Simulation-Based Engineering Lab
University of Wisconsin-Madison

Technical Report TR-2021-04

A summary of NASA's Curiosity-class mars rover model in Chrono

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Abstract

This Technical Report records the dimensions, functions, and mechanisms of the NASA's Curiosity moon rover.

Keywords:

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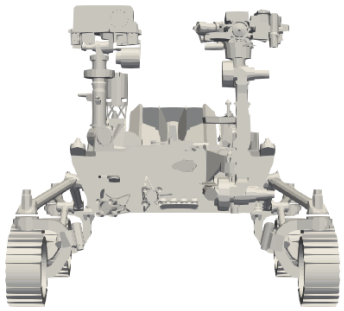
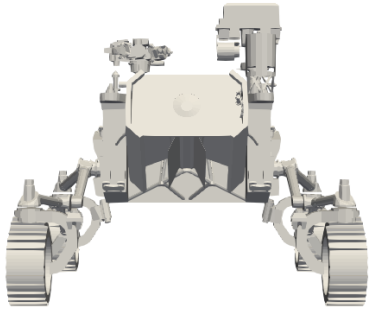
1 Introduction

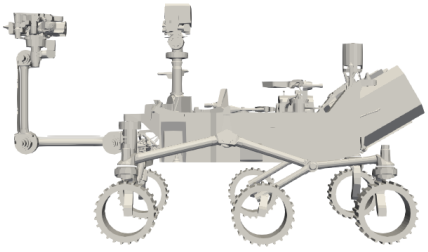
The current stage of rover model development also features full support of a six-wheel Mars rover with a Rocker-Bogie suspension system. The model uses the Curiosity Mars Rover which was launched by NASA on 26th November 2011 as a generic structural reference [1]. During the current stage of development, we have mainly focused on the components which are essential to wheel-terrain interaction and rover mobility, including wheels and Rocker-Bogie suspension mechanism. The rover chassis has an approximate length of 3.94 m, width of 1.56 m, and a height of 1.58 m. The total mass of the rover model is approximately 870 kg. The front, back, upper left, and 45-degree front view can be found in Figure 1.



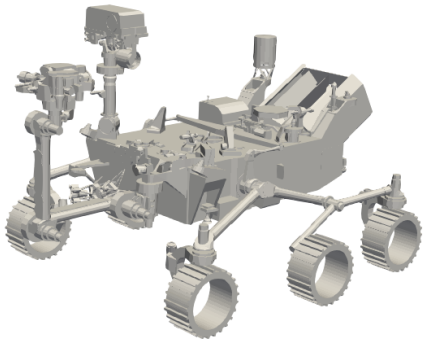
(a) Curiosity rover front view



(b) Curiosity rover back view



(c) Curiosity rover upper left view



(d) Curiosity rover 45-degree front view

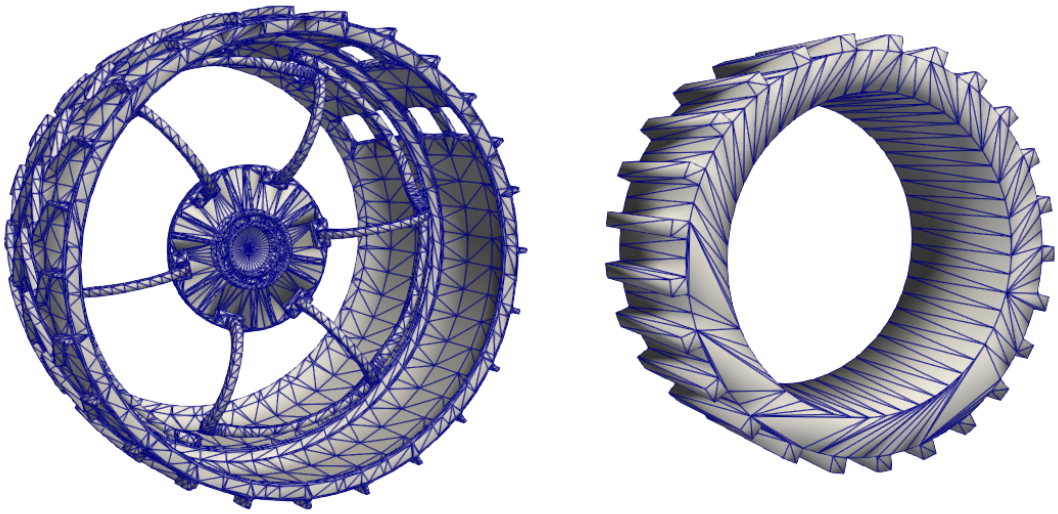
Figure 1: Curiosity Moon Rover Model with Customized Simplified Wheels

2 Design and Implementation Details

The complete Curiosity-Class rover design consists of 18 parts in total - 1 rover chassis, 2 Front Suspension Arms, 2 Back Suspension Arms, 2 Rocker-Boggie System Connecting Bars, One Roker-Boggie System Balancer, 4 Steering Rods, and 6 Rover Wheels. The screenshots of all parts except the wheels can be found in Figure 4.

The suspension system of the model has been designed to fully simulate the famous Rocker-Bogie Suspension system used in a wide range of rovers such as the NASA's opportunity mars rover, Perseverance mars rover, and the actual Curiosity mars rover. The Rocker-Bogie mechanism implementation details can be found in Figure 3, in which black arrows indicating revolute joint constraints and its constraint rotational directions. The implementation has been tested with obstacles on rigid and SCM terrain as shown in Figure 5. The suspension implementation can successfully prevent the rover from uncontrolled yaw and body motion, and the suspension can also prevent both sides of the rover's wheels being lifted up when one side of the rover hits an obstacle, in order to maintain traction on the soil and increase rover stability.

We obtained the geometry of the Curiosity from NASA's official website [2]. Similar to VIPER [**?**], we have also added an option of simplified wheel if the user would like to ease computation and reduce simulation runtime. The dimension of the simplified wheel is the same as the VIPER's. The diameter of the actual Curiosity's wheel geometry is approximately 0.45 m, and the thickness of the wheel is approximately 0.014 m. The grouser has a length of approximately 0.008 m and thickness of approximately 0.009 m. The geometries of the simplified wheel and the actual Curiosity wheel can be found in Figure 2.



(a) Actual Curiosity Wheel Geometry (b) Simplified Curiosity Wheel Geometry

Figure 2: Curiosity-Class Rover Wheel Options

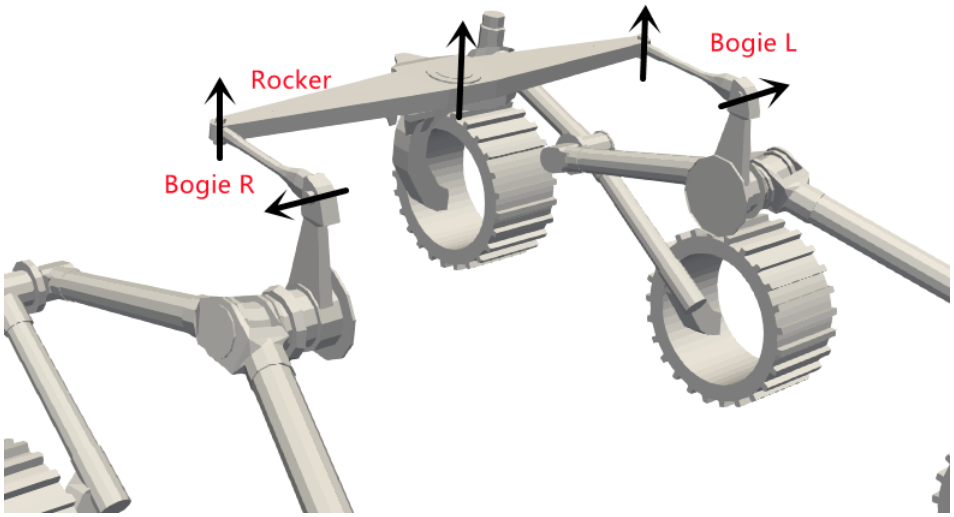


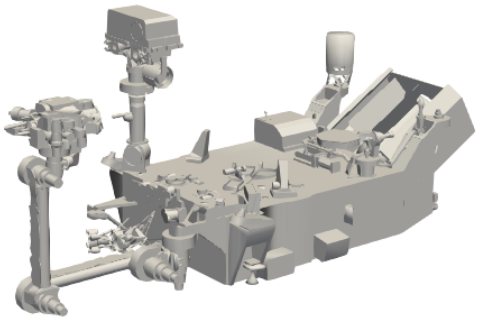
Figure 3: Details of Rocker-Bogie Suspension Mechanism Design

The steering capability of the Curiosity-Class rover model is completed by 4 steering motors (constant rotational speed motor link) installed between Left Front, Right Front, Left Back, and Right Back steering rods and their corresponding suspension arms, as shown in Table 1. All four steering motors can be independently controlled by sending out rotational speed commands. Two common types of steering maneuvers - one-side steering maneuver and spin steering maneuver can be achieved by user-defined algorithms, as shown in Figure 6 and Figure 7.

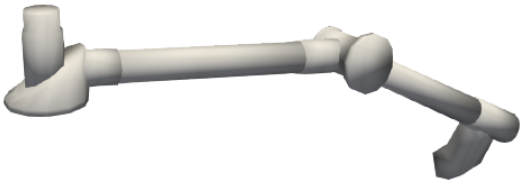
There are 21 constraints in total to form the full rover mechanical system, as shown in Table 1. There are two types of driving motors the users can choose from during the initialization phase - a constant rotational speed motor or a linear DC motor, the details of constraints implementation might differ based on the types of motor used on the rover. In the references table, the (0,0,0) position is located at the bottom center of the rover chassis. Positive x direction points to the front of the rover, positive y direction points to the Left of the rover, and positive Z direction points at the Upper of the rover chassis.

3 Current Flaws and Future Work

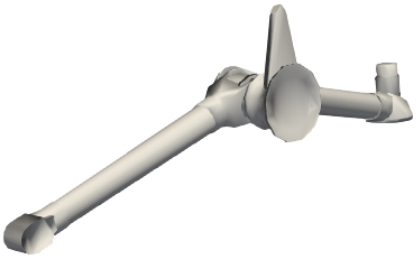
Under certain situations, we have observed strange rover dynamics on the Curiosity-class rover model. For example, in a 18-degree downhill simulation, the rover's chassis starts yawing uncontrolled, as shown in Figure 8. We are also planning to add more moving components to the model to allow simulations on different missions, such as the rotational and translation movement of the camera and drill.



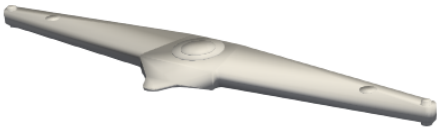
(a) Curiosity Rover Chassis



(b) Curiosity Rover Back Suspension (Left Side)



(c) Curiosity Rover Front Suspension (Left Side)

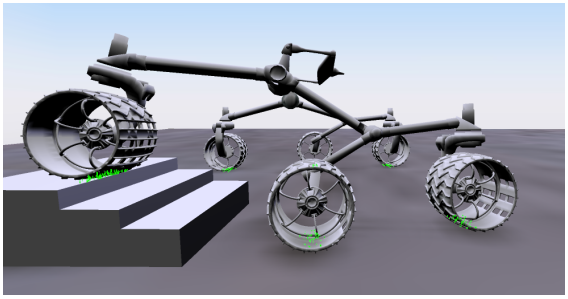


(d) Curiosity Rover Rocker-Boggie Suspension balancer

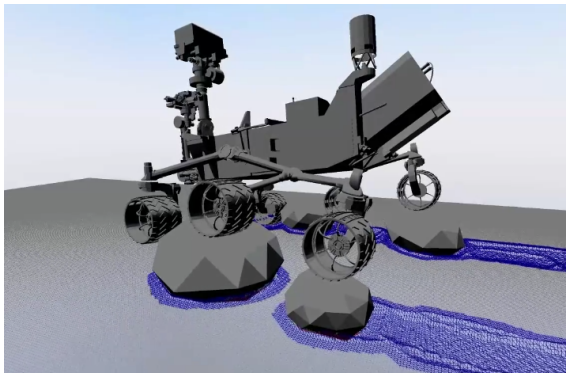
(e) Curiosity Rover Rocker-Boggie Suspension Connecting Bar (Left Side)

(f) Curiosity Rover Steering Rod (Left Side)

Figure 4: Screenshots of Curiosity Rover Parts

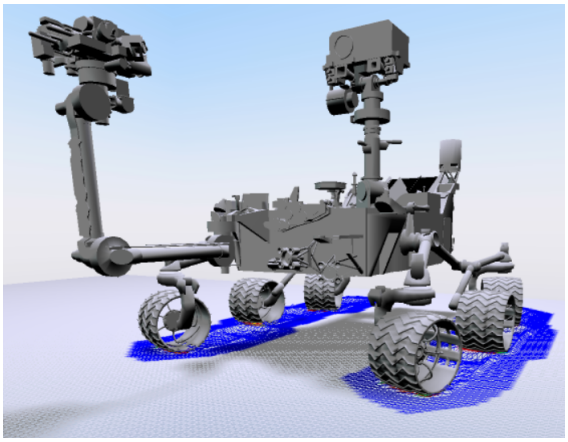


(a) Rocker-Bogie suspension tested with stair-shape obstacle on rigid terrain

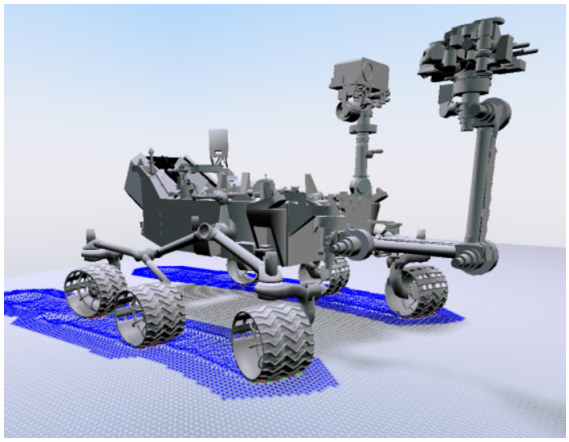


(b) Rocker-Bogie suspension tested with unsymmetrical obstacles on SCM terrain (See movie in [3])

Figure 5: Curiosity Rocker-Bogie Suspension Testing

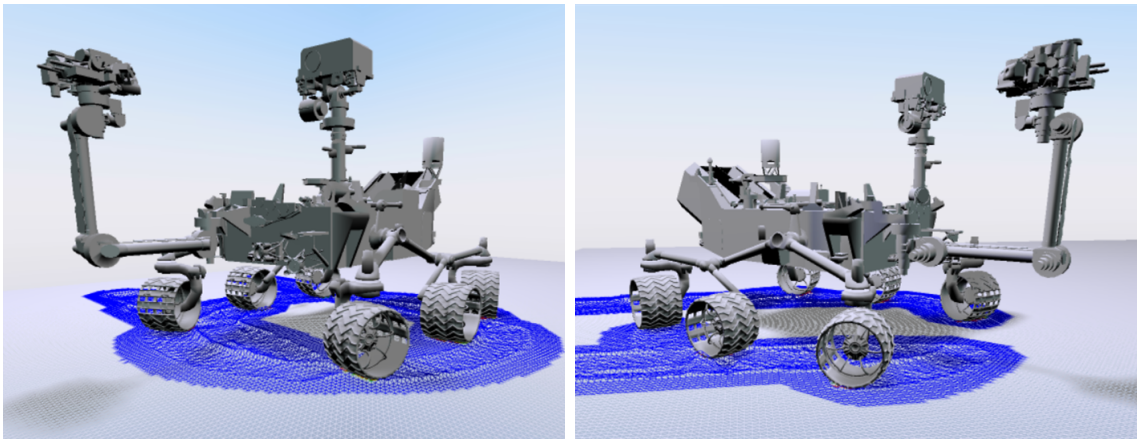


(a) Left View of the Curiosity Rover One-Side Steering



(b) Right View of the Curiosity Rover One-Side Steering

Figure 6: Screenshots of Curiosity Rover's One-Side Steering Implementation



(a) Left View of the Curiosity Rover Spin Steering

(b) Right View of the Curiosity Rover Spin Steering

Figure 7: Screenshots of Curiosity Rover's Spin Steering Implementation

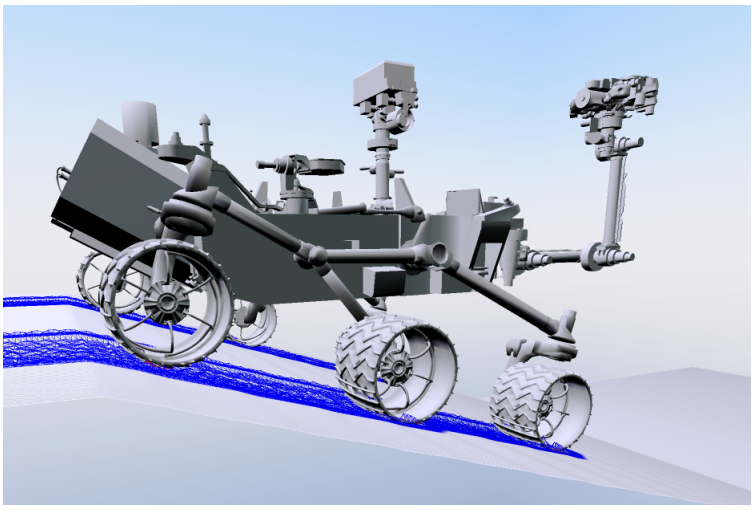


Figure 8: Uncontrolled Yawing of Curiosity Rover When Going Downhill on SCM Terrain

Table 1: All Constraints Used in Curiosity Rover Model

Constraint Type	Part I	Part II	Dir	Pos
Main Rover Structure				
Revolute Joint	Chassis	L-F Suspension Arm	y	[0.214, 0.604, 0.8754)]
Revolute Joint	Chassis	R-F Suspension Arm	y	[0.214, -0.604, 0.8754]
Revolute Joint	L-F Suspension Arm	L-B Suspension Arm	y	[-0.54, 0.845, 0.6433]
Revolute Joint	R-F Suspension Arm	R-B Suspension Arm	y	[-0.54, -0.845, 0.6433]
Revolute Joint	L-F Suspension Arm	L-F Steering Rod	z	[1.095, 1.063, 0.64]
Revolute Joint	R-F Suspension Arm	R-F Steering Rod	z	[1.095, -1.063, 0.64]
Revolute Joint	L-B Suspension Arm	L-B Steering Rod	z	[-1.163, 1.063, 0.64]
Revolute Joint	R-B Suspension Arm	R-B Steering Rod	z	[-1.163, -1.063, 0.64]
Rotational Motor	L-F Suspension Arm	L-F Steering Rod	z	[1.095, 1.063, 0.64]
Rotational Motor	R-F Suspension Arm	R-F Steering Rod	z	[1.095, -1.063, 0.64]
Rotational Motor	L-B Suspension Arm	L-B Steering Rod	z	[-1.163, 1.063, 0.64]
Rotational Motor	L-B Suspension Arm	L-B Steering Rod	z	[-1.163, -1.063, 0.64]
Rocker-Boggie Suspension System				
Revolute Joint	L-F Suspension Arm	L RB Connecting Bar	y	[0.214, 0.672, 1.144]
Revolute Joint	R-F Suspension Arm	R RB Connecting Bar	y	[0.214, -0.672, 1.144]
Revolute Joint	Chassis	RB Balancer	z	[-0.142, 0.0, 1.172]
Driving Motors (Constant Rotational Speed Motor)				
Rotational Motor	L-F Steering Rod	L-F Wheel	y	[1.095, 1.063, 0.249]
Rotational Motor	R-F Steering Rod	R-F Wheel	y	[1.095, -1.063, 0.249]
Rotational Motor	L-B Steering Rod	L-M Wheel	y	[-0.089, 1.194, 0.249]
Rotational Motor	R-B Steering Rod	R-M Wheel	y	[-0.089, -1.194, 0.249]
Rotational Motor	L-B Steering Rod	L-B Wheel	y	[-1.163, 1.063, 0.249]
Rotational Motor	R-B Steering Rod	R-B Wheel	y	[-1.163, -1.063, 0.249]
Driving Motors (Linear DC Motor)				
ChShaftsBody	ChShafts Assembly	L-F Wheel	y	[1.095, 1.063, 0.249]
ChShaftsBody	ChShafts Assembly	R-F Wheel	y	[1.095, -1.063, 0.249]
ChShaftsBody	ChShafts Assembly	L-M Wheel	y	[-0.089, 1.194, 0.249]
ChShaftsBody	ChShafts Assembly	R-M Wheel	y	[-0.089, -1.194, 0.249]
ChShaftsBody	ChShafts Assembly	L-B Wheel	y	[-1.163, 1.063, 0.249]
ChShaftsBody	ChShafts Assembly	R-B Wheel	y	[-1.163, -1.063, 0.249]

References

[1] NASA, "Mars curiosity rover." https://mars.nasa.gov/msl/spacecraft/rover/summary/.

[2] B. Kumanchik, NASA, and JPL-Caltech, "Curiosity clean,nasa 3d resources." https://nasa3d.arc.nasa.gov/detail/curiosity-clean, 2016.

[3] J. Zhou, "Chrono simualtion, Curiosity obstacle crossing on flat SCM terrain." https://uwmadison.box.com/s/mmwhad8ilmudvgbtpzrokbfpbu83zz9j, 2021. Simulation-Based Engineering Laboratory, University of Wisconsin-Madison.