PRACTICAL QUESTIONS AND TASK ANALYSIS OF REALIZATION AND OPERATION OF A LUNAR ROBOT FOR MOVING LUNAR SURFACE MATERIALS

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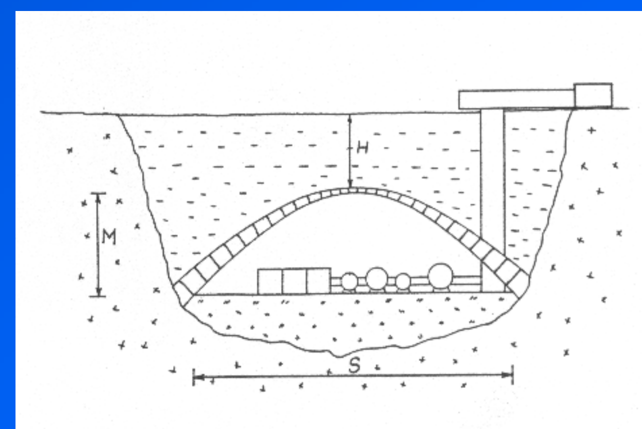
The essence of our proposal

The aim of the present paper is to review the issues in connection with the realization and operational conditions of Lunar robots for moving and transport materials under Lunar conditions as well as a few practical solution possibilities.

The background of the problem and the theory

In our earlier abstract in 2006 on the SRR VIII conference we studied the problems to create protected interior spaces of balanced temperature, of great size under Lunar conditions, which are suitable for industrial activity beyond human stay as well.



Connecting with the realization of the building, we found a problem. To create the building we have to move a lot of surface materials, regolith on the surface of the Moon. We didn’t found a suitable tool or engine for this purpose. We begin to working out a solution for moving materials and solving the connecting problems.

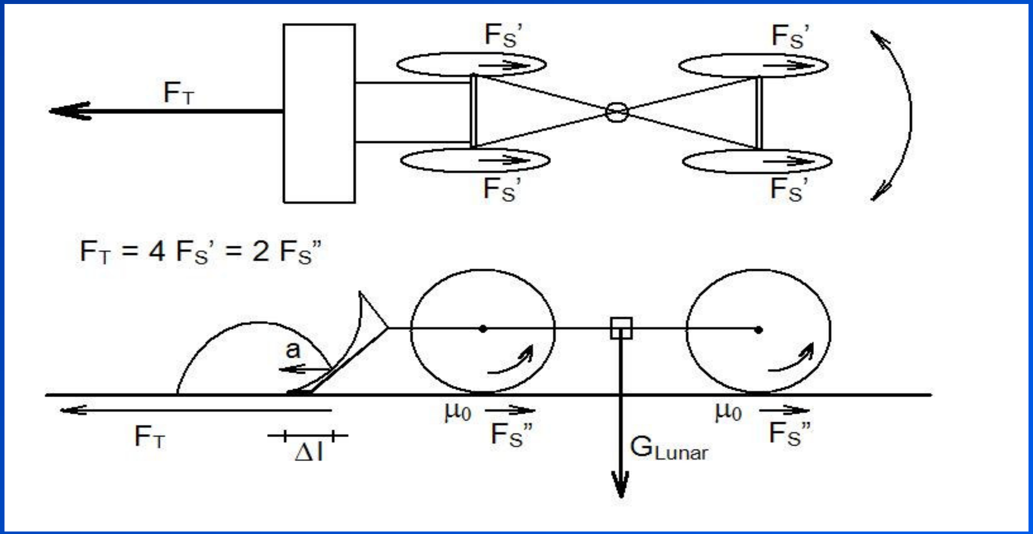
The related physical conditions of the Lunar surface environment:

- 1/6 gravity than Earth,
- special surface and soil conditions,
- surface dust,
- the lack of atmosphere,
- different irradiation cycle,
- wide range fluctuation of temperature

Due to the fact, that Lunar gravity is appr. 1/6 of that of the Earth, the pushing resp. pulling forces are also only one-sixth of that of the Earth under the same driving power.

We analyzed the theoretical possibilities and issues of the increase of the delivery output in our abstract No.1395 sent for the 38th LPSC.

Theoretical aspect of moving materials on the surface of the Moon on 'bulldozer principle'

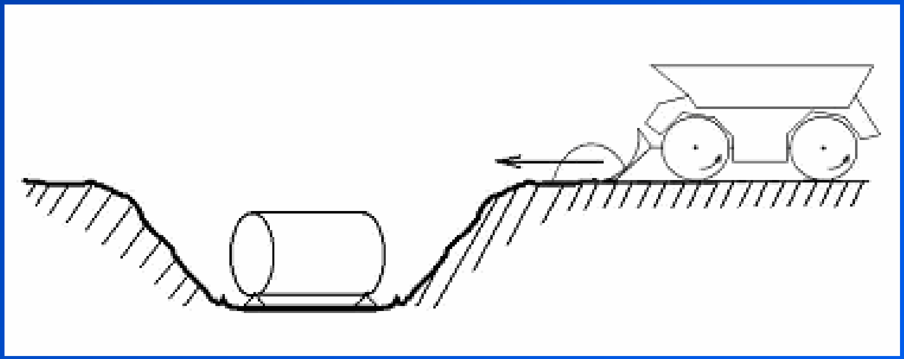


The decrease of the necessary pushing respectively pulling force due to the smaller Lunar gravity is compensated by loading the lunar moving equipment with local materials.

During this process the moving equipment is loaded with local Lunar material so as to increase the whole mass of the moving equipment. This way the pushing, respectively pulling force ensured by the lunar moving equipment increase as well while the sticking friction remains the same.

The material, soil to be delivered is suitable for this purpose, as the increase of the pulling resp. pushing force can be achieved by the proper loading of the moving vehicle.

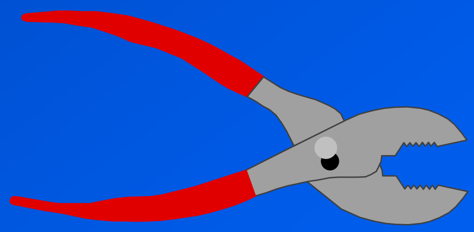
Practical questions of the operation of a Lunar material moving robot:



1. Main tasks: Material moving,
   Transport,
   Pulling,
   Pushing,
2. Maneuvering: Change of direction,
   Moving forward and backward,
   Fixing,
   Stabilization,
   Change of speed,
3. Overcoming surface obstacles, adjustment to surface conditions,
4. Self-sufficient loading, unloading,
5. Energy supply,
6. Communication,
7. Control, heading,
8. Detection, monitoring outside conditions,
9. Partially or fully automatic operation.

Issues of the construction:

- The robot must be light because of the transport to the Moon, at the same time it must have the proper mass to be able to carry out the tasks: transport, pushing and pulling force;
- Light basic structure production on the Earth, delivery by a spaceship, on-site assembly;
- Robust loadbearing structure, stable, strong construction;
- Loading container, loading space of suitable size;
- Issues of driving;



Issues of structural materials suitable for use:

- Heat-resistant materials which are cold-resistant as well;
- Radiation resistant materials;
- Application of materials with similar or same heat expansion coefficient within wide range of temperature;

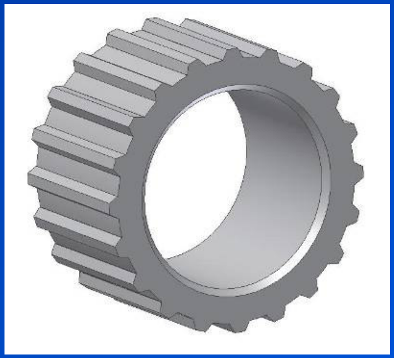
Issues of the drive:

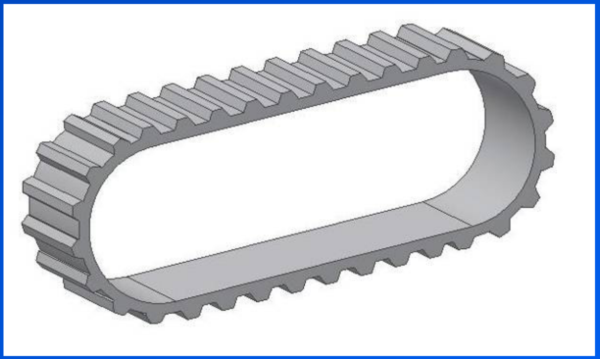
There are two main possibilities:

Wheel,

Caterpillar.

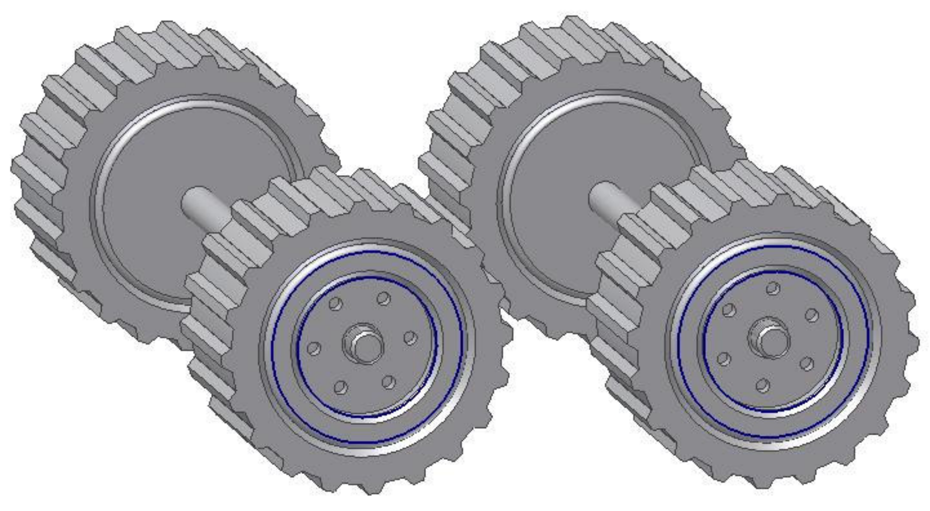
Both driving methods have their advantages and drawbacks.





Wheel drive:

- fewer axle,
- fewer rotating parts,
- smaller gripping surface,
- better manoeuvring ability,
- less energy for the drive.

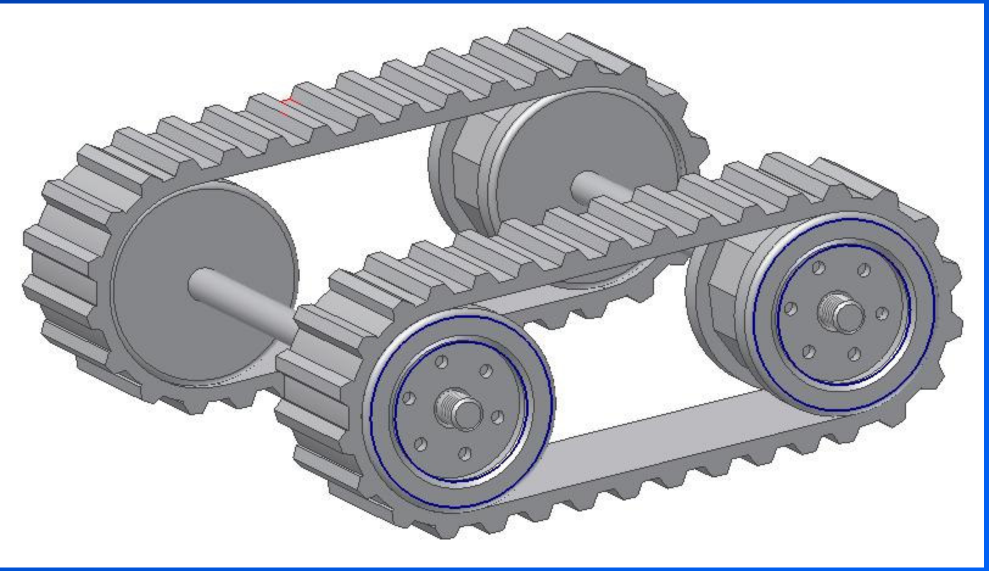


Determination of the number of wheels:

Two wheels, three wheels, four, or six, eight wheels.

Issues of the drive

Caterpillar drive



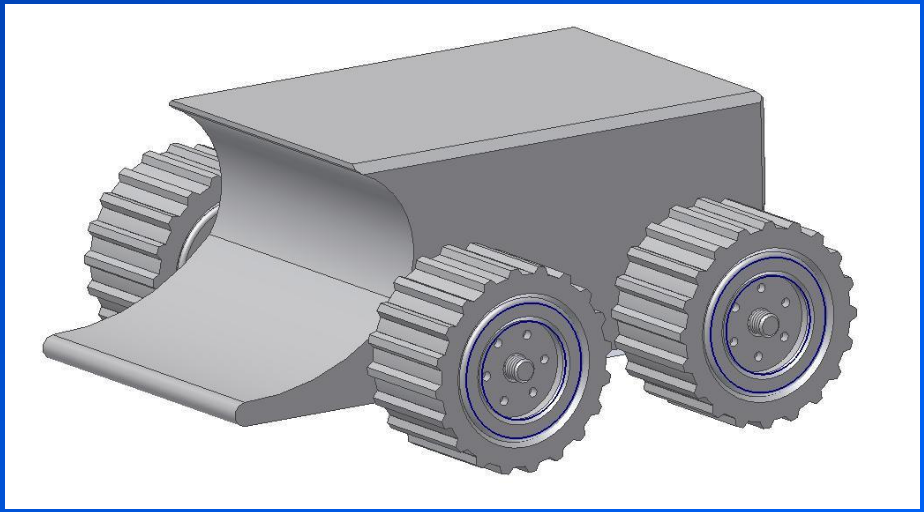
- more shafts,
- driving and complementary shafts,
- more rotating parts,
- bigger gripping surface,
- more energy for the drive,
- pressing force per unit is smaller.

The caterpillar has more benefits on extreme, erratic ground.

Overview of the practical solutions:

Wheel drive Lunar robot for moving materials on the surface of the Moon

The main characteristics of the wheel drive Lunar robot:



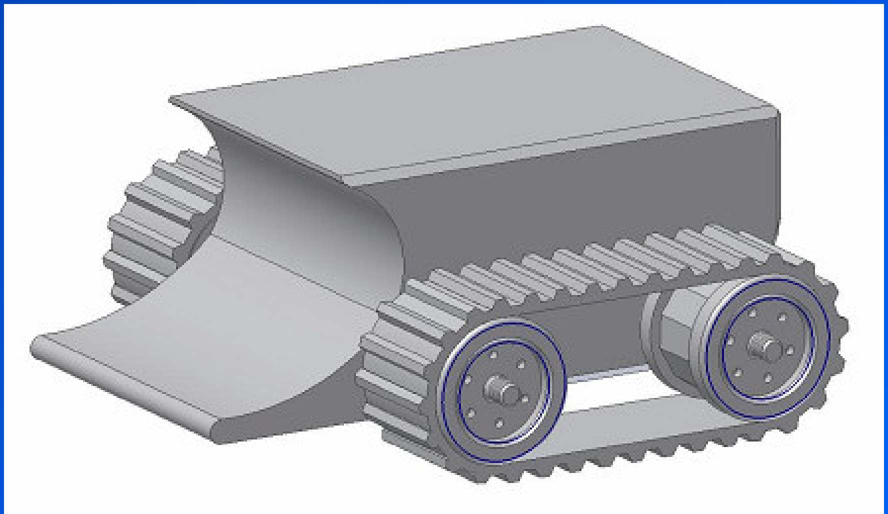
- fix first drive,
- power transmission,
- back steered,
- provided with inner container,
- electronic and driving control is placed in the upper 1/5 part

The pushing plate is built separately from the main structure of the robot, it can be moved vertically in the direction of the ground surface. The front of the pushing plate is rounded because of the mechanical endurance.

Cells to be charged by solar cells are provided for storing energy.
Electric engine built in the wheel hub provides drive. Pacing of engines is synchronized electronically, in case of obstruction synchron drive stops, so the structure can be removed from. Obstruction by asynchronous movements.
Net cover or ribs made of metal or plastic can be found on the outer surface of the wheel.

Overview of the practical solutions:

Carterpillar drive Lunar robot for moving materials on the surface of the Moon



The characteristics of the caterpillar drive:

- Separate drives on the right and left side, with separate cylindrical spreaders
- Lower cylindrical spreaders help overcome uneven ground
- Upper cylindrical spreaders grant tense of caterpillar

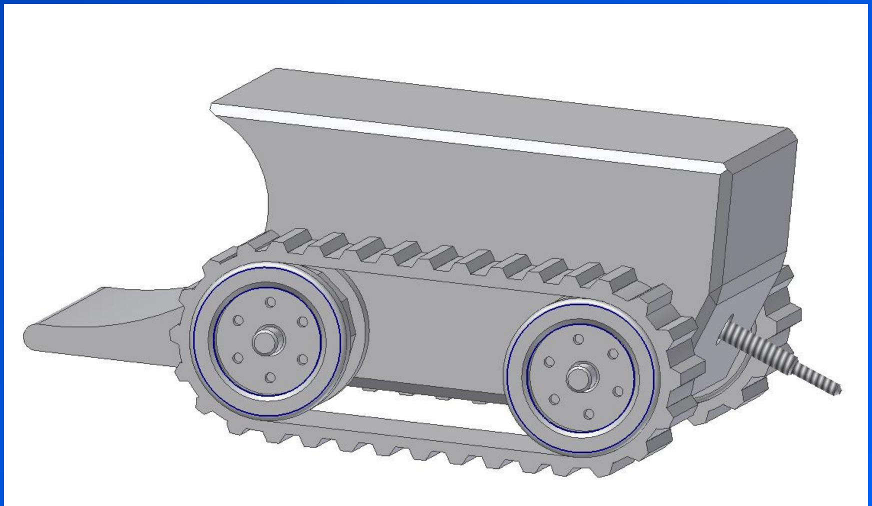
From going from one point to the other the robot can unload so much dust or regolith from its inner store with the help of a seeve system located on the bottom, that less energy is needed for getting to the aim more quickly and saving more energy.

Blunt metal spikes are placed on the driving wheels fitting into the hollows of the chain ensuring drive.

Overview of the practical solutions:

Self-loading and unloading combined Lunar robot with caterpillar drive

A self-loading and unloading combined robot can be produced by of wheel or caterpillar drive with soil collector with helical axle resp. lower discharger with shovel.



The robot must be properly loaded to ensure suitable pushing resp. pulling force.

The loading is made by loading of Lunar soil into the inner store of the robot

The loading can be executed with an outer device, but in case it is not available, the robot is provided with self-loading for the fully self-sufficient automatic operation, which is in given case a loader with shovel.

With the help of which as much material, regolith can be loaded from the outer environment into the inner store space of the robot, as necessary to achieve the proper pushing resp. pulling force.

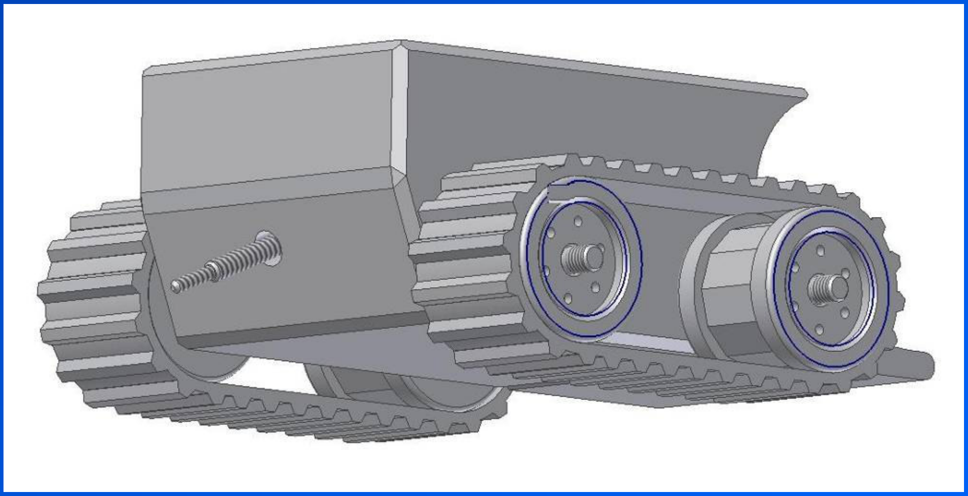
Overview of the practical solutions:

Self-loading and unloading combined Lunar robot with caterpillar drive

After executing the job, emptying of the inner store space of the robot might be necessary.

It can be carried out by an outer device as well, but the robot must be capable of self-emptying.

It can be partly carried out by the loader with helical axle turned inside.



Full emptying can be made with the help of gravity, which makes necessary the slanted formation of the bottom of the loading space.

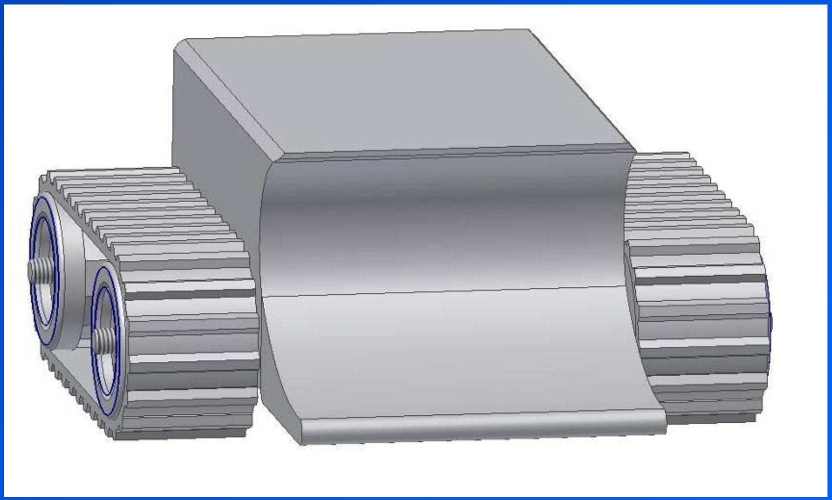
By opening partially or fully the lock while moving the robot, the loading material leaves the inner store space. It can be used for ground surface jobs, levelling the ground.

The emptying can be helped by a discharger with shovel placed in the bottom or back of the load space, ensuring full emptying.

Advantages, additional issues of realization

Self-loading and unloading combined Lunar robot with caterpillar drive

Highly probable, that in case of the first realizations direct solar energy supply will have to be used similarly to Martian rovers, because during the 14 day daylight period long, continuous operation is possible.



It is not necessary to consider too robust structures, but a structure of relatively smaller performance, but continuous operation with light structure is suitable in proportion with the possibilities provided by electric supply.

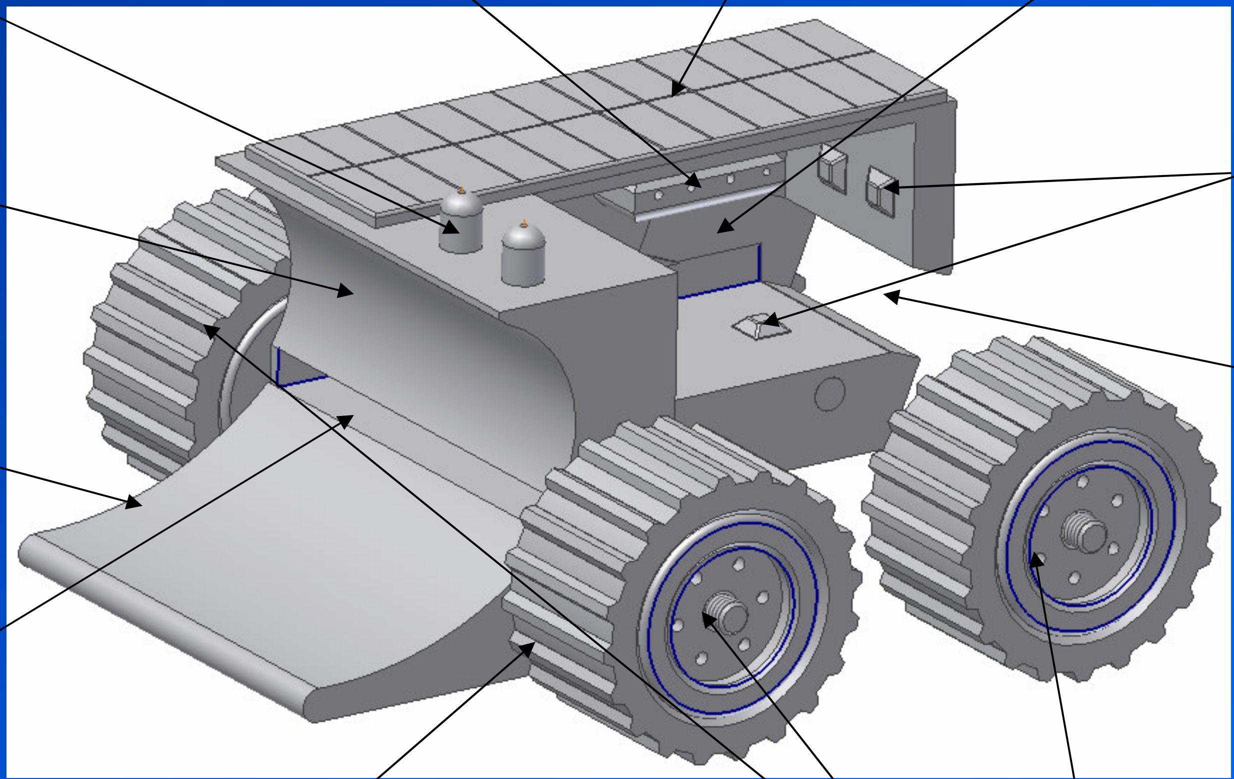
It is also advantageous from the point of view of optimizing, minimizing the mass to be delivered to the Moon.

It is important for the materials applied that extreme temperature and radiation conditions should be resisted. Special metal alloys are first of all suitable for this purpose, however these increase the mass to be transported.

The other possibility is the use of special plastics, respectively plastics coated with metal on the proper places.

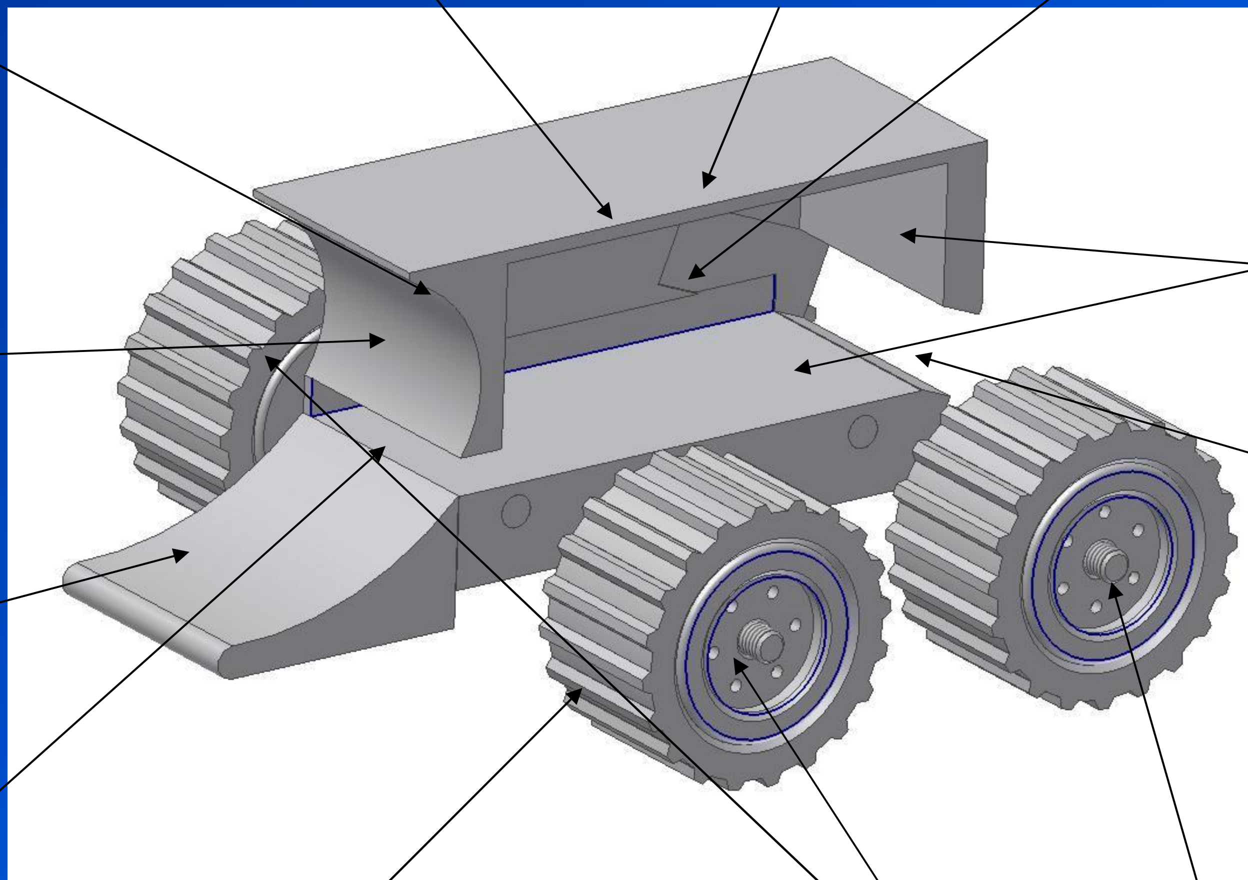
Task analisis of the construction and realization

Main questions of the construction



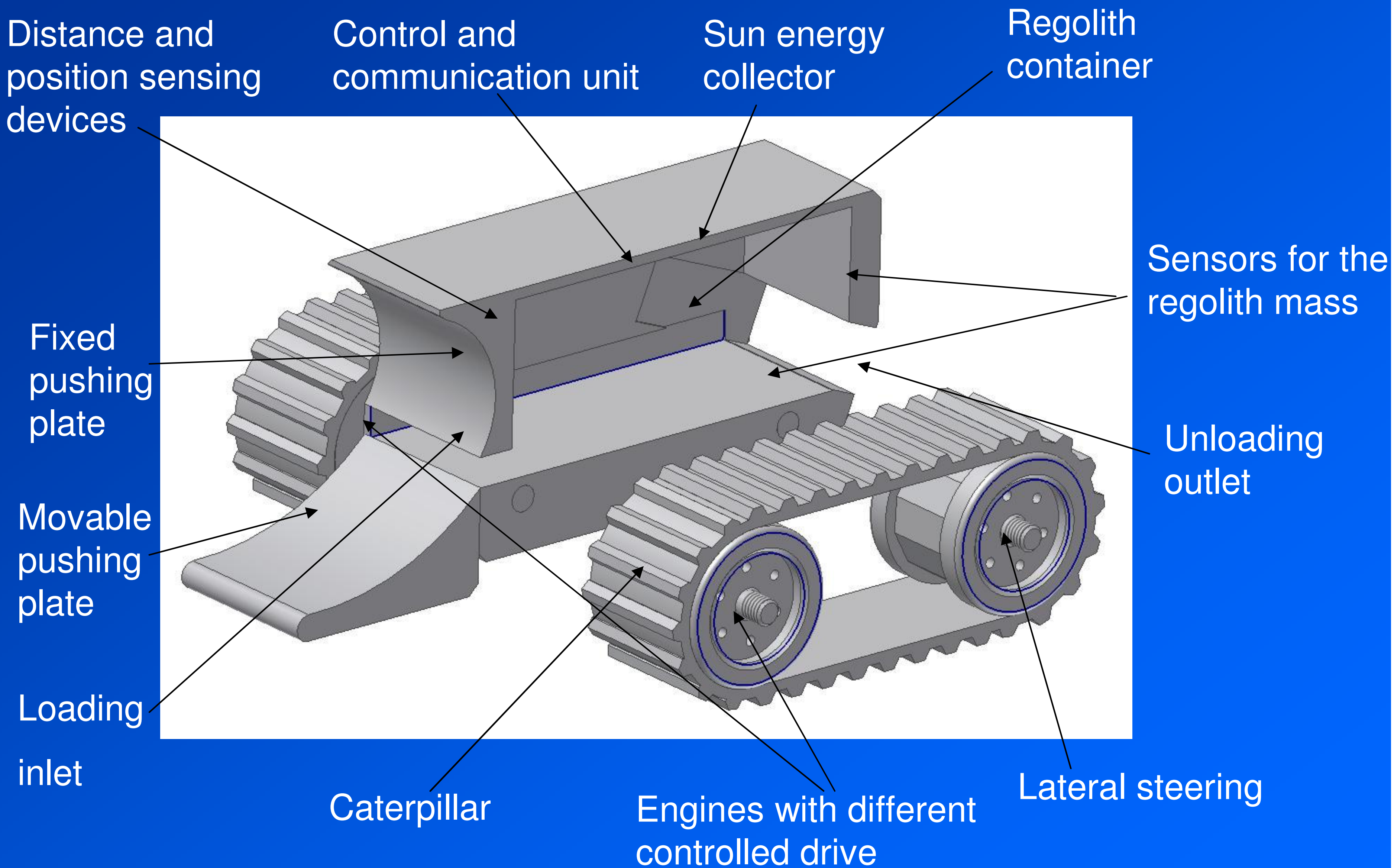
Section in part of a four wheel drive Lunar robot for moving Lunar materials

Task analisis of the construction and realization



Cross section of a four wheel drive Lunar robot for moving Lunar materials

Task analisis of the construction and realization

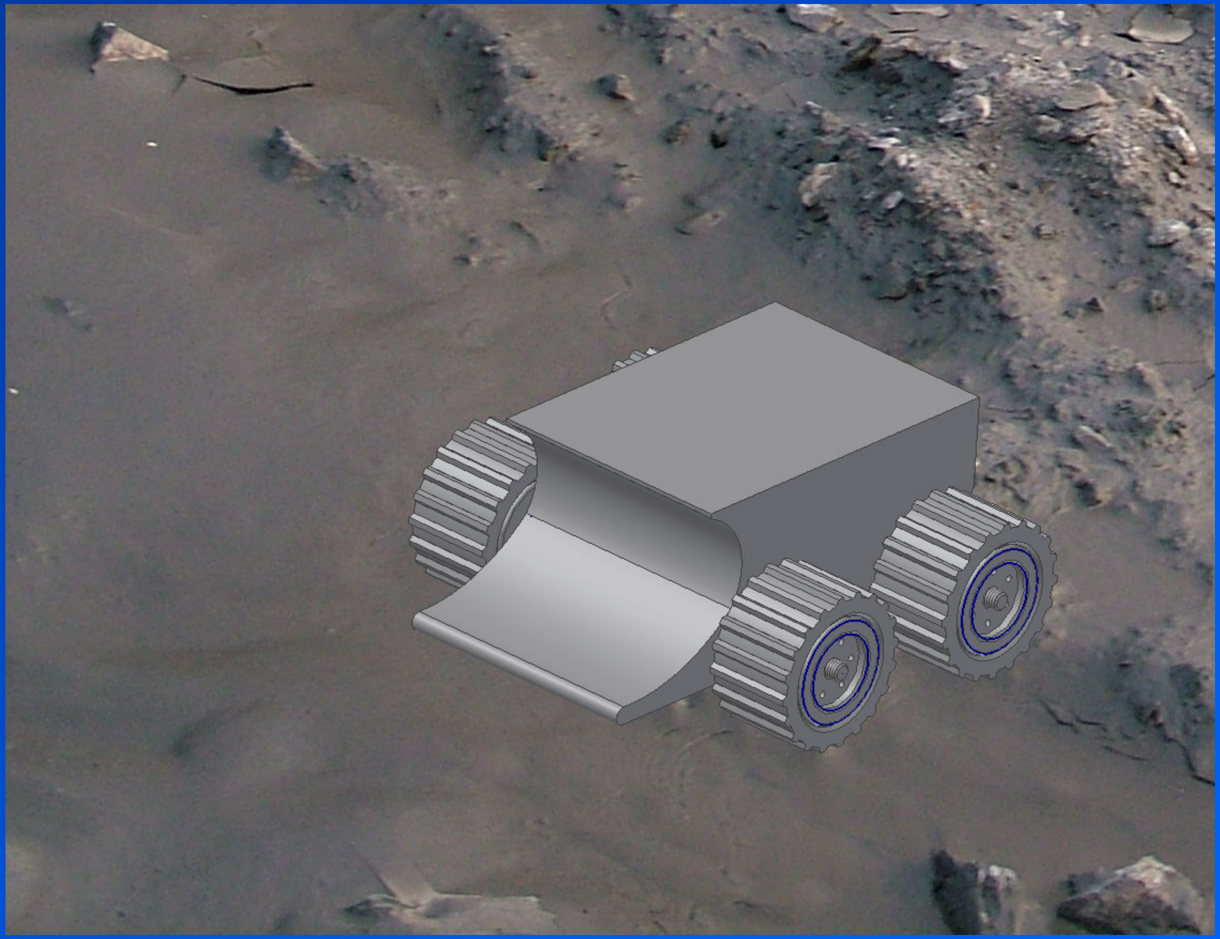


Cross section of a caterpillar drive Lunar robot for moving Lunar materials

Simulation of the operation of the robot in analogue environment on the Earth

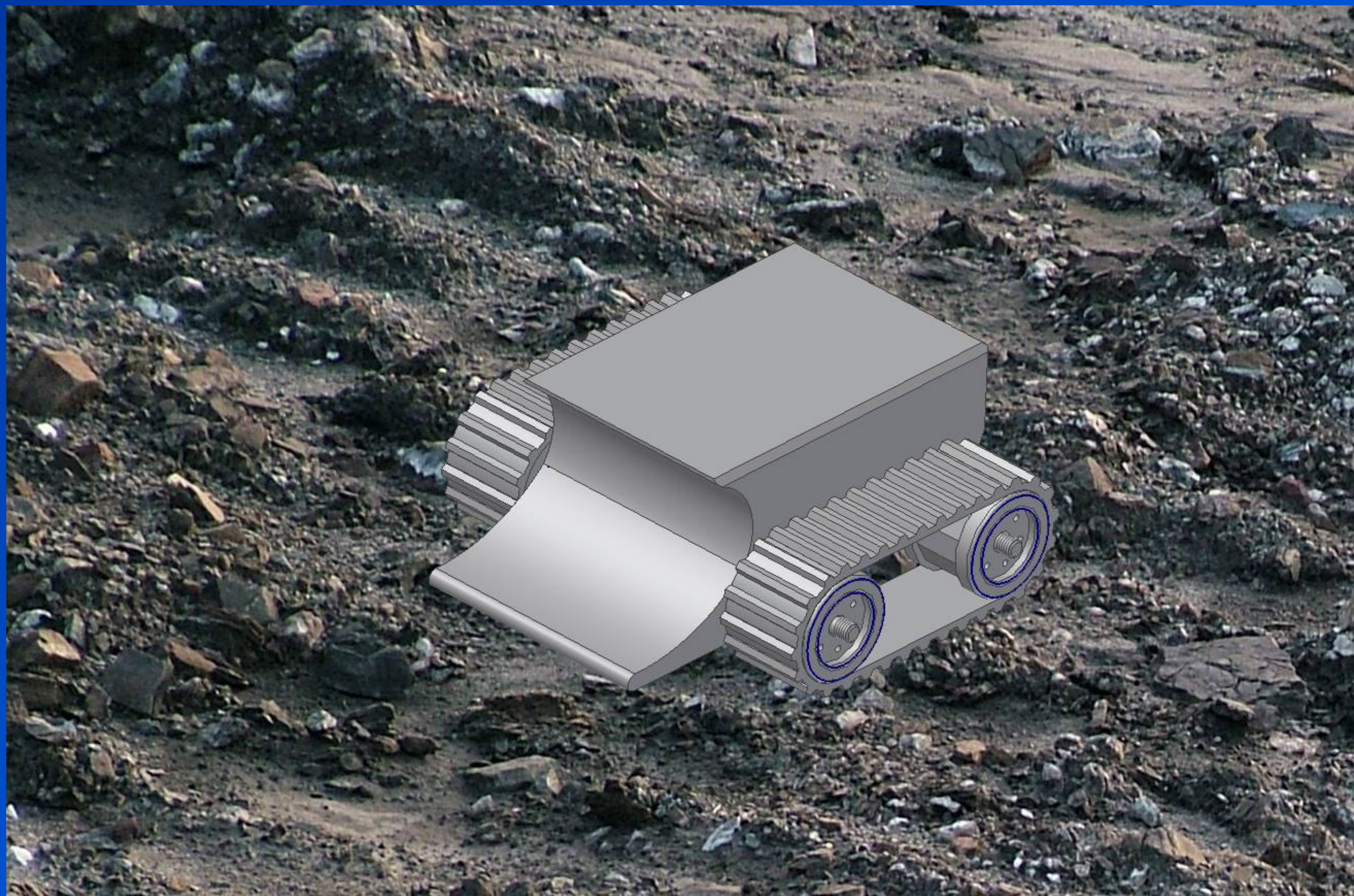
Analogue place in a strip mine in the Mecsek mountain in Hungary

Simulation of the operation of the robot in analogue environment on the Earth



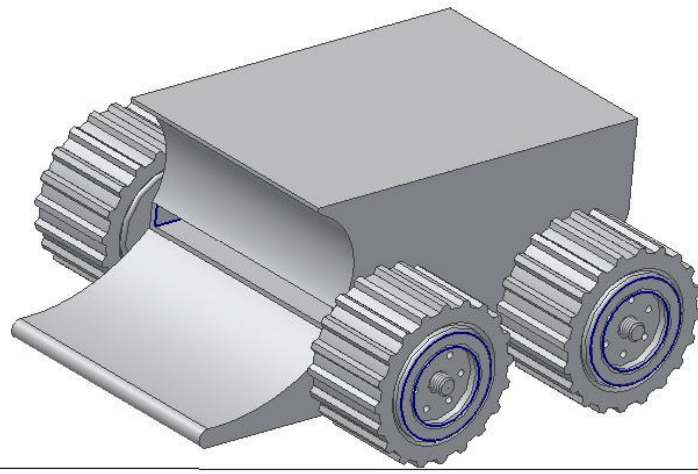
The soil of the strip mine is similar to the Lunar surface, because from the smail grain dust to the bigger rocks a lot of versions of the environmental forms can be found.

Simulation of the operation of the robot in analogue environment on the Earth



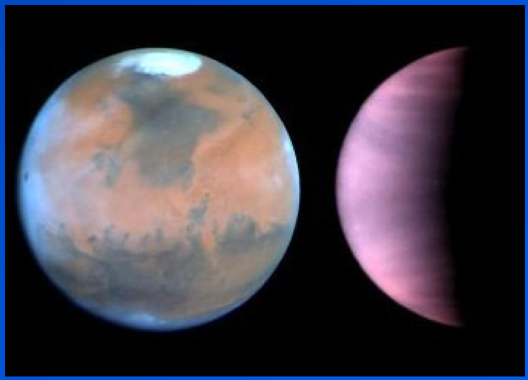
On the rocky Lunar surface the caterpillar drive may be better, than the wheel drive.

Animated operation of the Lunar robot



By the moving the robot is able to collect the Lunar surface materials.
In other part by the help of the improved pushing force, the robot is able for the efficent moving and alignment of the Lunar soil with the pushing plate.

Perspectives, targets for the future



Producing an operating model

- Overview the aspects of the structure and loadbearing
- Overview and selecting the suitable materials for the structure
- Developing of the multifunctional operation
- Developing of the controlling methods
- Installation of the robot with sensors and measuring equipments

Test on a Lunar analogue field

- Analogue places are found in the Mecsek mountain strip mines

Study of the possible applications on other planets and moons

Thank you for your attention!