Each of the various designs considered were in effect selections from a set of subsystems in different combinations. The first step in creating design candidates was to list several possible modes of propulsion and sample collection. Sensor suites and power generation were also considered, but in the end it was decided that any proposed design would have the same set of sensors and the same method of generating electricity.

Five different propulsion systems were considered: regular wheels on both fixed and articulated axes, omnidirectional wheels, tank treads, and an amorphous ferrofluid bag. Wheels on fixed axes are the simplest, as it is simply a straight shaft connecting the wheels to the drive system or motor. The wheels can also be connected directly to motors with only a very short axle, such as the wheels on the sumo robot. The next design was similar, but had the addition of individual suspension systems for each wheel. This allows each wheel to move up and down independently of the others. This is the current design favored by NASA, and is used on Curiosity. The articulated axles allow the rover to easily maneuver over rough or uneven terrain.

Omnidirectional wheels, or omniwheels, were another consideration. These wheels have the significant advantage of allowing the rover to move sideways in addition to forwards and backwards. This is accomplished by the design of the wheels; instead of a simple disc, each wheel is made of a number of cylindrical subassemblies on rollers. These are aligned perpendicular to the plane of the disc making up the main wheel and allow for sideways translational motion with the correct combination of powered and unpowered wheels. Treads, on the other hand, require the rover to drag itself when it turns and decrease mobility, but are simpler and more reliable than omniwheels.

The final propulsion design was a ferromagnetic bag of fluid, by far the most complex and creative solution, but also the least feasible. The basis of this design relies on ferrofluid, a material which flows normally until in the presence of a magnetic field. This can cause the fluid to change its shape and other properties. The design would use a bag of ferrofluid in conjunction with several electromagnets to pull itself along the ground.

There were also several methods of collecting surface samples considered. The chief proposals for collection were a scoop, an arm, and a drill. The scoop, the simplest of the three, would simply be a shovel-like container similar to those found on construction vehicles. It would be pushed into the ground by some kind of rotary motion and dig up a section of soil, which would then be deposited into an analysis chamber, the specifics of which are beyond the scope of the prototype, but in theory would involve spectrometers and other means of determining mineral composition.

The arm would be similar to the arms on current Mars rovers such as Curiosity. The arm would have five degrees of freedom, with a sensor suite and claw or manipulator on the end. The arm would move near interesting features of the surface, and either pick them up or use its sensors on the sample. Drawings of the arm and claw (separate) are included in the Appendix.

A drill was the final possibility for sampling. The drill would be positioned underneath the rover chassis and would periodically take core samples in the same way that ice cores may be collected on Earth. This would have the advantage of reading different strata of soil, but would not work effectively in rocky or otherwise unsuitable terrain.

Each rover design was assumed to have the same sensors and power supply. The sensors include atmospheric sensors to measure oxygen, carbon dioxide, and methane, as well as temperature, wind, and radiation sensors. For surface sensing, a number of spectrometers and chromatographers would be present, as well as a way to heat and vaporize samples for use in the instruments. Navigation and data collection would be aided by a number of cameras positioned on various positions around the rover.

From these subsystems several candidate designs were produced. The first combined the articulated axles, drill, and arm. The second had tread propulsion and the scoop. The third design was a combination of the ferrofluid bag and the arm. While the fourth and final design had articulated axles, omniwheels, a scoop, and a drill. Below are the decision matrix and rank-order table that were used to compare the effectiveness of each design.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Goals** | Durability | Speed | Cost | Collection Efficiency | Mass | Stability | Aesthetics | Sensor Accuracy | Sensor Precision | Maneuverability | Reliability | Total |
| Durability |  | 0 | 0 | 0 | 0 | 1 | 0 | 0.5 | 0.5 | 1 | 0.5 | 3.5 |
| Speed | 1 |  | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 9 |
| Cost | 1 | 0 |  | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 |
| Collection Efficiency | 1 | 0 | 1 |  | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 7 |
| Mass | 1 | 0 | 1 | 1 |  | 0.5 | 0 | 0.5 | 0.5 | 1 | 1 | 6.5 |
| Stability | 0 | 0 | 0 | 0 | 0.5 |  | 0 | 0 | 0 | 0.5 | 0 | 1 |
| Aesthetics | 1 | 1 | 1 | 1 | 1 | 1 |  | 1 | 1 | 1 | 1 | 10 |
| Sensor Accuracy | 0.5 | 0 | 1 | 0 | 0.5 | 1 | 0 |  | 0.5 | 1 | 1 | 5.5 |
| Sensor Precision | 0.5 | 0 | 1 | 0 | 0.5 | 1 | 0 | 0.5 |  | 0.5 | 1 | 5 |
| Maneuverability | 0 | 0 | 1 | 0 | 0 | 0.5 | 0 | 0 | 0.5 |  | 1 | 3 |
| Reliability | 0.5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |  | 1.5 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| Total (Weight) | 6.5 | 1 | 7 | 3 | 3.5 | 9 | 0 | 4.5 | 5 | 7 | 8.5 |  |

We rated stability as the most important criteria. Stability is essential for achieving all all other goals. Without stability, the robot will have difficulty maneuvering, sensing, and overcoming inevitable obstacles. The second most important category is reliability, because without reliability of the maneuvering and sensing, the robot may suffer system failures that would inhibit proper function. The third most important category was a tie between maneuverability and cost. The robot will need to be able to navigate the surface of Mars in order to collect samples, and the cost of the robots will have a large impact on the feasibility of the project as a whole. The next two categories we ranked were, in order, durability, sensor precision and sensor accuracy. Durability is ranked highly because given the cost of sending a rover to Mars, we want to ensure the longevity of our project. Sensor precision and accuracy accuracy are needed to enable the robot’s scientific mission. Speed, collection efficiency and aesthetics are at the bottom of the ranking because they are not essential to the robot’s mission.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Weight | Articulated axles, drill, arm | Treads, scoop | Ferrofluid bag, arm | Fixed axles, scoop | Articulated axles, omniwheels, scoop, drill |
| Durability | 6.5 | 8 | 9 | 6 | 9 | 7 |
| Speed | 1 | 8 | 6 | 6 | 7 | 7 |
| Cost | 7 | 6 | 9 | 5 | 7 | 5 |
| Collection Efficiency | 3 | 9 | 5 | 7 | 5 | 7 |
| Mass | 3.5 | 9 | 5 | 6 | 7 | 6 |
| Stability | 9 | 7 | 9 | 4 | 6 | 6 |
| Aesthetic Pleasure | 0 | 9 | 4 | 9 | 5 | 8 |
| Sensor Accuracy | 4.5 | 8 | 8 | 8 | 8 | 8 |
| Sensor Precision | 5 | 8 | 8 | 8 | 8 | 8 |
| Maneuverability | 7 | 8 | 3 | 10 | 5 | 9 |
| Reliability | 8.5 | 7 | 8 | 6 | 8 | 5 |
|  |  |  |  |  |  |  |
| Total Score |  | 415 | 406 | 355 | 387 | 365 |

The different design concepts were weight ranked taking into account the previous evaluation. The highest ranked design, the articulated axles, and arm and drill design was ranked so highly because it had the potential for good stability, and the potential for excellent durability and sensor accuracy and precision. The design of articulated axles allows each wheel to move independently of the others due to separate suspensions. This design, currently favored by NASA, allows for great mobility and obstacle avoidance.  The design’s weakest rating was on the stability, as the articulated axles only have so much flexibility, but still maintained high scores across the board. It is capable of achieving our goals and is not overly complex, keeping cost down. It is little surprise that this is the category of design that has been chosen for many rovers that have been sent to Mars.

The second ranked design is a rover with treads and a scoop. The treads are similar to those found on tanks, and the scoop is similar to that found on construction vehicles. This design scores points for the stability inherent to its tracked design. The tank style propulsion also gives the robot good durability at the cost of speed. This tradeoff is inline with our low ranking of speed. The tracked designs that we researched were all fairly complex, and the requirement for treads will significantly increase the weight of the vehicle. The sensor potential for this robot is not greatly influenced by its design, allowing it to maintain a fairly capable sensors suite. This robot is good at what it does, slow steady movement, but loses points on maneuverability, a design consideration we have ranked fairly highly.

The third and fourth designs are close in score, only separated by three and a half points. The two designs are a robot with articulated axles with omniwheels, a scoop, a drill, and a robot with fixed axles and a scoop. The former design scores very well in maneuverability, but the sensitivity inherent to the complexity of the omniwheels leads to lower scores in durability and weight; the omni wheels which are the center are built in such a way as to allow the rover to move in any direction without turning the main body. These wheels also result in a significantly higher cost, driving down the robot’s overall score. The sensors are again not heavily dependent on the major features of this design. The tradeoff of maneuverability is increased cost and weight as well as decreased reliability making this design impractical. The latter design, the robot with fixed axles and a scoop, is simpler than the highest ranked design, with a simpler method of propulsion and sample collection. Both of these methods are still effective, but the sample collection with a scoop is less efficient. The cost of this design is lower and it is more durable, but its simplicity creates shortcomings. The robot is less stable, a criteria that we ranked highly. The robot is also less maneuverable because it would be unable to clear obstacles that a robot with articulated legs could clear.

The lowest ranked design, the ferrofluid bag with an arm, suffers from several downfalls. The robot is incredibly complex as a result of its two sophisticated systems, both of which drive up the cost and drive down the durability. The robot is very maneuverable, but its bag based method of locomotion makes it fairly unstable and susceptible to damage. The bag of ferrofluid would also be heavy which, while not the most important consideration, drives down the score. This design is very good at maneuvering, but falls short in many other areas due to its form of locomotion.

Almost all of the potential designs had very close scores in the decision matrix, and in the end we decided to use the design with the omniwheels, articulated axles, drill, and scoop. This design was very stable and maneuverable, and has two methods for obtaining surface samples in different manners. No individual part of the design is very complicated, yet the design is sophisticated enough to accomplish a variety of tasks.