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TOWARDS AN AUTONOMOUS MICRO ROVER WITH NIGHT SURVIVABILITY FOR LUNAR EXPLORATION

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Abstract

In Europe, efforts are underway to develop key technologies that can be used to explore the Moon and to exploit the resources available. This includes technologies for in-situ resource utilization (ISRU), facilitating the possibility of a future Moon Village. The Moon is the next step for humans and robots to exploit the use of available resources for longer term missions, but also for further exploration of the solar system. A challenge for effective exploration missions is to achieve a compact and lightweight robot to reduce launch costs and open up the possibility of secondary payload options. Current micro rover concepts are primarily designed to last for one day of solar illumination and show a low level of autonomy. Extending the lifetime of the system by enabling survival of the lunar night and implementing a high level of autonomy will significantly increase potential mission applications and the operational range.

As a reference mission, the deployment of a micro rover in the equatorial region of the Moon is being considered. An overview of mission parameters and a detailed example mission sequence is given in this paper. The mission parameters are based on an in-depth study of current space agency roadmaps, scientific goals, and upcoming flight opportunities. Furthermore, concepts of the ongoing international micro rover developments are analyzed along with technology solutions identified for survival of lunar nights and a high system autonomy. The results provide a basis of a concise requirements set-up to allow dedicated system developments and qualification measures in the future.

1. Introduction and Background

Exploration of distant celestial bodies with unmanned systems in pursuit of scientific, technological, as well as commercial goals still involves enormous costs and high risks of loss. Systems such as the Mars 2020, Perseverance rover, with a mass of about 1025 kg and an estimated cost of approximately $2.7 billion for the entire mission [1] show the extremes in complexity, mass, and cost that have already been reached.

Future scientific and technological road maps for exploration of the lunar surface within the current decade published by space agencies in [2] and [3] motivate robotic and eventually human missions. The identification and characterization of potential resources for ISRU activities within future missions and for a deeper scientific understanding of the history of the Earth and the Moon have been identified as some of the most important goals. This includes, for example, the examination of lunar soil and search for water ice. As well as the characterization of the lunar environment, in terms of dust, charge and plasma environment. Here, the use of robotic systems is considered as a first step to pave the way for future missions, for example to prepare important infrastructure. For scientific missions as well as for commercial activities, the identification and mitigation of exploration risks has been identified as an important goal.

In particular, the use of small lunar rovers with a low mass and a high degree of autonomy can significantly reduce the cost of development, launch, and operation. At the same time, the use of more affordable systems enables the pursuit of more challenging goals, since a loss is more likely to be tolerated and risk mitigation by redundancy on system level can be achieved, more easily due to lower costs, for example with multi-robot systems for exploration.

When selecting a suitable landing site, permanently shadowed regions (PSRs) are of particular interest, as they have a high potential for the occurrence of water ice. These can be found, for example, in craters at the poles [4]. In addition to the poles, regions with identified lava tubes are of interest. Lava tubes provide, from a scientific perspective, important insights into the geological history of the Moon. Furthermore, the utilization of the lava tubes as shelter for future human explorations is conceivable. For the described landing sites and the resulting exploration scenarios, a high degree of autonomy of the robotic system is required, as there are times when no radio communication with Earth is possible. In the case of lava tubes, multi-robot systems are also necessary, since only through a cooperative exploration approach such a complex task like entering a lava tube is conceivable [5] Another important aspect is the mission duration. In order to pursue significant scientific and technological objectives, the capability of lunar night survival is absolutely necessary to extend the available mission run time. In this context, special attention must be paid to the surface temperature as it varies between approx. +120 °C during the day time and -170 °C at night [6]. In conclusion, the required degree of autonomy and the significant temperature difference on the lunar surface between day and night pose a particular challenge in the development of a lunar micro rover, as resources in terms of mass and energy consumption are severely constrained when considering systems with an overall mass of 15 kg to 20 kg.

1.1 State of the Art

Research on the exploration of the lunar surface with small robotic systems is ongoing worldwide. More and more commercial companies are taking part in this contest. These small platforms are more affordable and well suited for high risk technology demonstration. To be mentioned here are, for example HAKUTO from iSpace[7] with a approximate mass of 11 kg designed for the lunar south pole region and the CubeRover from Astrobotic [8] with a mass of up to 12 kg, suitable for the pole and equator region depending on the selected rover configuration. Both are expected to be launched in the mid 2020s equipped with small payload but with no night survivability. A promising development with night survival capabilities to be mentioned here is the COLD-MAPP rover which is supposed to survive the lunar night with a targeted rover mass of 15 kg. As of writing of this paper, an Indian Pragyan rover was launched on a Chandrayaan-3 lander aiming for the lunar south pole region. The rover has 27 kg and 50 W power, however it is also not designed to survive lunar night [9].

The mass limit to classify a rover vehicle as a 'micro rover' is not clearly defined [10]. While some sources set the limit at 10 kg [11], other literature states a more qualitative upper weight limit of 'a few kilograms' [12]. To make a clear distinction we draw the line at 30 kg.

1.2 Motivation

As outlined in the introduction, micro rovers provide a promising and cost effective approach for future lunar exploration reaching both scientific and commercial objectives. The present contribution to the space robotics community is a summary of the development carried out within the research project SAMLER-KI [*]. The main objective of this initiative is the development of a terrestrial demonstrator of a small lunar rover with a maximum mass of about 20 kg with night survival capabilities and a high degree of autonomy. The rover shall be powered by solar energy stored in rechargeable batteries. As this is an early technology demonstration only selected subsystems will be developed taking into account the specific requirements of lunar environment. The development of the thermal control system (TCS) and the development of the hardware and software stack implementing the autonomous navigation and control functions within a heavily constrained system budget in terms of mass and power were identified as the main focus points.

Aside from the mass and power budget, the selection of the landing site is an important design driver we have taken into account. The final landing site selection, selection criteria, as well as mission relevant and scientific opportunities related to the landing site are covered in section 3. This is followed by an detailed description of the developed mission sequence presented in section 4 and the resulting system design requirements in section 5. Within the present work we give just a brief overview of the developed system in section 6. The detailed system design is outlined in [13].

1.3 Rover Challenges

It is essential to define a lunar reference mission in order to be able to identify the required characteristics for a rover system as a basis for design and development. In this context, selected rover challenges

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[*] `https://robotik.dfki-bremen.de/en/research/projects/samler-ki`

Table 1: Requirements of rover challanges

	ESA ESRIC	NASA SRC	ARC	DLR SC	NASA LC	ERC	GLX	ESA LRC
Communication	x	-	-	x	-	-	-	x
Navigation	x	-	-	x	x	-	-	-
Mapping	x	-	x	x	-	x	x	-
Autonomy	x	-	x	x	x	x	x	-
Resource localiz.	x	x	-	x	-	-	-	-
Resource collection	-	x	-	x	-	x	-	x
ISRU	x	x	x	-	-	-	x	-
Manipulation	-	-	-	x	x	x	-	x
Uneven terrain	-	-	x	x	x	x	-	x

on lunar exploration were analyzed to match the required conditions and to be considered in the development of the lunar rover within the project specific objectives.

The considered challenges range from university level like the Australian Rover Challenge (ARC) [14], DLR Spacebot Cup (DLR SC) [15], NASA's Lunabotics competition (NASA LC) [16], and ESA Lunar Robotics Challenge (ESA LRC) [17]. Further challenges with advanced scientific and commercial goals to be named here are the ESA-ESRIC Space Resources Challenge (ESA ESRIC) [18], NASA Space Robotics Challenge (NASA SRC), the European Rover Challenge (ERC) [19], and the Google Lunar X Prize (GLX) [20].

Table 1 gives an overview of some key factors of the challenges. Communication mainly means here the latency-induced telecommunication. Navigation means not only the navigation but also the self localization in the respective area. It turns out that autonomy is an important desired skill of all challenges, but two. Resource localization and resource collection are less demanded. The ability for manipulation and the ability to cope with uneven and unknown terrain are required by at least half of the challenges mentioned. Not shown in the table are the required dimensions and maximum weights that a rover should have. This is where the challenges differ. However, it can be said that the highest permissible maximum weight is 100 kg. Taking into account the challenges of the mentioned rover competitions, We came to the conclusion that we need to develop a rover that should not only be light (under 100 kg), but also cover the following aspects:

- Autonomous localization, mapping and navigation
- Coping with challenging illumination conditions
- Latency-induced telecommunication
- Video and picture transmission
- Coping with uneven and unknown terrain
- Provide payload capabilities

2. Scientific Goals

A broad overview about science activities landing sites and future opportunities are given in the Global Lunar Landing Site Study [21] by the LPI-JSC Center for Lunar Science and Exploration and the Lunar Exploration Objectives and Requirements Definition [22] by ESA's Lunar Exploration Definition Team. Both have in common, that due to technical challenges a focus will on activities on the south pole aitken basin, what limits the availability on landing sites. Hence, there are efforts underway changing that by developing technologies for operation through the lunar night [23]. This might be the greatest challenge in equatorial regions where the night duration is over 14 days. However, a summary of latest landing sides for scientific interest like lunar bombardment, interior, volcanism, impacts, exosphere, etc. given by [24], [25] are in that region (Fig: 1), and requiring mobility and night survival capabilities.

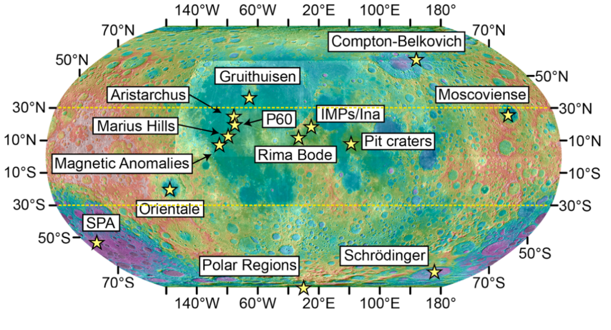

Fig. 1: Summary of high-priority landing sites, outlined in the lunar science for landed missions workshop findings report from 2018 at NASA Ames [24]. Orange lines mark the potential range for landing sites

The ESA proposes in its latest strategy for science at the moon [2] also a height demand for technologies being developed within the project SAMLER-KI. Especially for Campaign 3 (Geophysical measurements of the lunar interior) and Campaign 4 (Plasma, exosphere and dust environment and effects) night survival and operation capabilities are needed.

To pay these goals attention, the mission definition and the SAMLER-KI project goals tackle points that ends inevitably in technical challenges to expand scientific opportunities for upcoming missions.

2.1 Night Survival Capabilities

As robotic lunar exploration advances further and further, the prospect of long-duration missions on the Moon's surface becomes more and more realistic. One major challenge in such missions is the survival of all operating systems during the lunar night, which lasts approximately 14 Earth days, due to the extremely low surface temperature and missing solar irradiation. [26].

Surviving the lunar night, with such a small system, would revolutionise robotic exploration. Conceivable advantages amongst others are, for example, the significant expansion of research activities, long-term recording of measurement data, extension of the exploration radius, amortisation of financial costs over the longer lifetime of the system.

The harsh lunar night conditions pose an issue especially for smaller and lightweight systems such as Micro-Rovers without the capability of carrying a heavy heat generating source, such as an radioisotope thermal generator (RTG) [27].

The absence of sunlight during night-time rapidly leads to extremely cold environmental temperatures and prevents any power generation possibilities with conventional solar arrays. These conditions are exacerbated by the sheer length of 14 days in which they prevail. Temperatures of down to -170°C [28] pose a challenge to the TCS of the rover system, while the electrical power system (EPS) must be designed to provide sufficient energy to prevent freezing and a loss of mission. Furthermore, the components need to be selected adequately to guarantee only minor heat dissipation.

All these requirements must at the same time be compatible with the structural setup, the communication strategies as well as the planned mission operation. Understanding and addressing these challenges is crucial for enabling sustained and effective exploration of the lunar surface.

2.2 AI-based Navigation and Robot Control

Given the relatively brief mission lifespan, system autonomy becomes paramount in fully capitalizing on the available time frame for achieving scientific and commercial objectives. Autonomous decision-making, by obviating the need for external intervention, conserves valuable mission time. The use of artificial intelligence plays an important role. Example application scenarios are anomaly detection to cope with system failures, vision based navigation software, as well as robot control and intelligent trajectory planning based on boundary conditions like terrain or illumination.

At the same time, the selection of suitable processors for the execution of such algorithms on highly constrained systems in terms of computational power plays an important role. The application of anomaly detection and image estimation approaches on space equivalent processors with different performance classes has been tested in [29] with promising results. The detailed computer and network architecture, selected sensors as well as the software architecture for navigation and control of the rover can be found in [13].

2.3 Payload Capabilities

A concept of lunar exploration with an autonomous rover creates opportunities for third parties to participate in the mission by means of a hosted payload. Although constrained by rover capabilities (see table 3), its modular design with standard interfaces enables flexibility of such payload character, facilitates rapid integration and increases reliability.

Astrobotic, provider of Peregrine lunar lander characterizes 4 types of payload, depending on their power consumption and location ([30], see table 2). While deployable payloads are not foreseen on the rover within the mission described in this paper, both active and passive payloads could be hosted. This provides unique capabilities for scientific experiments [31].

Table 2: Examples of lunar payload [30]

	static	deployable
passive	memorabilia	ranging mirror
active	telescope	rover

Literature provides numerous examples of scientific experiment or technology demonstrator concepts compatible with these requirements. These include, but are not limited to: dust motion investigations [32], global navigation satellite system (GNSS) receiver [33], radiation environment characterisation [34], volatiles sampling [35]. The concept of an standardized, interchangeable, encapsulated lunar payload has been already successfully demonstrated, at least in terrestrial simulations. Roehr et al., within the RIMRES project [36], proposed a design of immobile so-called payload-items to serve as general purpose containers which can host scientific equipment and can be dynamically combined to form subsystems. They were able to verify the main capabilities: stacking and docking, thus composing a compound payload from multiple single payload-units. The idea of reconfigurable robots via interchangeable payload was later developed by Brinkmann et al. within TransTerrA project [37]. Several payload-items were developed to realize an adaption of the robots according to mission requirements; a battery module in order to extend the power capacity of robots and/or to allow the creation of standalone sensor modules, a camera assembly for observation purposes, a DGPS module to provide a high precision positional reference sensor (in earth bound test scenarios), and a device for collecting soil samples. These were also verified in laboratory and field campaign conditions. A whole architecture of a space mission focusing on modular components enabling configurable space robotics was presented by Sonsalla et al. within MODKOM project [38]. The overall formulation of such a modular building block system was provided, which encompassed technological, mechatronic and software design. Such developments will enable the realization of a modular robot configuration and implementation, as well as the ability to reconfigure the system online. A real application a proof-of-concept evaluation mission was defined to give an outlook of the concept.

3. Landing Site Selection

As the reference mission will be based on a technology demonstrator, we are looking for a landing site that takes into account scientific goals of ESA [2] and NASA [24], [39] for potential follow-on missions. Thus, the focus is on terrains and sites with demands a high need for mobility and night survival capabilities. Additionally, a soft target will be to capture spectacular images of unexplored regions of the moon which did not exist like this before.

Of many interesting landing sites (Fig: 1, we selected the Aristarchus plateau as it fits best in our requirement's. Its odd shape and extremes of low and high albedo, caused by different typs of rocks immediately catching the eye and fascinated scientist even before the age of space flights. The plateau is overlooked by the edge of the young Aristarchus crater and by the Vallis Schröteri.Due to its geologic complexity, the Aristarchus region is a point of height interest to potential scientific mission for geological research [21] [24]. An illustration of the plateau with its rills craters is shown in Fig. 2.

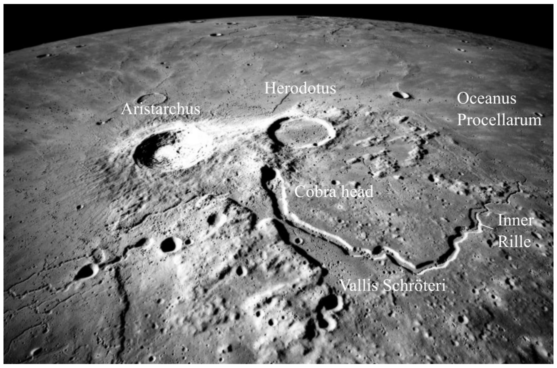

Fig. 2: View on the aristarchus plateau, taken from Apollo 15 (photo AS15-M-2610). The plateau contains numerous rilles, in the center is Schröter's Valley, a rille that is about 160 km long, up to 11 km wide and 1 km deep. The Cobra head marks the upper entrance and will be the landing site selected

The so called Cobra-Head of the Vallis Schröteri, consists of a deep pit, smaller craters, an inner rille, and a cliff face consisting of bright rocks. The material of that formation was brought on to the surface from great depths by the impact that formed the Aristarchus crater. Slid down the walls, made it accessible and from great interest to scientists. In addition to the scientific objectives, the exploration of this rugged region requires a platform that can operate robustly for long periods of time. Technologies such as night survival, hazard detection and mobility are therefore in high demand [24].

As a landing site we have chosen a point above a possible entrance to the Cobra Head at 24.79°N and 310.46°E. This provides a flat area for a 250x500m landing ellipse with a low density of boulders. Due to the possibility of long distances of line-of-sight radio communication between lander and rover, it allows to target nearby geological formations such as craters, rills and the slope of the cobra head. A slight hill to be climbed and will give the rover a view to the opposite cliff face, the floor of Cobra-head and into the entrance of the Valis Schröderli. Landing closer to the edge of cobra head would be desirable, however there is greater uncertainty as the areas starts sloping and the number of boulder increases. Thus, in addition to the almost limitless possibilities for landing sites, we expect this site to be great place for testing mobile technologies and providing spectacular images of the

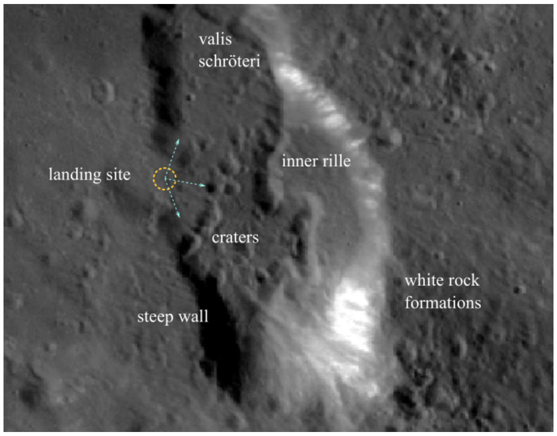

Fig. 3: Top view on the Cobra Head with marked points of interest. The arrows shows view directions of the rover

lunar surface, as well to prospect that region for future missions. Figure 3 shows the landing spot near by the cobra head with it exploration opportunities. A more detailed illustration of the mission scenario shows figure 5.

4. Mission Sequence

The proposed mission sequence covers two lunar days including the lunar night in between. This corresponds to a total of 42 earth days. The whole mission sequence is described in the following and depicted in Figure 4 and Figure 6.

4.1 Lunar Day 1

The first day, depicted in Figure 4 can be roughly divided into the mission segments:

- System deployment,
- exploration segments and mission execution,
- night survival check,
- transition to deep sleep.

In the following the different segments will be explained in detail.

Transfer sleep

Prior to launching the actual mission on the lunar surface, the journey to the Moon is required. This phase is not considered in detail here and it is assumed that the rover is completely deactivated in this phase.

System Deployment

The system deployment phase is divided into the subsequent segments:

- Wake-up on lander,
- deployment,
- after deployment check.

Wake-up on lander At the beginning of the system deployment the rover is still attached to the lander and a wake-up on lander sequence is initialized. This includes switching on the rover, basic system initialization and communication checks via the lander and transition to standby mode of the rover. After completion of the wake-up on lander sequence the rover will be released but still served with power and wired communication by the lander.

Deployment The subsequent deployment mission segment is comprised of the following activities:

- Establishment of a wireless communication to the ground control station (GCS),
- optical system check,
- decoupling of power and wired communication from lander,
- mechanical deployment,
- system check after the deployment.

Within the establishment of wireless communication to the GCS the camera systems will be initialized, telemetry data and test files will be send to measure the transmission path and check the transceiver. The optical system check, the mechanical deployment, and the system check after deployment are accompanied by visual inspection of the camera systems. This includes video test streams and pictures of the rover and the surrounding. In the end of the deployment segment the rover is fully decoupled from the lander, is running on battery, and the communication is established via wireless connection.

After Deployment Check The deployment segment is followed by the after deployment check. This segment includes the unfold of individual mechanisms and a check of the locomotion system as well as a full check of all subsystems. The after deployment check is finalized by an optical inspection of the rover environment performed by a 360° turn in front of the lander to capture a panorama view. In parallel, the lander cam is used to take pictures of the rover for optical inspection of the full system.

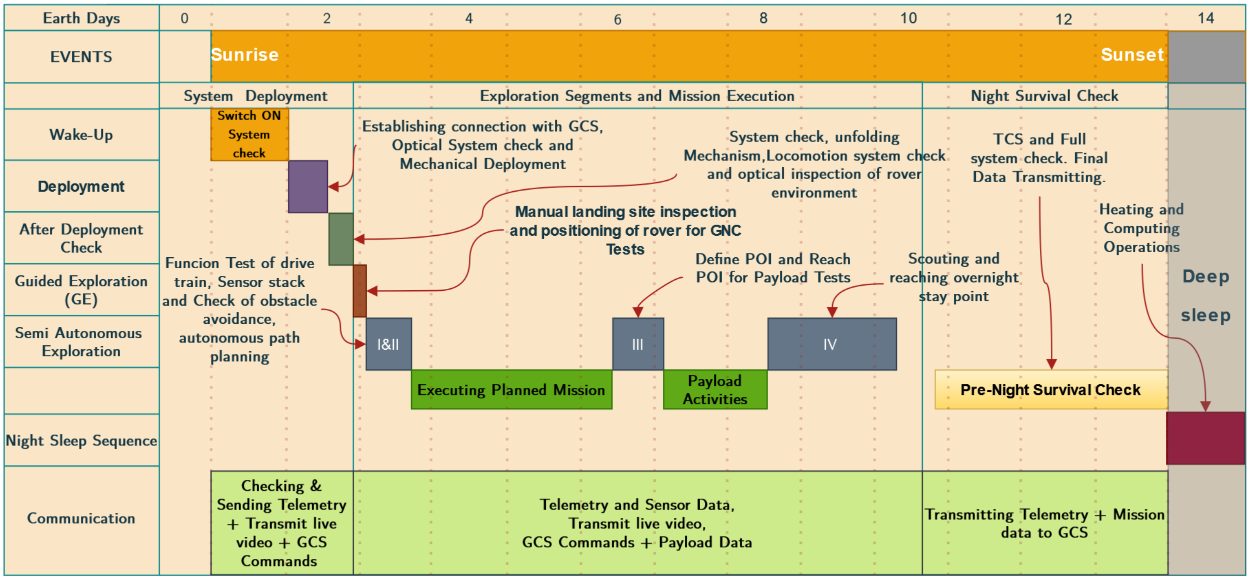

Fig. 4: Lunar day 1 of rover mission sequence

Exploration Segments and Mission Execution

The planned exploration of lunar day 1 is comprised of a first guided exploration followed by four semi-autonomous guided exploration mission segments with scouting and payload activities in between. An example driving sequence is shown in Figure 5. Roman I to IV mark the point of interests (POIs) at the end of each mission segment. The numbering corresponds to the semi-autonomous exploration segments in Figure 4.

Guided Exploration After successful completion of the after deployment check a remotely controlled drive sequence around the lander is performed. This allows the inspection of the landing site, to take picture of the lander, and a first video cast. Final step of the guided exploration is the positioning of the power for the following GNC test sequence.

Semi-autonomous Exploration - First Segment The first exploration segment involves mainly the function test of the GNC, drive train and sensor stack. Within this segment the rover drives 10 m straight followed by a right turn and again 10 m straight to reach the first POI (I). This sequence allows the check of the inertial navigation and localization and mapping functions.

Semi-autonomous Exploration - Second Segment Main goal of the second segment is the function check of the obstacle avoidance capabilities. An obstacle in a distance is selected and a reachable way-point behind the detected obstacle is set as the next POI (II). This is followed by an autonomous path planning to reach the selected way point and finally the execution of the planned mission.

Semi-autonomous Exploration - Third Segment The third exploration segment focuses mainly on the scouting of a suitable POI for foreseen payload activities. Driving distances up to 150 m are expected. The final selection of the POI (III) is selected in cooperation with the GCS.

Semi-autonomous Exploration - Fourth Segment The last exploration segment of the first lunar day has the main goal to scout an over night stay point for the upcoming lunar night. This involves scouting in a range of 50 - 100 m. The evaluation of possible over night stay points is performed in cooperation with the GCS.

Night Survival Check After about 10 earth days, the pre night survival check is performed. The TCS and the full system are checked, and telemetry and mission data are sent to the GCS. Transmission of relevant mission data is important, due to high chance of system loss during night. In preparation of the upcoming lunar night the termo electrical storage is loaded. Before the rover is finally sent to sleep the physical parameters of TCS are set to the state for night survival with high priority. Among other things, this means that the heating is raised accordingly and the radiator is decoupled.

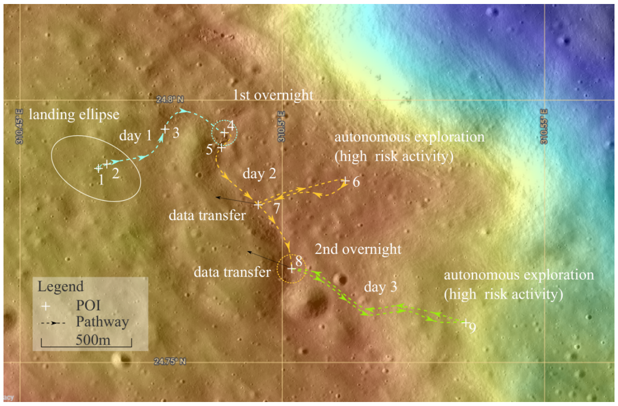

Fig. 5: Example drive sequence of the entire mission. Imagery from Lunar QuickMap[40] The expected landing site is marked with the white landing ellipse. The white crosses mark POIs such as overnight stay points. The dashed lines mark the planned pathways. According to the defined mission sequence, an example trajectory is given. Lunar day 1 includes way point 1 to 4. Lunar day 2 involves way point 4 to 8 of the trajectory. In addition, to the first two days an example trajectory for possible third day is depicted.

4.2 Lunar Night

During lunar night, the most important thing is to prevent freezing of the rover and subsystems. The heating system takes care of this. Other activities, to a rather limited extent, are computing operations and communication, if possible.

4.3 Lunar Day 2

The second day on the lunar environment starts similar to the first day. After about 28 earth days total mission time on the lunar surface the lunar night is over. The planned mission sequence of the second day, depicted in Figure 6 can be roughly divided into the mission segments:

- Wake-up and warm up phase,
- after deployment check,
- guided and semi-autonomous exploration,
- night survival check,
- transition to deep sleep.

Within the start of the second day the rover is put into wake-up mode. The full system is checked, as well as unfolding and the locomotion check. At the same time, communication takes place with the GCS, from where commands are sent to the rover. A live video with low data rate is sent from the rover to the GCS for visual recording of the status. Unlike the first lunar day, the rover starts with the after deployment check after waking up. Here a full system check is made, a locomotion system check and the optical inspection of the environment where the rover is located.

Guided and Semi-autonomous Exploration
The second day involves again different semi-autonomous mission planning and execution segments for further exploration and payload activities. When the main exploration and payload objectives are reached there is further room for high risk activities foreseen. This could be entering a crater or drive down the slope to the Vallis Schroteri. Temporally communication losses and shadowed areas are expected. In worst case this could lead to a full system loss.

5. System Design Requirements

The needs of the mission scenario results in technical requirements for the rover. Thus, the rover has to be designed to withstand the lunar night, to navigate semi-autonomously during communication timeouts and when crossing shaded areas and to carry a payload of at least 500 g. The primary objective is to acquire images for collecting surface information to prospect for upcoming missions. The table 3 summarises the key technical requirements for the system.

Table 3: Systems key requirements

Requirement	**Description**	**Value**
Mission	Duration	min. 2 lunar days
	Travel distance	>250 m per lunar day
	Landing Site	Lat. 0°- 30°
Physical	System mass	<20 kg
	Rover speed	0,1 ms^{-1} max.
	Maximum boulder height to climb	15 cm
Functional	Take pictures and videos	FHD resolution max.
	Payload	0,5 kg (Imager, Spectrometer)
	Navigation	semi autonomous
Power	Solar powered	⌀ 15 W
COM	Lander	256 kBit/s Telemetry, 1 MBit/s High Speed Link

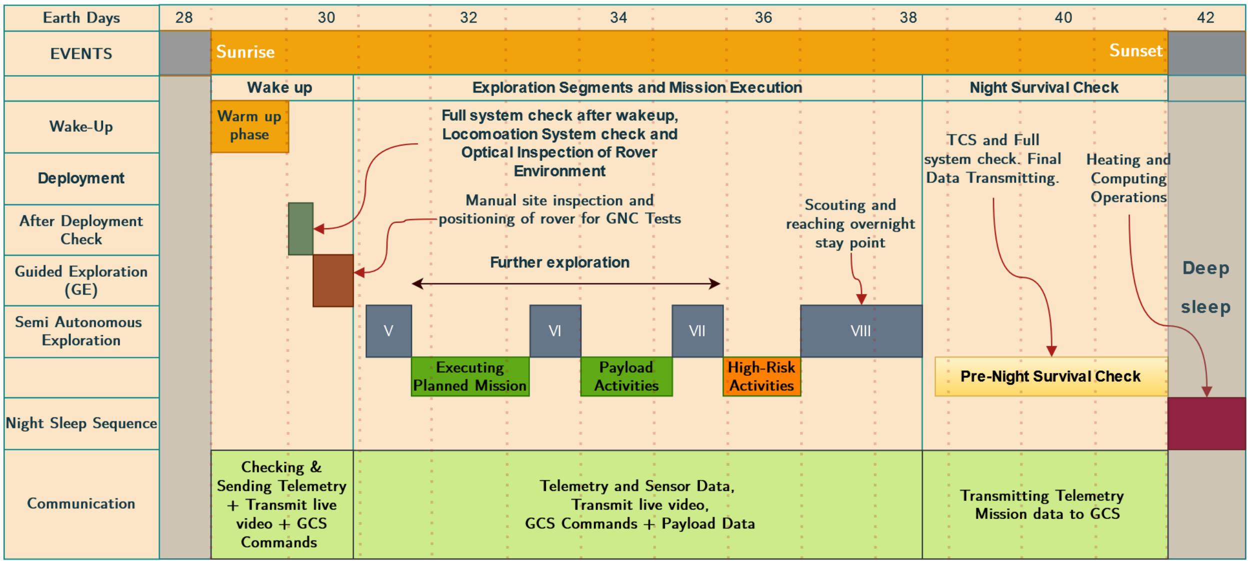

Fig. 6: Lunar day 2 of rover mission sequence

6. System Concept

To meet the technical challenges of the mission, a system design was developed for a small rover with a mass of approximately 20 kg. The design of the rover is significantly influenced by the requirements of the night survival and represents an approach to provide a nevertheless performant rover for the mission, realized with minimal resources. Figure 7 shows the rover in the simulated lunar environment. Its hull consists of a double shell construction with a double MLI separated by fiberglass tubes to keep thermal losses over night low. The surface of the system is equipped with solar cells to harvest as much energy as possible during the day time and an radiator on the top site for heat dissipation. For minimizing the power losses during operations, sensors and OBDH are kept on a low performance level. The GNC system consisting of a stereo camera for navigation and two cameras for near-field hazard detection. The rover can carry a payload of 500 g that can look via a dedicated cutout in th MLI outside of the rover. The project SAMLER-KI has just started, hence the development is at an early stage and the total mass of the rover is currently 22.7 kg, which shall be optimised to 20 kg over the course of the project. Hereby, the rover's battery has a mass of about 9 kg and further 2.1 kg is required for the MLI. Mobility is provided by the transversal bogie chassis, a simplified version of the rocker boogie chassis. Further information's are presented in [13].

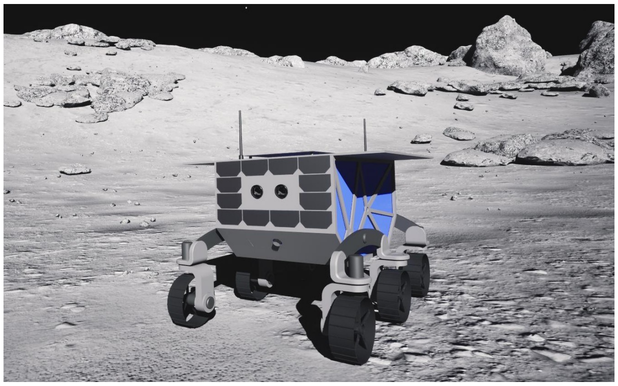

Fig. 7: SAMLER-KI rover concept in lunar environment simulation

7. Conclusion

The development of key technologies for exploration of the lunar surface is ongoing worldwide. Small robotic systems play here an important role. We see micro-rovers, which can autonomously explore the unknown lunar environment at higher risk while surviving the lunar night, as a key technology to advance robotic exploration at low cost.

In the present paper a developed reference mission for the deployment of a micro rover in the equatorial region on the lunar surface was presented. The selected landing side is located near to the Cobra Head of aristarchus plateau. The reference mission covers two full lunar days including the lunar night. This, together with a set of system requirements, forms the basis for the development of a micro-rover with night survival capabilities and a high degree of autonomy.

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