RETH

PURDUE UNIVERSITY

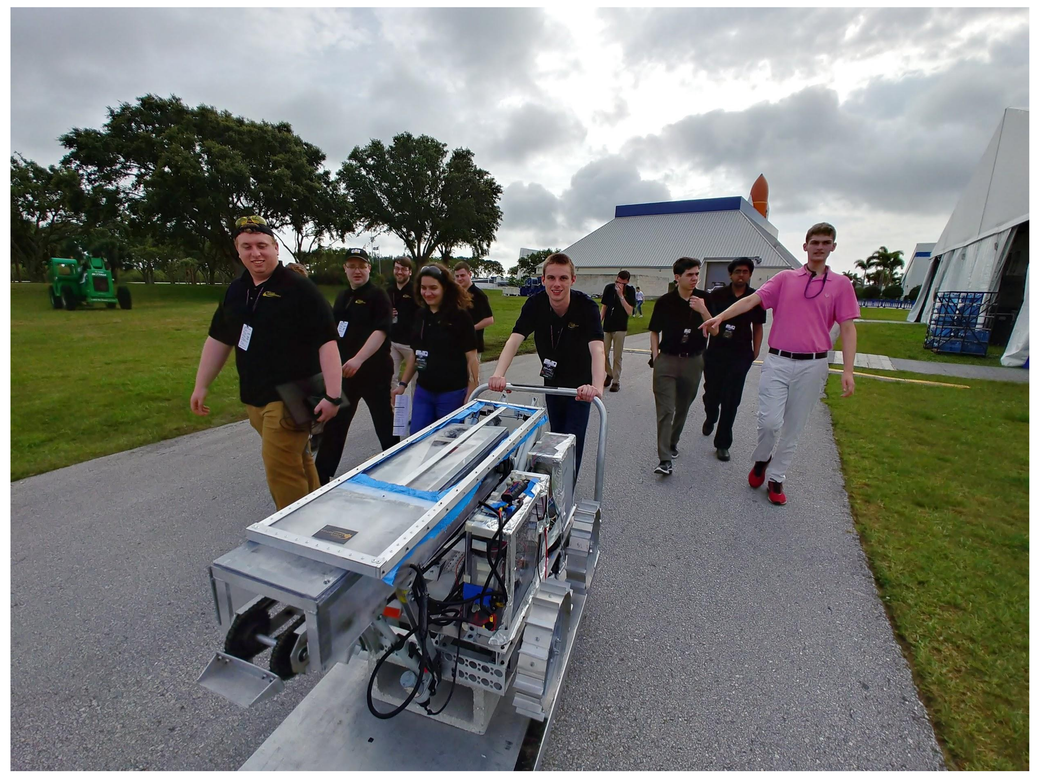
NASA RMC

PURDUE™ LUNABOTICS

RETH International Workshop, October 22nd - 23rd, 2018

What is NASA RMC?

NASA's Robotic Mining Competition (RMC) is for university-level students to design and build a mining robot that can traverse the challenging simulated, chaotic, off-world terrain, excavate the icy-regolith simulant (rock/gravel) and return the excavated mass for deposit into the collector bin to simulate an off-world, In-Situ Resource Utilization mining mission. The complexities of the challenge include the abrasive characteristics of the regolith and icy-regolith simulant, the weight and size limitations of the mining robot and the ability to tele-operate it from a remote Mission Control Center. Teams must also submit a systems engineering paper that explains their design approach, perform K-12 outreach into their communities and a presentation about their design philosophy at the competition.[1]



Benefits of NASA RMC

NASA RMC challenges our members to apply the skills of their majors in new and unique ways. As our members remain with the program, they utilize and implement the skills they have learned in each of their classes and become more well rounded students, regardless of major.

Our primary goal is focused on research and development of an autonomous rover with integrations of technology for development of off-world mining and colonization. Our members are some of the brightest engineering and technical students spread across Purdue University, who share a strong interest in the fields of aerospace, robotics and manufacturing. Through material properties testing, designing, building, and iterating on design ideas, our members can get a glimpse into the work they will have after graduating.

Last year, our robot successfully maneuvered a simulated Martian terrain to collect and transport simulated ice under the terrain's surface. Out of 50 teams, we achieved 12th place overall for our ability to execute these tasks while factoring in the robot's mass, power consumption, and data usage into our design and operation. While our team's overall goal is to improve upon our success of designing and building a new, more advanced robot from the previous year's competition, we will continue to promote STEM to diverse groups of children in the community.

[1]NASA RMC Rules and Regulations 2019

"RMC has taught me to implement all of my coursework into design, instead of just maintaining it as theory."

"RMC is one of the best experiences a young technical student can have."

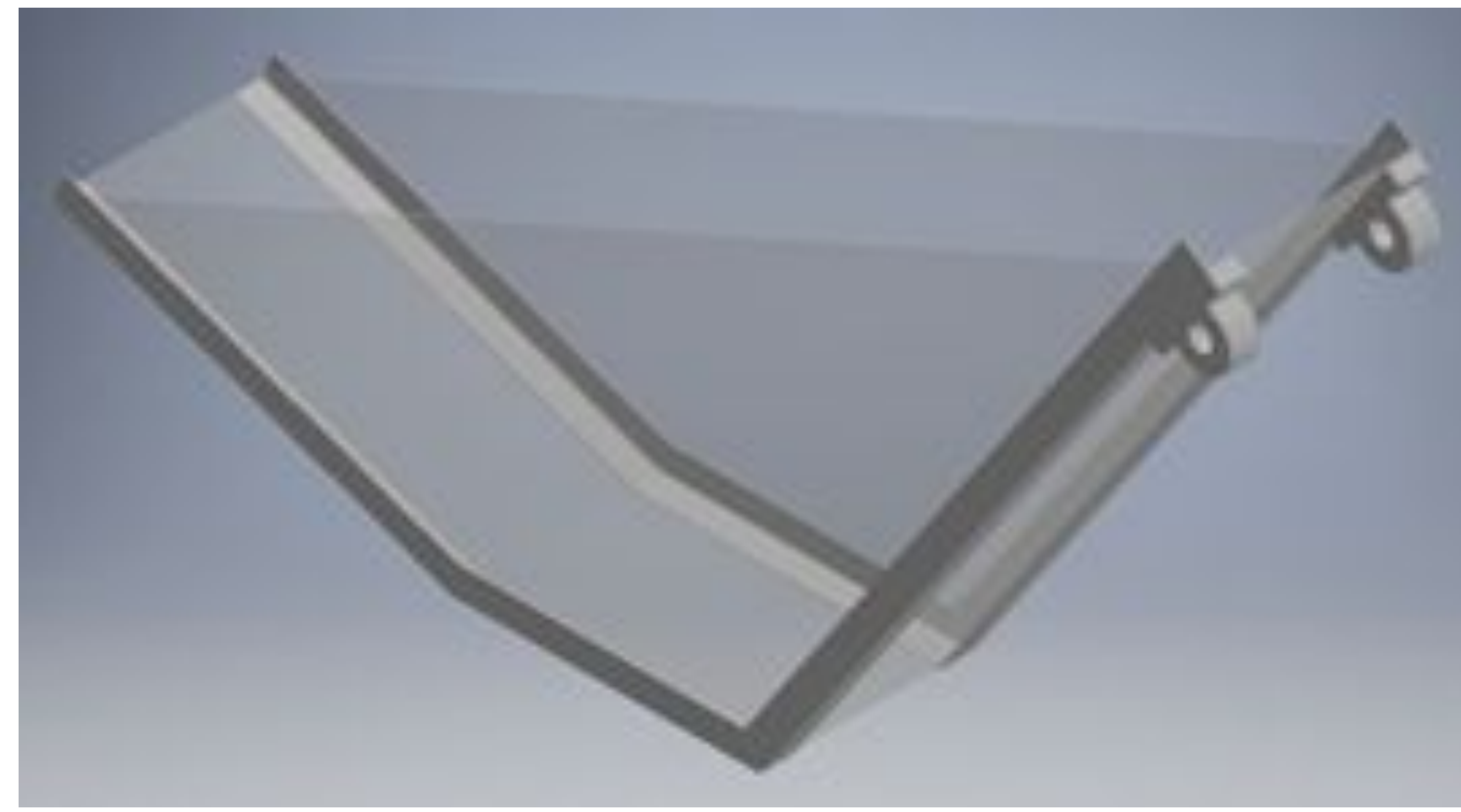
"The myriad of real challenges that are faced by our teams to define, design, build and test create the very best young engineering talent needed for the 21st century!"

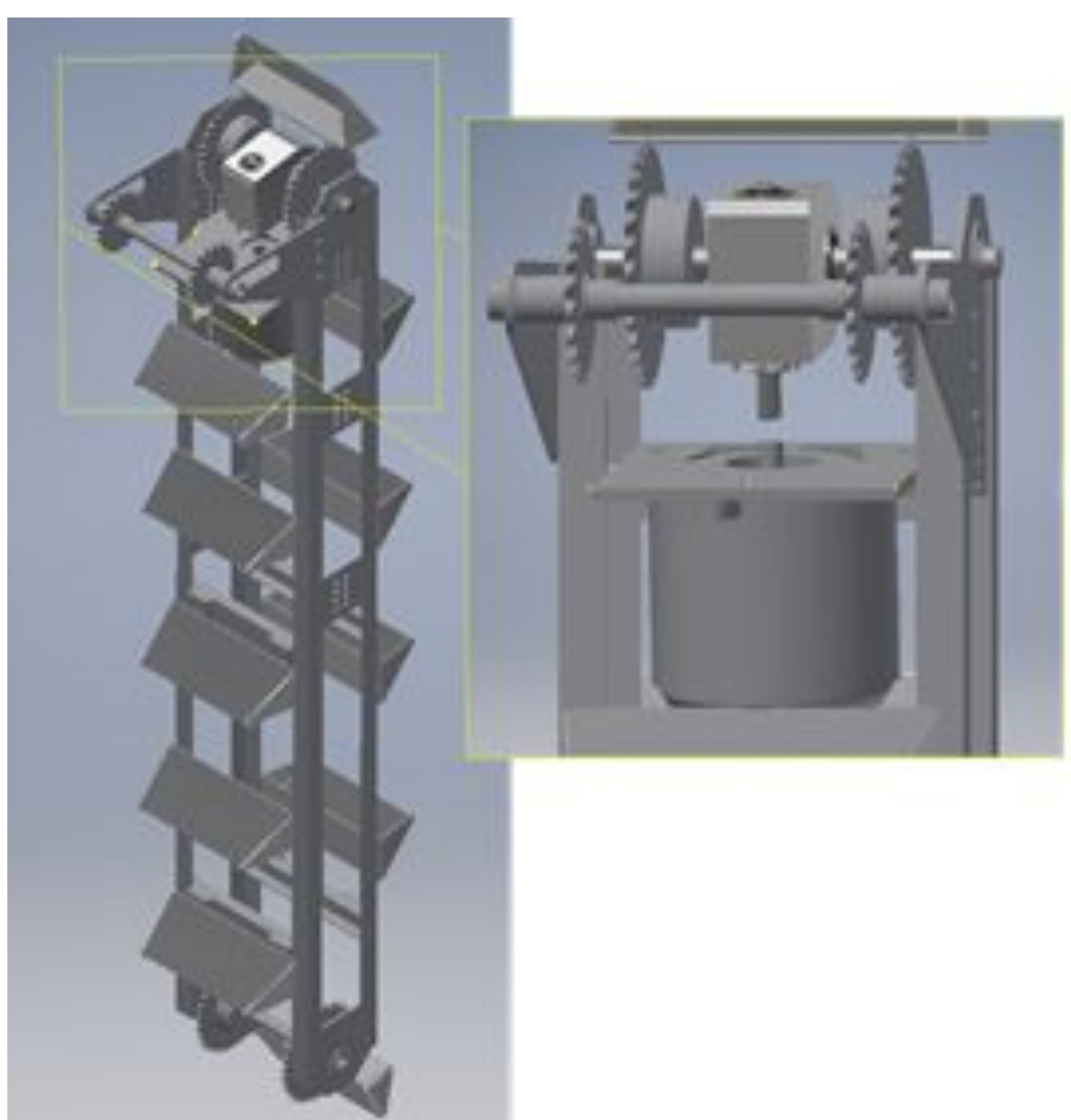
Excavation / Deposition

Challenges

Mining a simulated icy regolith creates a number of challenges that must be overcome in order to mine effectively. A majority of the difficulties arise from two factors, the depth of the icy regolith and the size constraints. Addressing each of these issues is crucial to designing an efficient system that accomplishes all of the objectives set for it.

The primary challenge that must be overcome before continuing on with any design is the depth that you must get to in order to effectively mine icy regolith. Normally, an easy way to circumvent this would just be to increase the size of the digging apparatus. What makes this problem difficult to solve is the size constraint. Making efficient use of the space that is given in order to extend the reach of the mining device offers a number of interesting design challenges.





Different Methods

One of the primary methods used to mine this icy regolith is a bucket elevator. This device is a series of buckets attached to a chain that is rotated with a motor. This rotating device is then lowered into the ground, mining the material and dropping it into a collection area. This system is effective because of the high rate at which it can excavate materials. The rotating rate of the elevator and the size of the buckets allow it to be one of the fastest mining systems. Some of the challenges that this system faces when mining icy regolith is its size and complexity. Due to the large nature of the device and the number of moving parts, it often runs into issues effectively collecting icy regolith. It also has a tendency to experience failures as a result of the large forces applied to this complex system.

An alternative method of excavation is the auger. This system consists of a steel screw contained within a tube. The screw is rotated using a motor and the entire system is lowered to the ground. The screw portion continues to rotate into the ground, pulling the material up through the tube and out of a hole in the side of the tube. It then falls down a chute into a collection area. The main advantage of this system is that it is great at piercing down deep enough to reach the icy regolith. The downsides to using this method are that the overall area that can be mined is small and the mining location must be moved often to continue collecting material. While these are not the only methods of effectively mining icy regolith, apart from a few unique systems they have proven to be the best methods of doing so. Comparing these two methods results in a few different conclusions. Overall, the auger is more effective at mining the icy regolith, but it tends to mine slower than the bucket elevator. The bucket elevator excavates much faster but also must move more material in order to get to the icy regolith, decreasing the efficiency of the system.

Chassis Design and Modeling

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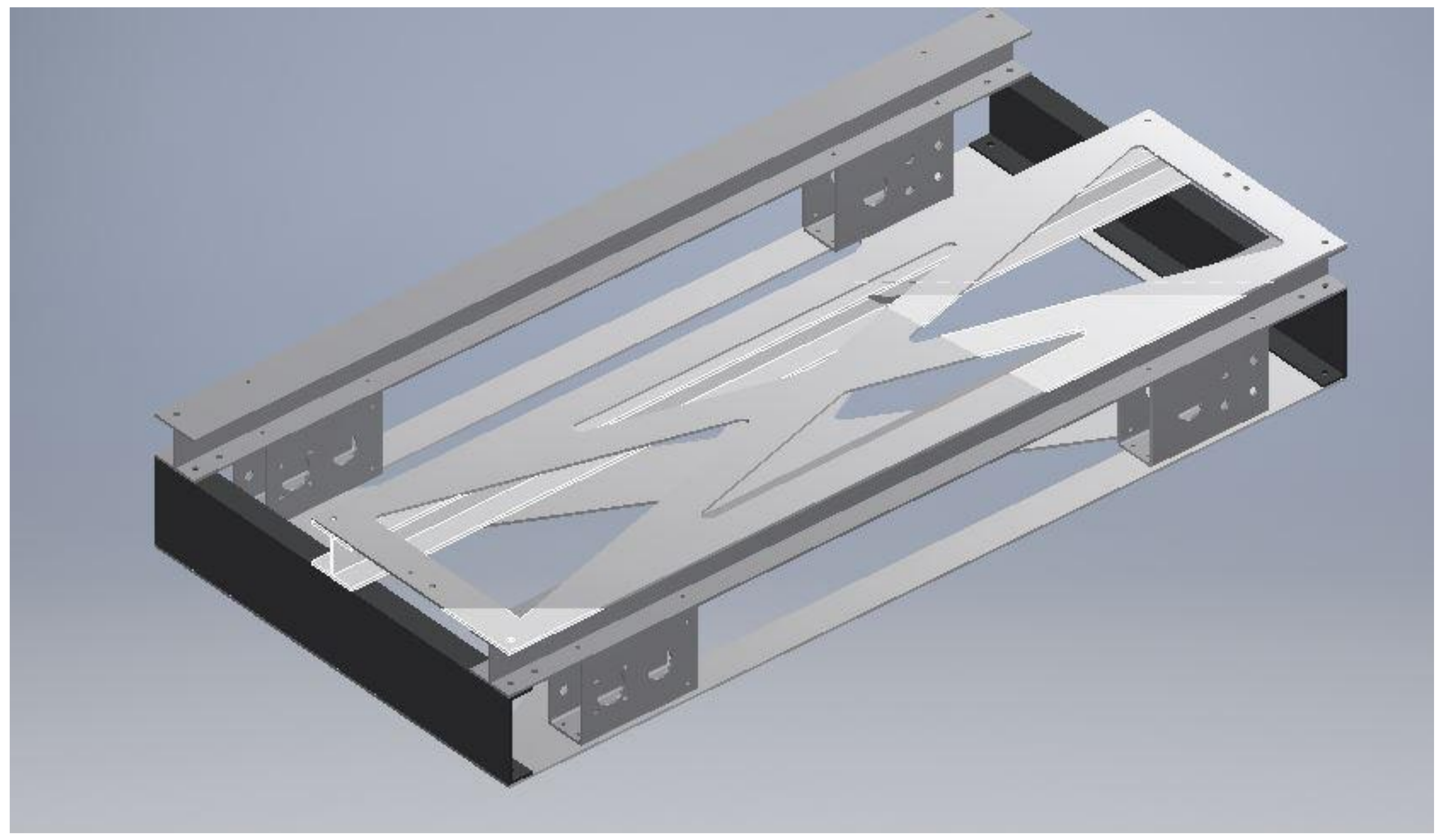
Background:

In-situ resource mining requires a platform of operations. This platform must be rigid enough to support the mining system while maintaining the ability to traverse hazards. The most popular design of chassis, since its inception, has been NASA's Rocker-Bogie structure. This structure, while robust, requires many motors and actuators to function, increasing system mass and mission cost.

An in-situ mining system should be easily manufactured and cost effective. NASA has requested all RMC participants find a solution to obstacle traversal and mining that is less than 80 kg.



Disadvantages to Design:

1. Design can only traverse rock obstacles of 17 cm or smaller.
2. Aluminum can be easily eroded within the Martian sandstorms
3. Lacks modularity for solar panels.
4. Lacks shielding for components from radiation.

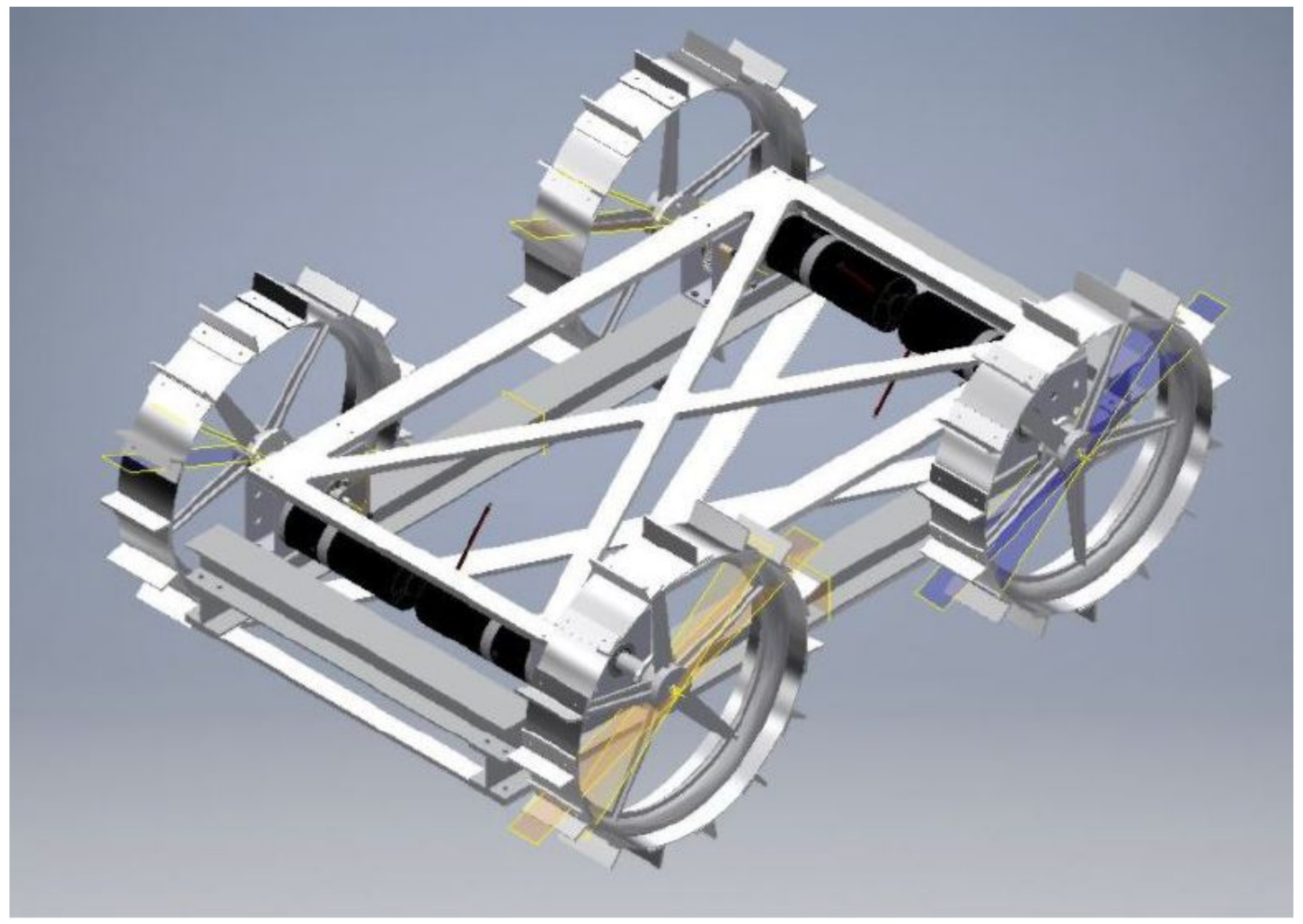
Advantages to Design:

1. Easily Mass Produced for large scale mining operations.
2. Costs under $200 to produce.
3. Two full mining systems can be placed on a Delta II. with less fuel requirements than the opportunity launch.
4. Travels at 0.39 m/s, almost 13 times faster than Curiosity.
5. Can carry 80 kg of mined material.

Technical Requirements:

Specification	Target Value
Mass	20.5 kg
Velocity (with 19.6 kg load)	0.35 m/s
Number of motors	2
Load Capacity	100 kg
Turning Radius	50 cm
Obstacle Traversal	30 cm

Resulting Design:



Conclusions:

Post testing analysis shows the chassis performed as expected. Its light weight and ease of manufacturing benefitted maintenance greatly. Further improvements will include better power management and improved layout for the mining platform.

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Risk Assessment

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Likelihood \ Consequence	Low	Mid	High
High		External Connection Point Damage	
Mid	Reduced Battery Performance	Electromagnetic Interference	Wire Cover Degradation
Low			Hardware Overheat

The largest risk of the software team and perhaps the largest risk of the robot this design cycle is autonomy failure. The requirement of constant proper operation of all algorithms, proper calculation and sensing based on data provided by LIDAR and cameras, and correct maintenance and triggering of excavation and deposition autonomously makes this risk significant and likely relative to its severity. Any other risks outlined by the team including miscalculation of marker distance, extended scan time, obstacle collision, and marker identification failure could lead to complete autonomy failure necessitating manual control. The only remedy for this risk is extensive testing of all systems and constant removal of bugs. This process is ongoing.

Likelihood \ Consequence	Low	Mid	High
High	Extended Scan Time		Autonomy Failure
Mid		Miscalculation of Marker Distance	Obstacle Collision
Low			Marker Identification Failure

The greatest risks related to power and hardware operation are external connection point damage, wire cover degradation, and hardware overheat. These could all cause hardware or power delivery failure, and hardware overheating is a more significant problem in this design than it was previously as a result of the hardware demands from autonomy algorithm calculations. External connection points and wiring were limited as a requirement from the beginning of the design cycle in consideration of those risks, and hardware overheat is intended to be prevented by sufficient separation between electronics components and ample ventilation without allowing dust infiltration.

Likelihood \ Consequence	Low	Mid	High
High	Gravel Loss through Bin Filtration		Motor Stall
Mid	Bucket Bending		Actuator Failure
Low			Linkage Failure

The biggest risk associated with the excavation and depositions systems is motor stall due to excessive required force to drive the bucket elevator at maximum depth.Motor stall would be a critical problem as it may cause damage to the drive motor of the bucket elevator, and its likelihood can't be discounted due to the considerable force to turn the bucket elevator with many contacting buckets at a 0.4-meter depth. Another major risk is failure of linear actuators to lift the bucket elevator or bin. Linear actuator failure would also be catastrophic as it could prevent the robot from effectively withdrawing the bucket elevator or depositing excavated gravel. These risks will be reduced through testing and accommodation of excavation speed control to load intensity.

Likelihood \ Consequence	Low	Mid	High
High	Chassis Bolt Dislodge	Filter Wire Dislodge	
Mid		Loss of Traction	Obstacle Entanglement
Low			Wheel Separation

The risks considered by the drivetrain team include obstacle entanglement, a phenomenon which ended a competition run last year, and filter wire dislodge, which could damage power delivery infrastructure. These are intended to be prevented by sufficient chassis clearance and effective object avoidance as well as additional wire protection and taping respectively.