Modeling and Simulation of a Mobile Robot for Polar Environments

Thesis Presented by Eric Akers

October 20, 2003

Committee Chair – Professor Agah

Committee Member – Professor Minden

Committee Member – Professor James

Overview

- Introduction
  - PRISM
  - Goal of this thesis
  - Modeling and Simulations
- Model and Design
- Experiments
- Results
- Conclusions

Introduction
PRISM

- Polar Radar for Ice Sheet Measurements
- Goal
  - Measure ice thickness
  - Determine bedrock condition beneath ice sheets
- SAR (synthetic aperture radar) gives a 2D picture
  - Monostatic or bistatic mode

Introduction
PRISM

- Autonomous rover carries necessary radar equipment and antenna
  - Survive for extended periods of time
  - Navigate in sometimes harsh arctic terrain
- Many areas of research involved
  - Robotics
  - Radar
  - Geology
  - Artificial intelligence

Introduction
Goal

- Build an accurate model of the rover
- Test the model to determine how the rover performs and some safe running parameters
  - Knowledge required to keep the rover running for long periods of time

Introduction
Modeling and Simulations

- Modeling Software
  - MSC.visualNastran 4D
  - ADAMS
  - Mechanical Desktop
  - SolidWorks
  - Solid Edge
- Simulation Software
  - MSC.visualNastran 4D
  - ADAMS
  - Khepera and Webots
  - RoboCup

Introduction
Modeling and Simulations

- Related Works
  - Modeling of a Snow Track Vehicle
    - University of Perugia
    - Test and improve on design of snow cat vehicles
  - Simulation of a Three-Wheeled All Terrain Vehicle
    - University of Arkansas
    - Demonstrate handling and suspension of three-wheeled ATVs

Introduction
Modeling and Simulations

- Related Works (continued)
  - Modeling Tracked Vehicles Using Vibration Modes
    - University of Michigan
    - Predict durability of track and the vibration inside the vehicle caused by the track

Model and Design

- Several different versions of the model were created as the design of the rover changed
  - Rover base
  - Wheel and track version
  - Roll cage and completely enclosed frame

Model and Design

- Design objective
  - Dimensions, weight, weight distribution as accurate as possible
  - Specifications manual and measurements
- Problems
  - Weight distribution not completely known
  - Where unknown, equal distribution used
- Objects such as engine, tires, track, and winch all had known weights

Model and Design

- Model consists of objects and constraints
- Constraints “constrain” two objects to allow movement in a specific way relative to each other
  - Revolute joints
  - Solid joints – act as one body
  - Belts and gears
  - Spherical joints
  - Rods and Ropes

Model and Design

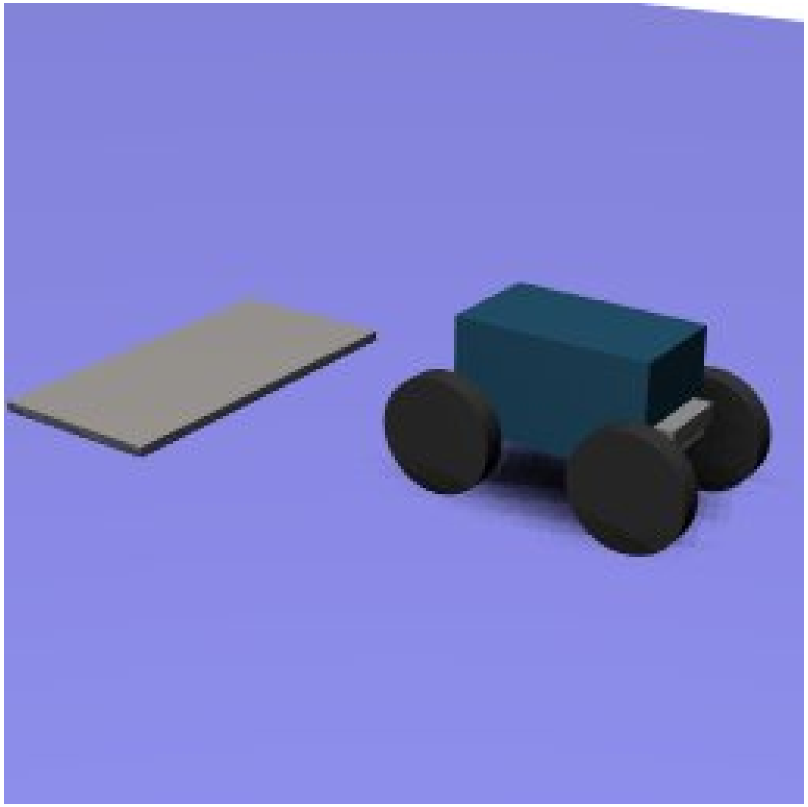
- Vehicle before modifications

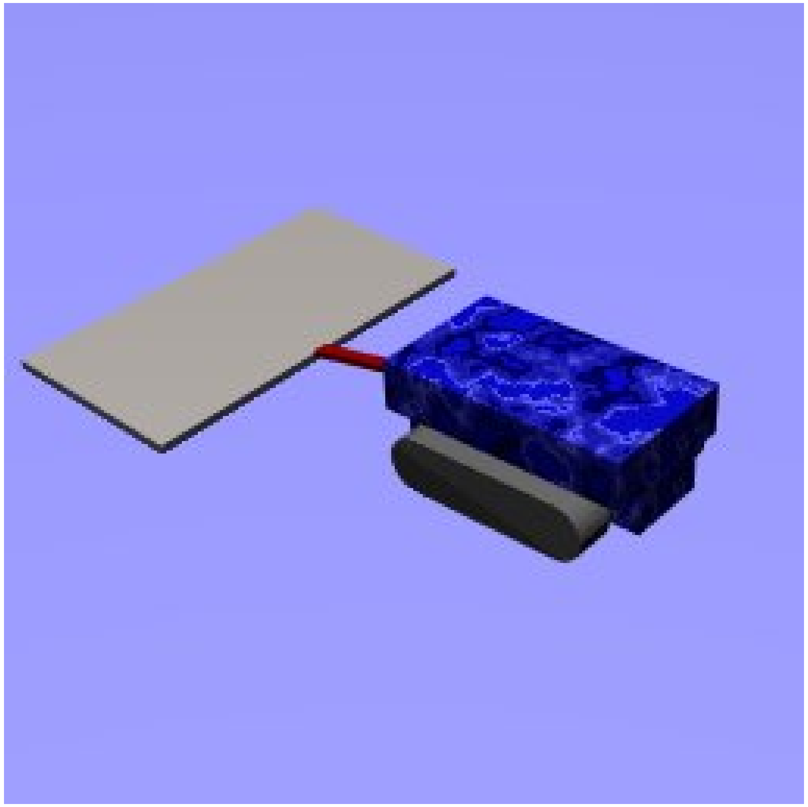
Model and Design

- Current vehicle

Model and Design

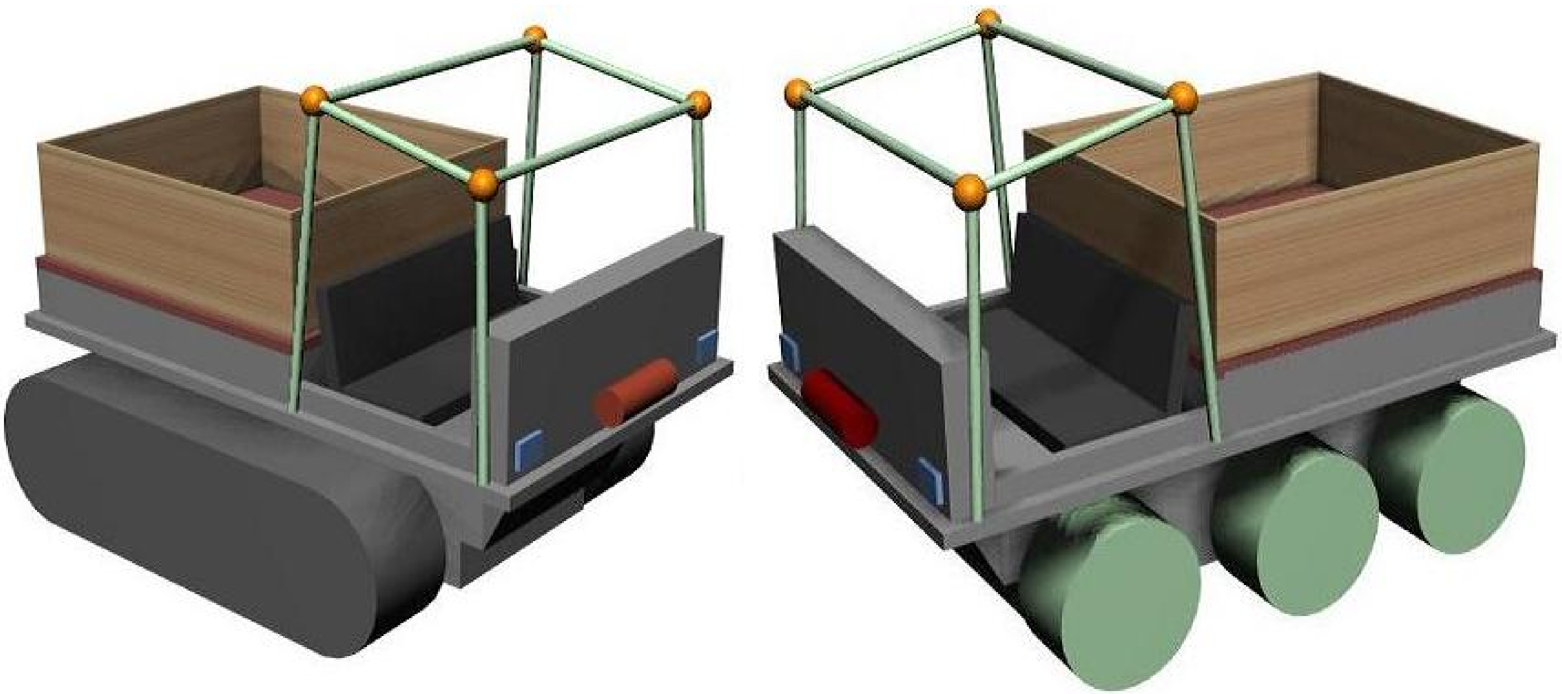
- Old models – different rover base





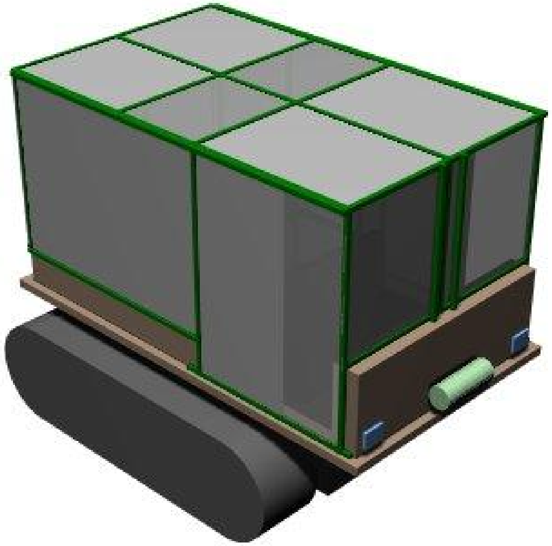
Model and Design

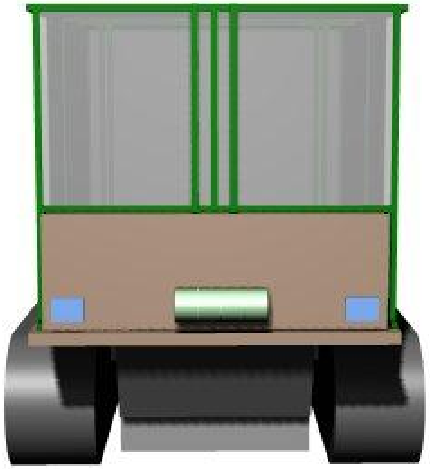
- Old models – current rover base



Model and Design

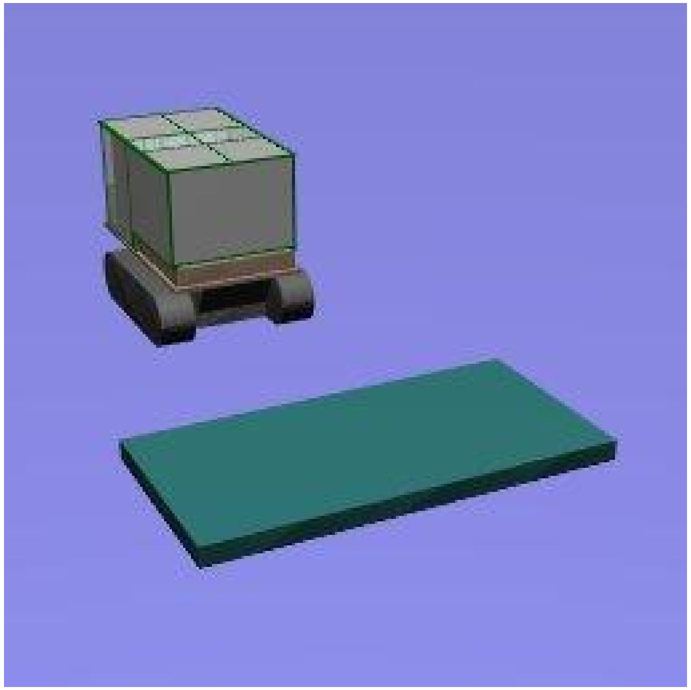
- Current model – current rover base





Model and Design

- Antenna modeled simply as a box
  - Dimensions and weight easily changeable



- Antenna Configurations
  - 2m x 4m - 400 pounds
  - 4m x 2m - 400 pounds
  - 2m x 2m - 200 pounds

Experiments

- Knowledge to determine
  - Slope vehicle can climb (pitch)
  - Angle the vehicle can handle (roll)
  - Turn radius
- This information gives us safe running parameters and some handling capabilities of the rover

Experiments

- Model configurations
  - Empty with no antenna
  - With antenna
    - Three different antennas
    - Four different towing mechanisms
  - With antenna and with different load distributions
    - One antenna used for these tests – 2m x 4m at 400 pounds

Experiments

- Antenna towing mechanisms
  - Single rope constraint
  - Two rope constraints
  - Single rod constraint
  - Two rod constraints
- Rope constraint allows a maximum distance between two bodies
- Rod constraint has a maximum and a minimum distance between two bodies
- Both allow rotation on both points of contact

Experiments

- Three different load distributions
  - Three locations for weight (front, middle, back)
  - 100, 400, 400 pounds
  - 100, 500, 300 pounds
  - 200, 400, 300 pounds
- A box with the specified weight was used to add the necessary weight

Experiments

- Experiments performed
  - Flat ground test
    - 15 meters with no obstacles or slope
  - Maximum slope test (pitch)
  - Turn radius test
  - Max roll test (roll)

Experiments

- Same experiments performed on each configurations of the model
- Turn radius experiments performed at different speeds

Results

- Empty model configuration

Flat ground test	5.88 seconds
Max slope test	18 degrees
Max roll test	58 degrees

Results

- With antenna configuration

Test with single rope	**2 x 4**	**4 x 2**	**2 x 2**
Flat ground	6.26 s	6.24 s	6.02 s
Max slope	10 degrees	11 degrees	14 degrees
Max roll	58 degrees	58 degrees	58 degrees

Results

- With antenna configuration

Test with two ropes	**2 x 4**	**4 x 2**	**2 x 2**
Flat ground	6.24 s	6.24 s	6.02 s
Max slope	11 degrees	11 degrees	14 degrees
Max roll	58 degrees	58 degrees	58 degrees

Results

- With antenna configuration

Test with single rod	**2 x 4**	**4 x 2**	**2 x 2**
Flat ground	6.24 s	6.24 s	6.02 s
Max slope	11 degrees	11 degrees	14 degrees
Max roll	58 degrees	58 degrees	58 degrees

Results

- With antenna configuration

Test with two rods	**2 x 4**	**4 x 2**	**2 x 2**
Flat ground	6.24 s	6.26 s	6.02 s
Max slope	11 degrees	11 degrees	14 degrees
Max roll	58 degrees	58 degrees	58 degrees

Results

- With load distribution configuration

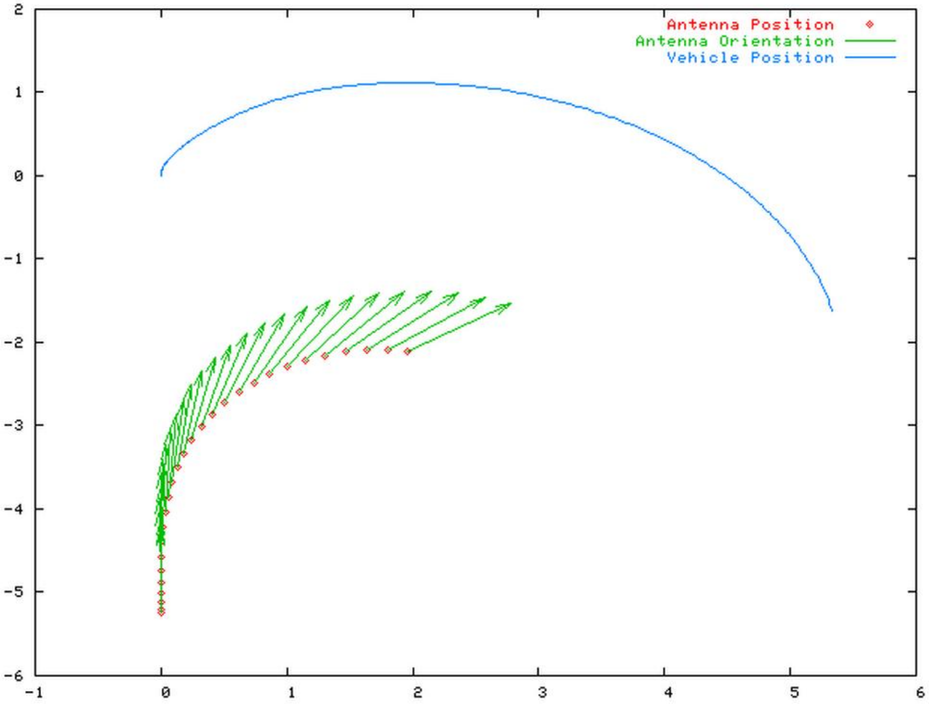
Test	**Load 1**	**Load 2**	**Load 3**
Flat ground	6.06 s	6.06 s	6.06 s
Max slope	13 degrees	13 degrees	13 degrees
Max roll	46 degrees	46 degrees	46 degrees

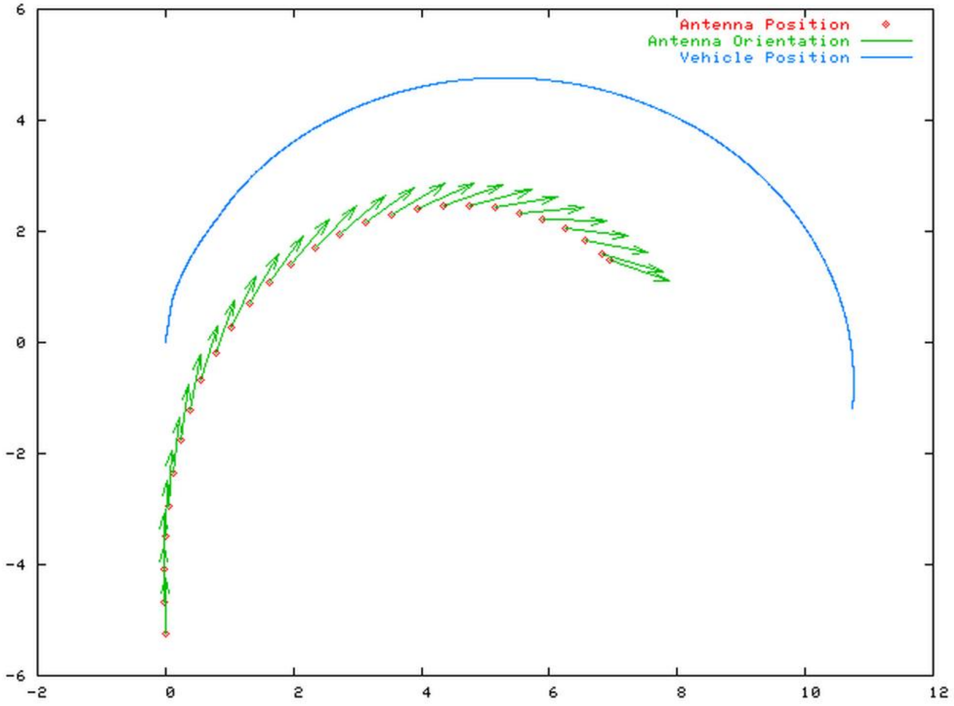
Results

- Weight is the single largest factor in how the rover performs
  - Antenna shape had little effect
- Slower speed better (turning)
- Two rods and two ropes better than single rod and single rope towing mechanisms
- No steep hills while towing the antenna

Results

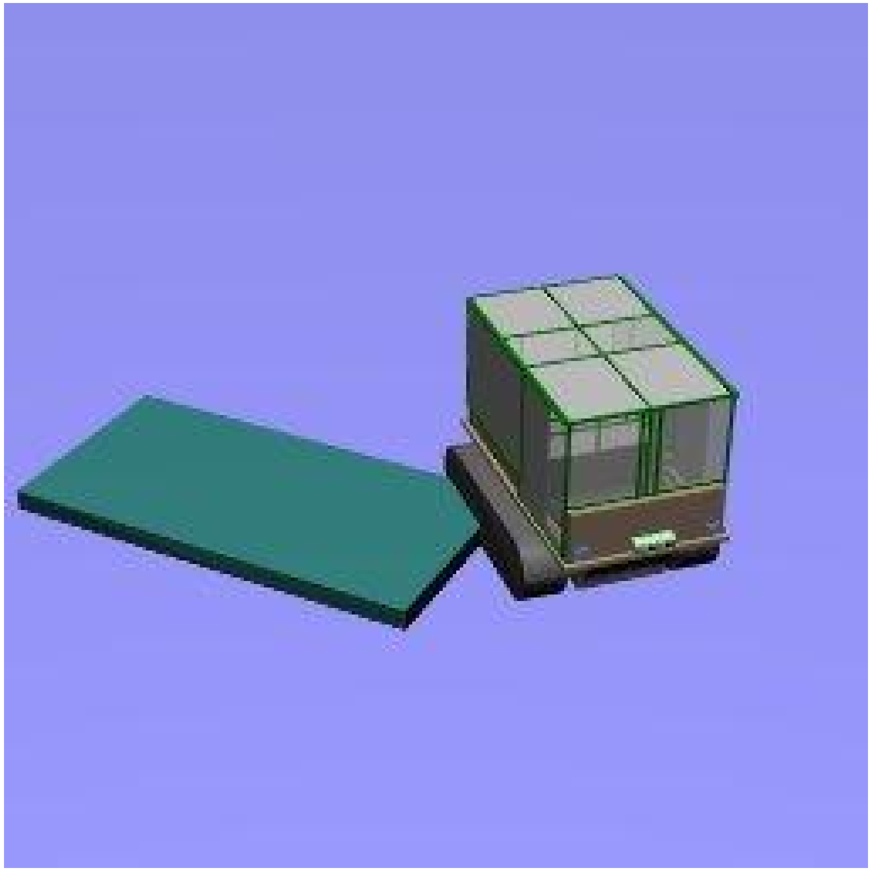
10 km/hr vs 2 km/hr with two ropes

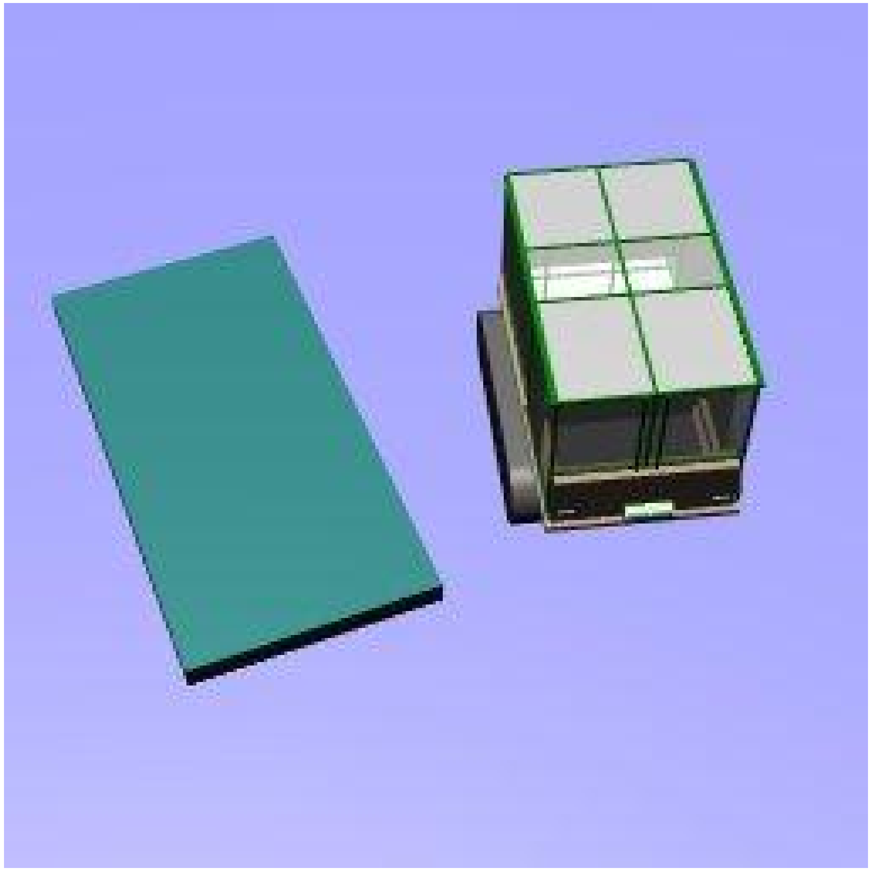




Results

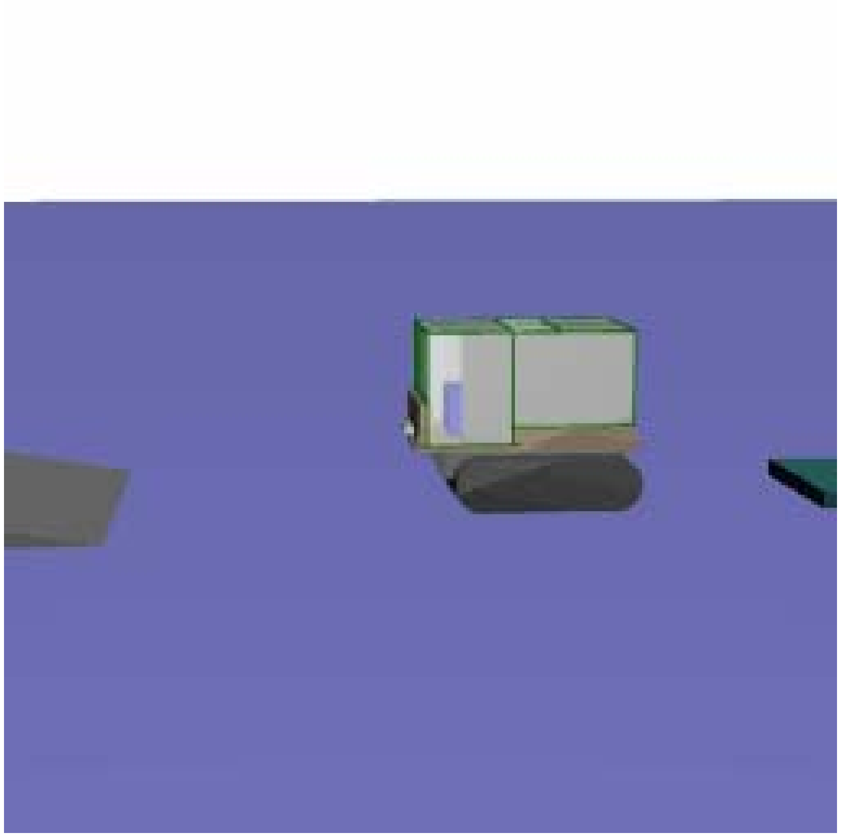
1 Rope vs 2 Ropes at 8 km/hr





Results

- Simulation from successful test



Results

- Turn radius simulations
  - 1 day for each series at all speeds
  - 2 weeks to finish all turn radius tests
- Average of 5 simulations for both max slope and max roll tests

Conclusions
Contributions

- Make decisions on the design and construction of the rover
- Give some approximate safe running parameters
- Give approximation of how vehicle handles while towing the antenna

Conclusions
Limitations

- Model and terrain an approximation of the world
  – Results are also an approximation
- Environment and terrain
  – Bumps, holes, obstacles
  – Actual terrain may vary greatly and cause rover to perform better or worse an some areas
  – Wind and blowing snow not accounted for

Conclusions
Limitations

- Model
  - Two motors instead of one
  - No testing of torque, all kinematics tests
  - Shape, weight, and weight distribution differences could cause incorrect results

Conclusions
Future Work

- Modeling of bumpy environment and testing how the different antennas handle
  - Modeling an environment with bumps and holes will allow a larger variation of results between the antenna towing mechanisms
- Make improvements to the simple antenna towing mechanisms

Conclusions
Future Work

- Any major changes such as adding accumulation radar to the front and depth sounder antennas to the sides
- Add more environmental conditions such as wind to the simulation

Questions

- Thank you to the committee members, the PRISM robotics team, my wife Vicki, and all who have attended