GEOTECHNICAL PROPERTY TOOL ON NASA AMES K-10 ROVER. K. Zacny[1], J. Wilson[1], A. Ashley[1], C. Santoro[1], M. Sudano[1], S. Lee[2], L. Kobayashi[2], T. Fong[2], M. Deans[2]. [1]Honeybee Robotics Spacecraft Mechanism Corporation (zacny@honeybeerobotics.com), [2]NASA Ames Research Center.

Introduction: Geological examination of the near subsurface will increase understanding of the formation and history of a planet or moon and, by extension, the history of the solar system. Soil physical properties are used to help interpret surface geologic processes and to constrain the origins and formation processes of the soils. In addition, regolith geotechnical properties are extremely important to planning mining and construction activities on the Moon or even Mars. Lack of knowledge of Martian soil, for example, resulted in the Mars Exploration Rover Opportunity being stuck for nearly five weeks (Figure 1).

To enable future robotic geotechnical measurements, Honeybee Robotics designed and build a Percussive Dynamic Cone Penetrometer for NASA Ames' K-10 rover.

Percussive Dynamic Cone penetrometer

The penetrometer is a stand alone device that requires limited to no human intervention to operate. It consists of a percussive actuator and a rod with a sharp 60 degree cone at the end. The penetrometer is driven into the soil under constant load and the penetration, converted to California Bearing Ratio, gives an indication of soil trafficability. The CBR scale is from 1 to 100, with 1 being very soft and 100 being very hard soil.

The PDCP is essentially a battery-operated percussive actuator attached to a linear slide. A rod and cone, which interact with the soil, are attached to the output of the percussive actuator. The percussive actuator moves up and down the slide via a motorized chain drive, which is responsible for deploying the penetrometer rod and cone into the soil and removing it after a test is complete. The penetrometer maintains a constant "weight-on-bit" applied to the cone as it penetrates into the soil. Since the applied load is constant, the rate of penetration of the cone can vary depending on the properties of the soil. The rate of penetration is then converted into number of hammer blows (or energy expended) per soil layer, which in turn can be converted into a CBR value. The resulting data from a PDCP test is CBR versus depth at a given location.

The PDCP is capable of penetrating up to 15 cm into soil below the K10 rover wheel base plane. Typically, it takes less than 60 seconds to penetrate to 15 cm in hard soils with less than 10 lbs of WOB. The PDCP weighs approximately 32 lbs, which includes the rod and cone, percussive actuator, deployment system, mounting structure, electronics and cabling, and its own battery.

Over the past few decades a number of correlations between the California Bearing Ratio and other soil properties have been developed. These include Bearing Capacity, Dynamic Modulus, and Modulus of Subgrade Reaction.

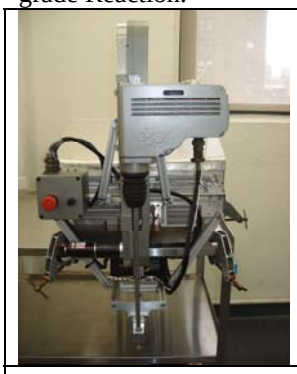

Figure 2. Percussive Dynamic Cone Penetrometer.

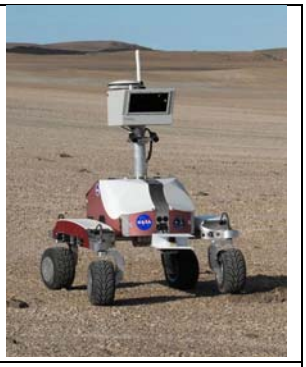

Figure 3. Nasa Ames K-10 rover.

K10 Mobile Platform

The K10 rovers are autonomous mobile robots designed to satisfy three

goals: (1) movement at human walking speeds; (2) low time-to-repair using commercial off-the-shelf parts wherever possible; and (3) the ability to operate in both high-friction indoor (concrete floors) and moderate natural outdoor (30 deg slope, hard-pack dirt) environments.

The NASA Ames Intelligent Robotics Group currently operates two K10's which are used for applications including human-robot interaction studies and multi-robot Lunar relevant site survey (resource mapping).

K10 has four-wheel drive and all-wheel steering with a passive rocker suspension, which allows it to traverse moderately rough natural terrain at speeds up to 90 cm/s. Hot-swappable Lithium-ion batteries provide the necessary power to run the drive system's motors and avionics. K10 weighs 80kg and can carry an additional 40kg payload. The current payload includes but is not limited to: an Optech LIDAR, stereo cameras, ground penetrating radar, a microscopic imager, HYDRA Neutron Spectrometer, Chemin, and a HoneyBee Penetrometer. The K10 rovers use NASA Coupled Layer Architecture for Robotic Autonomy software architecture running under a Linux operating system.