# Visual Mapping Identifiers to Support Autonomous Navigation of Space Rovers

Notable achievements in planetary exploration include the successful deployment of several Mars rovers, namely Sojourner, Spirit and Opportunity, and the Curiosity rover. These missions aimed to explore the surface and geology of Mars to discover the history of the planet's water activity, determine the geological processes that shaped the landscape, and assess the habitability of the environment, and much more. Autonomous mobile robots played a critical role in these missions by assisting the exploration and support human activities. However, localization and mapping are very challenging for the autonomous systems due to the visual similarity of the terrain in Mars and the unavailability of GNSS/GPS systems. On Earth, autonomous vehicles primarily depend on GNSS/GPS signals for localization, and perception technologies such as lidar, camera and radar are used for improved precision. The machine vision system in the vehicle extracts distinct features from the scene to calculate the relative positioning of the vehicle; however, as the vehicle continues to travel the error accumulates exponentially - especially in visually similar landscapes - eventually creating a significantly large positioning error. Due to innate challenges of Mars' terrain and the unavailability of GNSS/GPS, machine-vision based navigation and positioning are particularly challenging. Furthermore, using dedicated short-range wireless signals (i.e., DSRC signal that includes roadway data and safety messages) to assist with autonomous navigation is not a feasible solution due to increased levels of electromagnetic radiation in Mars, creating a high level of electromagnetic interference.

Connected Wise developed a machine-vision based communication technology that will support the autonomous navigation of space rovers on Mars' rough terrain. The system uses unique mapping identifiers that can be deployed as encrypted sign posts to assist with localization and mapping of these vehicles, eliminating the need for wireless signal transmission of mapping data. A conceptual description of the solution is shown in Figure 1.

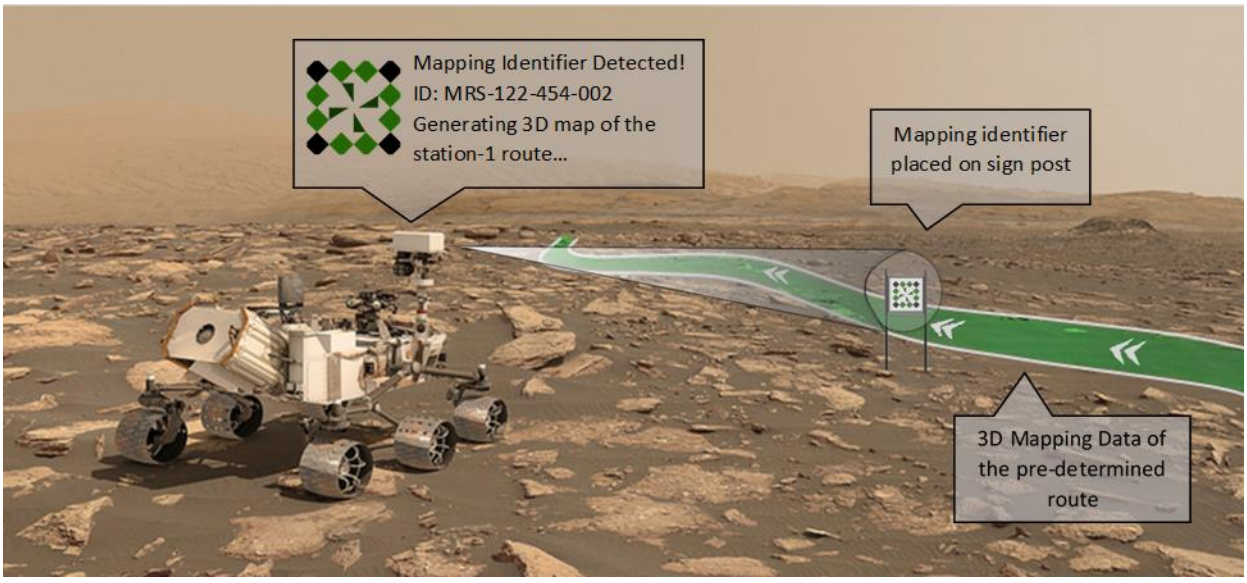


**Figure 1** The conceptual description of the solution for autonomous navigation of space rovers.

When the mapping identifier is recognized by the space rover's machine vision system, it calculates the relative position of the vehicle in reference to surveyed 3-dimensional mapping data. Furthermore, this position is calibrated until the identifier is not in sight of the camera, allowing for improved positioning accuracy. These mapping identifiers shown in Figure 2 enable the machine vision system to utilize robust image recognition. Hence, the system can operate under challenging circumstances created by extreme ambient conditions on Mars (e.g., camera over exposure due to solar radiation, low visibility during dust storms and occlusion of signs).

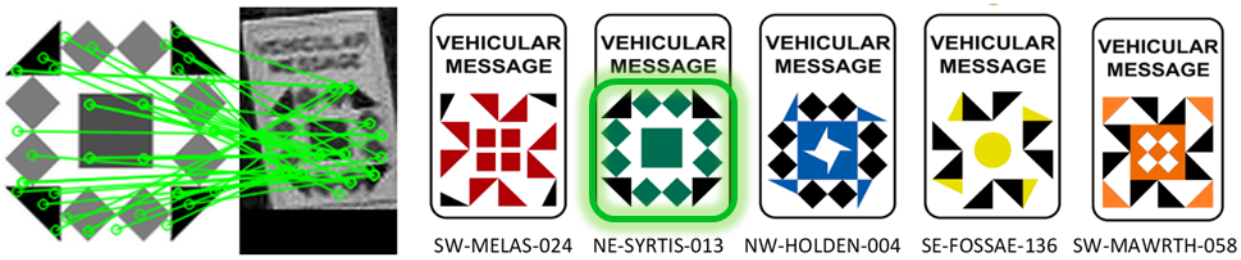


**Figure 2:** Robust matching of mapping identifier using image recognition.

The proposed system has superior advantages over using a matrix barcode system (e.g., QR code) as it performs image feature matching instead of simple message decoding. The barcode systems are designed to work effectively with laser scanners and possess innate challenges with camera-based applications, especially under the challenging conditions of Mars.

For this project, Connected Wise has established a strong team of engineering scientists, with diverse academic backgrounds essential for providing a robust and reliable technology solution. The key personnel, who will contribute to in the project, are shown below.

| **Key Personnel** | |
|---|---|
| Enes Karaaslan, PhD. | Principle Investigator, with expertise in artificial intelligence, deep learning, and autonomous vehicles. |
| Tolga Ercan, PhD. | Expert in intelligent transportation and connected automated vehicle systems. |
| Haluk Laman, PhD. | Expert in intelligent transportation systems, route optimization and simulation. |
| Mehrdad Agg, PhD. | Civil Engineering Scientist, with expertise in smart urban infrastructure resilience and safety. |
| Musa Ceylan, MSc. | Computer Scientist with expertise in deep learning research and autonomous vehicles. |
| Bernardin Dezius | Computer Scientist with expertise in computer vision systems and internet of things (IoT) devices. |
| **External Collaborators** | |
| Pei-Sung Lin, PhD. | Director of the Center for Urban Transportation Research (CUTR) at the University of South Florida (USF). |
| Xiaopeng Li, PhD. | Principle investigator in the connected and autonomous transportation systems lab at USF CUTR |
| Stephen Medeiros, PhD. | Professor and professional engineer, with expertise in remote sensing and geo-fencing technologies |