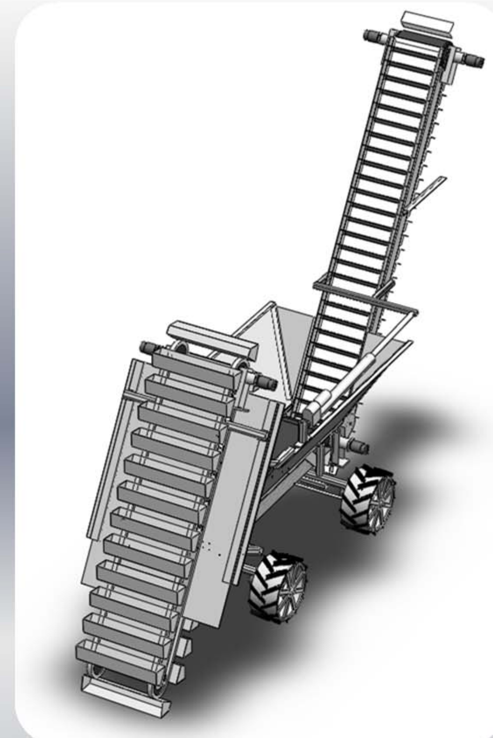

Laurentian University Lunabot

2nd Annual Joint PTMSS/SRR
Ottawa

June 19-22 2011

Greg Lakanen

Laurentian University

Located in Sudbury, Ontario, Canada

- ~200 miles North of Toronto
- Student population 9000+
- Campus surrounded by 5 lakes and Conservation area
- Strong expertise in fields such as business, engineering, health, and environmental studies
- 1st cohort of mechanical engineering graduated in spring of 2011

Acknowledgments

Professional Engineers Ontario

NORCAT
NORTHERN CENTRE FOR ADVANCED TECHNOLOGY INC.

NASA

EVC

The Team

Team Production:
Samuel Carrière
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Myles Chisholm
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Jeffrey Pagnutti
Jean-Sebastien Sonier

Academic Advisor:
Markus Timusk
Gregory Dalton

Team Production?

- Heavy Machinery
- Industry Outlook
- Mining Heritage

1. PURPOSE

Purpose – The Lunabotics Mining Competition

NASA's Lunabotics Mining Competition

- Is designed to engage and retain students in science, technology, engineering and mathematics (STEM)
- Encourages the development of innovative lunar excavation concepts
- Develops clever ideas and solutions which could be applied to actual lunar excavation device or payload

TEAM PRODUCTION

- LU's Mechanical Engineering program looked for a challenge for its first cohort
- Year long project with a focus on design rather than re-work
- Build on the team's expertise: hands-on experience and extensive CAD knowledge

2. CHALLENGE

Problem Statement

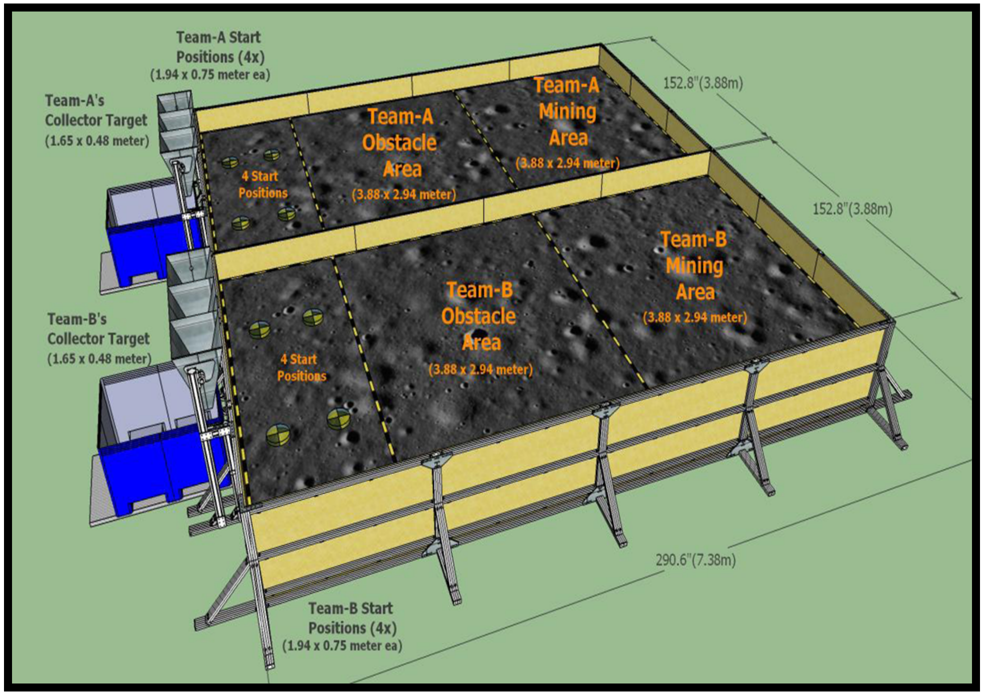
Design and build a remote controlled or autonomous excavator, called a Lunabot, that can collect and deposit a maximum amount of lunar simulant within 15 minutes.

Challenges imposed by NASA include:

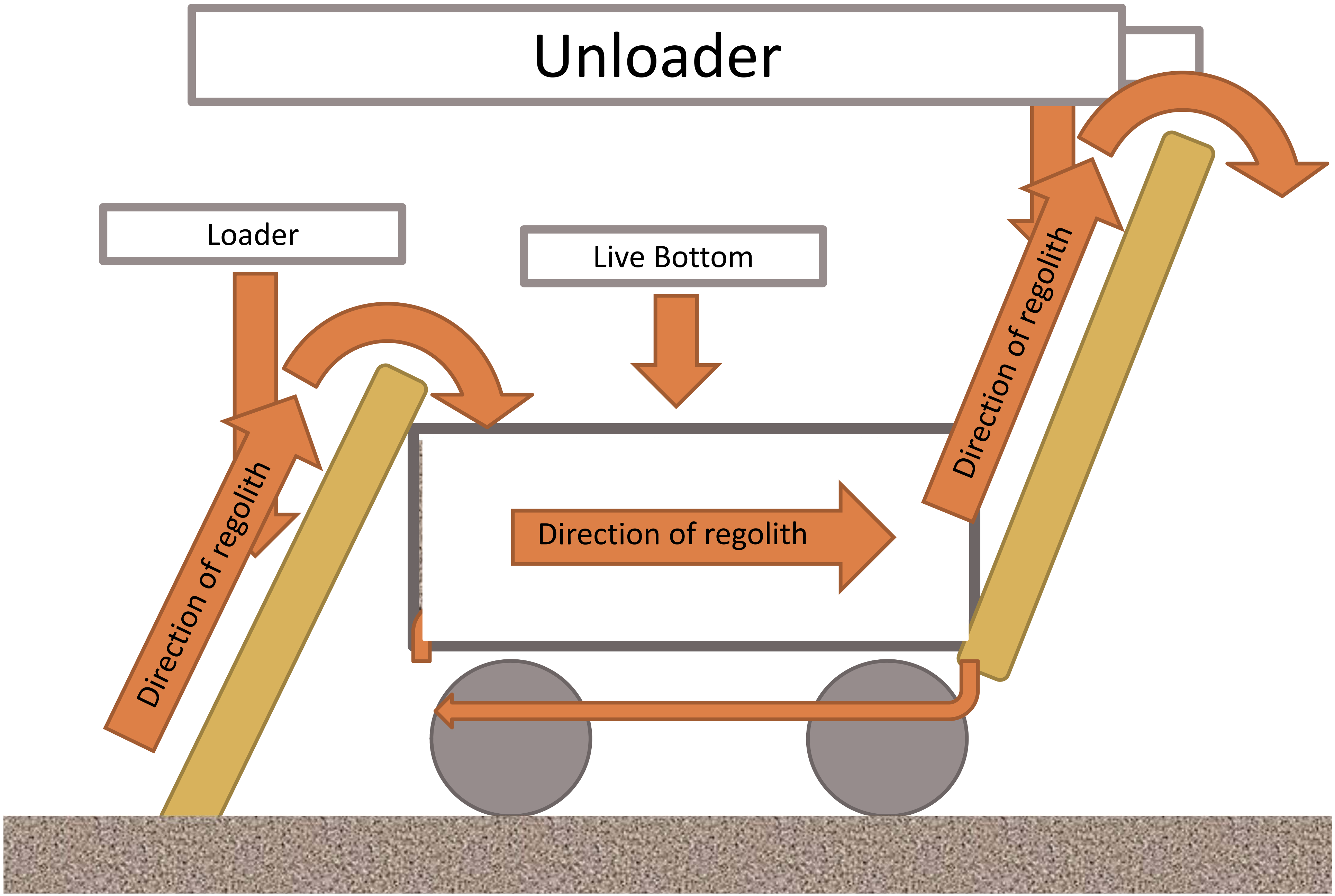
- Simulant with abrasive properties (BP-1)
- Work envelope of lunabot limited to 1.5m x 0.75m x 2m at start-up
- Lunabot mass must not exceed 80 kg
- Lunabot must be controlled tele-robotically
- 1 channel of network in use, operating at an average below 5 Mbps
- Cannot alter the chemical or physical properties of the simulant

Challenges Imposed by Team Production

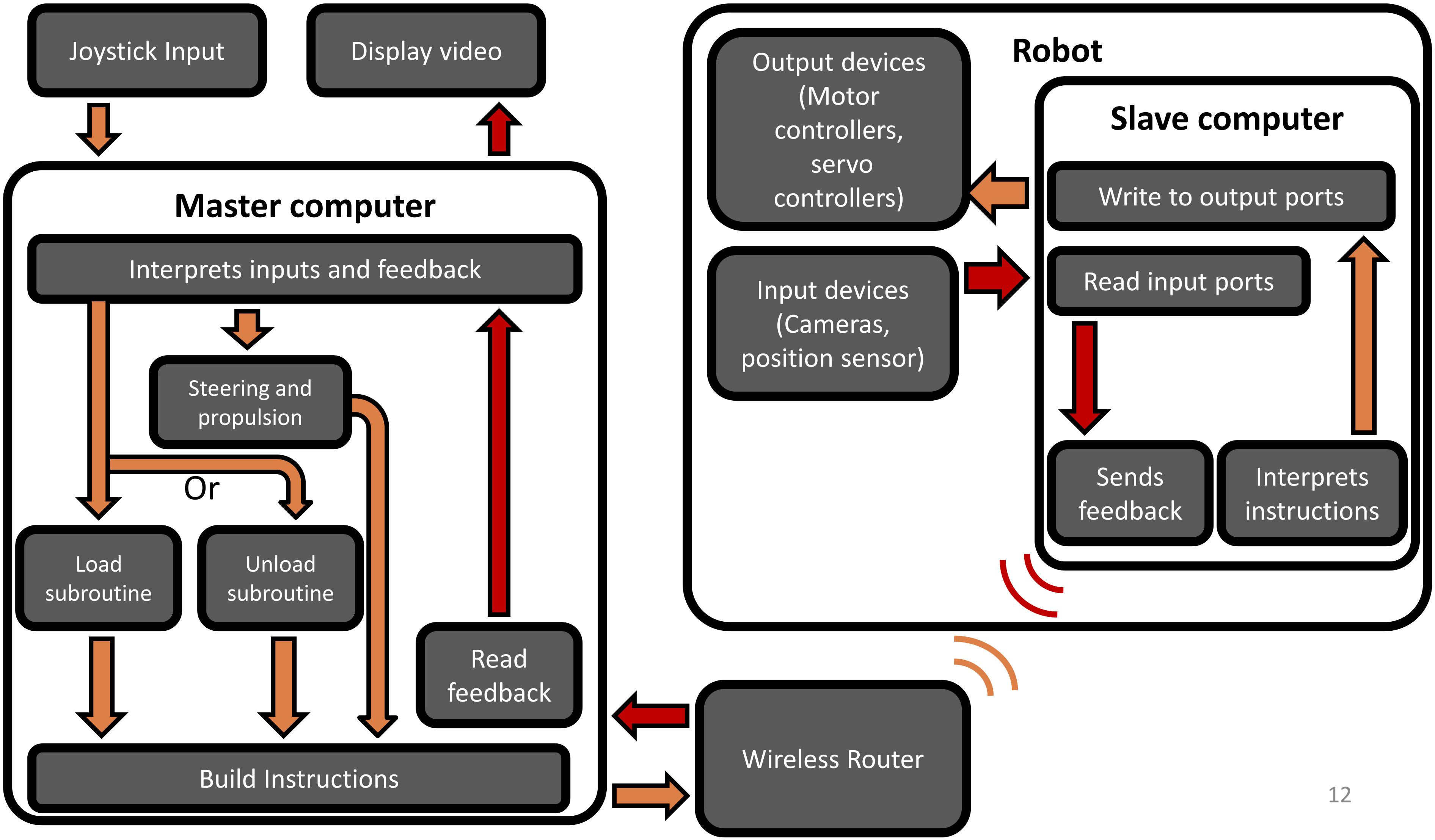
- Must be able to haul 80 kg in one trip
- Must run without any short term mechanical problems



3. THEORY OF OPERATION


Unloader
Loader
Live Bottom
Direction of regolith
Direction of regolith
Direction of regolith

Communications

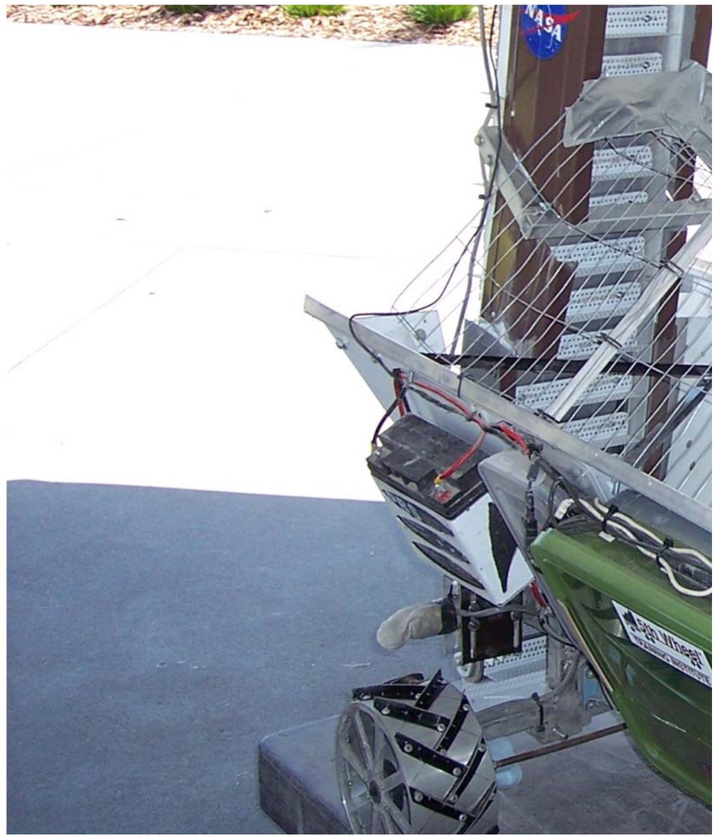


4. DESIGN PROCESS

Design Requirements

- Maximize each load transported from mining area to hopper
- Use as many off the shelf components as possible to allow for quick repair and modification
- Keep costs low while maintaining quality
- Components must be as lightweight as possible to minimize impacts on the overall mass to allow for final add-ons/adjustments
- Maintain low center of gravity to remain stable

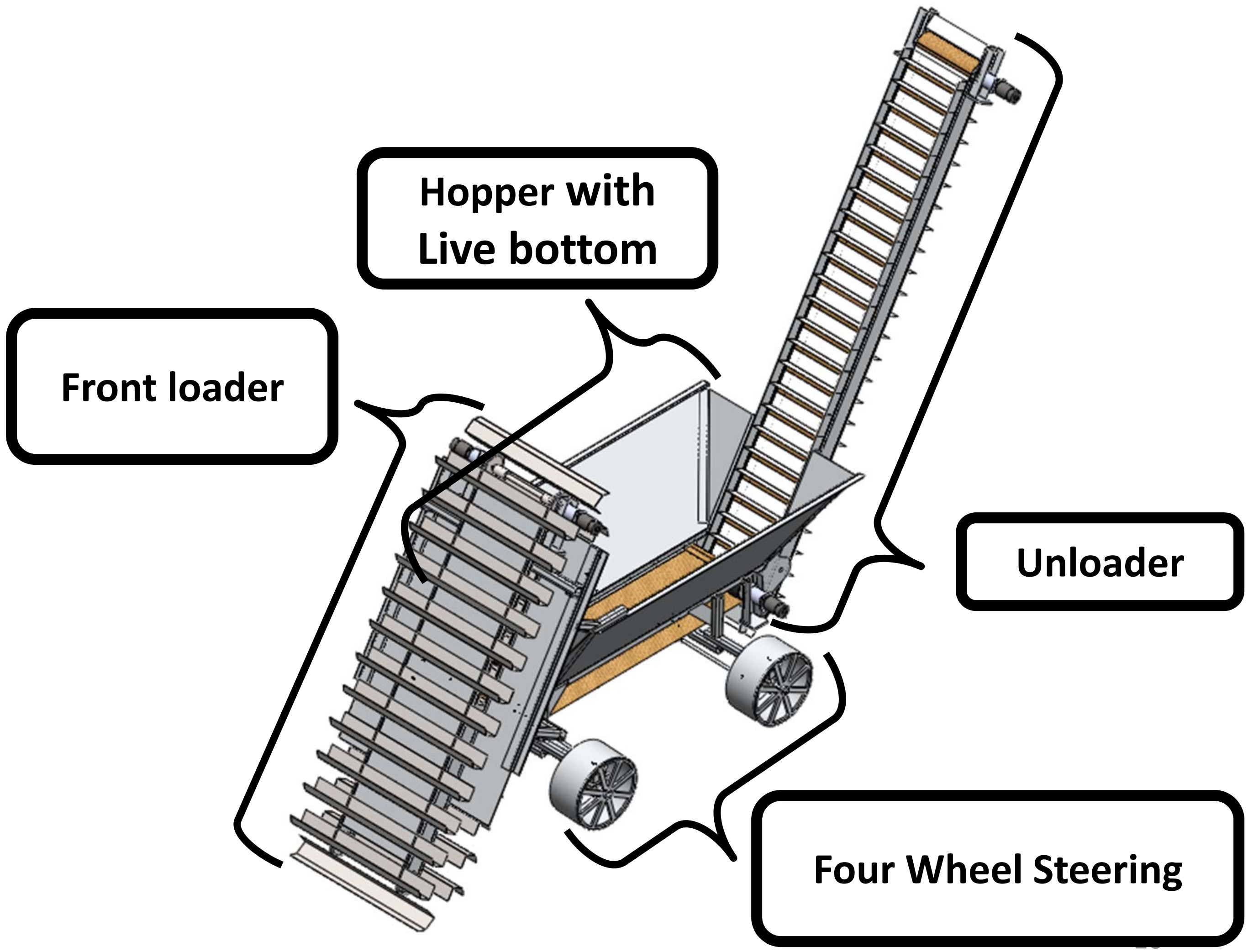
Baby Socks?



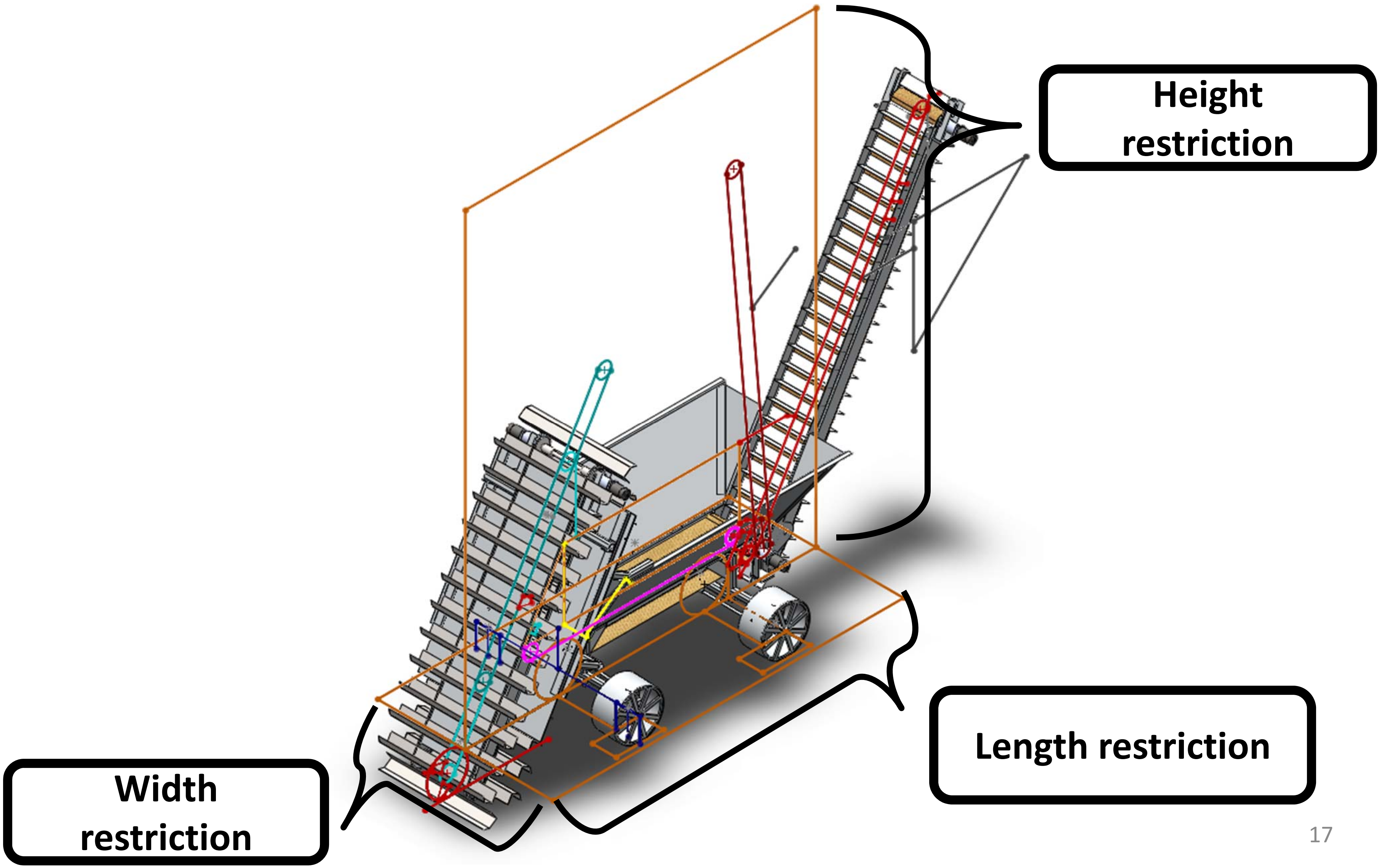
Preliminary Solid Model

Unique features:

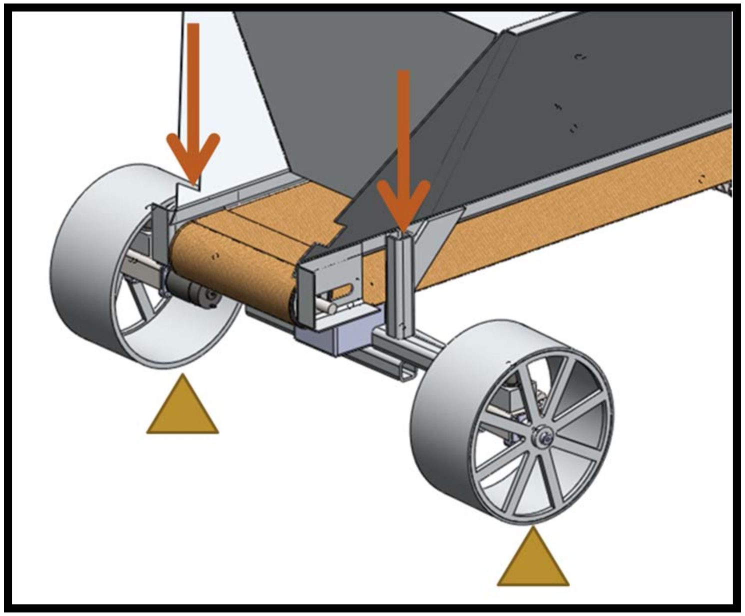
- Unibody construction
- Live bottom technology
- Four wheel steering with crab option
- Unfolds beyond work envelope



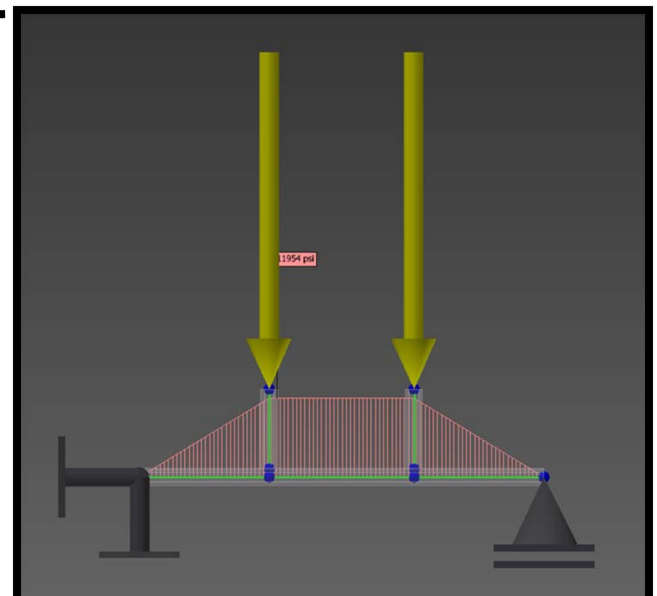
Advanced Modeling Technique



FEA on Front Axle



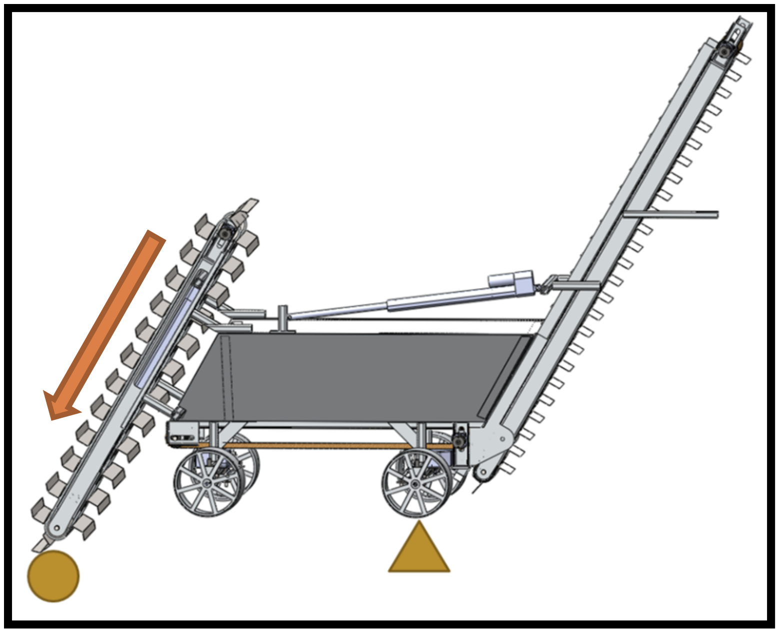
Loading condition
120 Kg load + 80 Kg Lunabot



1” x 1” x 1/8” 1060 T6 aluminum tubing

Yield strength= 27 000 psi
Smax = 11 954 psi
Safety Factor = 2.3

Front Actuator Force



A earthmover must be able to pick up its front end with the digging implement

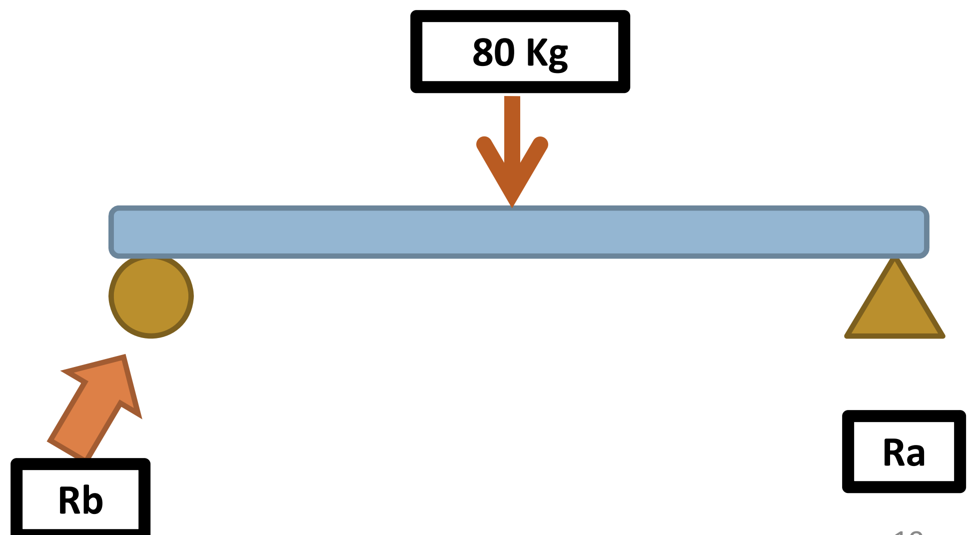
Force required to lift front end is 784 N

Linear actuator is capable of 2374 N

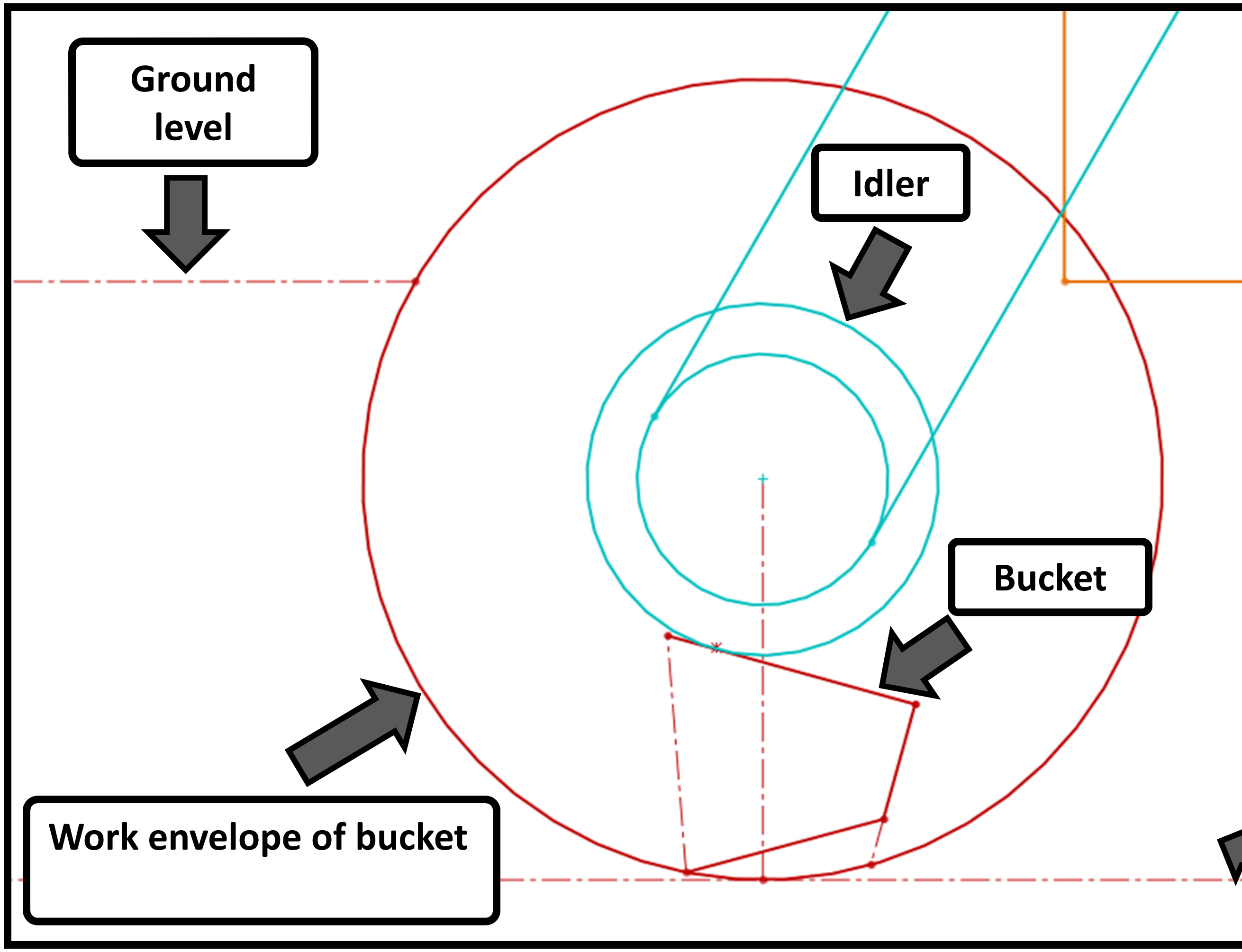
SF of 3

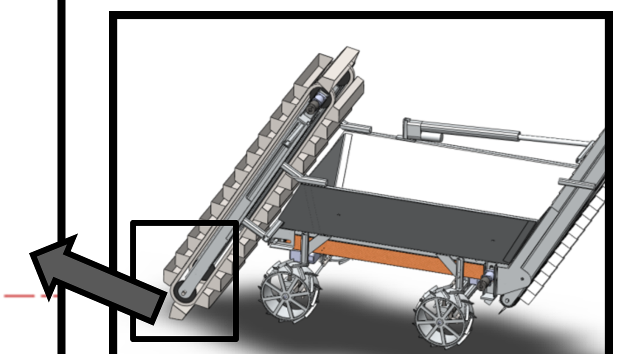
Forces: 784 N (80 Kg) Lunabot

Actuator angle: 60˚

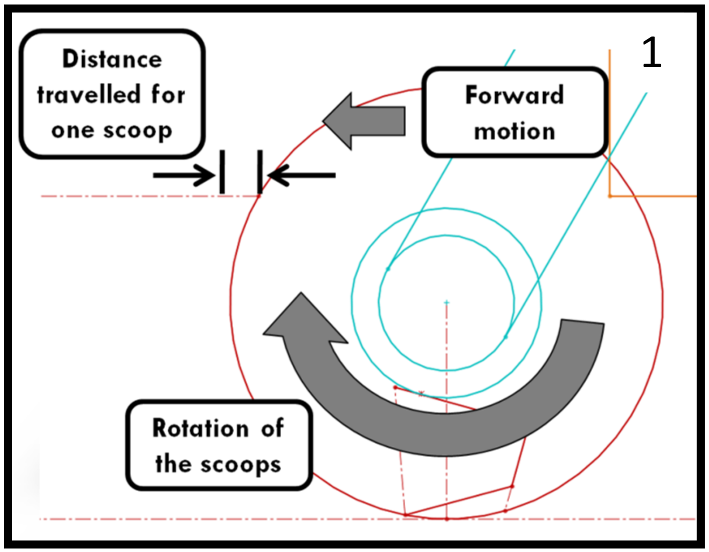


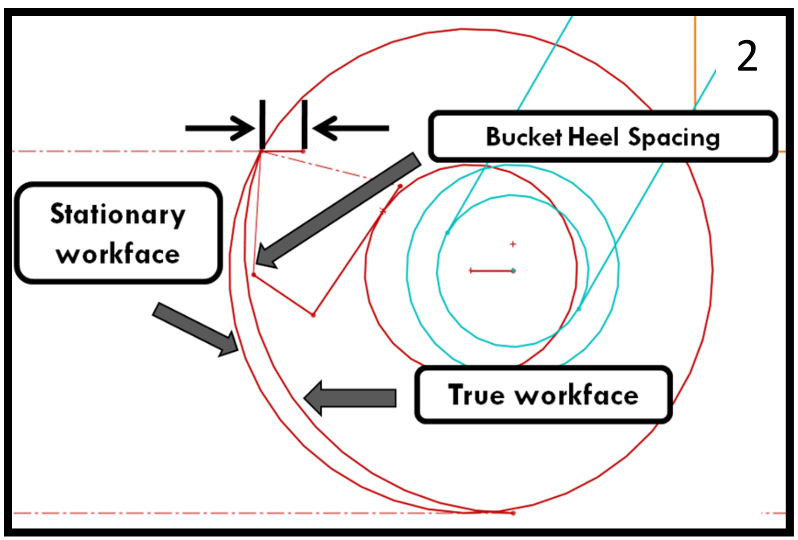
Bucket Design

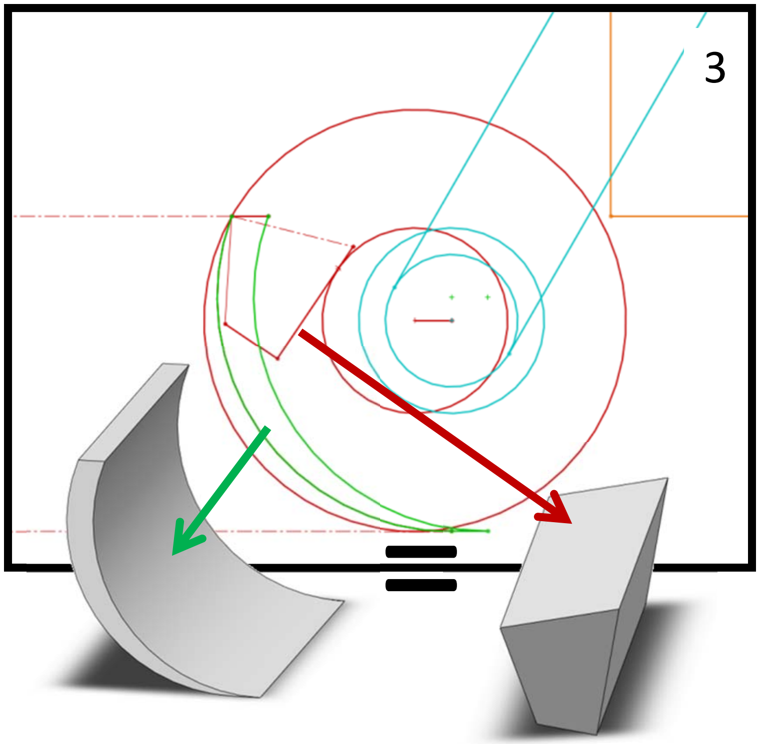




Bucket Design

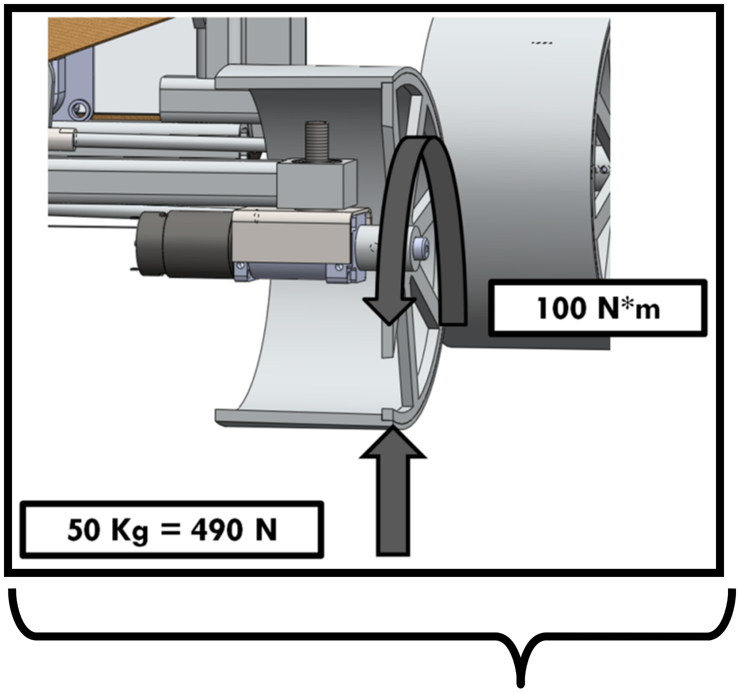


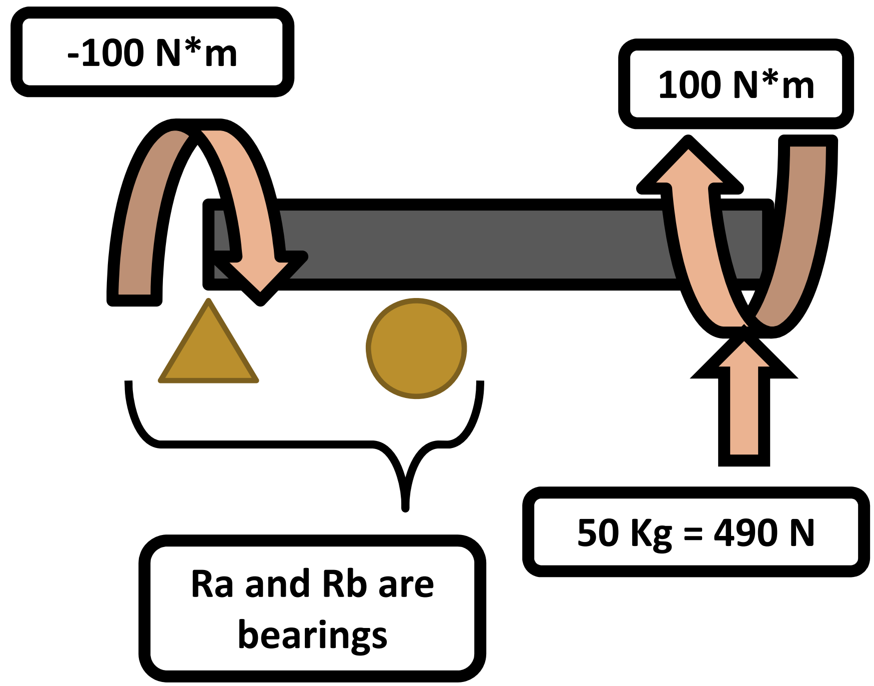




A true workface was calculated. This permitted the bucket heel setback to be determined.

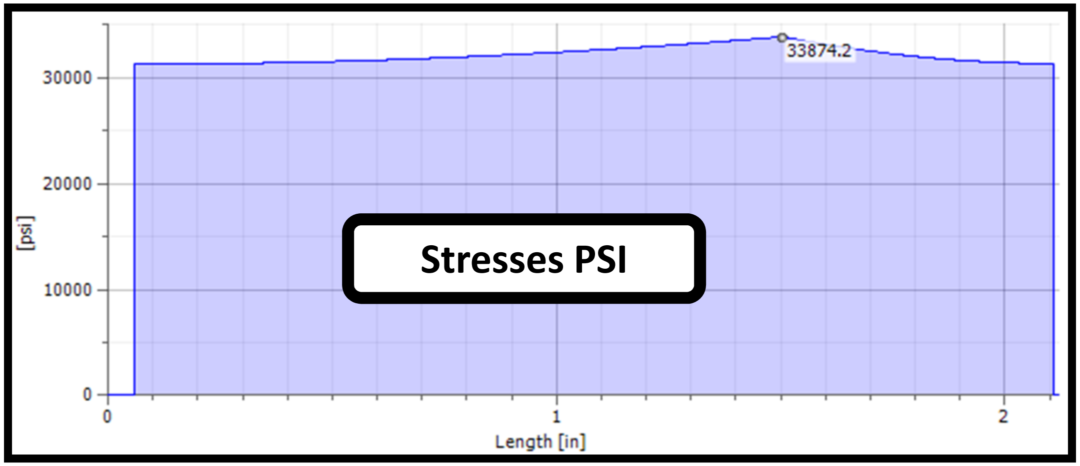
Forces Acting on the Axle Output Shaft





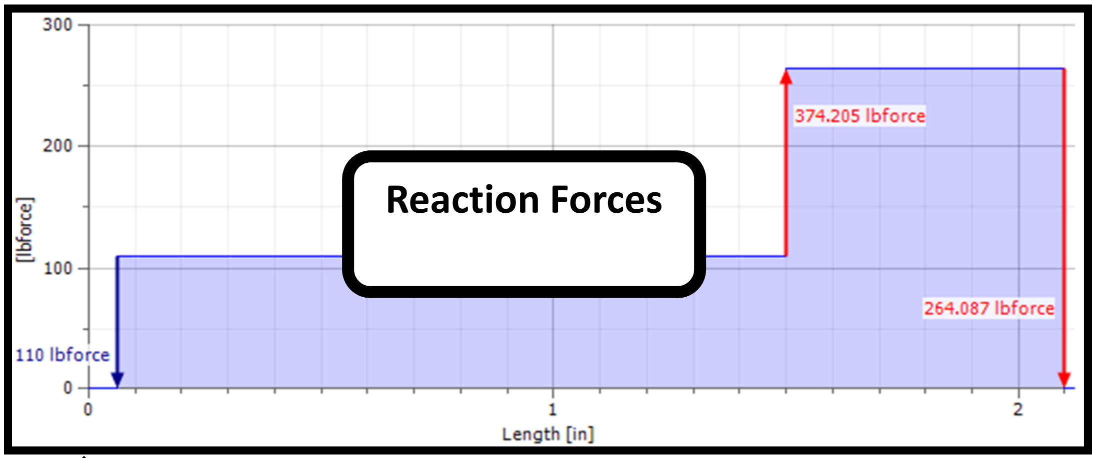
Loading condition:
(120 Kg load + 80 Kg Lunabot)/4 wheels.

Forces Acting on the Axle Output Shaft



Yield Strength = 116 Ksi
Stress in Shaft = 34 Ksi

SF = 3.4



Load rating on R8 bearing is 500 Lbs

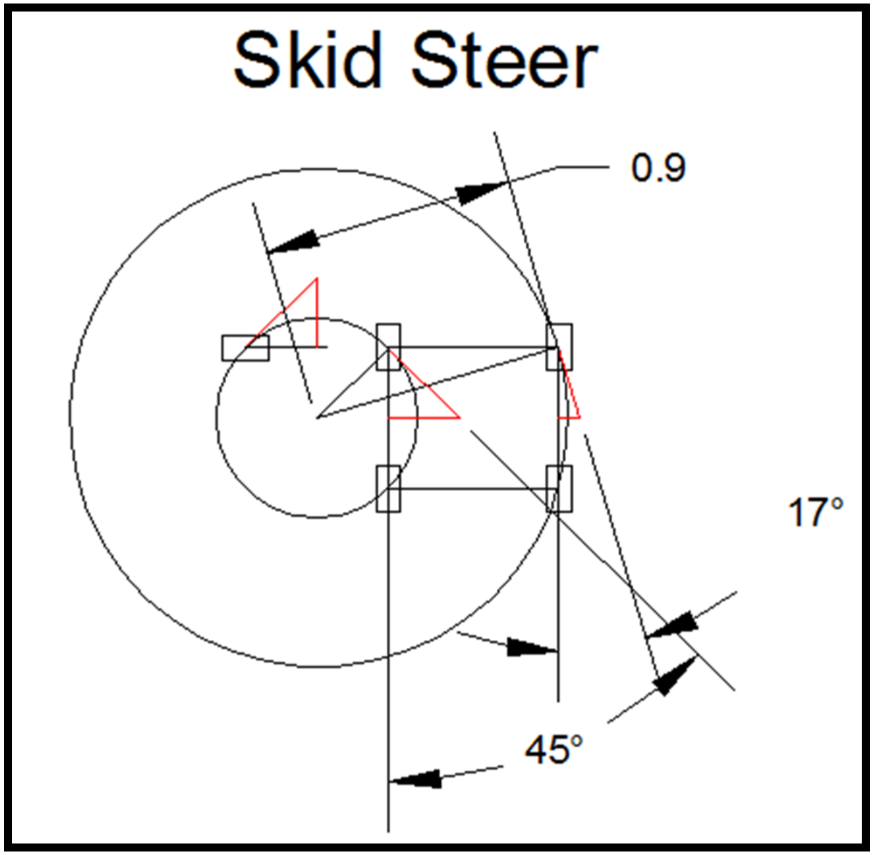
SF = 1.33

Output shaft end

Bearing location

Four Wheel Steer

The skid steer design was idealized because it is difficult to know how much the wheels will dig into the ground during a turn.



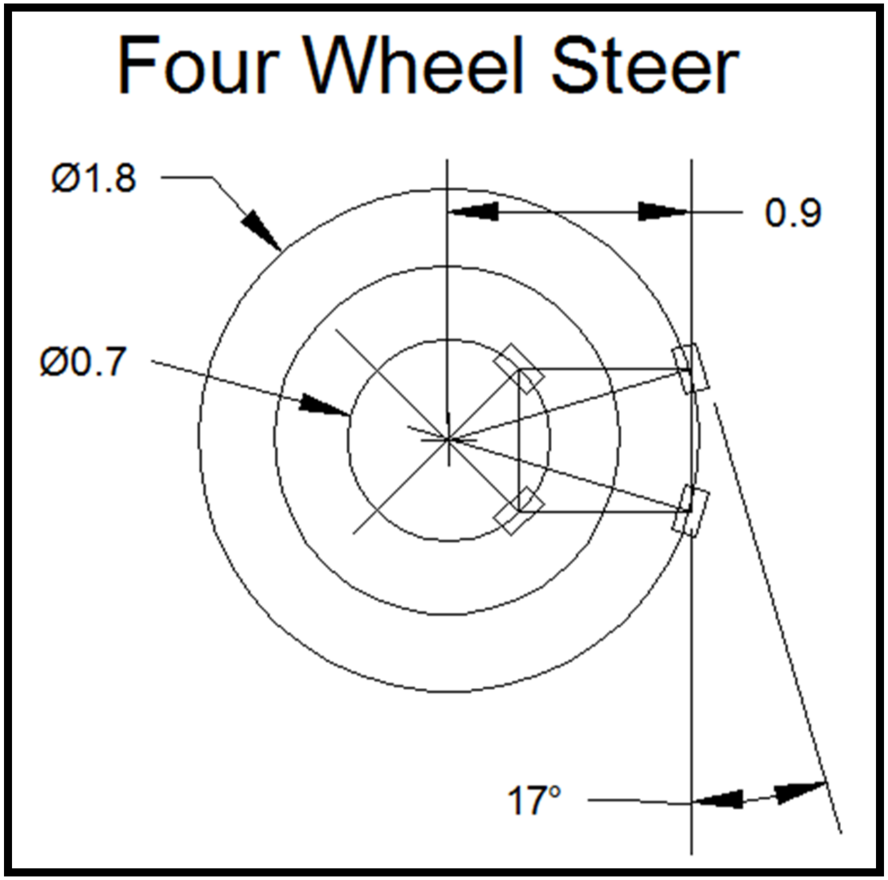
- The vectors were decomposed and only the vector perpendicular to the wheel was considered to generate the skid

For a 0.9 meter radius turn,

6.4 meter of skid

Four Wheel Steer

The four wheel steer design was considered to have all the wheels turning at the same rate.



- The distance difference between the inner wheels and the outer wheels generates the skid

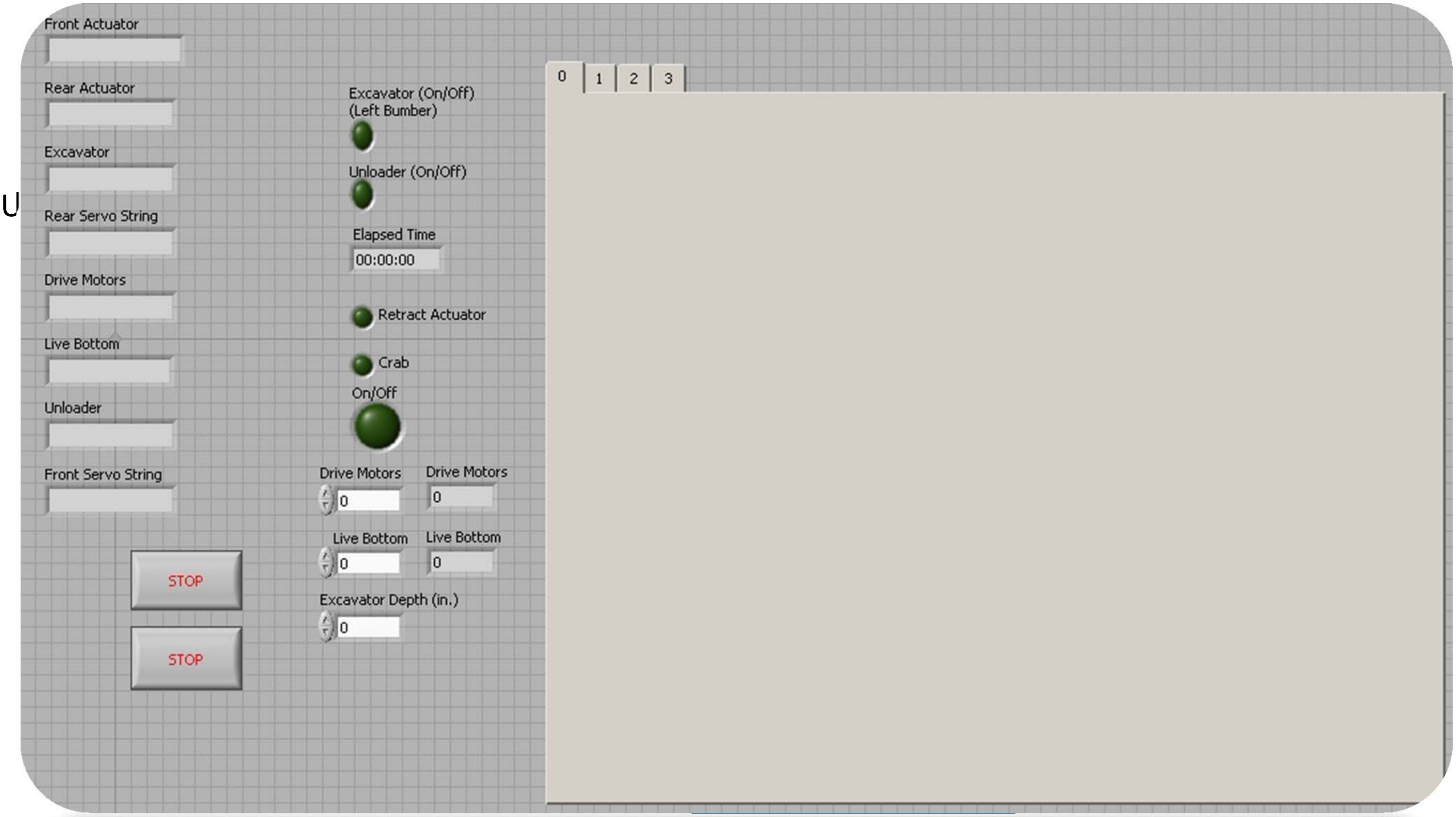
For a 0.9 meter radius turn,

3.44 meter of skid

The Four wheel steer design has a reduction of 190% skid. This analysis is only correct for hard surfaces. In reality under loaded condition with soft soil the skid steer design would dig in and generate substantially increased turning resistance.

Software Architecture
Manual Operation

U



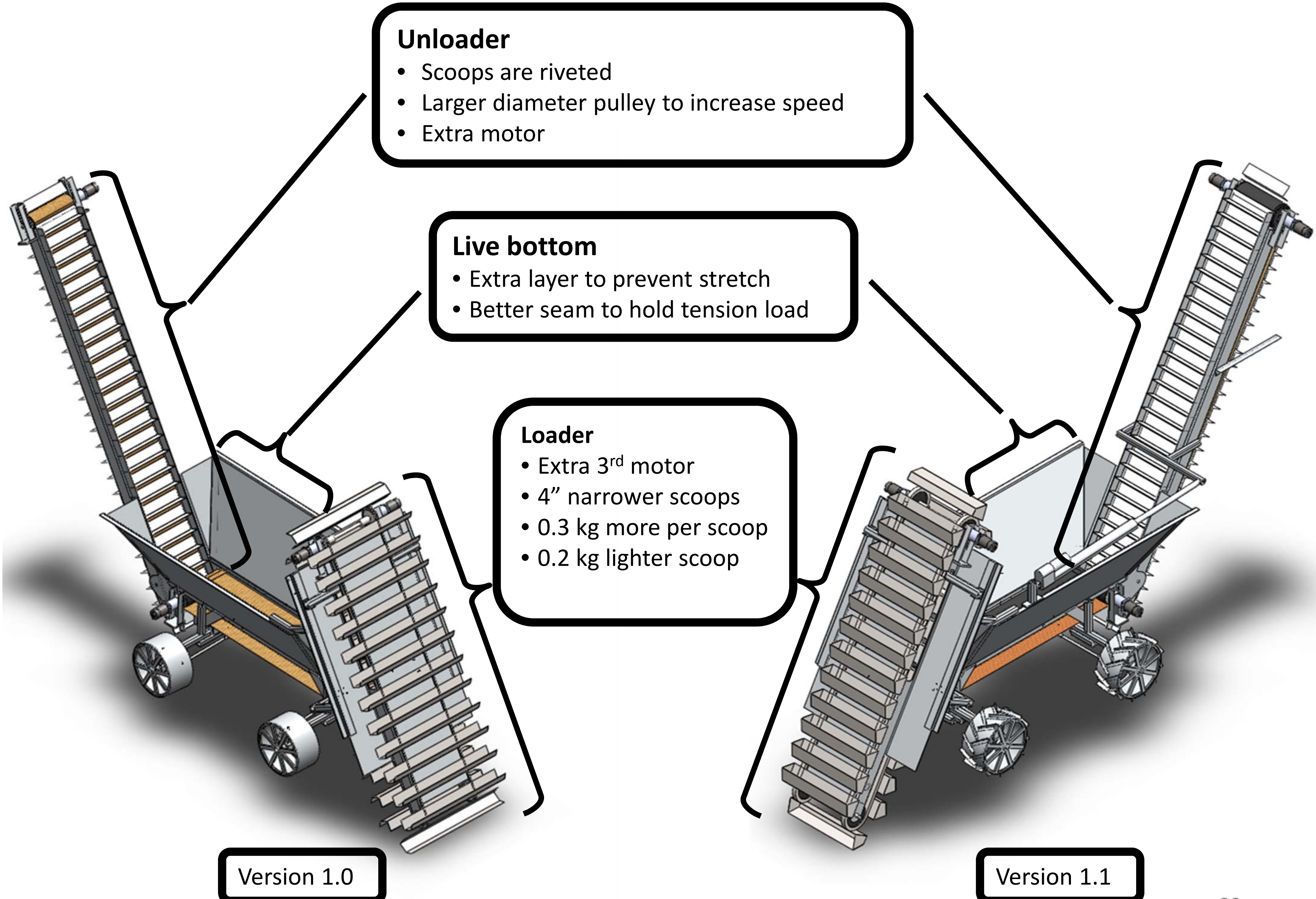
Software Architecture
Autonomous Operation

E

Autonomous Control

Acquire Front Actuator Feedback	Convert String to Number	Condition Feedback	Initialize Automatic Digging Sequence	Trigger Live Bottom Speed

5. MODIFICATIONS


Unloader
• Scoops are riveted
• Larger diameter pulley to increase speed
• Extra motor
Live bottom
• Extra layer to prevent stretch
• Better seam to hold tension load
Loader
• Extra 3rd motor
• 4” narrower scoops
• 0.3 kg more per scoop
• 0.2 kg lighter scoop
Version 1.0
Version 1.1

6. TESTING

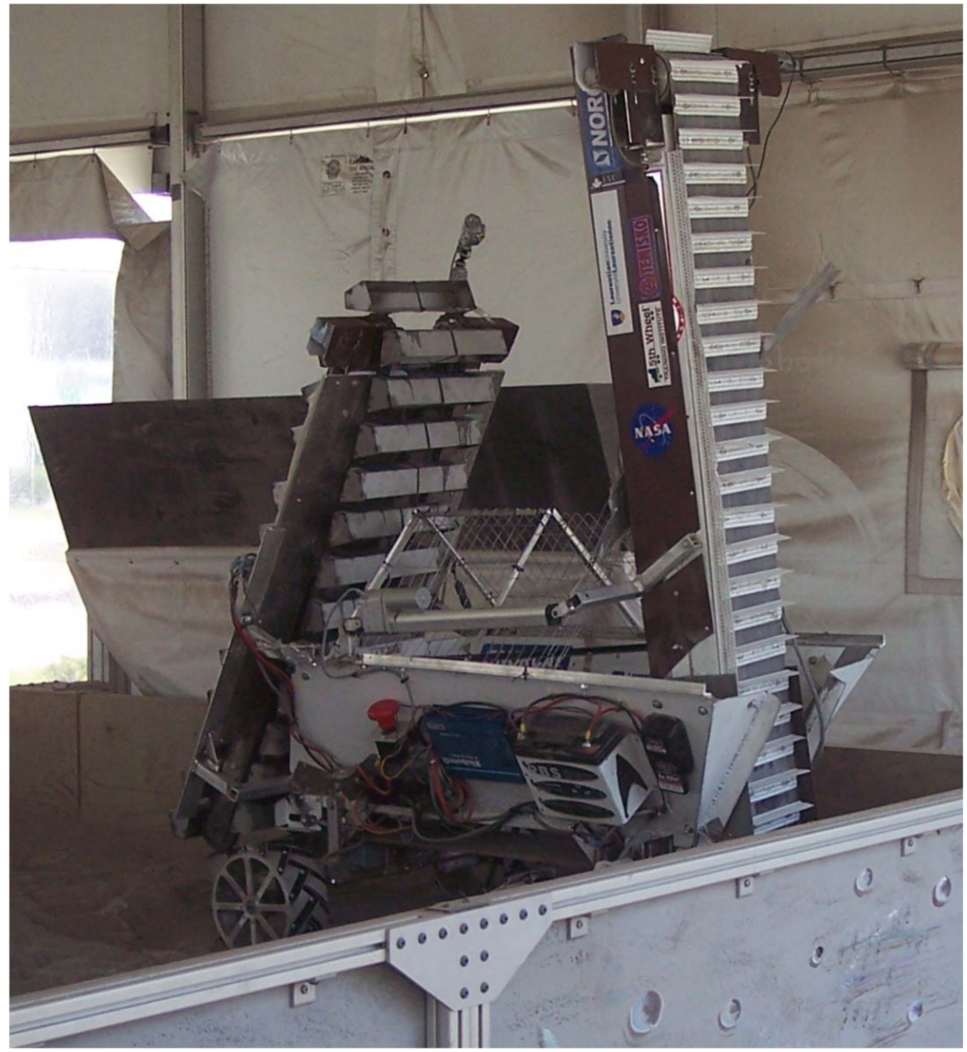
Excavation Trials

- First excavation yielded 80kg
- Best result: 137kg taking 90 seconds to excavate and 70 seconds to unload.
- Optimal digging depth of 6” in test bed

7. FINAL MODIFICATIONS

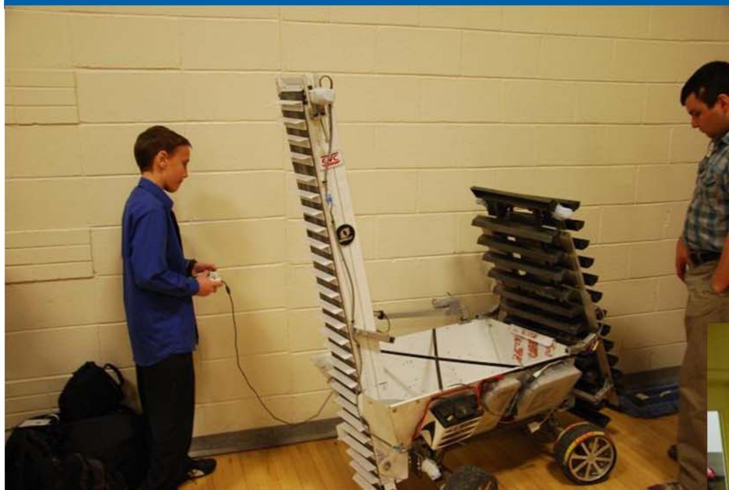
Final Modifications

- Fascia on rear unloader
- Chicken wire sieve
- 2’’ digging depth



Competition Run

Outreach



8. CONCLUSION

Conclusion

- Great Competition
- Technical Changes next year?

Questions?