

**Кухаренко Андрей Валерьевич, студент, Сибирский государственный университет науки и технологий им. академика М.Ф. Решетнева, Красноярск**

**e-mail: [andrei04102006@mail.ru](mailto:andrei04102006@mail.ru)**

**Евченко Дарья Вячеславовна, студент, Сибирский государственный университет науки и технологий им. академика М.Ф. Решетнева, Красноярск**

**e-mail: [evchenkodaria@mail.ru](mailto:evchenkodaria@mail.ru)**

**Карчава Ольга Витальевна, старший преподаватель кафедры деловых иностранных языков Сибирского государственного университета науки и технологий им. академика М.Ф. Решетнева, Красноярск**

**e-mail: [i.karchava@mail.ru](mailto:i.karchava@mail.ru)**

**Kukharenko Andrey Valeryevich, Student, Reshetnev Siberian State University of Science and Technology, Krasnoyarsk**

**e-mail: [andrei04102006@mail.ru](mailto:andrei04102006@mail.ru)**

**Evchenko Daria Vyacheslavovna, Student, Reshetnev Siberian State University of Science and Technology, Krasnoyarsk**

**e-mail: [evchenkodaria@mail.ru](mailto:evchenkodaria@mail.ru)**

**Karchava Olga Vitalievna, senior lecturer of the Department of Business Foreign Languages Reshetnev Siberian State University of Science and Technology, Krasnoyarsk**

**e-mail: [i.karchava@mail.ru](mailto:i.karchava@mail.ru)**

## **ЭКСПЕРИМЕНТАЛЬНАЯ МОДЕЛЬ ПЛАНЕТОХОДА**

### **EXPERIMENTAL MODEL OF A PLANETARY ROVER**

В данной работе предпринята попытка создать экспериментальную функциональную модель планетохода, предназначенного для исследования экзопланет земного типа, отвечающую высоким требованиям к проходимости в различных условиях местности. Для разработки общей концепции дизайна была изучена история создания планетохода, а также выявлены интересные и

полезные инженерные решения и подходы к проектированию нового транспортного средства. Дизайн разрабатывался с учетом всех возможных условий работы на поверхности потенциально обитаемых экзопланет. Конструкция марсохода сочетает в себе различные типы движителей: шагающие, колесные и лопастные. Модель марсохода была изготовлена с использованием станков с ЧПУ и различных материалов. Получившаяся конструкция марсохода функциональна, была протестирована на различных поверхностях и может послужить основой для создания настоящего планетарного марсохода.

This work attempts to create an experimental functional model of a planetary rover designed for exploring Earth-like exoplanets, meeting high requirements for traversability in various terrain conditions. To develop the general design concept, the history of planetary rover construction was studied, and interesting and useful engineering solutions and approaches to designing a new vehicle were identified. The design was developed considering all possible working conditions on the surfaces of potentially habitable exoplanets. The rover's design combines various types of propulsion mechanisms: walking, wheeled, and paddle-wheel. The rover model was manufactured using CNC machines and various materials. The resulting rover design is functional, has been tested on different surfaces, and can serve as a basis for constructing a real planetary rover.

**Ключевые слова:** планетоход, исследование экзопланет, конструкция, прототип, шагающий механизм, лопастное колесо, зубчатая передача.

**Keywords:** planetary rover, exoplanet exploration, design, prototype, walking mechanism, paddle wheel, gear transmission.

## Introduction

Humanity is actively searching for potentially habitable planets beyond the Solar System, similar in characteristics to Earth and located relatively close to us. The exploration of these planets' surfaces will be carried out by autonomous planetary rovers. The requirements for these machines will be extremely high—they

must perform their mission in unpredictable terrain conditions. In unforeseen situations, there will be no one to assist the rover, so its mechanics must be adaptable to any scenario.

### Main Content

1. Information and Analytical Development Stage  
The list of potentially habitable exoplanets, ranked using the Earth Similarity Index developed by the Planetary Habitability Laboratory at the University of Puerto Rico at Arecibo, includes 60 confirmed exoplanets [1]. The list is sorted based on similarity to Earth, considering parameters such as basic habitability level, distance from the habitable zone, atmospheric composition, planetary class, habitability class, and temperature [2].
2. To sustain life (as we understand it), a planet must have an iron core, a crust, an atmosphere, and liquid water. Such planets are rare in the known universe, but they do exist. Examples include:
  - Gliese 667 Cc (constellation Scorpius)
  - Kepler-62 f (constellation Lyra)
  - Gliese 832 c (constellation Grus)
  - Tau Ceti e (constellation Cetus)
  - Gliese 581 g (constellation Libra) [3].

These planets are characterized by Earth-like terrain—presence of open or mineral-bound water, rocky or desert landscapes, and impassable or difficult-to-traverse areas.

The study and exploration of exoplanets will, at some stage, be conducted using mobile planetary rovers. Rovers have several advantages over stationary landers: they can survey larger areas, can be redirected to investigate objects of interest during the mission, can adjust their position relative to the Sun for efficient solar panel use in winter, and can conduct microscopic-level research and experiments[4].

An analysis of existing rover designs revealed that most use various types of wheeled propulsion, though some tracked and walking mechanisms have also been developed [5]. Of particular interest is the Mars Prop-M (Passability Assessment Device) (Fig. 1), a Soviet Mars rover. Identical rovers were part of the Mars landers intended to reach the Martian surface in 1971. The Mars 2 lander crashed on November 27, 1971, during a failed soft landing attempt. The Mars 3 lander successfully touched down on December 2, 1971, but the signal from the lander (to which the rover was connected via cable) was lost after 14.5 seconds.



Figure 1. Mars Prop-M (Passability Assessment Device)

<https://images.app.goo.gl/ETuE5K28pM2YD6s96>

These rovers stood out due to their unique locomotion system: they were designed to move using two walking "skis" mounted on the sides. This system was chosen due to the lack of data on Mars' surface conditions [6]. Existing rovers were designed for planets with solid ground, excluding the presence of water. However, the presence of water on Earth-like exoplanets is a prerequisite for colonization. Therefore, rover designs for such planets must account for various water obstacles: open water bodies, swamps, rivers, etc. A water-traversing mechanism is necessary to overcome these obstacles and study water resources.

After studying the working conditions of a rover on Earth-like planets, we hypothesized that these conditions resemble uninhabited, hard-to-reach regions

on Earth. We examined several primary terrain types to determine optimal traversal methods:

1. Desert – Optimal traversal: large, lightweight wheels with anti-slip paddle plates.
2. Water surfaces – Options include boats, catamarans, sail-powered, propeller-driven, or paddle-wheel mechanisms.
3. Swampy terrain (or tundra-like) – Minimal ground pressure is crucial. Suitable options: tracked vehicles, large low-pressure wheels, or walking excavator-like movement.
4. Mountainous terrain – The most complex and unpredictable, requiring maximum degrees of freedom for overcoming rocks and self-recovery in critical situations.
5. Flat, hard ground – The simplest surface, requiring only basic wheels. \

## 2. Design

Based on the outlined tasks and technical solutions, the design of experimental prototypes began, including walking mechanisms and wheeled structures (Figs. 2–4).



Figure 2. Prototype of a walking mechanism

Figure 3. Prototype of a walking mechanism with low-pressure wheels

Figure 4. Prototype of a walking mechanism with paddle wheels

After extensive testing of the walking mechanism prototype [7] and the wheeled walking mechanism prototype [8], we proceeded to design a new rover structure incorporating the developed solutions.

The primary goal was to create a compact, lightweight rover with specified capabilities to test the general concept and experiment with the design. The design was developed using KOMPAS 3D.

For the propulsion system, we considered factors such as mass, dimensions, power-to-weight ratio, and availability. We selected popular Chinese motor-gearboxes commonly used in Arduino-like kits. The rover uses four motor-gearboxes (Fig. 5). Gear transmissions were widely used in the design. An online gear calculator [9] assisted in their development.

The rover's overall structure is a catamaran, split lengthwise but connected by adjustable mechanical hinges, featuring a walking mechanism and paddle wheels with internal floats and radially mounted paddle plates (Fig. 6).

### Gear motor

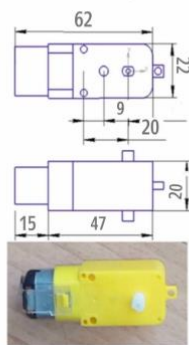


Figure 5. Propulsion system

### The design of the planetoid

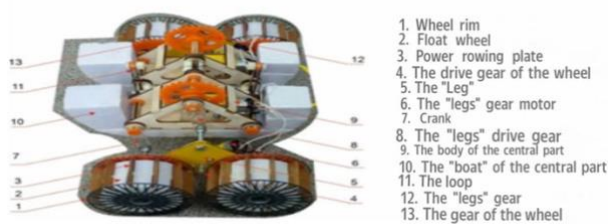


Figure 6. Rover design

Control is implemented via tank steering (independent left and right sides), enabling various movements and positions for overcoming obstacles and self-recovery. The walking mechanism is located on both "hulls" of the catamaran and operates

independently, utilizing gear transmission and cranks to convert rotational motion into linear movement.

The catamaran hulls are made of foam board, chosen after buoyancy tests.

The mechanical hinge (Fig. 7) allows the catamaran hulls to separate up to 90 degrees relative to each other, enhancing maneuverability on rocky terrain and even enabling movement in an inverted position

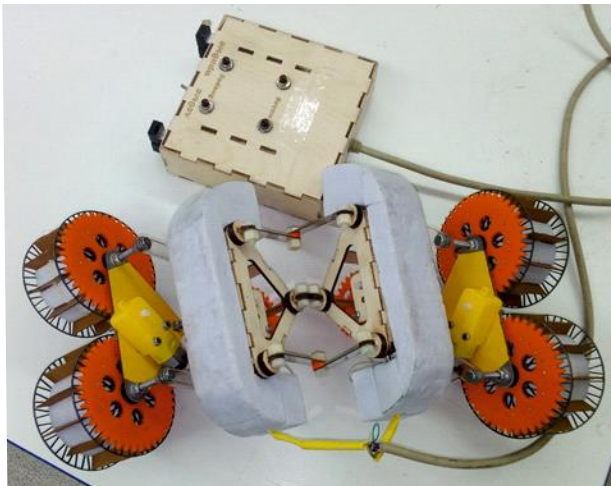


Figure 7. Mechanical hinge control block

Currently, the model is controlled via wired connection using a microswitch block (Fig. 7).

### 3. Modeling and Assembly

Materials were selected based on lightweight, rigidity, ease of processing, availability, and cost:

- The catamaran frame was laser-cut from 3 mm plywood.
- The hulls were made from foam board using a thermal cutter.
- The "legs" were made from 1 mm cold-rolled steel for maximum rigidity.
- Wheel rims were laser-cut from 1 mm steel, designed with a "spoked" structure for lightness and rigidity.
- Paddle-wheel floats were made from foam board, and paddle plates from pressed cardboard, glued with PVA.
- Cranks were laser-cut from 4 mm acrylic glass. > ты iPhone,они-Samsung☹: - Gear transmissions (10 gears total) were also made from 3–4 mm acrylic glass.

- Axles were assembled from 3 mm plywood with interlocking joints for quick assembly and durability.
- The mechanical hinge was made from 1 mm stainless steel, fastened with nylon bolts and nuts.

The final model weighs 760 grams, maintaining sufficient rigidity and strength for testing.

#### 4. Field Testing

Tests were conducted on various surfaces:

1. Flat ground (Fig. 8) – Stable, maneuverable movement with multiple position adjustments. Wired control was a limiting factor [10].
2. Movement with extended hinge (Fig. 9) – Capable of traversing narrow crevices with wheels at 90-degree angles. Limited walking mechanism efficiency in this mode. Possible to move upside-down [11].
3. Water traversal (Fig. 10) – Movement via paddle wheels. Walking mechanism provides limited propulsion in open water but may be more effective in swamps. Speed is lower than on solid ground [12].
4. Simulated mountainous terrain (Fig. 11) – Capable of overcoming obstacles inaccessible to wheeled vehicles. Requires skilled operation [13].



Figure 8. Movement on flat ground

Figure 9. Movement with extended hinge

Figure 10. Water traversal

## Figure 11. Simulated mountainous terrain traversal

### Conclusion

A functional planetary rover model was designed, built, and tested. The design successfully integrates various propulsion mechanisms, demonstrating adaptability to diverse terrains. Key findings: - The rover is operational and can serve as a basis for future designs.

- Some components require refinement (e.g., step length for mountains, paddle-wheel width for water traversal).

- Control is complex due to multi-plane movements; a real rover would need additional cameras and operator support.

### Литература

1. Текущий список потенциально обитаемых экзопланет. [Онлайн]. Доступно: <http://phl.upr.edu/projects/habitable-exoplanets-catalog>
2. Список потенциально обитаемых экзопланет. Википедия. [Онлайн]. Доступно: [https://ru.wikipedia.org/wiki/List\\_of\\_potentially\\_habitable\\_exoplanets](https://ru.wikipedia.org/wiki/List_of_potentially_habitable_exoplanets)
3. 7 планет, потенциально пригодных для жизни. [Онлайн]. Доступно: <https://fishki.net/1496742-7-planets-potentially-suitable-for-life.html>
4. Авотин Е.В. \*Динамика планетоходов\*. М.: Наука, 1971.
5. Кемурджян А.Л. \*Планетоходы\*. Москва: Машиностроение, 1993.
6. Планетоход. [Онлайн]. Доступно: <https://aboutsacejournal.net/spacecraft/rovers/>
7. "Лягушка – первый прыжок" [Видео]. Доступно: <https://youtu.be/1XZHh6DkpkQ>
8. "Шагающий вездеход" [Видео]. Доступно: <https://youtu.be/EVXpmPj3OZc>
9. Онлайн-калькулятор снаряжения. [Онлайн]. Доступно: <http://jeromeleary.com/>
10. "Движение по ровной местности" [Видео]. Доступно: <https://youtu.be/cFZ--sDGrvs>

11. "Движение по стене" [Видео]. Доступно: <https://youtu.be/JFi-L21Ml8U>
12. "Переход по воде" [Видео]. Доступно: <https://youtu.be/Mkw6T1NsLCU>
13. "Переход по горной местности" [Видео]. Доступно: <https://youtu.be/i8HkpYBU7Ek>

## Literature

1. Current list of potentially habitable exoplanets. [Online]. Available: <http://phl.upr.edu/projects/habitable-exoplanets-catalog>
2. List of potentially habitable exoplanets. Wikipedia. [Online]. Available: [https://ru.wikipedia.org/wiki/List\\_of\\_potentially\\_habitable\\_exoplanets](https://ru.wikipedia.org/wiki/List_of_potentially_habitable_exoplanets)
3. 7 planets potentially suitable for life. [Online]. Available: <https://fishki.net/1496742-7-planets-potentially-suitable-for-life.html>
4. Avotin E.V. \*Dynamics of Planetary Rovers\*. Moscow: Nauka, 1971.
5. Kemurdzhian A.L. \*Planetary Rovers\*. Moscow: Mashinostroenie, 1993.
6. Planetary rover. [Online]. Available: <https://aboutsacejournal.net/spacecraft/rovers/>
7. "Frog – First Jump" [Video]. Available: <https://youtu.be/1XZHh6DkpkQ>
8. "Walking All-Terrain Vehicle" [Video]. Available: <https://youtu.be/EVXpmPj3OZc>
9. Online gear calculator. [Online]. Available: <http://jeromeleary.com/>
10. "Movement on Flat Ground" [Video]. Available: <https://youtu.be/cFZ--sDGrvs>
11. "Movement on a Wall" [Video]. Available: <https://youtu.be/JFi-L21Ml8U>
12. "Water Traversal" [Video]. Available: <https://youtu.be/Mkw6T1NsLCU>
13. "Mountainous Terrain Traversal" [Video]. Available: <https://youtu.be/i8HkpYBU7Ek>