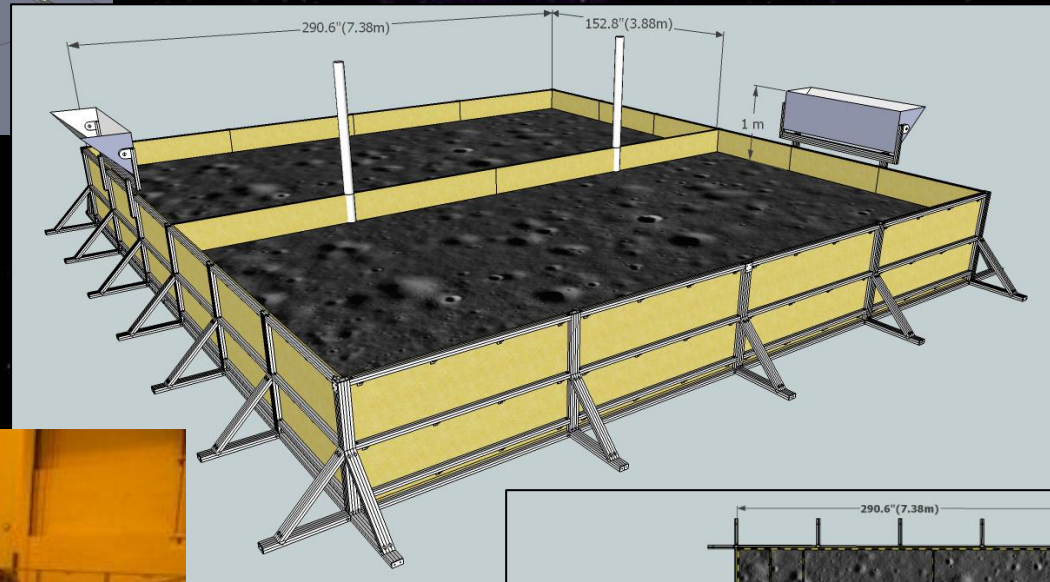
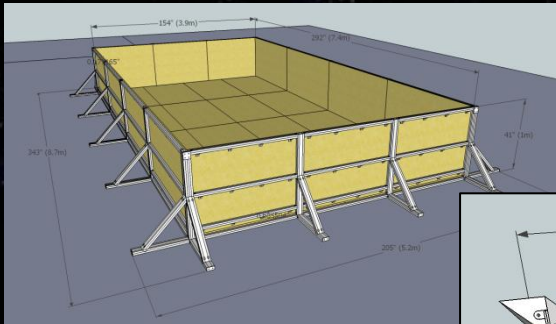
Competitors

- Akron, Univ. of
- Alabama, Univ. of
- Arkansas, Univ. of
- Auburn Univ. / Tuskegee Univ.
- Bridgeport, Connecticut, Univ. of
- Carnegie Mellon Univ. / Hampton
- Colorado School of Mines
- Embry Riddle Aeronautical Univ. FL
- Florida Institute of Technology
- Florida State Univ. / Florida A&M
- Iowa State University
- John Brown University
- Milwaukee School of Engineering, WI
- Montana State University
- North Carolina-Charlotte, Univ. of
- North Dakota School of Eng. & Mines
- Prairie View A & M Univ.
- South Dakota School of Mines & Tech
- Southern Indiana, Univ. of
- Temple University, PA
- Virginia Tech
- Western Kentucky University

Over 250 students participated, gained valuable skills and were inspired !



Lunarena



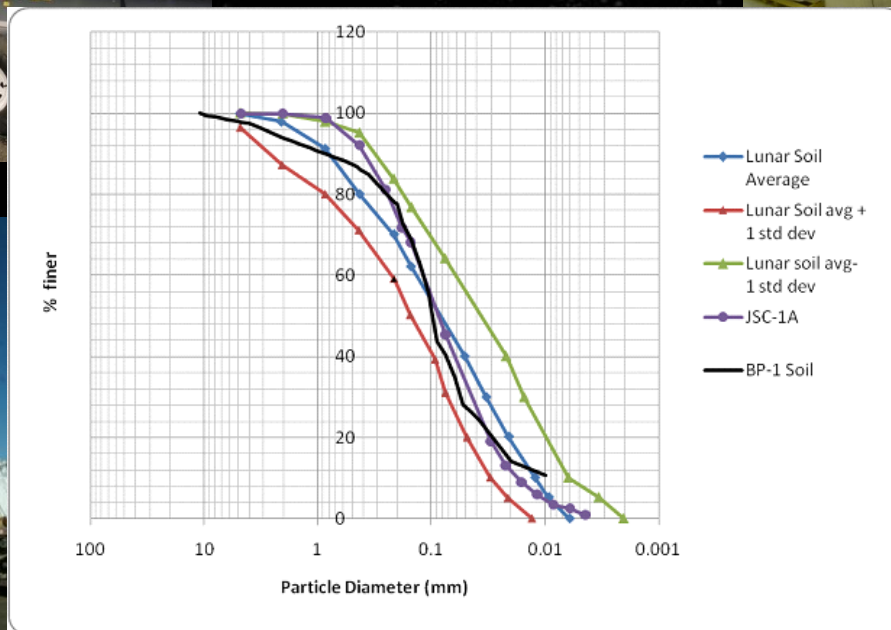
Lunarena





Black Point 1 (BP-1)

Discovered during 2009 Desert RATS in Flagstaff, AZ



2010/04/13

Joe Kosmo Award for Excellence



Grand prize trip to NASA Desert RATS awarded to team with highest cumulative score



Trophy designed and built by Pre-Engineering students from Rocklin High School, California





2010 Competition Winners

- In-Situ Mining: Montana State University
- Systems Engineering Paper: Auburn U.
- Outreach Project: Embry-Riddle AU Daytona
- Slide Presentation: Western Kentucky U
- Team Spirit: Univ. of Southern Indiana
- Joe Kosmo Award: Montana State University



Lunabotics 2011

- KSC will host NASA Lunabotics 2011
- Possible International Participation at Satellite Lunarenas (S. Korea, Netherlands)
- Rules will not change
- We are already planning for 2011!
- You are invited to participate

Lunabotics Mining Competition POCs



For more information contact NASA KSC:

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Gloria Murphy

Gloria.A.Murphy@nasa.gov

Phone: 321-867-8934

Competition Website: www.nasa.gov/lunabotics

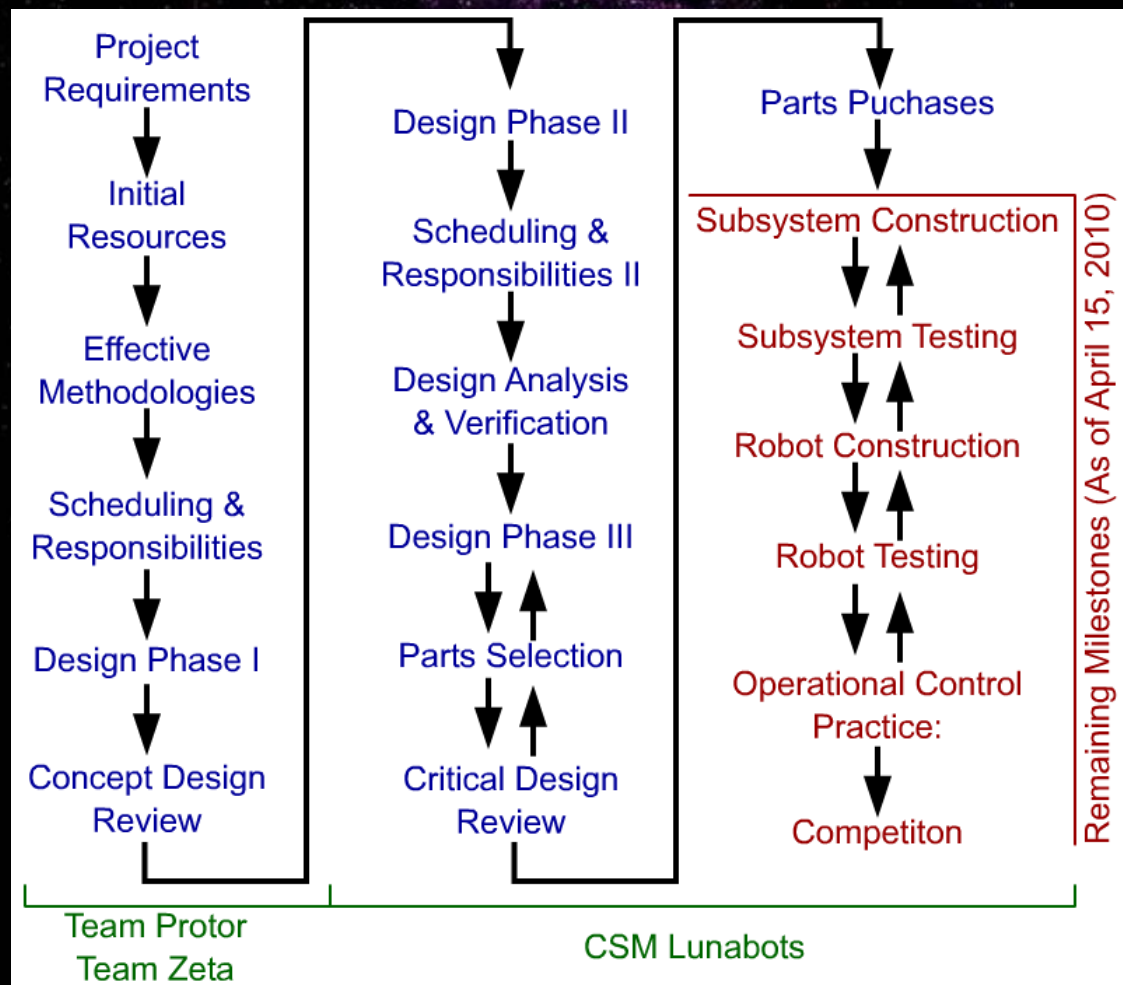
Facebook Page: www.facebook.com/Lunabotics

Perspective from a Participating University: CSM



- Run as senior design capstone project
- 2 semesters (Aug 2009 – Apr 2010)
- Budget of roughly \$15k (\$9k materials, \$6k travel for 8)
- Variety of sources of funding
 - Co Space Grant (\$7k)
 - Companies fundraising (\$800)
 - Senior Design / Engineering dept (\$7K)

Design Approach





Methodologies

Documentation

Brainstorming and Ideation

Quality Functional Deployment

Black Box Models

Decision Matrices

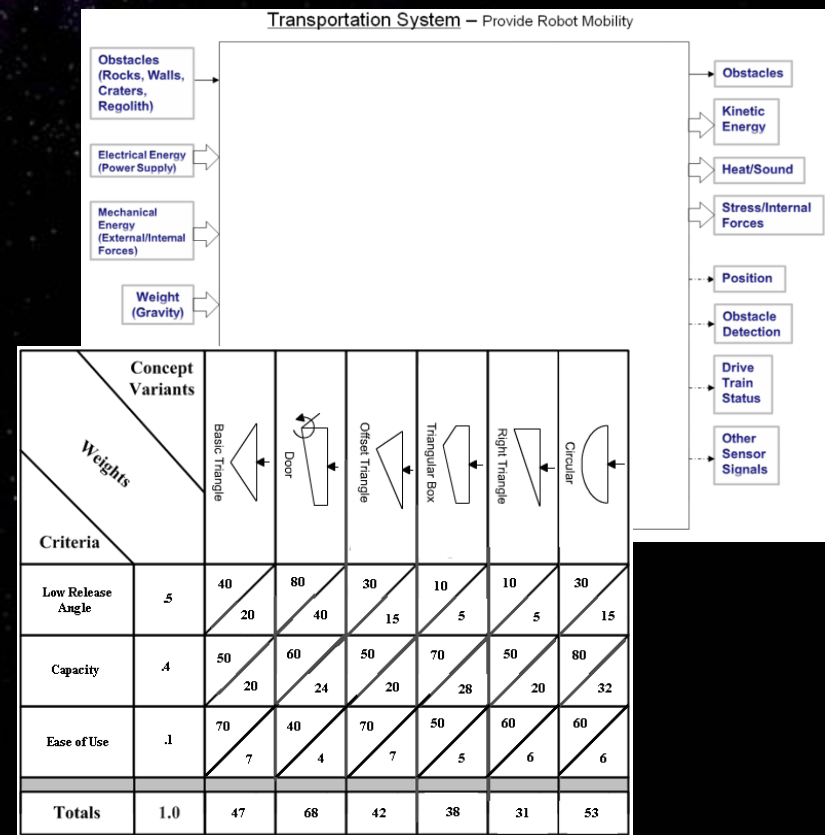
Work Breakdown Structure

Organizational Chart

Gantt Chart

Budgets (Mass, Cost, Space)

Bill of Materials





Schedule

ID	Task Name	Duration	Start	Finish	9/18/25	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10
1	LETTER OF INTENT	4 days	Wed 10/28/09	Mon 11/2/09									
2	WORK ON LETTER OF INTENT	4 days	Wed 10/28/09	Sat 10/31/09									
3	LETTER OF INTENT DUE	0 days	Mon 11/2/09	Mon 11/2/09		11/2							
4	ORAL PRESENTATION	5 days	Wed 10/28/09	Tue 11/3/09									
5	WORK ON ORAL PRESENTATION	2.5 days	Wed 10/28/09	Fri 10/30/09									
6	ORAL PRESENTATION (DUE)	0 days	Fri 10/30/09	Fri 10/30/09		10/30							
7	ORAL PRESENTATION	2 mins	Tue 11/3/09	Tue 11/3/09									
8	PROJECT PROPOSAL AND LETTER OF TRANSMITTAL	3.5 days	Tue 11/10/09	Fri 11/13/09									
9	WRITE AND COMPILE PROJECT PROPOSAL REPORT	3 days	Tue 11/10/09	Thu 11/12/09									
10	EDIT PROJECT PROPOSAL REPORT AND WRITE LETTER OF TRANSMITTAL	0.5 days	Fri 11/13/09	Fri 11/13/09									
11	PROJECT PROPOSAL REPORT AND LETTER OF TRANSMITTAL DUE	0 days	Fri 11/13/09	Fri 11/13/09			11/13						
12	REQUEST FOR PROJECT SPONSORS	72 days	Mon 11/16/09	Wed 2/10/10									
13	DETERMINE TARGET COMPANIES	2 days	Mon 11/16/09	Tue 11/17/09									
14	Create Generic Donation Letter	54 days	Mon 11/30/09	Sat 1/30/10									
15	MAIL DONATION LETTERS	1 day	Mon 2/1/10	Mon 2/1/10									
16	SEND FOLLOW UP EMAIL AND/OR PHONE CALL	3 days	Mon 2/8/10	Wed 2/10/10									
17	Conceptual Design Review	22.5 days	Thu 11/12/09	Fri 12/11/09									
18	CONCEPTUAL DESIGN VARIANTS	13.4 days	Sat 11/14/09	Thu 12/3/09									
19	6-3-2 Design Method	0.4 days	Sat 11/14/09	Sat 11/14/09									
20	Brainstorming	13 days	Sat 11/14/09	Thu 12/3/09									
21	Final Conceptual Design Formulation and Subsystem Variants	16.1 days	Thu 11/12/09	Fri 12/4/09									
22	Assign Responsible Engineers to Subsystems	0.1 days	Thu 11/12/09	Thu 11/12/09									
23	Research Patents	10 days	Thu 11/12/09	Tue 11/24/09									
24	Phase 1 Subsystems (Locomotion, Excavation, Mechanism of soil trans., and Int)	5 days	Thu 11/12/09	Wed 11/18/09									
25	Phase 2 Subsystems (Motor selection, frame design, Power, Control Board, int)	7 days	Mon 11/16/09	Tue 11/24/09									
26	Phase 3 Subsystems (Control, Power, Final Integration)	8 days	Sat 11/21/09	Fri 12/4/09									

Project: Gantt Chart
Date: Mon 4/12/10

Task



Milestone



External Tasks



Split



Summary



External Milestone



Progress



Project Summary



Deadline

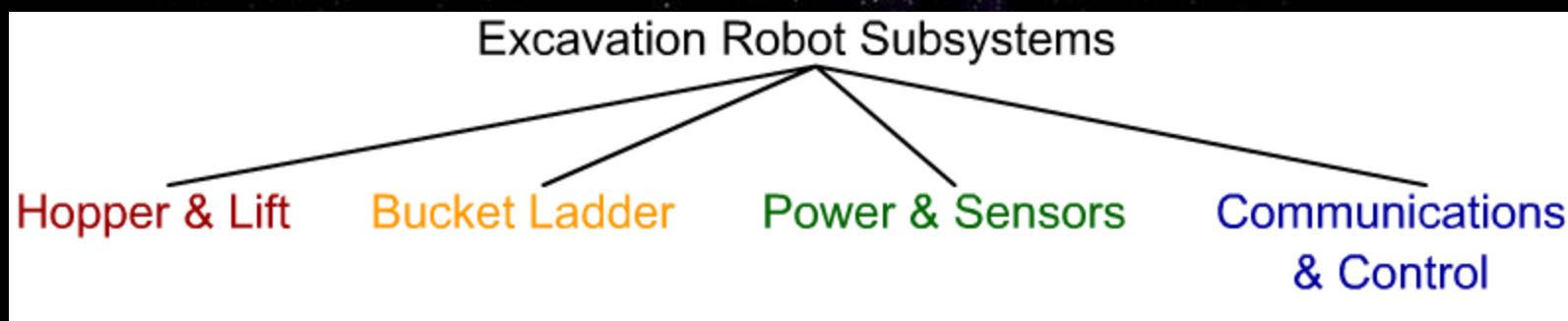


Strategy

- 3 trips
- 90kg each
- 5 min per trip

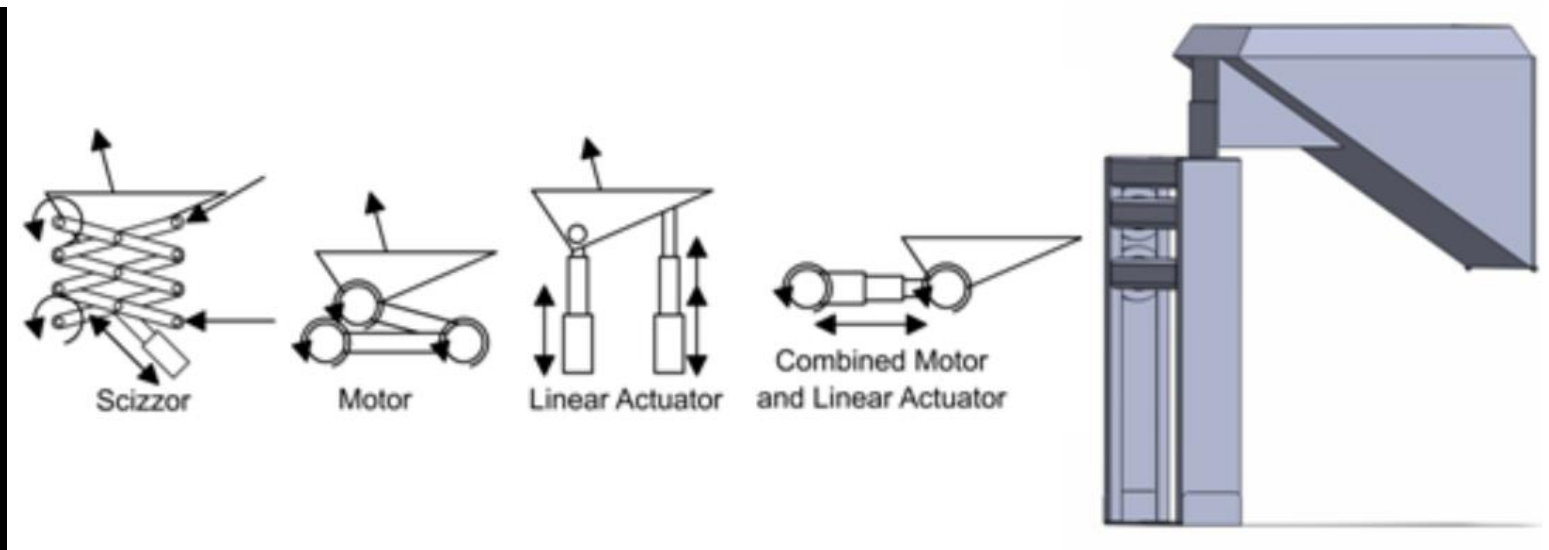
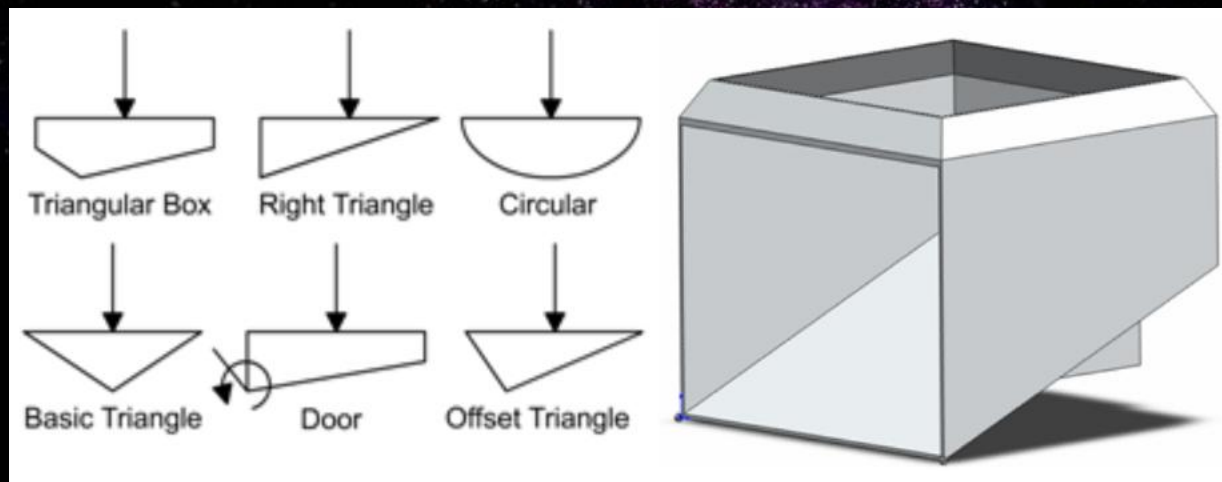


Subsystems

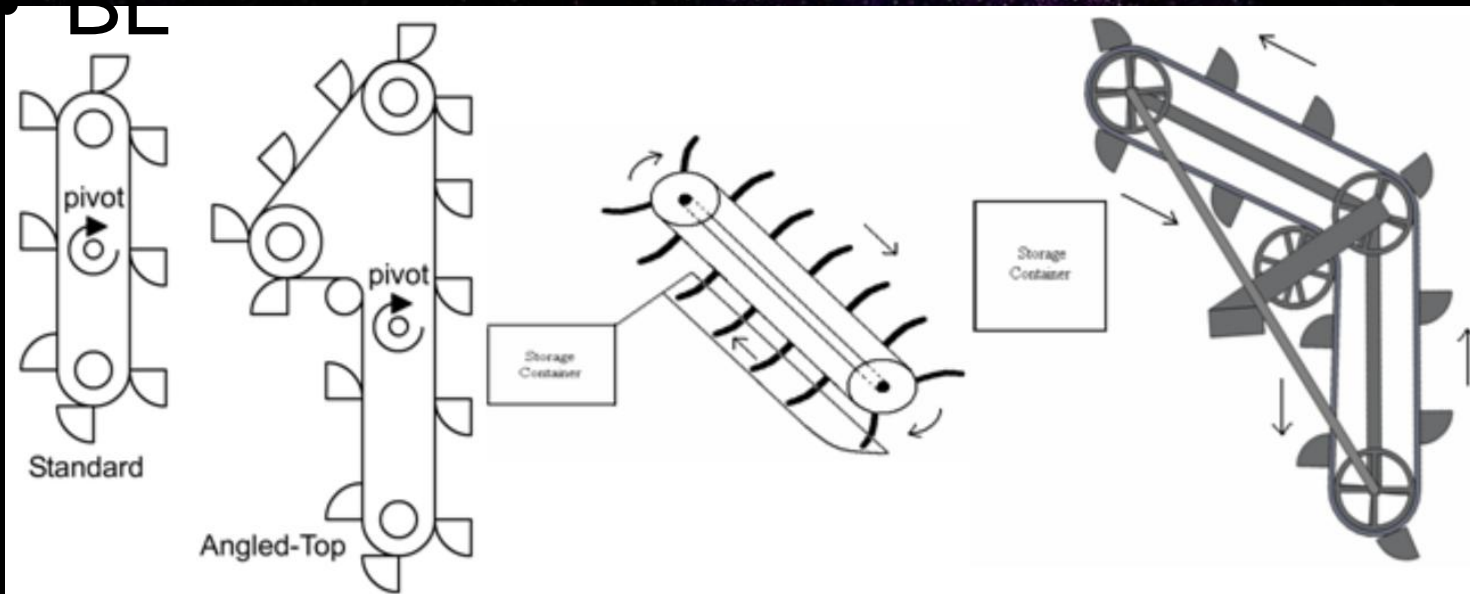


- Work in Parallel
- Interfaces well defined

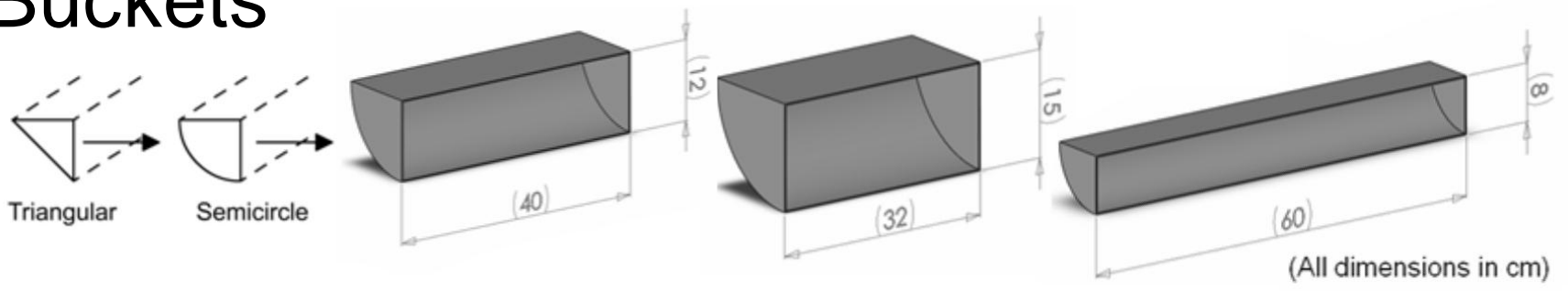
Hopper/Lift Subsystem



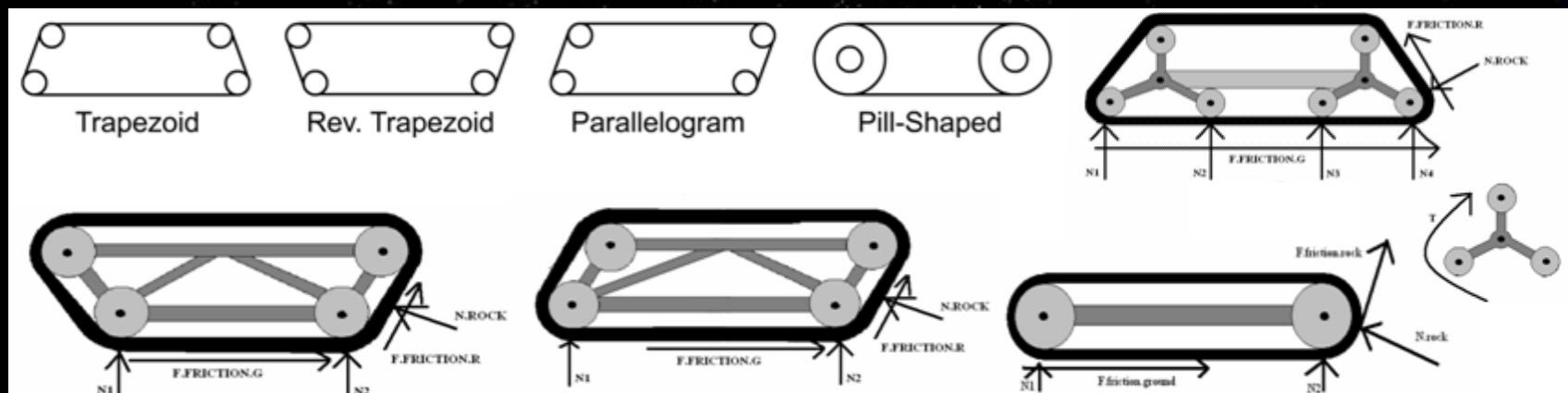
BucketLadder Subsystem



BUCKETS

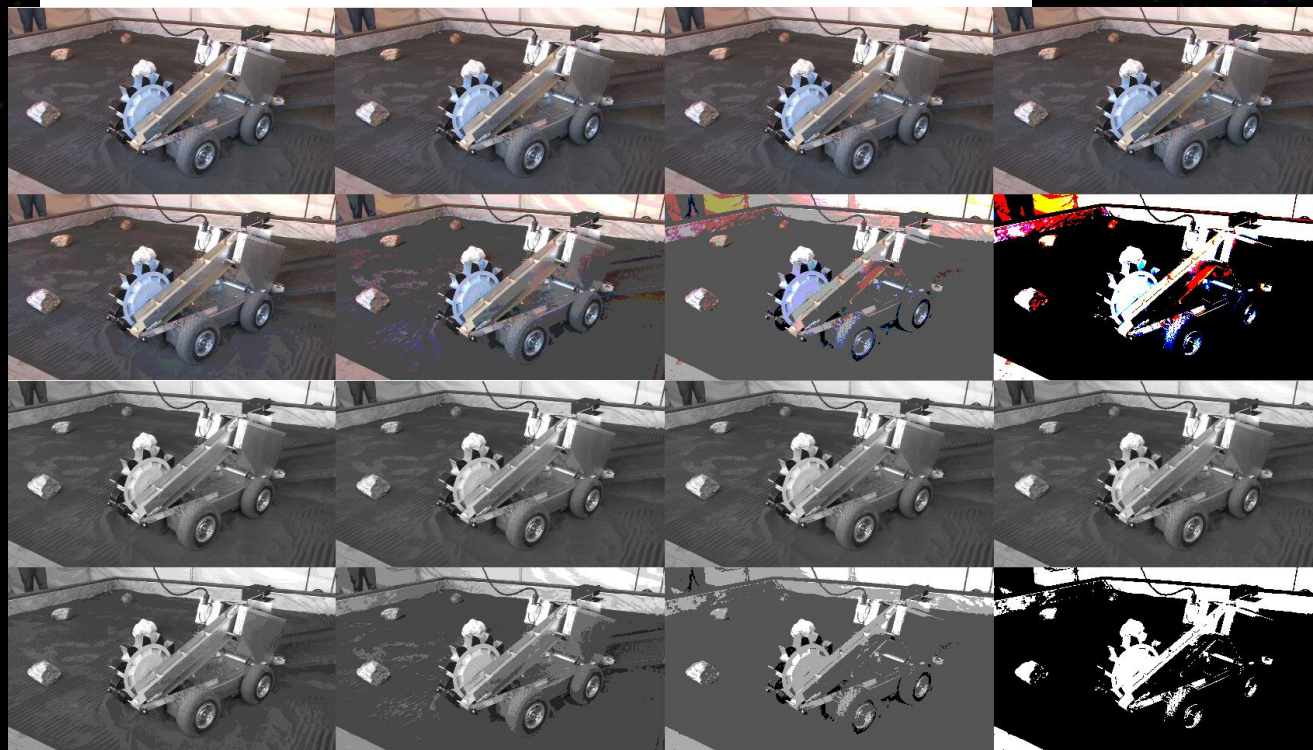
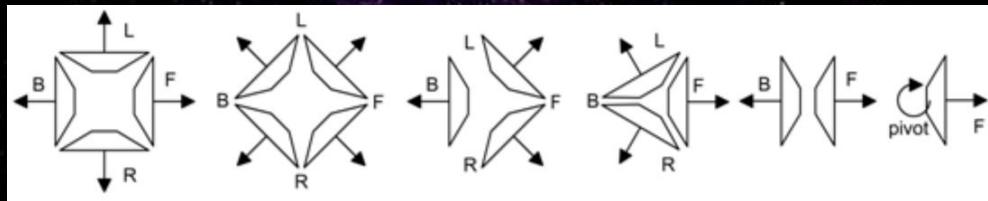


Track/Frame Subsystem



Cameras & Sensors

- Number
- Location
- Data





Communications/Control

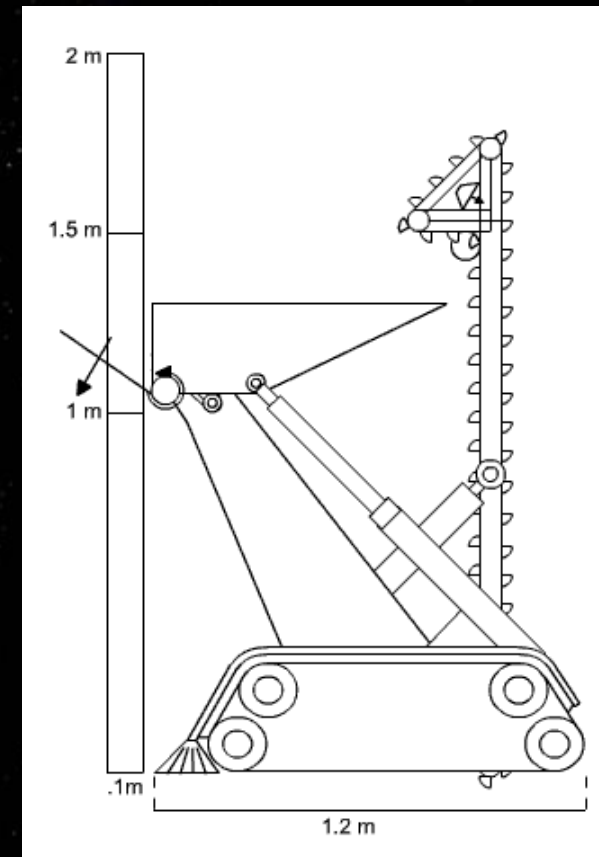
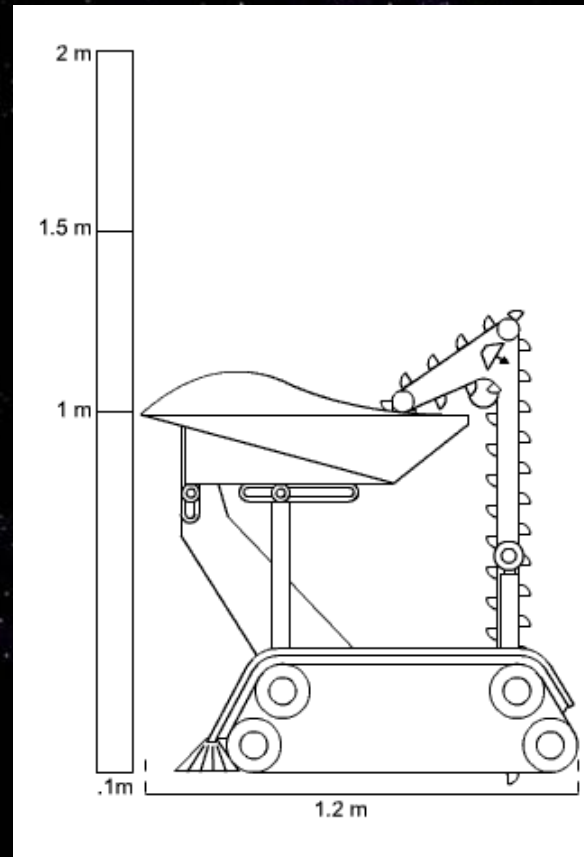
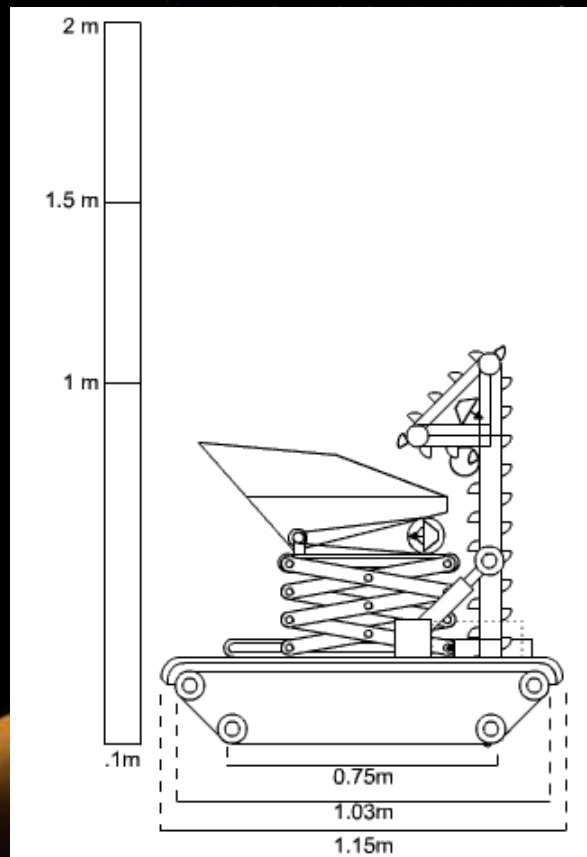
- GUI

Overhead Forward	Overhead Backward	Bucker Ladder Excavation	Deposit Hopper
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mission Time: 15:00:00 <input type="text" value="Zero"/>			
Mbit/s: 2.50 0 <input type="range" value="5"/>			
<div>Focused Cam</div>			
End Sensor: REACHED DEPOSIT BOX			
Bucket Ladder: 0.00 Amps 0.00 Hz +0.10 cm Inc Speed: <input type="text" value="0.10"/> <input type="text" value="++"/> (m/s) <input type="text" value="--"/> <input type="text" value="Zero"/> <input type="text" value="s1"/> <input type="text" value="s2"/> Inc Position: <input type="text" value="0.01"/> <input type="text" value="++"/> (cm) <input type="text" value="--"/> <input type="text" value="Top"/> <input type="text" value="Center"/> <input type="text" value="Bottom"/> ForkLift: 0.00 Amps 0.25 m/s +0.50 m Set Position: <input type="text" value="Obstacle"/> <input type="text" value="Excavate"/> <input type="text" value="Deposit"/> Tracks: 0.50 Amps L 0.10 m/s L 0.50 Amps R 0.10 m/s R Hopper: 90.50 kg			

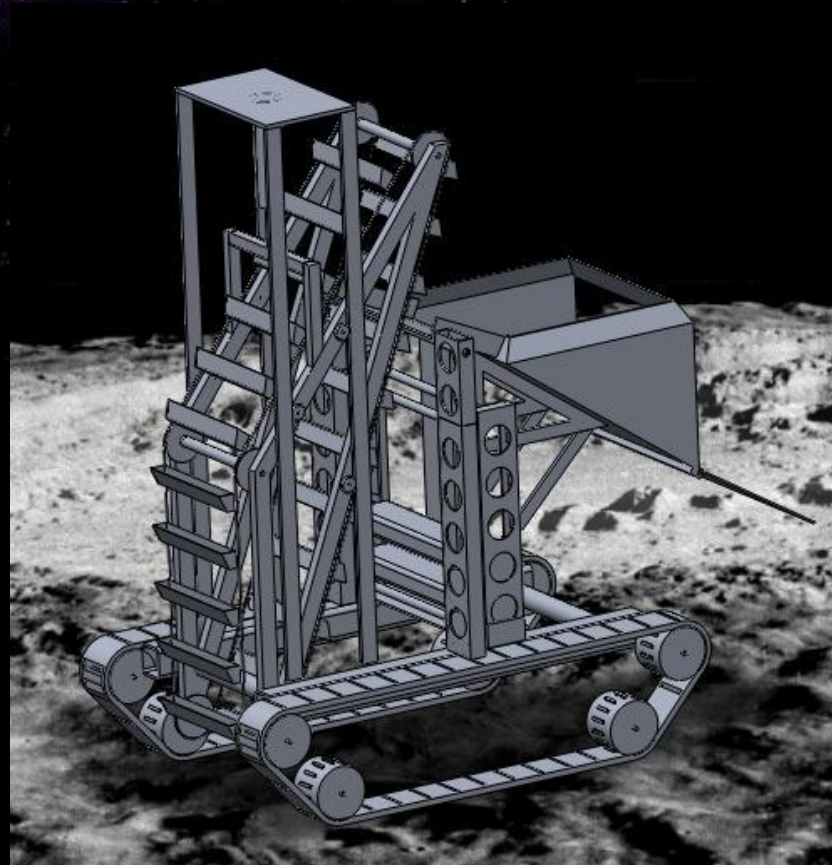
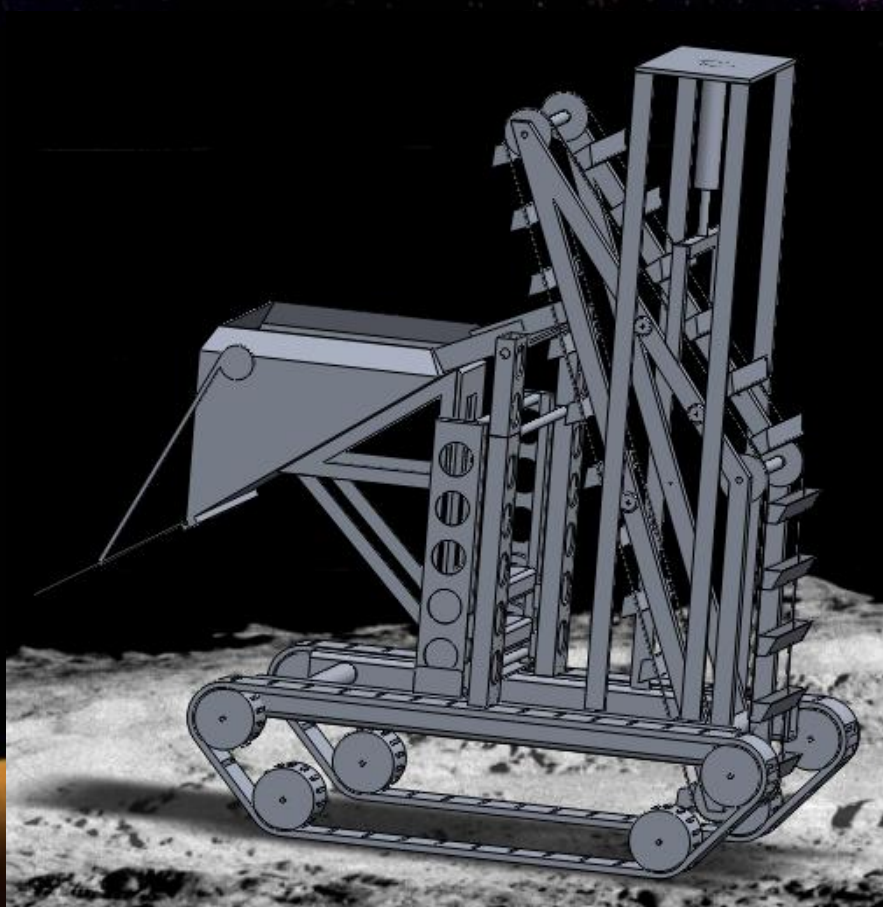
Mission Time: 15:00:00 <input type="text" value="Zero"/>	Overhead Forward	Overhead Backward	Bucker Ladder Excavation	Deposit Hopper	Bucket Ladder: 0.00 Amps 0.00 Hz +0.10 cm Inc Speed: <input type="text" value="0.10"/> <input type="text" value="++"/> (m/s) <input type="text" value="--"/> <input type="text" value="Zero"/> <input type="text" value="s1"/> <input type="text" value="s2"/> Inc Position: <input type="text" value="0.01"/> <input type="text" value="++"/> (cm) <input type="text" value="--"/> <input type="text" value="Top"/> <input type="text" value="Center"/> <input type="text" value="Bottom"/> ForkLift: 0.00 Amps 0.25 m/s +0.50 m Set Position: <input type="text" value="Obstacle"/> <input type="text" value="Excavate"/> <input type="text" value="Deposit"/>
Mbit/s: 4.50 0 <input type="range" value="5"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<div>Focused Cam 1</div>	Tracks: 0.50 Amps L 0.10 m/s L 0.50 Amps R 0.10 m/s R Hopper: 90.50 kg			<div>Focused Cam 2</div>	
End Sensor: REACHED DEPOSIT BOX					

Sensor List 1:

Design History

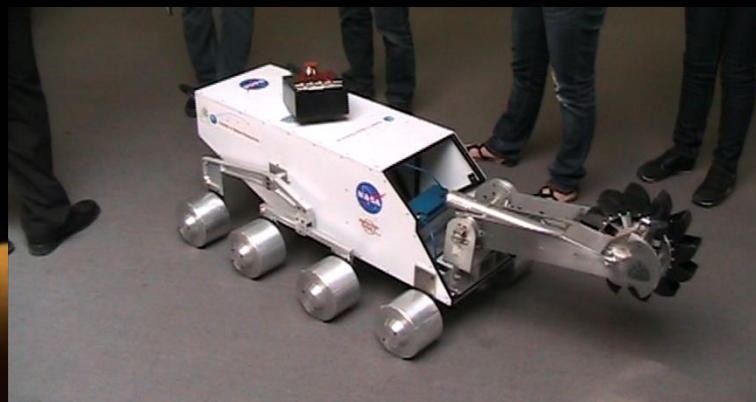


Design History

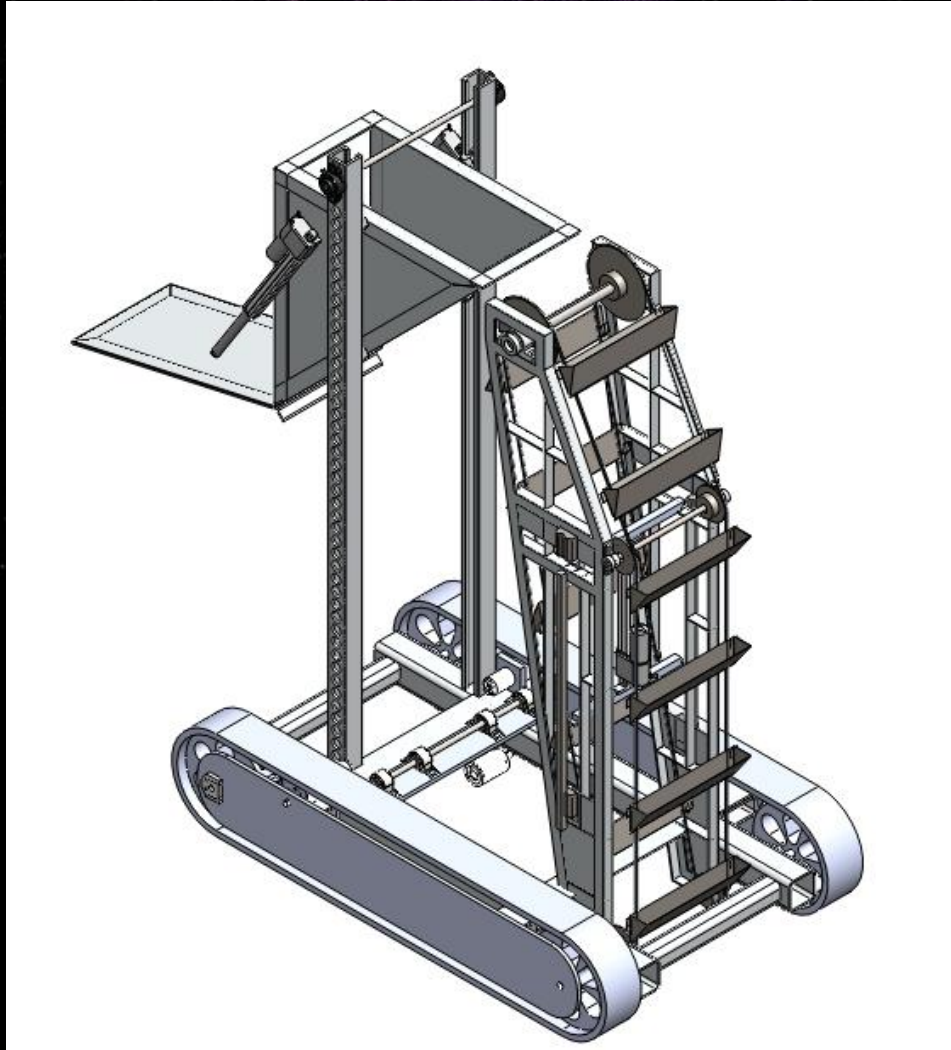




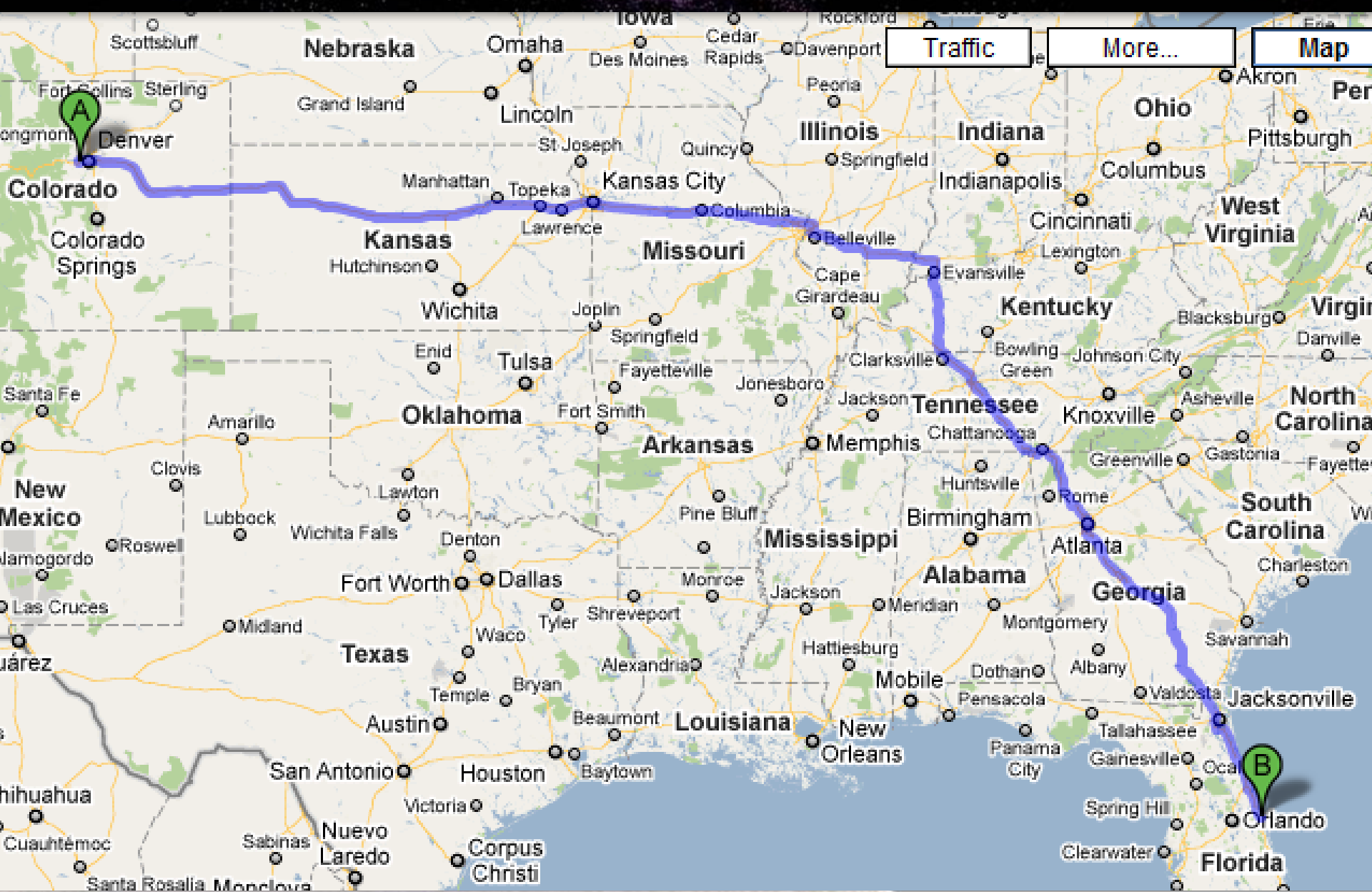
Outreach Project



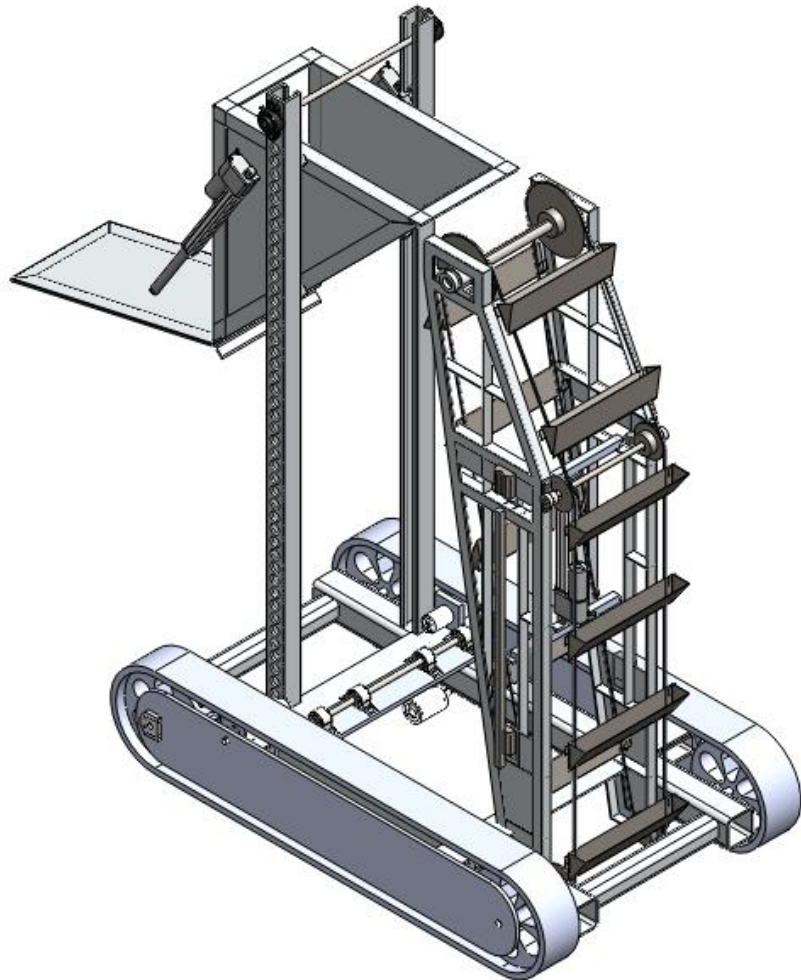
Critical (Final) Design



34 hrs later...



Critical (Final) Design



- After arrival at KSC:
 - Put robot together from parts
 - Eliminated 9kg – put together again (79.8 kg)
 - Fixed numerous electronic issues
 - Typo's in run 1 (SSID)
 - Replaced motor driver (graciously supplied by other team)
 - Communication problems with router during run 2 (probably due to condensation)

Astronaut Hall of Fame (astronaut experience)



Robot and team







Results

- Learned a lot
- Made good friends with other universities
- Had good fun
- Did not sleep much
- Creative manufacturing
- Saw Atlantis return, Saw rocket launch, visitor center, KSC tour
- Will try to participate again in 2011



Questions?