DEVELOPMENT OF AN OPEN SOURCE ROVER FOR PLANETARY SCIENCE. S. W. Hobbs[1], D.J. Paull[1], J. Haythorpe[2], and J. D.A. Clarke[2], [1]School of Physical, Environmental and Mathematical Sciences, University of New South Wales Canberra, Northcott Drive, Canberra, Australian Capital Territory 2600, Australia, [2]Mars Society Australia. P.O. Box 327, Clifton Hill, VIC 3068, Australia

Introduction: Although no rover smaller than Sojourner has ever landed on Mars [1], a 2 kg class vehicle would be cheaper to build and launch and still return useful science. Such a small vehicle would make it an ideal secondary payload with its own independent mission in a similar manner to Cubesat missions. We have built an A4-sized rover to test and characterise skid-steer mobility and of science data collection for a nanorover class vehicle in Mars analogue environments.

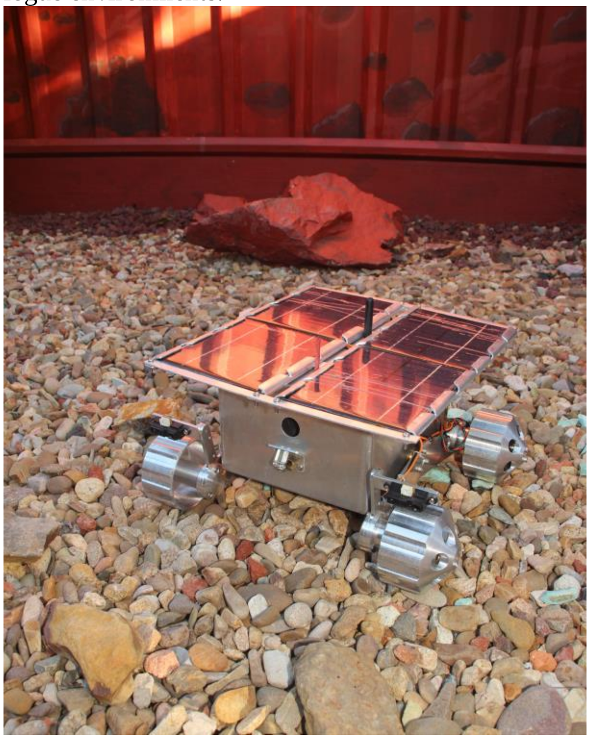

Figure 1. A4 sized nanorover undergoing mobility trials within a custom built Mars yard.

The current design of the A4 Rover, named "Crab", is shown in Fig. 1. Crab consists of a four wheeled rocker bogie chassis machined from aluminium. The rover is driven by four Maxon 16S GB 24 motors with GPX19A gearheads providing a turn rate of 45 RPM. We used open source electronics for our rover, including Raspberry Pi for imaging, and an Arduino Mega and Polulu VNH5019 motor controller [2]. The science payload of the Crab consists of a Raspberry Pi camera, a Melexis non-contact thermometer [3], a three axis accelerometer for infurring surface roughness, and a UVM-30A UVA/UVB sensor [4]. Power is supplied from three Sony Lithium-Ion cells providing a peak voltage of ~12 V. Four solar cells generating 10 Watts provide charging power for the rover. As our focus was on mobility testing we used direct teleoperation for control of our rover. We also recorded engineering data from the vehicle such as battery voltage, internal temperature and motor current draw.

In order to trial and characterize the rover's mobility we built a custom made Mars yard consisting of a variety of surface types (Fig. 1). We also used a custom made wooden ramp that could be positioned at angles ranging from zero to 20^o in 5^o incriments. We used trials on this high-grip surface as a "best case" scenario representing optimal, no-slip conditions [5]. Trials of a similar nature were performed on the Spirit and Opportunity rovers in order to understand peak loads and mobility impacts different surfaces would impart on the vehicle [6, 7, 8]. In this work we drove Crab up our custom made wooden ramp. The rover transmitted via wireless modem current draw 50 times per second, which we received and recorded on a remote laptop. We also measured voltage during the traverses, as well as time taken for each drive in order to calculate power consumption and rover speed respectively.

Figure 2. Crab nanorover, without the solar panels, undergoing slope trials within the Arkaroola Desert.

In addition to the ramp tests we conducted endurance trials on various terrains in the Arkaroola Desert, South Australia (Fig. 2). The solar panels had not been built at this time however we ballasted the vehicle in order to simulate the added weight of the panels.

Results: Our testing in the Arkaroola Desert indicated that the Crab is able to traverse a variety of Mars

analogue surfaces ranging from dune sand to loosely consolidated, pebbly material (Fig. 2). Range tests showed we could maintain control and telemetry reception to a distance of at least 50 m.

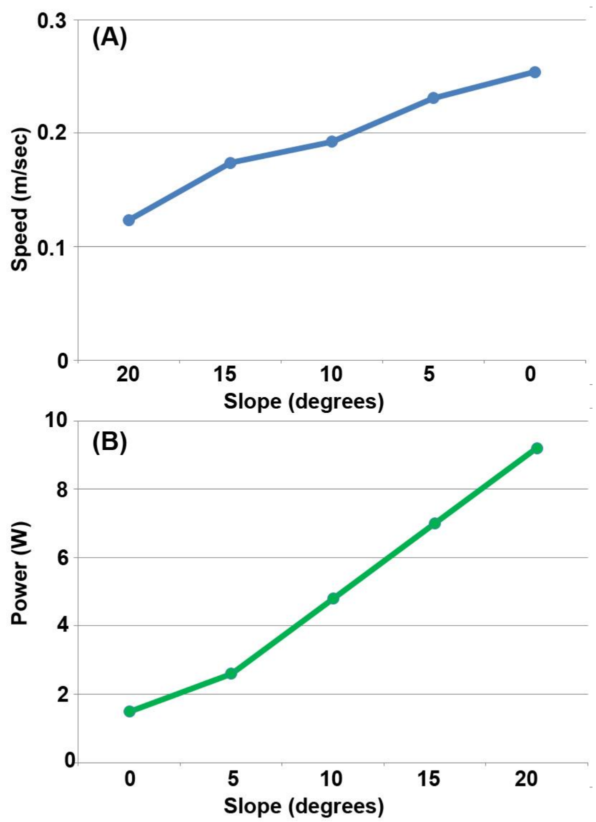

Figure 3. (A) Speed and (B) total motor power consumed by the rover during high stick ramp tests.

We noted chassis temperature remained stable (~2-4 degrees above ambient) during test drives with endurances of up to 20 minutes at a time. We found the suspension of the Crab experienced difficulties with fixed obstacles of 5 cm in height. The rover would frequently bottom out on these obstacles, causing it to rotate off track or be hung up.

Figure 3 shows the results of our high stick surface ramp tests. The speed of the Crab decreased from 0.25 m/sec with no slope to less than half this original speed of 0.12 m/sec at 20^o (Fig. 3A). Power consumption for the motors dramatically increased from 1.5 W to 9.2 W from nil to 20^o slopes. This increase was linear from 5–20^o and within the 10 W maximum power capacity of the solar panels.

We were also able to successfully obtain useful telemetry from three of the Crab's four science sensors. Our non-contact thermometer allowed us to sample regolith temperatures in order to assist us in determining thermal inertia of different surface types. The accellerometer and UV data were also successfully logged, which will be subject to future analysis.

Discussion: We developed and tested a nano-rover class vehicle, the Crab, in field conditions and controlled environments in order to gain metrics on rover speed and power draw. We found that the rover was able to negotiate slopes consisting of high stick and pebbly surfaces of up to 20^o. Range testing showed the Crab would be able to sample an area within at least a 50 m radius of a base station; this could possibly be extended with direct-to-orbit communications.

We did note limitations in the rover suspenseon with the vehicle becoming hung up on 5 cm obstacles. This is likely due to the rocker arm dihedral angle being too small. Although we could mitigate this by constraining the Crab to exploring smooth sites such as Meridiani Planum on Mars [9], we aim to repeat the mobility experiments using two sets of rockers with larger angles. These will provide the Crab with greater clearance while we conduct testing on the effect on stability the higher centre of gravity will have.

Conclusion: The A4 Rover project is designed to develop and field test a 2 kg nano-rover in Mars-like conditions in order to develop a space qualified vehicle for planetary science. The Crab was built in order to characterise the suspension design and return critical data on power generation and limits of the vehicle. We found that the Crab was able to negotiate rough terrain consisting of rocks up to 5 cm in size and traverse slopes up to 20^o on firm surfaces. We were also able to obtain useful engineering and science data from the vehicle which will be subject to ongoing analysis. Our work has generated key metrics that will be used to refine the design and electronics of the Crab, our machined rover, as we progress towards building a space ready vehicle.

References: [1] Hayati, S., et al. (1997) *IEEE Robots & Automation, 2458-2464*. [2] Polulu, (2016) *http://www.polulu.com/docs/0J49/all*. [3] Afafruit (2015) http://learn.adafruit.com/using-melexis-mlx90614-non-contact-sensors.com. [4] DFRobot (2016) http://www.dfrobot.com/wiki/index.php/UV_Sensor_(SKU:TOY0044). [5] Lindemann, R. (2005) *ASME Technical Conference*, CA. [6] Grotzinger, S J. (2012) *Space Sci. Rev.* 170. [7] Lindemann, R., et al. (1999) *33rd Aerospace Mechanisms Symposium*, NASA/CP-1999-209259. [8] Arvidson, R., et al. (2010) *Science* 305, 821-824. [9] Barlow (2008) *Cambridge*, NY, 264 pp.