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DESIGN OF A ROVER PROTOTYPE MANUFACTURED BY ADDITIVE TECHNOLOGIES

Abstract: *This paper examines ROVER-type systems, aimed at transporting human crew for research on other planets, and the development of such a prototype using additive manufacturing technologies. A classification of these technologies is presented. The main aim of the paper is to develop a prototype of the ROVER system at scale, to highlight its main features, and to use this type of additive manufacturing technology during its life cycle, thus benefiting from the realization of parts, sub-assemblies and assemblies. Several conclusions distinguish the main points of the paper and future objectives of the study.*

Keywords: *ROVER, additive manufacturing, design, redesign, prototyping, space exploration.*

1. INTRODUCTION

The aerospace and research industry is enjoying strong interest from both governments and humans, similar to the Apollo missions, with the main goal of researching Mars and a subsequent human journey, culminating in a base on Mars [1].

Thus, both the search and the movement of crews in such an environment is conditioned by the use of a vehicle, providing a larger area of discovery, as well as ease of sample collection and transport.

The term rover generally refers to vehicles designed to explore the surfaces of planets or other space bodies. They can have the purpose of both vehicles intended to carry human crews and semi-autonomous or fully autonomous robots, and are generally designed to land on other planets using spacecraft [2]. They are designed to collect information about the ground, as well as collecting samples of dust, soil, rocks and even liquids.

The first ROVER made to send it to the lunar surface belonged to the Soviets in 1969, called Lunokhod 0, but it was destroyed after a failed launch. However, Lunokhod 1 managed to land on the lunar surface in November 1970, the first remote-controlled ROVER to land on any celestial body, and it managed to operate for 11 months until September 1971 [5].

Concurrently with these launches, NASA succeeded in sending the first human crew to the lunar surface on Apollo 11, 11 July 1969, followed by other manned missions, culminating in Apollo 15, 16 and 17 where they were assisted by a lunar rover, covering a distance of about 90 kilometers, which was impossible to achieve without such a platform [4].

But after the Apollo missions ended, manned missions to other space bodies were stopped, mainly for economic reasons, followed mainly by missions to Mars using autonomous ROVER systems. Their evolution has been impressive, from the Sojourner ROVER in 1997, which was able to transmit images and analysis of the soil and climate for two months, to the Perseverance ROVER today, whose main purpose is to search for potential traces that could indicate the presence of past life on Mars.

2.PRESENTATION OF ROVER PLATFORMS

2.1 Operating principles of rover platforms

ROVER platforms are designed according to various operating principles, with the main purpose of replacing human-dedicated activities, mainly those dedicated to research in hard-to-reach locations. However, depending on the activity, it has to be designed following different principles, such as locomotor and control principles, thus being a combination of mechanical, electrical and computer disciplines, called mechatronics.

The locomotor principle is based on the system's main means of locomotion. The most common is the wheel-based system, but you can also find systems such as the legged, wheeled or crawling system. These are chosen according to the type of movement desired, this being a necessity conditioned by the running surface.

Thus we can have a classification like:

- Flow in a tunnel, with vortices as the kinematic principle and hydrodynamic forces as the main resisting force to the movement;
- Torsion, with longitudinal vibration as the kinematic principle, and frictional force as the main force resisting movement;
- Sliding, with sliding as the kinematic principle and frictional force as the main resisting force to motion;
- Running, having as its kinematic principle the oscillatory motion of a pendulum with several joints, and the main force of resistance is the loss of kinetic energy;
- Jumping, having as its kinematic principle the oscillatory motion of a pendulum with several joints, and the main resisting force is the loss of kinetic energy;
- Walking, with the kinematic principle being the rolling of a polygon, and the main resisting force being gravitational force.

Another aspect that needs to be taken into account between these types of movement is energy consumption, which is an extremely important criterion of this research.

Another principle is that of endurance can be represented by the control system of the ROVER-type platform, so it can be controlled both directly, like a normal vehicle, from a distance, using a simulator or similar system, and autonomously, using an already known route, or using artificial intelligence.

The strength of this system is similar to that of any other vehicle, with a chassis at the base, on which the rest of the assemblies and sub-assemblies are placed, such as the locomotive system, engine, bodywork, also providing the necessary strength.

2.2 Classification of rover systems

The classification of these types of systems can be done in a branched way, by dividing and classifying the various assemblies found on them [3]. Thus, ROVER type systems are classified according to:

- Locomotor system:
  - With legs:
    - One leg;
    - Two legs;
    - Four legs;
    - Six legs.
  - With wheels:
    - By number of wheels:
      - Three wheels;
      - Four wheels;
      - Six wheels;
      - Eight or more wheels.
    - By type:
      - Standard (2 degrees of freedom);
      - Pivoting (2 degrees of freedom);
      - Omnidirectional (3 degrees of freedom).
  - Other types:
    - With chain tracks;
    - Feet with wheels.
- Control system:
  - Manual;
  - Remote controlled;
  - Autonomous.
- Fuel used:
  - Electricity;
  - Solid fuel;
  - Liquid fuel.
- Its purpose:
  - Passenger transport;
  - Freight transport;
  - Sample collection;
  - Visual research.

2.3 Main components of the rover system

ROVER systems, especially those designed to carry human crew, are complex systems, consisting of a large number of assemblies and sub-assemblies, mostly following the principles found in conventional vehicles. However, they are adapted to meet the requirements of the harsh environment they are subjected to, such as extreme temperatures and dust.

Thus, the main elements are:

- ➢ Chassis;
- ➢ Body;
- ➢ Propulsion system;
- ➢ Steering system;
- ➢ Communication system.

These elements will be analysed and developed later in this research, as they are in turn represented by a multitude of subassemblies and considerations that need to be taken into account in the context of meeting the necessary requirements.

In the context of this research theme, one of the objectives is to develop a modularized ROVER platform. Thus, it would benefit both from an easier assembly and maintenance, as well as the interchangeability of different modules, such as adding storage space, a prehension system, additional tank, thus using the same platform for different tasks.

3. MATERIAL ADDITIVE MANUFACTURING TECHNOLOGIES

3.1 Presentation of material addition manufacturing technology

Additive manufacturing is the name of the industrial process of 3D printing, a computer-controlled process that creates three-dimensional objects by depositing materials, usually in layers [6].

It is based on computer-aided design (CAD) or 3D scanning of objects, so additive manufacturing allows the creation of objects with precise geometric shapes. Making them layer by layer is an advantage over traditional manufacturing because it generally does not require, or does not require as much machining or other techniques to remove excess material.

This technology will be used in this research theme both in the prototyping of the ROVER and to make various component parts in the context of making them on Mars, as the travel time between Mars and Earth is very long, and very expensive, so making the necessary component parts and tools using 3D printing technologies is vital.

3.2 Classification of additive manufacturing technologies

Additive manufacturing is divided into several branches, depending on the technology used:

FDM (Fused Deposition Modeling) - Thermoplastic extrusion molding

- The most widely used technology, used in modelling, prototyping and production applications;
- The principle of operation is that with the help of dedicated software, the 3D model is "sliced" into cross-sections representing the layer. The technology consists of passing a plastic filament through an 'extruder' that heats it up to the melting point and then applies it uniformly layer by layer by first extrusion;
- Materials used: ABS, PLA, PVA, polycarbonate, HDPE polyethylene, polypropylene, elastomer, PPSU, PPSF, POLYAMIDE, casting wax.

SLA (Stereolithography)

- Rapid prototyping technology, widely used in the industrial field to make moulds, models and even functional parts;
- It involves using a laser beam with ultraviolet light to solidify a liquid photopolymer resin in the printer's

build tank. Thus, using software that 'slices' the 3D model into cross-sections, ultraviolet laser light passes through the resin, which solidifies in successive layers resulting in the 3D model;
- Materials used: photo-sensitive liquid resins, ceramic materials.

DLP (Digital-Light Processing) - Digital Light Exposure
- Represented by an additive manufacturing process based on the use of UV light to solidify liquid polymer resins. Its main element is the DMD (Digital Micromirror Device) chip, which is an array of micro lines used for rapid spatial modulation of light;
- Materials used: resins, photopolymers, transparent resins, wax-based polymers.

SLS (Selective laser sintering)
- Patented in 1980, it is close to SLA, involving the use of a high-power laser beam to melt (sinter) powders in successive layers to produce a 3D model;
- The principle of operation is also cross-sectioning of the 3D model, and based on this, the moving laser beam selectively melts the powder layer on the build platform inside the vessel. Once the cross-section is complete, the platform on which the 3D models are built is lowered for the next layer, a new layer of powder is applied and then smoothed, and the process is repeated until the model is complete;
- Materials used: plastic powders, thermoplastics (nylon, polyamide, polystyrene, elastomers, composites), metal powders (steel, titanium, alloys), ceramic powders, glass powders.

LOM (Laminated Object Manufacturing)- Laminated Object Manufacturing
- Allows layered fabrication of the 3D object from layers of paper or plastic that are glued together, one on top of the other, and cut out using a knife or laser;
- The pattern is converted into cross-sections, then using a laser source or a knife, the printer cuts out the layers that will make up the 3D part from the solid sheet. The rest of the unused material from the cutting process is then cut away by knife or laser, so that it can be removed by hand at the end of the process. The finished layer is glued to the previous layer using an adhesive applied to the underside of the sheet;
- Materials used: paper (regular sheets), plastic (rolls).

PJP (Polyjet printing) - photopolymer polyjet printing
- SLA-like technology, still using liquid photopolymer photo-solidification, but similar to regular inkjet;
- Materials used: photopolymers of various types (rigid, malleable, transparent, opaque, bio-compatible, elastomers).

3.3 Materials used in prototyping using additive manufacturing technologies

The prototyping process will use thermoplastic extrusion moulding technology. This is the most widely used technology today, being used both for prototyping, in industry and in recent years even in domestic use. It aims to analyze the product before it goes into production. These analyses, which can be both visual and functional, provide valuable information both about subsequent manufacturing processes and about how the product functions under real conditions.

The principle of operation is the use of dedicated software, with which the 3D model is "sliced" into cross-sections, representing the layers. The technology consists of passing a plastic filament through an 'extruder' that heats it to the melting point, and then applying it uniformly layer by layer by first extrusion.

The materials used in this process are diverse and have different properties, such as:

PLA (polylactic acid)
- Bioplastic type material, being derived from corn or sugar cane starch, thus having the property of being biodegradable;
- The melting point is around 150-160 degrees Celsius;
- Being a thermoplastic material, it can be heated to the melting point, cooled and reheated without significantly affecting the properties of the material.

Advantage:
- Ease of 3D printing;
- Renewable and biodegradable resource;
- It is odorless, non-toxic.

Disadvantages:
- Relatively low transition temperature (between 44 and 63 degrees Celsius);
- Relatively brittle compared to other materials in the context of use in functional prototypes;
- Low flexibility;
- It is not resistant over time, nor to long use.

PET (polyethylene terephthalate)
- One of the most widely used thermoplastics, generating a demand of 56 million tonnes annually, it is most commonly used for bottling as well as clothing;
- The filament made of this material has a melting point between 220 and 250 degrees Celsius, requiring a heated bed around 50 and 70 degrees Celsius;
- Can be melted repeatedly without undergoing changes.

Advantage:
- Strong, flexible and very light material;
- High success rate in 3D prototyping;
- Recyclable material;
- Able to withstand humid environments, and temperatures up to 75 degrees Celsius;
- Good chemical resistance to lubricants, oils, alcohols, acids and alkalis.

ABS (acrylonitrile butadiene styrene)
- Hard oil-based material;
- Offers good value for money and durability;
- The melting point is above 220 degrees, it is hard to break but can be easily shaped.

Advantage:

- Easy to process, can be easily glued, treated with acetone and even painted;
- Hard material, does not break easily, does not scratch;
- Resistant to heat and mild chemicals;
- Printing with this material gives very good results.

Disadvantages:

- Strong, toxic odour with carcinogenic potential;
- Difficult to print, requiring high temperatures, around 100 degrees Celsius for bedding and the use of adhesives;
- It is recommended to use a special enclosure of the printer to avoid shrinkage caused by temperature differences;
- Can bend over time, most often if the printed objects have a large surface area.

ASA (engineering plastic)

- An alternative to ABS, with similar properties, but with the advantage of UV resistance;
- The name "engineering plastic" is given to the way it retains its properties after prolonged exposure to sun, cold, rain, wind and even salt water.

Advantage:

- Higher strength than ABS;
- Antistatic material;
- Highly resistant to impact forces;
- Water and chemical resistant.

Disadvantages:

- During melting it releases potentially hazardous smoke;
- Requires high temperatures, thus consuming a lot of energy;
- Gradual cooling as well as the use of an enclosure during printing.

Flexible material, TPU/TPE

- They contain both plastic and rubber;
- Soft and rubbery texture;
- Used in many industries, from wires and cables or fibre optics, to children's cutlery as well as in the medical industry, sports equipment;
- The main characteristic is elasticity, they can be stretched at room temperature to twice their original length, returning to their original shape.

Advantage:

- Elasticity;
- Very good grip;
- No heated bed required;
- High durability as well as low and high temperature resistance;
- Absorb shocks well.

Disadvantages:

- Printer settings and special features;
- Requires rapid cooling due to its malleability.

Nylon (polyamide)

- Tough, durable material with relative flexibility;
- It is a hygroscopic material and can be further processed with various types of paint, but it also absorbs moisture and loses its printing properties;
- Its usefulness is found in various industries such as textiles, electronics, automotive and sports.

Advantage:

- High impact and abrasion resistance;
- Flexibility if printed in thin layers.

Disadvantages:

- It is prone to deformation;
- Requires drying of filament before printing.

Presenting these main materials for prototyping, to highlight the capabilities of 3D printing technology both for prototyping and for making functional products, as well as for later development of a functional prototype of the desired model.

4. MODELLING OF THE STRUCTURE THAT WILL UPHOLD THE ROVER SYSTEM

4.1 Description of the software programs used in modelling

For the design of the ROVER system, both a 3D modelling software program will be used for prototyping with 3D printing technology and 2D design for the construction dimensions. Thus the software chosen for this is Fusion 360, offering the possibility of a good 3D design with a multitude of functions and quick changes that can be made, as well as the possibility of adding materials and subsequent rendering that helps in the visualization of the desired product.

At the same time, it provides a good support in the production of parts/assemblies to be made using 3D printing technologies.

In addition to this, other software to be used is Ultimaker CURA, as well as Prusa Slicer. It takes a 3D model, which it "slices" transversely into layers, layers that are to make up the desired physical shape. Thus, once the desired part is "sliced", and the printer settings are entered, this program generates a code, called G-CODE, which represents the programming of the printer.

4.2 Drawing of a concept prototype of the ROVER-type system

A first step in choosing the design of the basic elements is a comparative analysis of existing designs and concepts, so that different variants can be extracted that can add value to the chosen design.

One of the most popular vehicle concepts aimed at exploring Mars is being developed by NASA (Figure 1).

Figure 1 NASA concept rover [7].

This NASA-made connector is distinguished primarily by the use of a 360-degree swivel wheel system, providing maximum maneuverability. It can carry two passengers at a speed of 10 km/h, or even four passengers in emergency situations.

Its other technical specifications are:

- Weight: 3000kg;
- Maximum load weight: 1000kg;
- Length: 4480 mm;
- Wheelbase: 3960 mm;
- Height: 3050 mm.

As pluses in this concept can be listed:

- ➢ Using the castor wheel system;
- ➢ Possibility in the front to place a gripping system to handle various objects of interest;
- ➢ Increased visibility;
- ➢ Shelter space in the event of a solar event, leading to increased solar radiation levels;
- ➢ Modular design.

The minuses are:

- ➢ Reduced speed;
- ➢ Reduced crew;
- ➢ The wheels used are not suitable for the ground surface.

A second concept presented is more recent and is also offered by NASA (Figure 2).

Figure 2 ROVER NAVIGATOR, NASA [10].

This being a relatively recent concept, it has both a futuristic look and a host of new technologies.

Thus, as in the previous case, a first aspect to be considered is the traction and steering system. In this case, the system offered is a conventional one, with one axle at the front and two at the rear, thus taking weight evenly. The unconventional aspect is provided by the wheels, which can offer both low rolling resistance, providing a small contact area with the ground, and high rolling resistance, providing a large contact area with the ground, and can be shaped if necessary to get over difficult terrain such as rocks or excessive sand [9].

The back is a mobile laboratory, which has various solar panels mounted on the outside to minimize electricity consumption.

So we have as pluses:

- ➢ High speed: maximum of 110 km/h;
- ➢ Increased useful dimensions;
- ➢ Similarity to a conventional vehicle;
- ➢ Reduced weight: 2250 kg.

As minuses we find:

- ➢ Modularisation can be problematic;
- ➢ Lack of a prehension system;
- ➢ Difficult handling.

Thus, in order to start modelling both assemblies and sub-assemblies, which together will represent the final product, it is necessary to make sketches, which are a good starting point in the subsequent definition of a design (Figures 3-5).

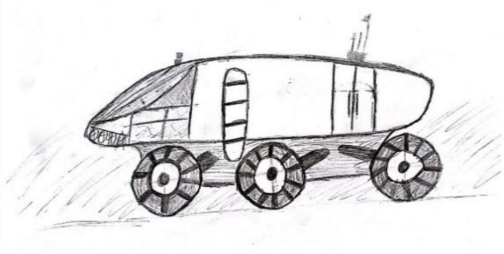

Figure 3 Sketch side view.

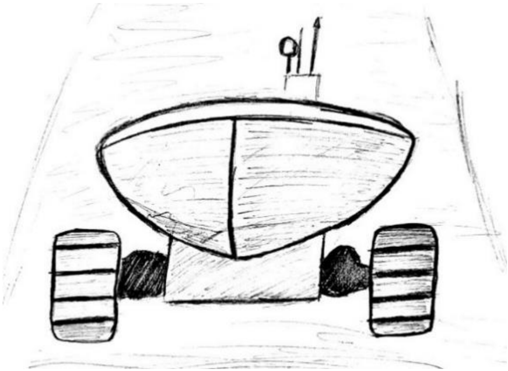

Figure 4 Front view sketch.

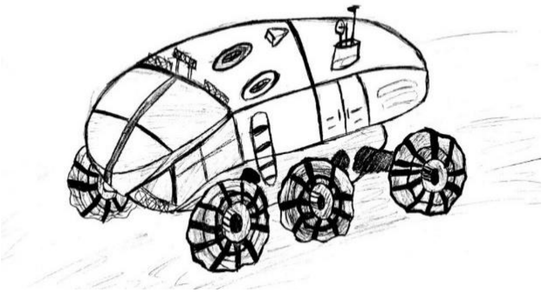

Figure 5 Perspective view sketch.

In the conception of these hand sketches, a few ideas on the basic elements were based, which were later detailed in detail and modified according to requirements found later:

- The use of a 6x6 drive system, offering a good ratio between manoeuvrability, energy consumption, stability and adaptability to the type of difficult terrain encountered;
- The realisation of a modular concept of the cabin, represented by: the cockpit in the front area, a middle area representing the main access route and a multi-role area, where additional seats and a storage area can be added, while the rear part of the ROVER can be both a closed and an open storage area, of the bena type, being able to transport different samples as well as human crew or materials needed for future missions;

- The chassis is the propulsion and energy storage system, with a robust structure required for the difficult terrain it is subjected to.

4.3 3D modelling of the ROVER concept prototype

Thus, once the main ideas have been put down on paper, 3D modelling can be carried out using the software, based on the sketches presented above (Figures 6-7).

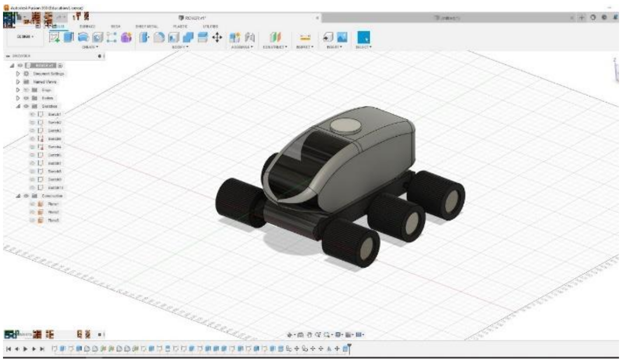

Figure 6 Perspective view from the FUSION 360 program.

Figure 7 Perspective view of the rendered model.

This 3D concept modelling will be the basis for the modelling of the actual assembly, with the final aim of assembling and operating the basic elements:

- booth;
- chassis;
- traction and steering system.

4.4 Prototyping the ROVER system concept

Once a CAD concept model has been created, it can be translated into a physical model using the 3D printer. This is achieved primarily by choosing the material used, which is PLA, using FDM additive manufacturing technology.

We chose this material because of the ease of printing as well as the printing speed offered, being a first model, it does not require functional aspects.

To achieve this process, the CAD model is converted into STL (Standard Tessellation Language) format, this format being used by the software used in the "cutting in layers" of the model, which is Ultimaker CURA [8]. In addition to this, the software also makes various printer settings such as the temperatures used, printing speeds, layer orientation, the use of filler patterns so that the material used is kept to a minimum while maintaining the necessary mechanical properties, and many other settings (Figure 8).

For this stage of the research, we have chosen to model the whole ROVER assembly, then analysed and prototyped each main element, to be assembled in order to realize the functional prototype (Figure 9).

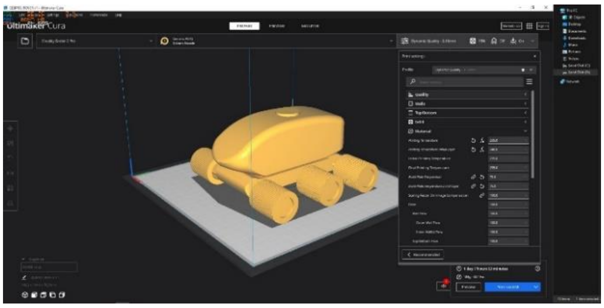

Figure 8 CAD model in CURA slicer software.

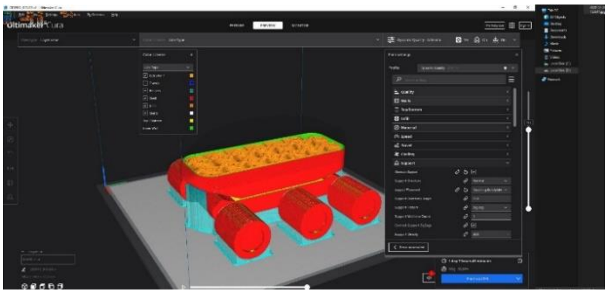

Figure 9 View of the internal structure of the model to be printed.

Main settings made for prototyping:

- Layer thickness: 0.2 mm;
- Number of side walls: 3 (using a 0.4 mm nozzle results in a wall thickness of 1.2 mm);
- Number of upper/lower walls: 4; Filling: 7%;
- Nozzle temperature: 200°C; Bed temperature: 60°C;
- Speed: 30-40 mm/s; Bracket generation: yes.

4.5. 3D printing of the ROVER concept prototype

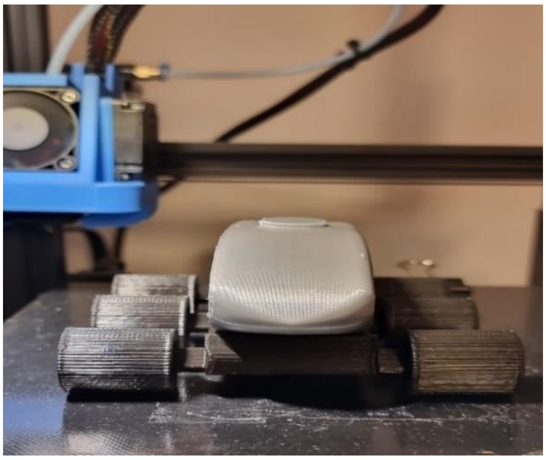

Figure 10 Front view of the printed prototype.

The realization of this prototype represents the highlighting of the basic components, their proportions, as well as the possibility of future analysis in order to assemble them forming the final product.

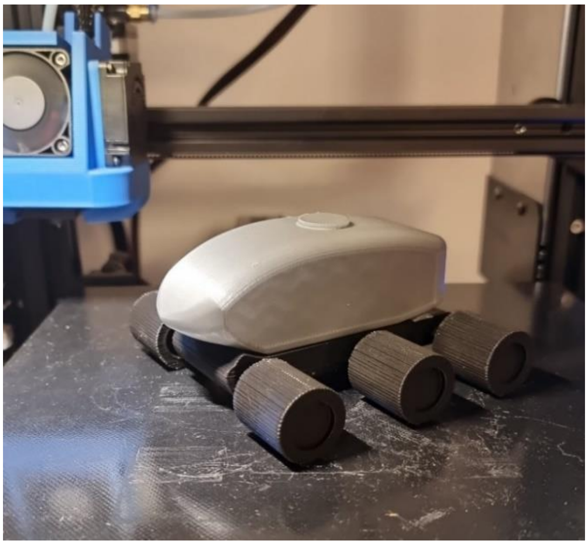

Figure 11 Side view of the printed prototype.

5. Prototyping the ROVER system

5.1 Conclusions after the first prototype

Once a first concept of this type of system is made, a number of advantages and disadvantages can be analysed and highlighted.

Advantage:

- Modular design with a chassis that is easily detachable from the bodywork;
- Use of a 6-wheel drive system.

Disadvantages:

- Incorrect protrusions between the body and its wheels;
- Difficulty in attaching devices, such as a prehension system;
- Lack of interior space;
- Difficulty in installing a door that allows both people and bulky items to enter.

Thus, the main conclusion in the further development of a prototype ROVER system is to redesign it, having as main reference points:

- The body should be made of 2 parts, as follows: in the front part, the cab will be located, representing its command and control point, and in the rear part, it will be possible to attach to the chassis various systems depending on the needs, such as a passenger cabin, additional energy system, laboratory type cabin, prehension system;
- The chassis will be represented by the same principle, in which the propulsion and energy storage systems will be located;
- Locomotive system, wheels and suspension need redesign

5.2 Realisation of a new bodywork assembly

Due to both the difficulty of transporting the ROVER system and the need to make the space in it more efficient, its body will be divided into several variants, such as:

- Cab + additional cabin;
- Cabin + energy storage system;
- Cabin + laboratory;
- Cab + prehension system;
- Cab + drone.

Thus to achieve this type of design, the cab was redesigned, adopting a conventional shape, so as to use as much space in the cab as possible and to provide good visibility and easy access.

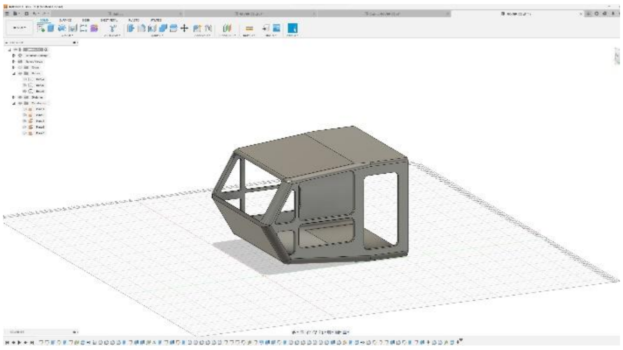

Figure 12 Perspective view of the cabin in the fusion programme.

Figure 13 Perspective view of the rendered model.

It has the following dimensions:

- Length: 2300mm;
- Width: 2500mm;
- Height: 2000mm.

The need for these dimensions arises from the need to move passengers through the cabin, with the access point located at the rear side. Also, in this prototype, the cab is made without the rear wall, for ease of prototyping, to be connected with the additional cab.

Various other outdoor systems can also be easily added to it, such as additional lights, storage areas for various necessary accessories and other equipment.

The second component to be represented in the future prototype is a cabin, located in the second part of the chassis, connected to the cockpit, which is intended both to carry additional passengers and to adapt it for a laboratory, to carry various necessary equipment.

Its main feature is its simplicity, the efficiency of the interior space, and a ramp in the back with which bulky objects can be added inside. To maximise interior space, it will be wider than the cab.

You can also add various side storage areas for equipment, additional lights as well as the possibility of placing equipment in the upper area. Access can also be gained by means of a staircase located at the side.

Main dimensions:

- Total length: 4580mm;
- Inner length: 2800mm;
- Width: 2660mm;

- Total height: 2180mm;
- Interior height: 2060mm.

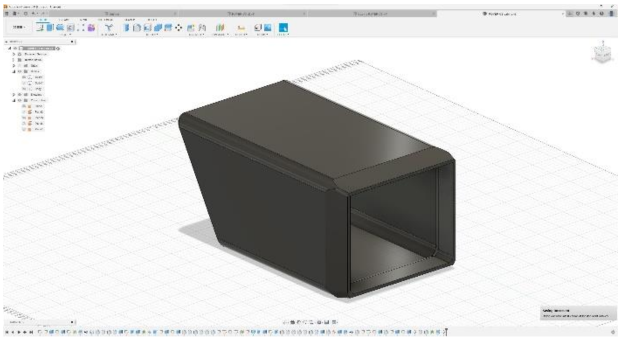

Figure 14 Front view of additional cab in FUSION 360.

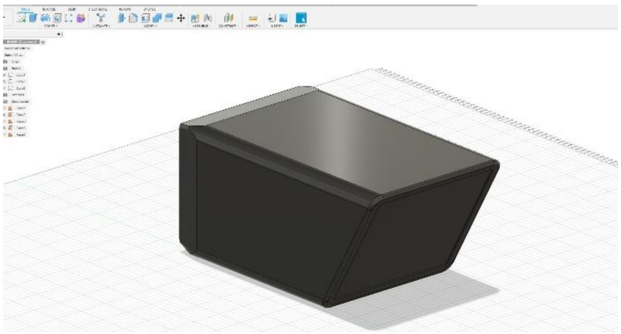

Figure 15 Rear view of additional cab in FUSION 360.

So once these aspects are defined, the body will have the following appearance (Figures 16-17):

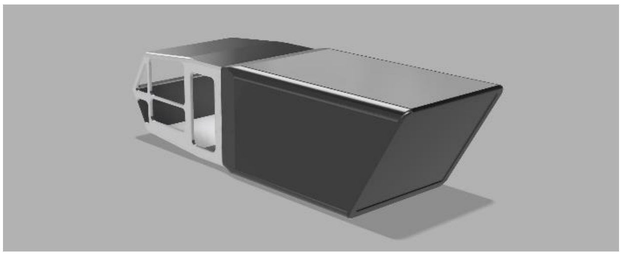

Figure 16 View of the rear of the bodywork.

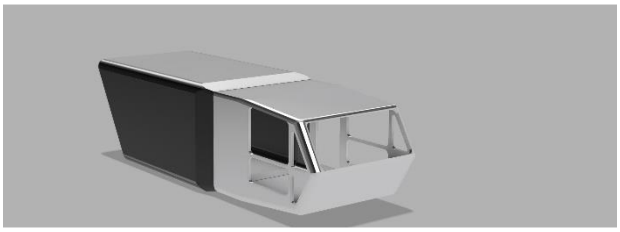

Figure 17 Front view of the bodywork.

5.3 Prototyping the bodywork

Once the body has been created in the Fusion 360 3D modelling program, the body is prototyped using the FDM 3D printer, using PLA as material.

The first step was to open the control cabinet model in the slicer software, Prusa Slicer, to set the printer settings:

- Model size: 3%; Layer thickness: 0.2mm;
- Average printing speed: 35mm/s;
- Wall thickness: 0.8mm;
- Printing head temperature: 200;
- Material: PLA, aluminium grey;
- Printing time: 5 hours and 54 minutes.

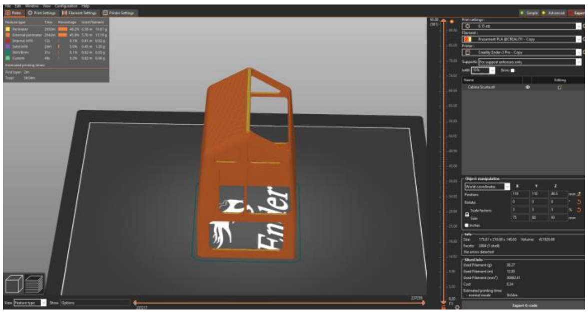

Figure 18 Control cab in Prusa Slicer.

The next step was to make the additional cab module in a similar way, in a different material colour, black, to highlight the modular body structure. This took 13 hours and 22 minutes.

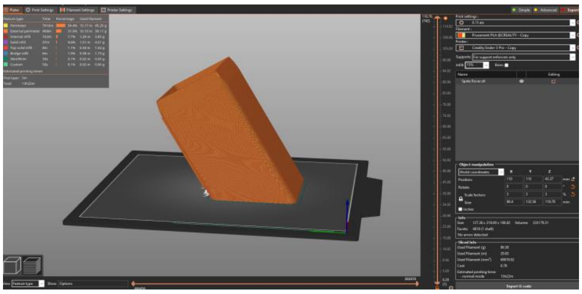

Figure 19 Additional cab in Slicer Prusa.

Thus, the result of the body prototyping is:

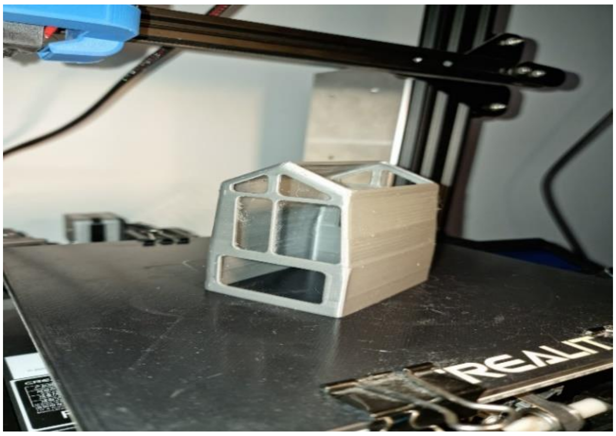

Figure 20 Prototyping the cockpit.

The main conclusions resulting from the prototyping of this model are:

- The model is much easier to modularize than the concept model;
- Offers good practicability;
- Its increased size may present difficulties in transporting it;

- The rear ramp can be both an advantage in terms of practicability and a disadvantage due to the additional weight.

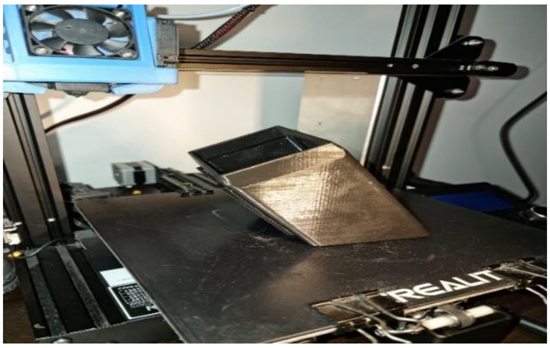

Figure 21 Prototyping the secondary cab.

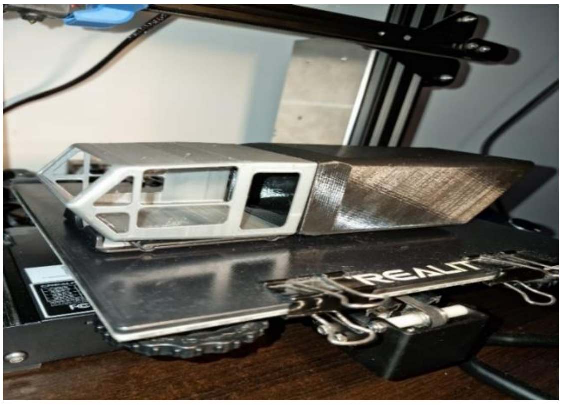

Figure 22 Side view of the prototype.

Figure 23 Rear view of the prototype

6. CONCLUSIONS AND FUTURE OBJECTIVES

The main conclusion that emerges from this study is the necessity of the usefulness in the development of a ROVER type system of manufacturing technologies by addition, from the beginning, from the concept stage in order to highlight the main characteristics, and later both at the stage of prototype to scale, functional prototype, and at the realization of the final model, so as to avoid transporting parts, which is a long and very expensive process.

Thus, additive manufacturing technologies represent the main element in the life cycle of a ROVER system, managing to solve one of the main problems, the distance required to transport various components, components that are largely represented by specially made parts with complex geometries.

The future objectives of the study are the development of a chassis, locomotor suspension system and the integration of the propulsion and energy storage system into the chassis, which represent both the main and the most complex components of this study.

The second objective is to achieve a redesign based on the environmental conditions in which it will operate, establishing the necessary materials, construction principles, assemblies and sub-assemblies that can be made using additive manufacturing technologies so that a prototype of this final model is finally realized.

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