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University of Wisconsin-Madison
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A summary of NASA's VIPER moon rover model in Chrono

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Abstract

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

Keywords:

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1 Introduction

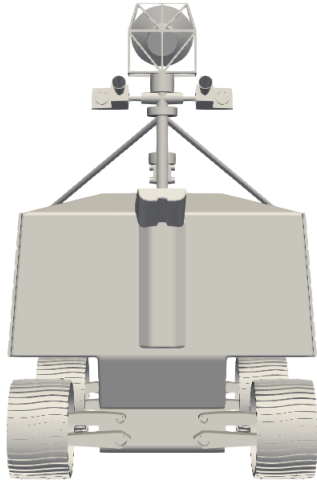
The integration of VIPER moon rover into Chrono allows the users to easily import the four-wheel rover system to a user defined dynamic simulation. The rover model has a spring-damped suspension system, four constant rotational speed motors or four linear DC rotational motors, and full steering capability. The model also provides interfaces to allow data reading and controlling of the driving motors and steering motors throughout the mobility simulation.

In the current development stage of this VIPER model, we just focused on the basic components which are essential to a wheel-terrain interaction. More parts of rover which might be interacting with the terrain are still under development. The front, rear, upper left, and 45° front views of the rover are provided in Figure 1. For more details of the VIPER rover, the reader should access the public data at [1].

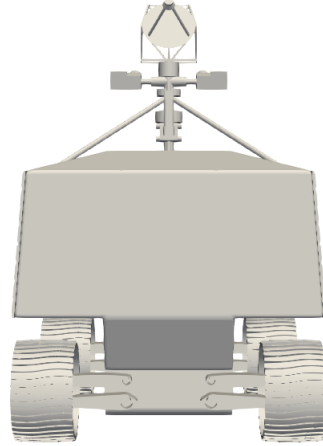
2 Design and Implementation Details

The dimensions of the VIPER rover body (including searchlight and antenna) are 1.74 m (length), 1.53 m (width), and 2.26 m (height). The mass of the rover is 417 kg. Due to the expert-controlled policy of NASA, we do not have access to data regarding the details of the suspension system. However, we have designed a suspension system based on public information which is available on NASA’s website [2]. More details of the designed suspension system can be found in Figure 2. More specifically, the suspension contains two kinds of connecting bars, which are upper and lower bars, respectively. These two bars are connected to the rover chassis body at the connecting Axis A and B through revolute joints. The direction of the joints’ axis are pointing to the front/back of the rover body. These two suspension bars also connect to a hub on which a steering motor and a main driving motor are installed. The steering motor is installed to change the motion direction of the rover. The main driving motor is installed in the hole of the central rotational cylinder to drive the rover. This suspension system forms a four-link mechanism, allowing the rover wheels to move upwards or downwards to cross over obstacles. Figure 3 shows the suspension mechanism with the wheels lowered or lifted. An electrical motor is expected to perform the lowering, lifting, or simply just maintaining a pose of the four-link mechanism. The implementation of the electrical motor is still under development which will be briefly described in the conclusion section. Currently, a spring is employed, connecting the Connecting Axis A and the steering hub to maintain the overall suspension system. This simplified implementation of the suspension system is important as it affects the obstacle-crossing ability of the VIPER rover.

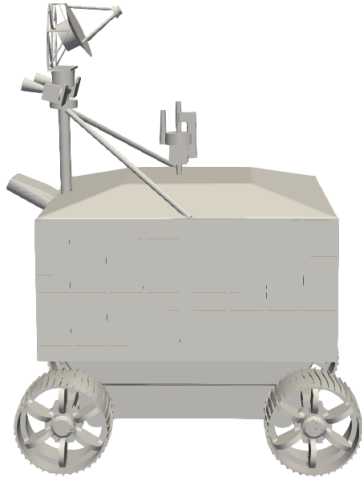
Two types of wheels are available in this designed VIPER rover models. One is the M2020 Rover Wheel, which is being used on the 2020 Mars Rover Perseverance [3]. The other one is a Simplified Wheel Geometry which can also be shared with the Curiosity Rover Model, as shown in Figure 4. The M2020 wheel geometry has a diameter of 0.46 m, and a thickness of 0.009 m. The grouser on the M2020 wheel has a height of 0.009 m and a thickness of



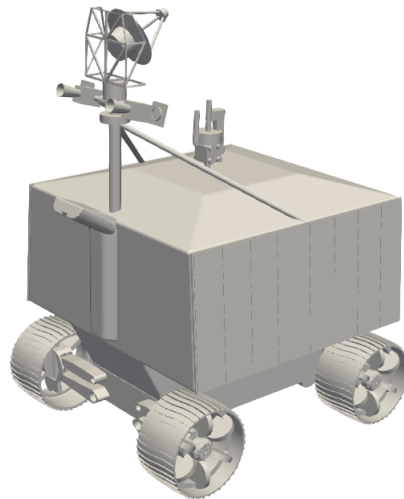
(a) Front view



(b) Rear view



(c) Upper left view



(d) 45° front view

Figure 1: VIPER Moon Rover Model with M2020 Wheel Geometry

0.009 m. The simplified wheel geometry has a diameter of 0.5 m, a thickness of 0.05 m. The grouser on the simplified wheel geometry has a height of 0.02 m and a thickness of 0.02 m. Since the mesh of the simplified wheel has relative coarser mesh, it can be used in most of the SPH and DEM simulation with high computational efficiency. A simplified version of the M2020 wheel geometry has been used in Rigid and SCM terrain for faster collision detection.

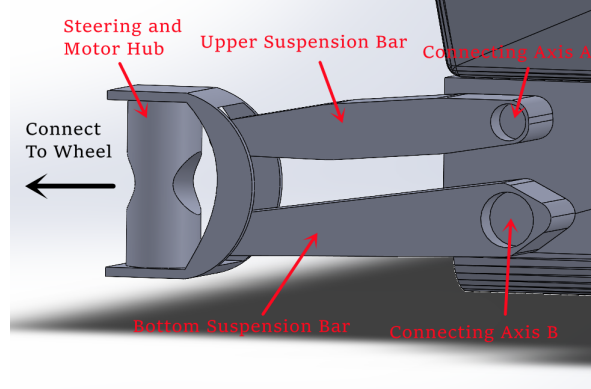


Figure 2: Details of the Suspension Mechanism Design

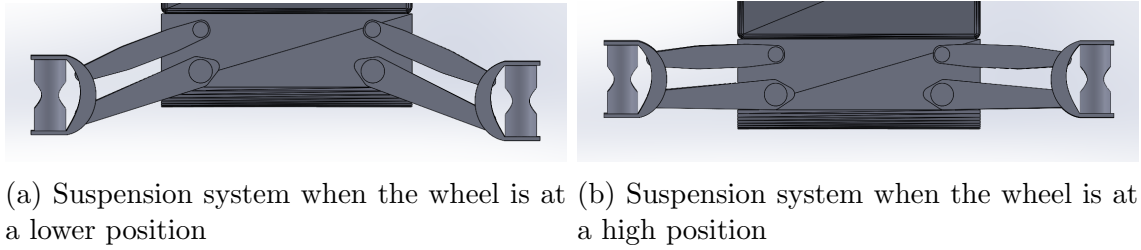
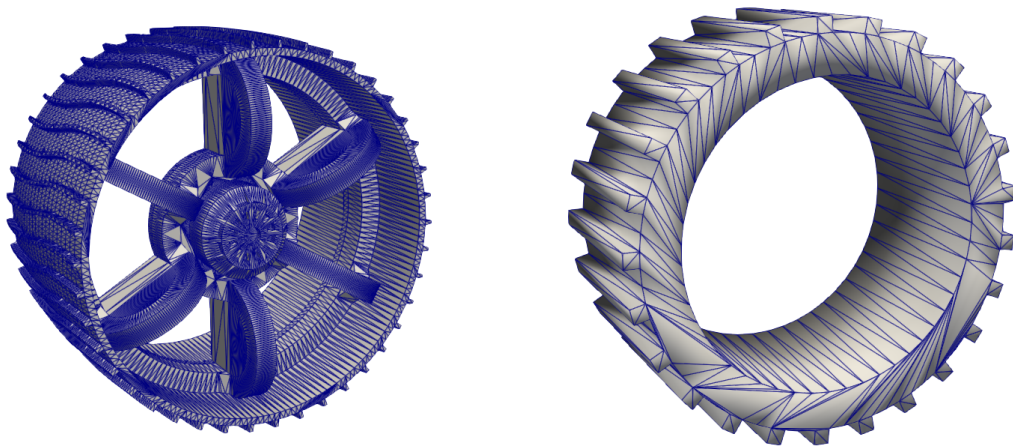


Figure 3: VIPER Suspension Mechanism

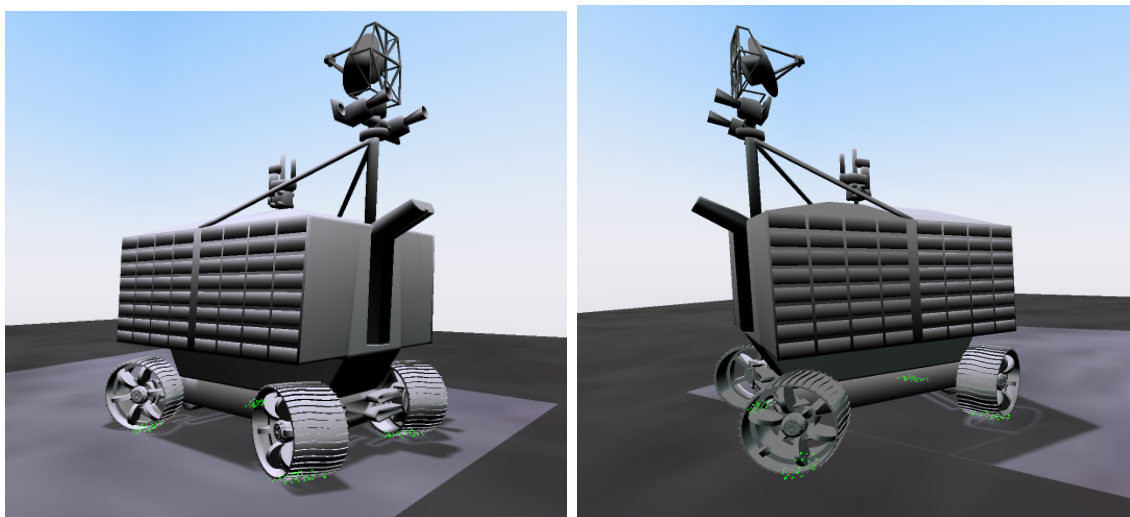
The steering functionality of the VIPER is completed by four steering motors installed on the Steering and Motor Hubs shown in Figure 2. Currently, the motors are controlled by direction and speed commands, and the steering limitation is set to -30° to 30° . These steering motors can either be controlled together to perform full vehicle steering maneuvers or be controlled independently by sending four independent steering commands to each of the steering motors. The full rover steering is shown in Figure 5.

The VIPER rover model consists of 17 solid bodies - 1 Rover Chassis (Figure 6a), 4 Upper Suspension Bars (Figure 6c), 4 Bottom Suspension Bar (Figure 6b), 4 Steering and Motor Hubs (Figure 6d), and 4 Rover Wheels. All constraints added to the rover mechanical system are listed in table 1. The details of the four driving motor constraints might change based on user's preference on the implementation of the driving motors. The motor can either be defined as a constant rotational speed motor, or a linear DC motor. [4] In the references table, the (0,0,0) position is located at the bottom center of the rover chassis. Positive x



(a) M2020 Wheel Geometry Obtained From NASA Website (b) A Customized Simplified Wheel Geometry

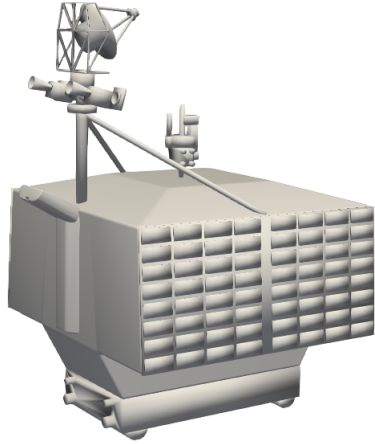
Figure 4: VIPER Rover Model Wheel Options



(a) Four-Wheel Steering Left-Side View (b) Four-Wheel Steering Right-Side View

Figure 5: VIPER Rover Steering

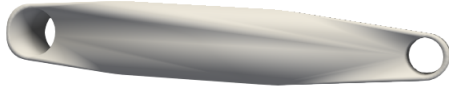
direction points to the front of the rover, positive y direction points to the left of the rover, and positive Z direction points at the upper of the rover chassis.



(a) Chassis



(b) Bottom Suspension Bar



(c) Upper Suspension Bar



(d) Steering and Motor Hub

Figure 6: Screenshots of VIPER Rover Parts

3 Current Flaws and Future Work

The suspension system of the VIPER is still under development, since the temporary simplified suspension using two springs can cause both sides of wheels being lifted up when crossing obstacles, as shown in Figure 7. Also, as the function of the spring is simply adding damping to the four-link suspension mechanism, this temporary fix will only hold the rover assembly without falling. However, many other rover maneuvers such as lifting up and lowering down

Table 1: All Constraints Used in VIPER Rover Model

Constraint Type	Part I	Part II	Dir	Pos
Revolute Joint	Chassis	L-F Bottom Suspension Bar	x	[0.6418, 0.2067, -0.0525]
Revolute Joint	Chassis	R-F Bottom Suspension Bar	x	[0.6418, -0.2067, -0.0525]
Revolute Joint	Chassis	L-B Bottom Suspension Bar	x	[-0.6418, 0.2067, -0.0525]
Revolute Joint	Chassis	R-B Bottom Suspension Bar	x	[-0.6418, -0.2067, -0.0525]
Revolute Joint	Chassis	L-F Upper Suspension Bar	x	[0.6418, 0.2067, 0.0525]
Revolute Joint	Chassis	R-F Upper Suspension Bar	x	[0.6418, -0.2067, 0.0525]
Revolute Joint	Chassis	L-B Upper Suspension Bar	x	[-0.6418, 0.2067, 0.0525]
Revolute Joint	Chassis	R-B Upper Suspension Bar	x	[-0.6418, -0.2067, 0.0525]
Revolute Joint	L-F Hub	L-F Bottom Suspension Bar	x	[0.6418, 0.5267, -0.0525]
Revolute Joint	R-F Hub	R-F Bottom Suspension Bar	x	[0.6418, -0.5267, -0.0525]
Revolute Joint	L-B Hub	L-B Bottom Suspension Bar	x	[-0.6418, 0.5267, -0.0525]
Revolute Joint	R-B Hub	R-B Bottom Suspension Bar	x	[-0.6418, -0.5267, -0.0525]
Revolute Joint	L-F Hub	L-F Upper Suspension Bar	x	[0.6418, 0.5267, 0.0525]
Revolute Joint	R-F Hub	R-F Upper Suspension Bar	x	[0.6418, -0.5267, 0.0525]
Revolute Joint	L-B Hub	L-B Upper Suspension Bar	x	[-0.6418, 0.5267, 0.0525]
Revolute Joint	R-B Hub	R-B Upper Suspension Bar	x	[-0.6418, -0.5267, 0.0525]
Spring Damper	Chassis	L-F Hub	-	[0.6418, 0.2067, 0.0525] [0.6418, 0.5267, -0.0525]
Spring Damper	Chassis	R-F Hub	-	[0.6418, -0.2067, 0.0525] [0.6418, -0.5267, -0.0525]
Spring Damper	Chassis	L-B Hub	-	[-0.6418, 0.2067, 0.0525] [-0.6418, 0.5267, -0.0525]
Spring Damper	Chassis	R-B Hub	-	[-0.6418, -0.2067, 0.0525] [-0.6418, -0.5267, -0.0525]
Rotational Motor	L-F Hub	L-F Steering Cylinder	z	[0.6418, 0.6098, 0.0]
Rotational Motor	R-F Hub	R-F Steering Cylinder	z	[0.6418, -0.6098, 0.0]
Rotational Motor	L-B Hub	L-B Steering Cylinder	z	[-0.6418, 0.6098, 0.0]
Rotational Motor	R-B Hub	R-B Steering Cylinder	z	[-0.6418, -0.6098, 0.0]
Rotational Motor or DC Motor	L-F Wheel	L-F Steering Cylinder	y	[0.6418, 0.6098, 0.0]
Rotational Motor or DC Motor	R-F Wheel	R-F Steering Cylinder	y	[0.6418, -0.6098, 0.0]
Rotational Motor or DC Motor	L-B Wheel	L-B Steering Cylinder	y	[-0.6418, 0.6098, 0.0]
Rotational Motor or DC Motor	R-B Wheel	R-B Steering Cylinder	y	[-0.6418, -0.6098, 0.0]

when the chassis of the rover is too low and the rover needs to lift up. We have tried several different methods to solve the problem, such as adding a lifting motor on the Connecting Axis B in Figure 2. However, many of the attempts failed as the wheel starts leaning to the rover body and becoming unstable, and the rover assembly collapsed in the end.

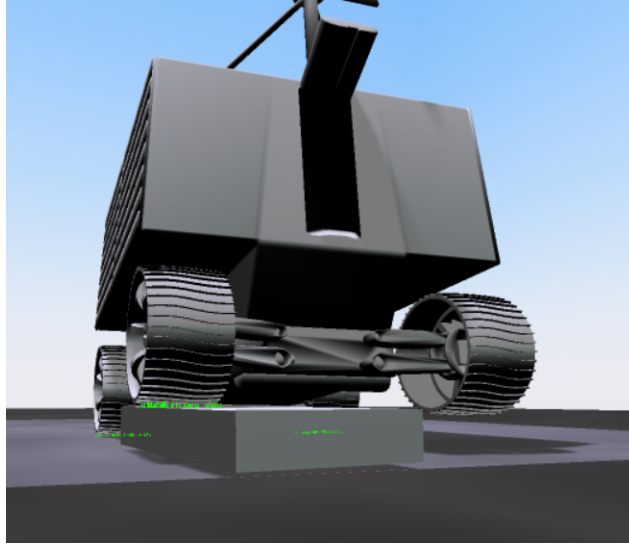


Figure 7: The Spring-Damped Suspension Design Could Cause Problems When One Side of The Rover is Lifted

References

- [1] R. Chen, “Nasa’s next lunar rover progresses toward 2023 launch.” <https://www.nasa.gov/feature/ames/nasas-next-lunar-rover-progresses-toward-2023-launch>, 2021.
- [2] R. Hoover, “Viper’s many brains are better than one.” <https://www.nasa.gov/feature/ames/vipers-many-brains-are-better-than-one>, 2020.
- [3] NASA and JPL-Caltech, “M2020 wheel desktop model 5inch,nasa 3d resources.” <https://nasa3d.arc.nasa.gov/detail/Mini-Perseverance-Rover-Wheel>, 2020.
- [4] J. Zhou, W. Hu, R. Serban, and D. Negrut, “Modeling linear dc motor in chrono rover models,” tech. rep., Simulation-Based Engineering Laboratory, University of Wisconsin-Madison, 2021.