Hybrid walking and driving rover

The SherpaTT rover is equipped with a wheel drive and actuated suspension system. It is intended for planetary exploration and uses redundant embedded CAN networks.

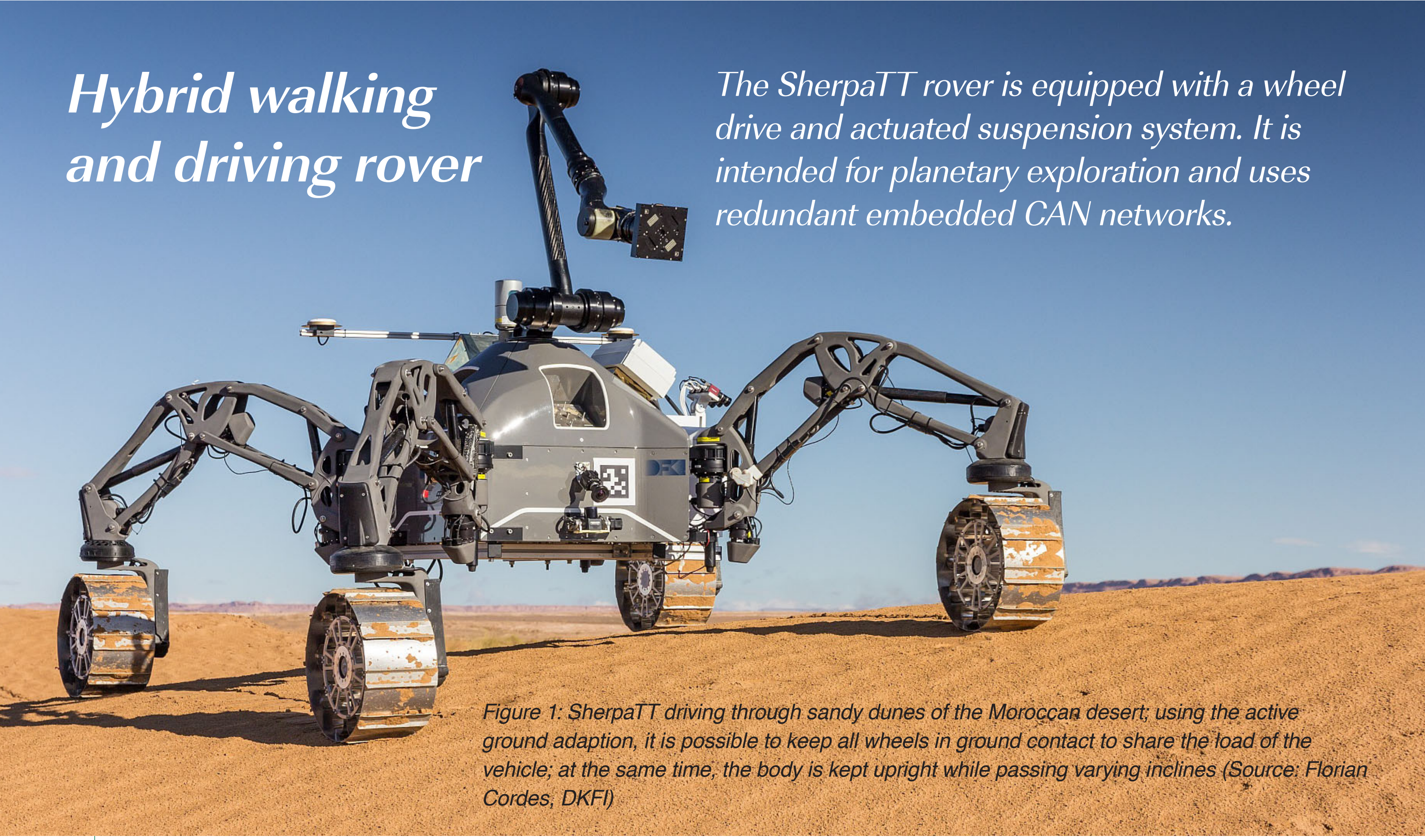

Figure 1: SherpaTT driving through sandy dunes of the Moroccan desert; using the active ground adaption, it is possible to keep all wheels in ground contact to share the load of the vehicle; at the same time, the body is kept upright while passing varying inclines (Source: Florian Cordes, DKFI)

The DFKI German Research Center for Artificial Intelligence has developed the hybrid walking and driving rover. Recently, it was tested in the deserts of Morocco. The 200-kg robot was running new software enabling a 1300-m drive through sand and stones.

Using the actuated suspension system, it is possible to generate combined walking/driving motions and even short traverses of pure walking motion. The objective is to have an energy efficient (wheeled) locomotion that can be advanced in difficult situations using the active suspension or "legs" of the system. The SherpaTT rover was developed in a first version within the Rimres (reconfigurable integrated multi exploration system) project (2009 to 2012). The second version now active in various field trials was developed in the project Transterra (2013-2017). The tasks of both versions encompass the transportation of a walking scout robot and the transportation and assembly of scientific payloads.

Originally, the SherpaTT rover was not equipped with CAN networks. The researchers used their own LVDS-based (low-voltage differential signaling) communication system, also known TIA/EIA-644. "However, as a secondary aspect, we developed a version of the motor control electronics for a space qualification process in the project", explained Florian Cordes from the DFKI. "This version is indeed equipped with a redundant CAN interface and is aspired to replace SherpaTT's motor control units in a future space qualified rover system."

Intended for a Mars expedition

The deserts of Morocco close the border of Algeria are similar to the conditions on the Mars. In early December 2018, the two meters long SherpaTT robot was tested there. Some 30 scientists from eleven countries collected findings for the European Peraspera (Latin meaning: Through hardships to the stars) project. The rover with articulated legs is aspired to be used for the exploration of the red planet. In the test, the rover used new software, which enabled an autonomous long-distance travel over steep slopes and gorges as well as opportunistic science, meaning that the rover chose rocks to be further investigated on its own during the mission.

The tested SherpaTT prototype is not yet radiation-hardened and is not designed to withstand extreme temperatures. To achieve this, it will be equipped for example with redundant CANopen networks compliant with the ECSS-E-ST-50-15 specification.

In both versions, the rover features an active suspension system for increased maneuverability and a multi-purpose manipulator arm that can be used for both, manipulations and locomotion purposes. The suspension system is constructed from four independent legs each equipped with a wheel. It uses active and passive suspension on different scales. Flexible metal wheels are employed to cope with ground irregularities on a small scale and to provide high traction in soft soils. Springs in the lifting actuators of the rover form a kind of serial elastic actuator that copes with bigger irregularities below one wheel diameter (These springs are not present in the second version anymore). Big obstacles and body leveling in sloped terrain are dealt with by actively actuating the suspension system [1].

With the suspension redesign, a second lifting actuator was introduced, resulting in a knee in each leg. The linear actuators are installed in such a way that they experience tensional forces while the wheel has contact with the ground. This leads to a stiffer system compared to the ▷

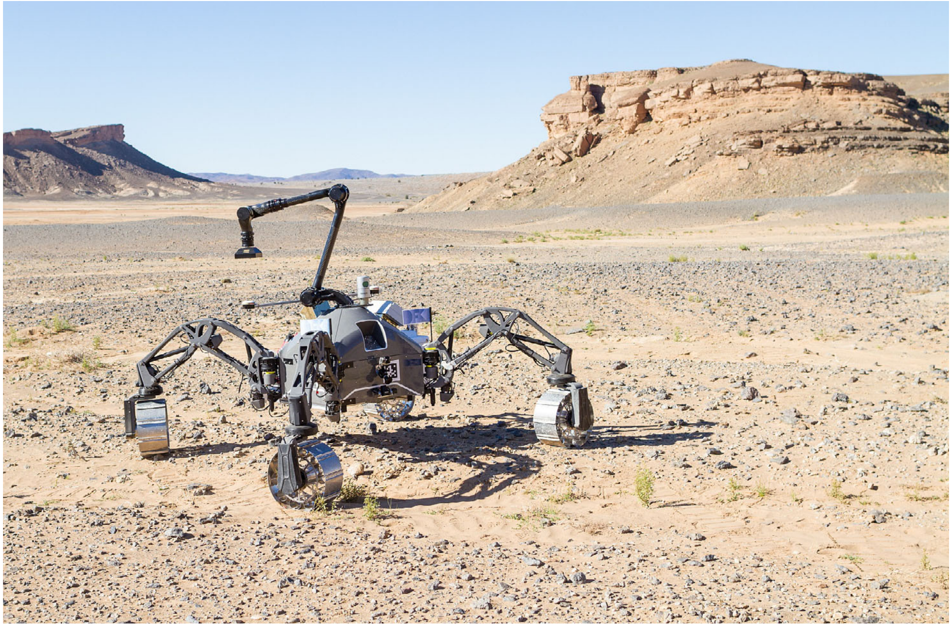

Figure 2: SherpaTT on a rock covered patch of desert in Morocco; an autonomous traverse with a total distance of more than 1 km was successfully conducted in this terrain; path planning, obstacle avoidance and path following are completely calculated on board, without the need for interaction with a ground control station (Source: Jonathan Babel, DFKI)

original Sherpa design where the actuator has to provide a push-force and mechanical slackness leads to high position variance.

A set of modularized actuators of different power classes has been developed at DFKI, these modules are used for the Sherpa redesign, reducing the number of different actuators in the system for improved maintenance and control. For communication between the actuator modules and the central control electronics it is intended to apply CANopen networks based on the above-mentioned ESA specification.

Joints with redundant CAN networks

The DFKI-X joints used in the SherpaTT robot comprise torque optimized brushless DC motors. They are used in combination with a harmonic drive gearbox on a single hollow shaft. The direct coupling allows a stiff transition of the drive torque leading to a high level of accuracy and dynamics. To reach a high level of compactness Hall and temperature sensors are directly integrated in the motor unit. It is envisaged to combine both, the motor and the control electronics in one housing leading to a compact multi-purpose robotic joint for space applications. The motor electronics are designed to support an 80-W BLDC (brushless directed current) motor at 28 V_{DC}. The design approach is based on COTS (commercial off-the-shelf) products, which were specifically chosen to resist the space environment.

It contains a flash FPGA with MRAM (magnetic RAM) data storage, a GAN-FET (field-effect transistor) power stage, an analog-to-digital converter, a redundant CAN interface, Hall as well as BEMV commutation and includes redundancies and self-monitoring along with a latch-up protection for every function block. The FPGA as central processing unit is used within the joint to control the motor and perform data handling from all integrated sensors. This enables a system wide decentralized processing architecture with a CAN interface directly integrated in the joint. The used VHDL code is adopted from terrestrial applications and hence not considering single event upsets (SEU). An SEU is a change of state caused by one single ionizing particle (e.g. ions, electrons, or photons), which may happen in the outer space.

During a one-week test campaign the DFKI-X joint undertook a preliminary total ionizing dose (TID) and neutron radiation test. During those tests the motor was coupled to the mechanical load. Further tests including environmental testing for pre-qualification purposes have been performed already. Among others, this included tests against mechanical loads, thermal-vacuum, radiation, and EMC. The tests for qualification purposes were carried out using the updated DFKI-X motor and electronic units [2]. ◀

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based on information by DFKI

References

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[2] Roland U. Sonsalla, Hendrik Hanff, Patrick Schoeberl, Tobias Stark, and Niklas A. Mulsow (all DFKI): DFKI-X: A novel, compact and highly integrated robotics joint for space applications