IAC-25-A3-IPB-18-x98355

Promises and Challenges of Robotic Quadrupeds for Space Exploration

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Abstract

After numerous successful space missions with wheeled rovers such as Curiosity or Perseverance to explore open areas and collect samples, space agencies and private ventures around the world are shifting their focus to also explore more challenging environments. These include lunar lava tubes and Martian caves, which hold great promises to scientific discoveries. In these scenarios, the accessibility for large and wheeled robots would be limited, such that (small) legged robots capable of climbing, jumping, and dynamically adapting their gaits to different environments become necessary. However, despite the recent advances and increased commercial availability of quadrupedal robots, the exact requirements that a quadruped has to fulfill in a space setting remains an open topic. To address this question, this paper reviews current solutions and capabilities of robotic quadrupeds to assess the specific benefits that this technology offers as part of a robotic team for operations on celestial surfaces such as the Moon and Mars. Additionally, the main open challenges are identified to adapt the state-of-the-art technology in terrestrial systems for in-space deployment and operations. For this analysis, we leverage findings from the ISS technology demonstration mission, Surface Avatar. In two space-to-ground experiment sessions, three astronauts in orbit teleoperated a small quadrupedal robot to survey its environment and retrieve small objects. These insights were extended in a follow-up mission in July 2025, in which multiple quadrupeds were included operated by the astronauts for different tasks. Additionally, this new session included a cave exploration scenario. The experiment findings and astronaut feedback were evaluated under consideration of preparatory work carried out for planned quadruped space missions such as ESA's LEAP project and NASA's NeBula-SPOT. By examining and analyzing the experimental results and astronaut feedback from our Surface Avatar mission with the current state of technology, this paper derives specific requirements to employ quadrupedal robots in space, either in a remote control setting or for autonomous tasks. Based on the identified requirements, we will propose design recommendations for both control strategies of robotic quadrupeds to be included for different tasks in human-robot teams for future space exploration.

1. Introduction

Wheeled rovers such as Curiosity [1] and Perseverance [2] have proven highly capable in exploring open terrains, performing in-situ science, and collecting samples on Mars. However, as planetary exploration extends toward more challenging terrains such as lunar lava tubes, Martian caves, and steep crater walls, the limitations of wheels become apparent [3]. These environments feature loose regolith, sharp inclines, irregular obstacles, and confined passages that significantly constrain mobility for large, wheeled systems. To reach and operate in such terrains, legged robots offer a promising complement to existing rover platforms. Among possible legged designs, especially quadrupeds offer a compelling balance between terrain adaptability, mechanical simplicity, and energy efficiency [4]. Compared to hexapods and other multi-legged robots, they require fewer actuators and control resources while still providing improved stability and robustness over biped solutions. This makes them the most likely configuration to enable adaptable and agile locomotion to explore diverse terrains in envisioned space missions and terrestrial applications alike [5]. Thus, research efforts for these systems have increased drastically in recent years, and many systems have become commercially available [6–8] and are being tested in space analog environments [9]. Yet, the quadruped research often focuses on locomotion control and perception performance in isolation [10], leaving open the broader operational question: **for which tasks are quadrupeds most suitable and how should they be designed and controlled to be integrated into human–robot teams for actual space missions (Fig. 1)?**

To address this gap, we draw on recent findings from the ISS-to-Earth demonstration mission *Surface Avatar* [11, 12]. In this mission, astronauts aboard the International Space Station (ISS) remotely operated a team of different robots on Earth under space-realistic communication conditions. The most recent session, conducted in July 2025 at the German Aerospace Center (DLR) in Oberpfaffenhofen, marked a milestone: for the first time, multiple quadrupeds were controlled alongside a rover and a humanoid robot to perform cooperative tasks in the Mars-analog environment (Fig. 2). The included quadrupeds displayed different features giving each advantages for specific tasks: The small and very robust quadruped *Bert* of the DLR [13] had to be navigated into a cave using teleopertation, while the more mobile *Spot* robot [7] integrated by the European Space Agency (ESA) was equipped with a robotic arm and tasked to locate and retrieve objects in autonomous and teleopertated mode. The experiments of this demonstration mission provide rare, high-fidelity data on astronaut–robot interaction, multi-robot task allocation, and the opportunities of shifting autonomy in realistic mission contexts.

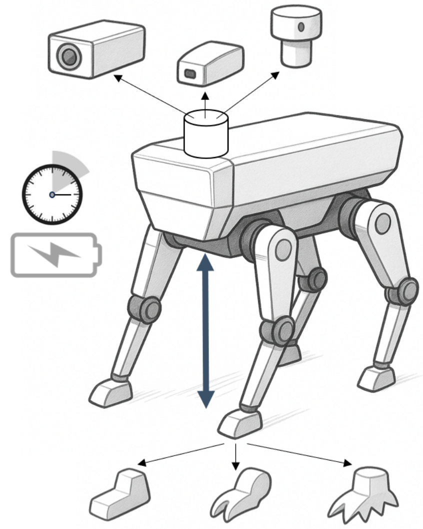

Fig. 1: Quadruped design in terms of body morphology and sensor equipment depends on specific mission tasks.

This paper builds on the operational insights from the Surface Avatar ISS technology demonstration telerobotic mission, in combination with the current state-of-the-art of quadruped technology, to identify how these systems can best complement human-robot teams in upcoming space missions. In this context, we do not address the widely investigated topics of quadruped control methods and gait selections [5, 10], nor methods to enhance the systems' perception and autonomous reasoning. Instead, we focus on identifying specific use cases, for which quadrupeds may provide the greatest value, taking into account known limitations of quadruped systems. For each identified use case, we outline the task and, if applicable, how it was implemented and tested in the Surface Avatar mission. Based on the requirements of the task and our experiences from the experiment, we identify dedicated mechanical features for a quadruped, giving individual design recommendations to be best suited for the task at hand. Additionally, we consider the required level of autonomy and how the quadruped should be implemented in the human-robot team. Specifically, we highlight the opportunities enabled through scalable autonomy and teaming strategies that allow astronauts to effectively command multiple quadrupeds in different scenarios.

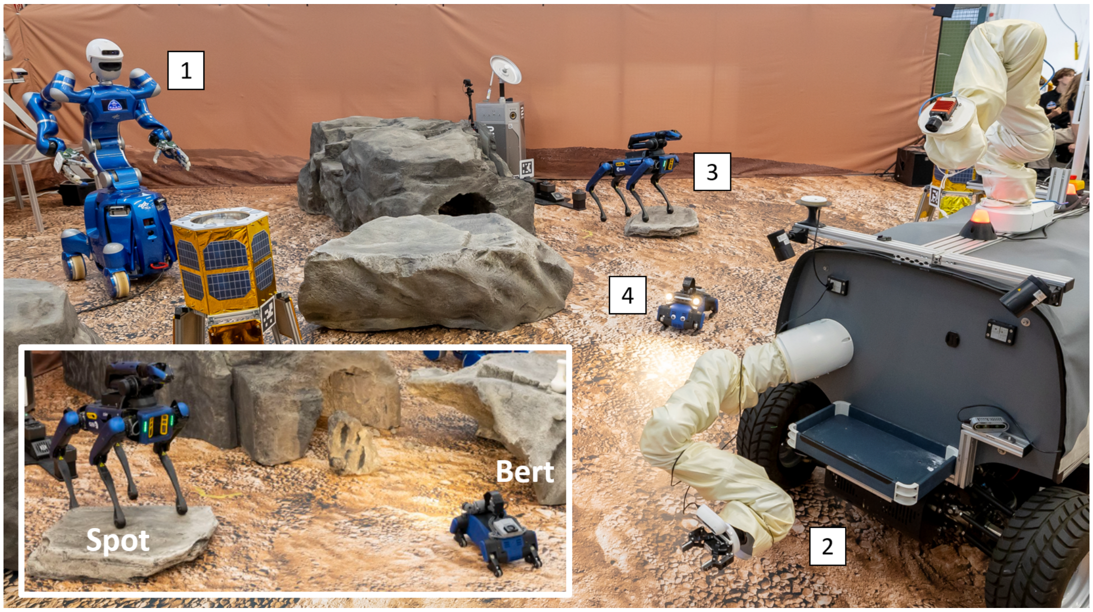

Fig. 2: Overview of the Surface Avatar setup used in the latest ISS-to-Earth demonstration mission, including four different robotic systems with individual strengths: 1) Rollin' Justin, 2) Interact Rover, 3) Spot, and 4) Bert. The zoom shows the size and morphology differences of the two quadrupeds, Spot and Bert, each designed to suit a different task.

By situating our analysis in real astronaut-in-the-loop experiments and planned mission concepts, we aim to provide actionable recommendations for the deployment of quadrupeds as integral members of robotic teams for future planetary surface exploration.

2. Background and Related Work

2.1 Legged Systems for Space Applications

Rovers remain the backbone of planetary surface exploration, but the wheeled systems meet their limits in cluttered, high-slope, and subsurface terrains. Here, legged systems offer more mobility and flexibility due to the possibilities of foothold selection, body re-positioning, and easy height adjustments, which enable them to also access narrow passages or low caves.

These advantages of quadruped systems first became apparent in terrestrial applications. This has helped mature the quadruped technologies in recent years and led to multiple commercial systems such as Boston Dynamics' Spot [7], ANYbotics' ANYmal [8], and Unitree's Go series [6], which are now being deployed for industrial inspection, search and rescue, surveying, and research [14]. Their strengths lie in reliable locomotion on uneven terrain, autonomous mapping using LiDAR and vision, and the ability to carry sensors or manipulate small payloads [4]. Thus, the applicability of quadruped technologies for space is being explored and matured in several projects. The ESA-funded LEAP concept adapts ETH's ANYmal to the Moon, explicitly targeting dynamic gaits and jumping for Aristarchus Plateau [15]. It was shown that especially dynamic maneuvers like hopping and pronking become energetically attractive in the low gravity of celestial bodies as presented by the research prototype SpaceBok [16, 17]. In parallel, NASA's Jet Propulsion Laboratory (JPL) developed the uncertainty-aware framework *NeBula* for Spot [7], which aims at enabling resilient and modular autonomy solutions by performing reasoning and decision making for the quadruped [18, 19]. These works have advanced mechanical design and autonomy for single-robot demonstrations in analog conditions, working towards the application of quadrupeds in actual space missions.

Despite this progress, terrestrial designs cannot be transferred directly to space. Most commercial systems rely on sealed bearings, conventional lubricants, and standard electronics, which degrade under vacuum, radiation, and extreme thermal cycling. Their actuators and joints are vulnerable to abrasive lunar and Martian regolith, which can cause rapid wear [10]. Recent NASA materials and dust-mitigation reports summarize the wear mechanisms and testing gaps that directly impact leg mechanisms and actuators; they also stress the need for standard testbeds and simulants [20]. Terrestrial robots also assume access to frequent charging and network connectivity; in contrast, planetary missions require extreme energy efficiency, tolerance for long communication delays, and the ability to deal with unexpected and unknown environments that may still require human intervention. Thus, in a realistic scenario, it is likely that an astronaut will still need to be remotely present in explorations through robotic teams stationed on celestial bodies [21]. Thus, not only hardware and control requirements need to be addressed, but also the question of how to best implement quadrupeds in human-robot teams and which tasks should be allocated to them.

2.2 *Scalable Autonomy and Robot Team Integration*

Since future mission plans for extraterrestrial explorations have moved from single-platform mobility toward team-of-systems concepts, methods to balance between astronaut control and robotic self-reliance were needed. Through a decade-long collaboration between DLR and ESA, different modes of telecommanding robots have been demonstrated from the ISS to Earth in *METERON SUPVIS Justin* [22], *Analog-1* [23,24], and *Surface Avatar* [11,12].

In SUPVIS Justin, astronauts aboard the ISS supervised DLR's humanoid Justin on Earth, directing it through high-level commands while the robot handled the low-level details. This "supervisory control" paradigm demonstrated the feasibility of operating dexterous robots remotely in conditions of high latency and first formalized *Scalable Autonomy* as a design principle for space operations. In the Analog-1 experiments, the ISS astronauts had to carry out diverse tasks with ESA's Interact Rover, first in a simulated experiment environment indoors [23] and finally in a realistic outdoor scenario on the moon-like surface of Mount Etna [24].

Building on this foundation, the Surface Avatar experiments extended the framework of scalable autonomy established within the previous experiments of the METERON programme by introducing more command modalities and a heterogeneous team of robots to be commanded simultaneously [11, 12]. In the first session in 2022, Marcus Wandt coordinated the ESA Interact Rover and the humanoid Justin to jointly insert a peg into a hole [25], making use of force feedback rendered to the astronauts on the ISS. This mission also first featured the remote control of a quadruped robot from the ISS [13]. In the follow-up mission of July 2024, astronauts Tracy „TC" Dyson and Jeanette Epps commanded the same robotic platforms to perform more complex tasks. During this session, they demonstrated seamless switching between supervised autonomy and direct teleoperation, while also addressing purposefully introduced error scenarios [26, 27]. In the most recent mission, remote control was extended beyond DLR's small quadruped Bert [13,28] to include ESA's deployment of the Boston Dynamics robot Spot [7]. This illustrates that even within the same robotic class, design diversity can be advantageous depending on the operational context and task requirements.

The progression from SUPVIS Justin to Surface Avatar demonstrates a clear trajectory: autonomy is no longer limited to individual robotic systems but now extends to heterogeneous teams. This diversity allows complementary task allocation, with each platform contributing unique capabilities — ranging from large-area scouting to precise manipulation and exploration of hard-to-access terrain. In this context, scalable autonomy not only reduces astronaut workload but also becomes a crucial enabler for coordinating multi-robot systems in complex planetary environments [12]. Furthermore, the experiments highlight the specific requirements that different robots must incorporate to perform their designated tasks [29]. These requirements vary not only across robot types but also within the same class of systems, which will be explored further in the following for the specific case of quadruped systems.

3. Identification of Use Cases

As already outlined, quadruped robots are poised to complement traditional wheeled systems in space missions by addressing tasks where mobility, agility, and human interaction are critical. This entails that the most relevant field will be outside of routine tasks in human-built habitats, which will be designed to be easily accessible for robots with wheels. Additionally, general limitations of quadrupeds should be considered: They face constraints in battery life, payload, manipulation capacity, and environmental robustness. The extent to which these capacities are needed differs for different mission scenarios. Thus, these limitations should be individually addressed depending on the needed capabilities for a task, guiding engineers and mission planners in design and task allocation of quadruped systems. Based on the known advantages and capabilities shown in terrestrial applications, two primary application domains appear obvious for space scenarios: **1) surface exploration and scouting**, and **2) inspection of confined or complex spaces**. Both scenarios have been considered in the latest Surface Avatar session, using two different types of quadrupeds (Fig. 2).

Additionally, a third application seems promising: **3) human companionship**. Although currently not a research focus, in long-duration missions, quadrupeds may also function as human companions for crew members onboard an orbiter or within habitats. Especially in the absence of other humans, interactions with robots can mitigate loneliness, improve mood, and enhance psychological health in isolated environments [30]. Since quadrupeds share general morphology and appearance with dogs, one of the most popular domesticated pets, they are more readily accepted as companions compared to other robots [31].

Each of the three identified domains imposes specific design requirements. By tailoring size, sensing, and actuator capabilities to the intended operational domain, quadrupeds can deliver meaningful value in both scientific exploration and human-centered space operations. The following sections aim to guide the selection and development of each quadruped platform for the different tasks by suggesting design and control recommendations. The findings are summarized in Tab. 1.

Fig. 3: ESA's integrated Spot robot dropping a sample in the handover station.

4. Surface Exploration and Scouting

4.1 Task Specification

The ability to move their feet individually and adjust the step pattern and center of mass makes quadruped robots particularly valuable in navigating uneven or difficult terrain. Thus, they are specifically important for scientific and reconnaissance missions in areas like crater rims, rocky fields, or lava tubes. For these missions, the quadrupeds need to be able to traverse large distances, map terrain, detect points of interest, and, where possible, collect samples or deploy instruments.

Within the latest Surface Avatar mission, this mission scenario was emulated using ESA's implementation of the Spot robot (Fig. 3). It was tasked to autonomously find and collect samples scattered around the Mars-like test environment, where different-sized stones were randomly arranged to challenge the robot's maneuverability. The quadruped placed the collected samples in a handover station, where they could be picked up by the humanoid Justin robot for further analysis, showcasing the collaboration between the different robot types. Additionally, the astronaut was able to take over the control of the quadruped, such that Spot could also be steered manually, either to inspect the environment or to support the robot in its collection task.

4.2 Design Recommendations

Since quadrupeds for exploration should be able to cover large areas to collect information and samples on various sites, they need to be specifically energy-efficient. Therefore, they should have longer legs that allow for long strides and use hopping gaits, which are especially energy-efficient in low-gravity [16]. The hopping efficiency can potentially be further increased when the robot's mechanical dynamics are designed in a way that they naturally align with the motion, reducing the control effort [28, 32].

In order to collect information and map the environment, quadrupeds for scouting need multi-modal sensing, including LiDAR, stereo cameras, and inertial measurement units (IMUs). They should also have moderate manipulation capabilities for sample collection or interactions with the environment. Consequently, to provide enough payload capacity for all the scientific instruments, and carry larger batteries for extended work range, such quadruped systems should be medium- to large-sized. The larger size may also enhance stability in disturbances like dust storms. Nevertheless, the robot needs to be able to recover from falls autonomously, which makes 3 degrees of freedom (DOF) per leg preferable and implies a large joint limit per DOF. An envisioned quadruped system with these requirements in depicted in Figure 5 on the left.

4.3 Autonomy and Team Integration

As showcased in the Surface Avatar mission, tasks like scouting and sample collection are well-suited to be carried out autonomously by the robot. Therefore, robust navigation and feature recognition are mandatory to map the environment and detect obstacles or sampling sites. The level of cognition and reasoning should be high, especially when larger areas are covered, so that astronauts do not have to supervise the quadruped constantly. However, the robot should alert the astronaut if needed, e.g., to decide what samples to collect or when an unexpected scenario occurs.

In these cases, maintaining the ability to switch to direct remote control is beneficial such that the astronaut can use the quadruped to inspect specific points of interest or override badly planned actions. Therefore, the control input for the scouting quadruped should be prepared in a way that the astronaut can smoothly transition between the control modalities, although the focus for this use case should lie on the system's autonomy features.

5. Inspection of Confined Spaces

5.1 Task Specification

Due to their adaptability, quadrupeds also hold great potential to access narrow spaces with varying ground, like shafts for maintenance, or Martian caves for exploration. In such scenarios, the ability to maintain stability on steep inclines, climb over loose rocks, and use precise foot placement is critical, especially when lighting is limited. The primary mission objectives include inspecting surfaces for hazards or points of interest and identifying areas for maintenance or scientific study. Because communication signals may be weak or intermittent inside caves or isolated areas, robots may need to perform extended segments of operation semi-independently, prioritizing reliability and consistency in task execution.

Such a scenario was tested in the Surface Avatar mission using the small elastic quadruped Bert. The robot was transported to the cave location with the Interact Rover (Fig. 4, top). At the site, it was released to the ground. The astronaut was then tasked to use a joystick to remotely control the robot to walk into a cave, where different points of interest had to be identified (Fig. 4, bottom).

5.2 Design Recommendations

Quadrupeds designed for inspection tasks in confined spaces such as Martian caves must prioritize compactness, agility, and robustness over payload capacity or range. Only essential components, such as lighting, high-resolution cameras, and proximity sensors, should be integrated to minimize weight and energy demands. Additional environmental sensors, e.g., for temperature, gas, or dust, may be integrated depending on mission objectives. Manipulation is of secondary importance, although a minimal manipulator may provide additional utility. Since these missions are typically shorter in duration, smaller batteries are sufficient, especially if the robot is deployed close to the target site by other systems, as showcased in the Surface Avatar mission with the Interact rover (Fig. 4, top). In order to increase the traction on uneven or slippery surfaces, the quadruped feet may implement retractable claws, and the center of mass should be kept low to maximize stability in narrow or tilted passages. Robust mechanics are critical, as frequent contact with rock walls or debris is likely and must not compromise functionality. Thus, incorporating elastic elements such as springs into the leg design may be advantageous as it aids in absorbing shocks from uneven terrain and reduces mechanical stress on joints during repeated contact with rocky surfaces. Communication remains one of the main challenges in such environments, as wireless signals degrade quickly underground, which was already seen in the emulated cave exploration of the Surface Avatar mission. Therefore, tethered solutions or relay-based communication strategies may be necessary to ensure reliable data transmission. The described quadruped characteristics are displayed in the middle of Figure 5.

5.3 Autonomy and Team Integration

While mapping and autonomy remain relevant for quadrupeds in inspection scenarios of confined spaces, especially when data connection is lost, remote operation is expected to play a more prominent role than full au-

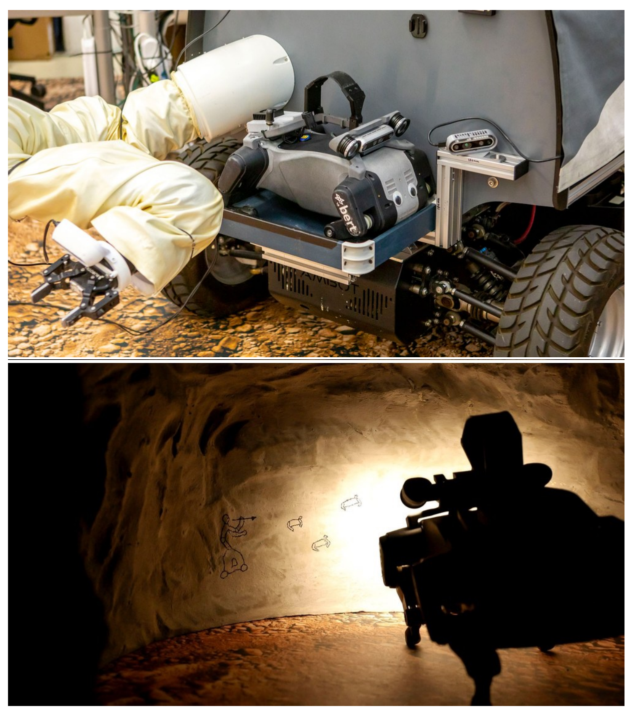

Fig. 4: The small-sized quadruped Bert during the Surface Avatar mission being transported by ESA's Interact rover (top) and during the exploration of a cave (bottom).

Table 1: Design recommendations for quadrupeds in space by use case

Application	**Size**	**Key Sensors**	**Manipulator**	**Autonomy/ Control**
Surface Exploration Scouting (Sec. 4)	medium to large	LiDAR, stereo cameras, IMU, thermal sensors	moderate: sample collection, small tool handling	High autonomy for navigation and mapping
Inspection of Confined Spaces (Sec. 5)	small, agile	High-resolution cameras, proximity sensors	minimal: light object handling if needed	Semi-autonomous with frequent remote operation
Human Companionship (Sec. 6)	small to medium	Cameras, microphones, tactile sensors	minimal: human interaction or light object delivery	Shared autonomy for following and interactions, strong learning capabilities to adapt social behaviors

tonomy. In routine traverses, the robot could operate under shared autonomy, where onboard SLAM handles footstep planning, obstacle avoidance, and stability [33], while an operator selects goals or regions of interest. For delicate maneuvers like narrow squeezes or ledge crossings, control, the astronaut could take over steering via direct teleoperation, although safety features should remain with the robot, enabling it to avoid or recover from unsafe maneuvers [27]. Conversely, when communications drop, the system should switch to failsafe autonomy, e.g., using pause–assess–retreat behaviors [34].

6. Human Partner- and Companionship

6.1 Task Specification

Quadrupeds viewed to be human partners and companions are not intended for heavy payload or long-range mobility, but rather for interaction-rich roles: following crew members, responding to gestures and voice commands, providing comfort through touch, and offering simple assistance such as fetching or holding small objects. Human-companion quadrupeds must therefore continuously perceive human presence, recognize expressions or social cues, and respond in ways that reinforce engagement. Their task execution emphasizes safety, predictability, and reliability, ensuring that interactions remain positive and non-intrusive while promoting crew trust and confidence.

Although this aspect was not considered in the Surface Avatar mission, its significance is anticipated to grow in upcoming missions.

6.2 Design Recommendations

Quadrupeds for social interactions should likely adhere to other design requirements than functional robots for exploration or inspection. Research has shown that not only the appearance, but also the movement patterns, specifically gaits, influence how humans perceive quadrupeds. Especially ”bouncy” gaits are perceived as warmer and less discomforting [35]. This has also been observed in human interactions with the small elastic quadruped Bert, which embeds hardware elasticities that result in bouncy, more natural-appearing movement patterns, which people intuitively seem to perceive as friendly. Additionally, Bert features googly eyes (Fig. 4), adding to its likability since facial features like round eyes improve trustworthiness and attitude towards social robots [36].

Consequently, quadrupeds for companionship in space should be small to medium in size and prioritize approachable, animal-like locomotion and appearance over the functional complexity of their counterparts for exploration. Given the importance of affective touch in human-robot interaction [30], incorporating a strokable haptic surface is recommended for companion robots. A small manipulator can enhance utility by assisting the human partner in simple tasks, such as fetching objects or passing tools, but heavy manipulation is likely unnecessary. The sensor suite should focus on human detection and interaction, including cameras for face and gesture recognition, microphones for voice commands, and optional proximity sensors to maintain safe distances. Robustness and energy efficiency remain important, but given the limited mobility needs and short-range operations within a habitat, battery and structural requirements are moderate. Autonomous recharging capabilities can be integrated to minimize downtime and ensure reliable operation. A general design based on these considerations is suggested in Figure 5 on the right.

6.3 Autonomy and Team Integration

Human-companion quadrupeds should operate under shared autonomy, balancing autonomous social behaviors with human supervision. Routine interactions, such as fol-

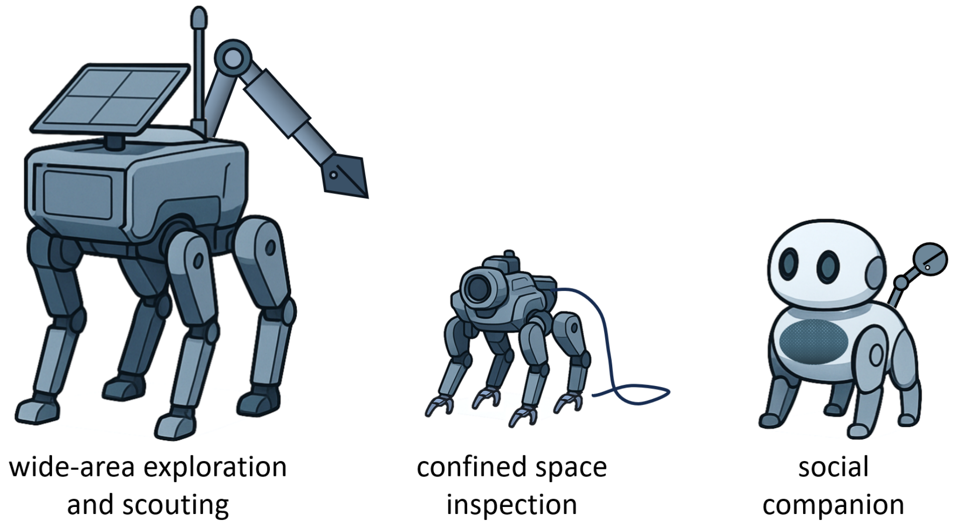

Fig. 5: Characteristic features of quadrupeds tailored to different identified use cases in space applications with specific design recommendations tailored to the given tasks.

lowing crew members, responding to gestures, or providing reminders, can be handled autonomously, while astronauts can intervene to adjust behavior, set priorities, or manage the robot's positioning within the habitat. Even minimal social behaviors can positively impact crew well-being, while more advanced autonomy and learning capabilities can further enrich the human-robot interaction experience. Thus, the quadruped companion should be capable of learning from crew interactions, adapting and refining its responses and activity patterns over time to align with individual preferences and social cues. Integration into the habitat's robotic ecosystem involves coordinating with other systems: companion quadrupeds may communicate with environmental sensors to monitor crew activity, or with mobile utility robots to assist in delivering small items. The autonomy framework should support fail-safe behaviors, maintaining safety and minimizing disruption if a conflict or unexpected scenario occurs, while continuously promoting social engagement and crew well-being.

7. Discussion

The analysis of quadruped robots for space applications highlighted three primary use cases: wide-area exploration, inspection of confined spaces, and human companionship. Each use case imposes distinct requirements on design, autonomy, and team integration, to address the limitations and challenges in each scenario (Fig. 5).

For exploration, quadrupeds must traverse uneven terrain, map complex environments, and, where possible, interact with the environment through sample collection or instrument deployment. The main limitations are battery life, payload capacity, and stability on steep or loose terrain, which constrain operational range and the size of instruments or samples that can be carried. To mitigate these issues, energy-efficient actuation concepts and gait selection are important, therefore suggesting a big and robust quadruped with advanced autonomy features. Especially, cooperation with aerial scouts may be beneficial to survey larger ranges and aid in mapping of unknown areas.

In cave and confined-space inspection, quadrupeds benefit from compact, agile designs with minimal or no manipulators and sensors optimized for close-range perception. The primary challenges are communication constraints, navigation in narrow passages, and robustness to environmental interactions, such as collisions with walls or rocks. Dropping repeaters along the path or tethered communication, and elastic leg designs with springs can help overcome these challenges. Shared autonomy is advised, where the human remote control plays a bigger part in maneuvering passages or inspecting points of interest. These missions also highlight the importance of heterogeneous teams, where small quadrupeds with limited battery capacity can be transported by larger systems to the inspection area. Current state-of-the-art quadrupeds have only limited experience in strongly constrained, communication-limited environments, marking this as a critical area for research.

The use of quadrupeds as human companions promises improved psychological well-being in isolated habitats. Design priorities include social presence, safe interaction, and adaptability to individual crew preferences. Critical features are vision and audio sensors for social cue recognition, haptic surfaces, and light manipulators for small assistance tasks. While less demanding in terms of payload and reach, companion robots must exhibit robust social autonomy and learning capabilities. Research in this area is still emerging, largely in the context of healthcare and eldercare, but adapting these insights to quadrupeds in space habitats may be promising to enhance crew mental health.

Across all use cases, potential pitfalls include overestimating autonomy capabilities, underestimating communication constraints, and hardware limitations under space conditions. Quadrupeds are unlikely to replace wheeled or tracked robots for long-distance transport or heavy lifting, and their deployment must be carefully integrated with other robotic systems. Due to the more complex mechanics, environmental conditions in space, like dust storms, extreme temperatures, and uneven gravity, pose greater challenges to quadruped systems and need to be addressed. Shared autonomy features will be critical throughout all use cases, such that robot autonomy and human intuitiveness can be combined to overcome challenges of each task.

8. Conclusion

Overall, quadrupeds offer versatile platforms capable of complementing other robotic systems in space. Depending on the use case, the systems' design, autonomy, and team integration should be tailored to the specific mission needs, suggesting that one-size-fits-all solutions may not be applicable. Implemented in a robotic team, quadrupeds can enhance exploration, inspection, and crew support, but continued research is required to fully realize their potential under the unique constraints of extraterrestrial conditions.

Acknowledgements

We thank the whole Surface Avatar Team at the DLR Institute of Robotics and Mechatronics, the German Space Operations Center (GSOC), the European Astronaut Centre (EAC), and the European Space Research and Technology Centre (ESTEC). A special acknowledgment goes to Florian Schmidt, Robert Burger, and Jörg Butterfass for their support in keeping our robots running. We are deeply grateful to the ESA and NASA astronauts Marcus Wandt, Tracy C. Dyson, Jeanette Epps, and Jonny Kim for their participation in our experiments and invaluable feedback.

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