# Chapter 25
# Prototyping of Lunabotic Excavator Robotic System

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## ABSTRACT

*In this chapter, the design and prototyping of a lunar excavator robotic system is proposed. The lunabotic excavator was developed for participating in 2010 NASA Lunar Excavating Competition. Being remotely controlled by operator using a computer via Wi-Fi telecommunication, the autonomous lunabotic excavator can perform the tasks of excavating regolith stimulant, collecting it in the dumpster, and dumping it into the assigned collector box. The design and prototyping of the lunabotic excavator robotic system are discussed. The excavator includes multiple modules including mechanical frames, front/rear wheels, excavating conveyor, steering system, dumping system, power supply and distribution system, actuation system, switch control system, data acquisition system, and telecommunication system. The lunabotic excavator robotic system has been implemented. The excavator can perform the expected functions as designed. The lunabotic excavator designs in NASA Lunar Excavating Competition may lead to new and effective robotic excavators for planetary exploration. The design and prototyping strategies used in the lunabotic excavator may be extended to other ground wheeled vehicles or remotely-controlled robotic systems as well.*

## INTRODUCTION

Robotic systems have been widely used for aerospace applications for a long time. They have been proven to be very useful tools to help explore the outer space and extend the human presence in other planets. The outer space generally has harsh conditions, such as extremely high or low temperatures, high-energy radiations, different gravity levels, lack of oxygen and water, etc. These harsh conditions pose potential hazards for astronauts to perform the expected tasks in the outer space directly. As a result, robotic systems are widely used in aerospace exploration to expand the capacity of astronauts in space operation tasks, or to help explore the planets which are not suitable

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for human landing. Robotic systems can perform various jobs such as terrain exploration, planet soil sample collection, taking images/videos, maintaining/repairing satellites, etc. Robotic systems have accomplished many outer space missions, such as Apollo moon landing, Skylab, Mir, the Space Shuttle, and the International Space Station. For example, as described by NASA Lyndon B. Johnson Space Center (1973), NASA (National Aeronautics and Space Administration) has accomplished both unmanned and manned moon landing with its Apollo missions ever since 1960s. Various robotics systems have been used in the missions of moon landing. In 2003, NASA has started its Mars Exploration Rover (MER) mission to launch two robotic rovers, Spirit and Opportunity, to explore the terrain and geology in Mars. As described by Crisp et al. (2003), the rovers are six-wheeled, solar-powered robots equipped with navigation system and cameras. The robotic rovers have sent back high resolution panoramic images and other valuable information from Mars. Robotics has also been used in International Space Station (ISS). As a habitable artificial satellite, ISS travels around the Earth in low Earth orbit. It allows scientists to do experiments in various fields (e.g. biology, physics, astronomy) in a microgravity environment. As described by Stieber et al. (1997), robotic systems play a critical role in the on-orbit assembly, external maintenance and operations of the International Space Station.

With increased interest in the colonization of the Moon, NASA is planning to construct a lunar outpost, a permanent human-inhabited facility on the surface of the Moon between 2019 and 2024, as described in NASA Lunar Outpost (n.d.). The ambitious plan requires special tools and equipment adapted for the environment on the Moon, which may be very different from that on the Earth. Some easy tasks on the Earth such as digging or excavating may become serious challenges on the Moon, due to different physical properties of regolith, reduced gravity level, the absence of air and water on the Moon. In order to attract more students into the robotics field for aerospace applications, NASA wishes to extend their robotic research to the undergraduate students in US universities. Since 2010, NASA is conducting annual Lunabotic Mining Competition (n.d.) for students enrolled in US schools and universities. The goal of the competition is to promote interest among students in the robotics field, and attract more students to become aerospace robotic engineers. The competition also helps promote students' interest in space activities and STEM (Science, Technology, Engineering, and Mathematics) fields. The competition focuses on regolith excavation, which is the necessary first step towards moon resources mining and building human-habitable bases on the Moon. The unique physical/chemical properties of lunar regolith, reduced 1/6th gravity and vacuum environment make excavation much more challenging than on the Earth. The ideas and innovations developed in the competition may potentially benefit NASA in its future planetary exploration missions. In this chapter, we proposed our work on design and prototyping of "UB (University of Bridgeport) Excavator", a lunabotic excavator for participating in NASA's 2010 annual Lunabotic Mining Competition. Being remotely-controlled by operator via Wi-Fi telecommunication, the excavator can perform the tasks of digging regolith stimulant, collecting it in the dumpster, and dumping it into the collector box. The design and prototyping strategies used in the lunabotic excavator may be extended to other ground wheeled vehicles or similar robotic systems as well.

Some research works about the design and prototyping of robotic systems for planetary exploration have been reported. Muff et al. (2004) proposed a bucket wheel excavator which has the capability of continuous excavation for digging regolith on the Moon, Mars and Phobos. A small bucket wheel excavator with similar size as the rovers carried to Mars on the Mars Exploration Rover Mission was prototyped. One of the advantages of the bucket wheel excavator was that

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