Cratos: A Simple Low Power Excavation and Hauling System for Lunar Oxygen Production and General Excavation Tasks

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The development of a robust excavating and hauling system for lunar and planetary excavation is critical to the NASA mission to the Moon and Mars. Cratos was developed as a low center of gravity, small (.75m x .75m x 0.3m), low power tracked test vehicle. The vehicle was modified to excavate and haul because it demonstrated good performance capabilities in a laboratory and field testing. Tested on loose sand in the SLOPE facility, the vehicle was able to pick up, carry, and dump sand, allowing it to accomplish the standard requirements delivery of material to a lunar oxygen production site. Cratos can pick up and deliver raw material to a production plant, as well as deliver spent tailings to a disposal site. The vehicle can complete many other In-Situ Resource Utilization (ISRU) excavation chores and in conjunction with another vehicle or with additional attachments may be able to accomplish all needed ISRU tasks.

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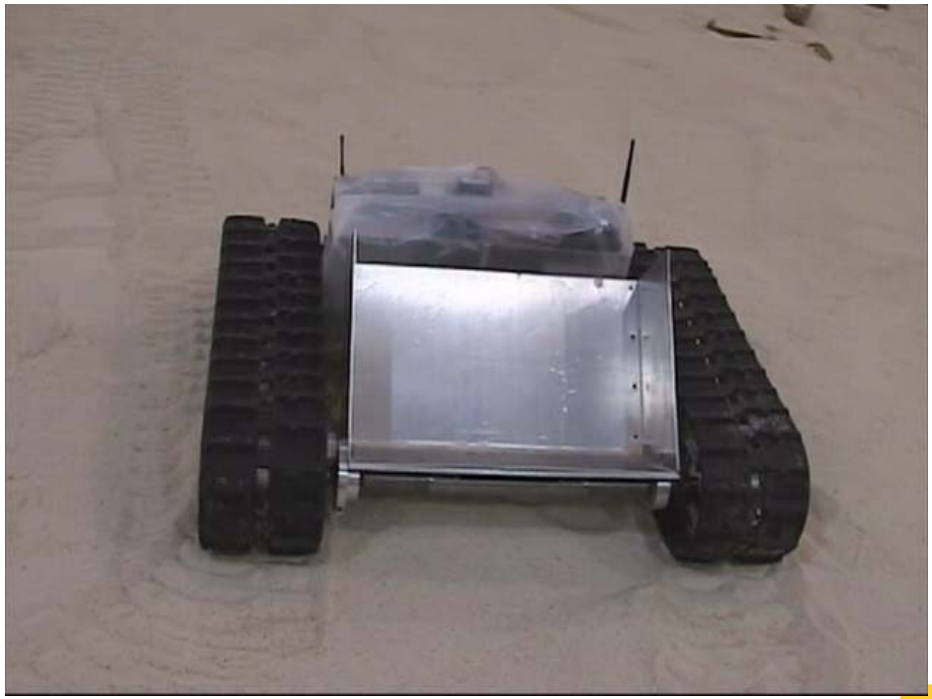
- Dimensions
  - Height of track 23cm (bottom surface to top surface with grouser profile ignored)
  - Idler diameter 19cm (and minor diameter of sprocket)
  - End to end length of track 79cm (grouser profile ignored)
  - Axel center to center 56.5cm
  - Width of vehicle 90cm (outside edge to outside edge on tracks)
  - Distance between inner edges of tracks 57cm
- Mass
  - Cratos weighs 175lbs
- Bucket volume
  - Length = 33cm width =50.8cm Depth = 16.8cm
- Power supply
  - Twin 12v, 18Ahr Sealed Lead Acid
  - 4 to 6 hrs operation @ 2A continuous
  - 3 hrs operation @ 4A continuous
- Drive Motor horsepower
  - Operate at 2A @n 24v
- Bucket motor power
  - Operate at 1.6A @ 24v
- Housekeeping power
  - Operate at 0.08A @ 24v



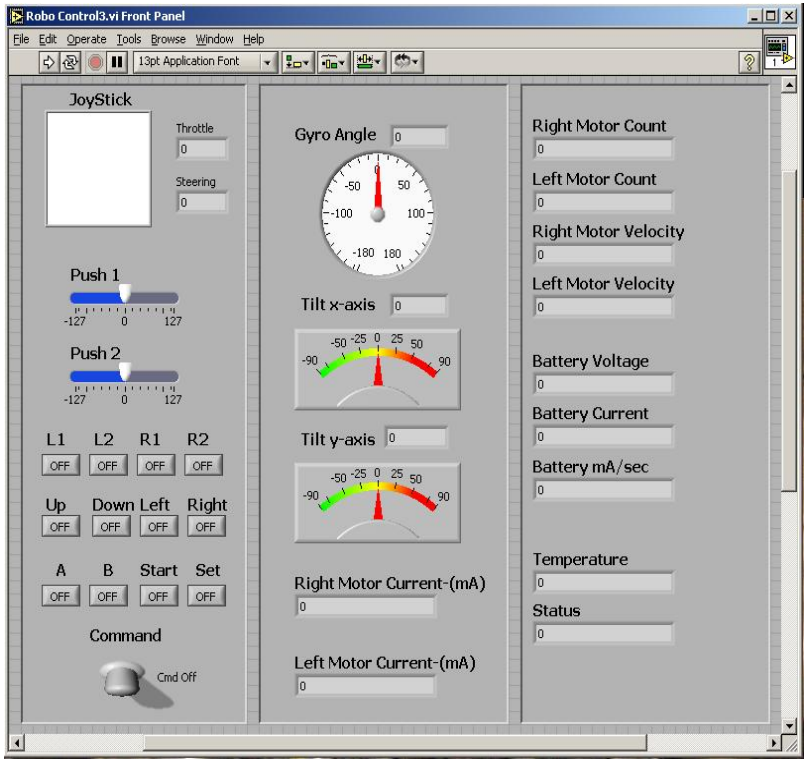
Robotic Controller

A robotic controller was designed and built to expedite the design cycle of varied robotic platforms requiring telecommunication, sensor fusion and moderate computation capability.

Features

- Dual 25 MIPS 8051 core processors
- 16 multipurpose (analog, digital, counter, interrupt, frequency generator, PWM) I/O channels
- 16 servo channels, 8 relay output channels
- Configurable radio network
- External RS232 serial port
- Battery fuel gauge and voltage monitor
- JTAG interface
- C source code

Controller User Interfaces



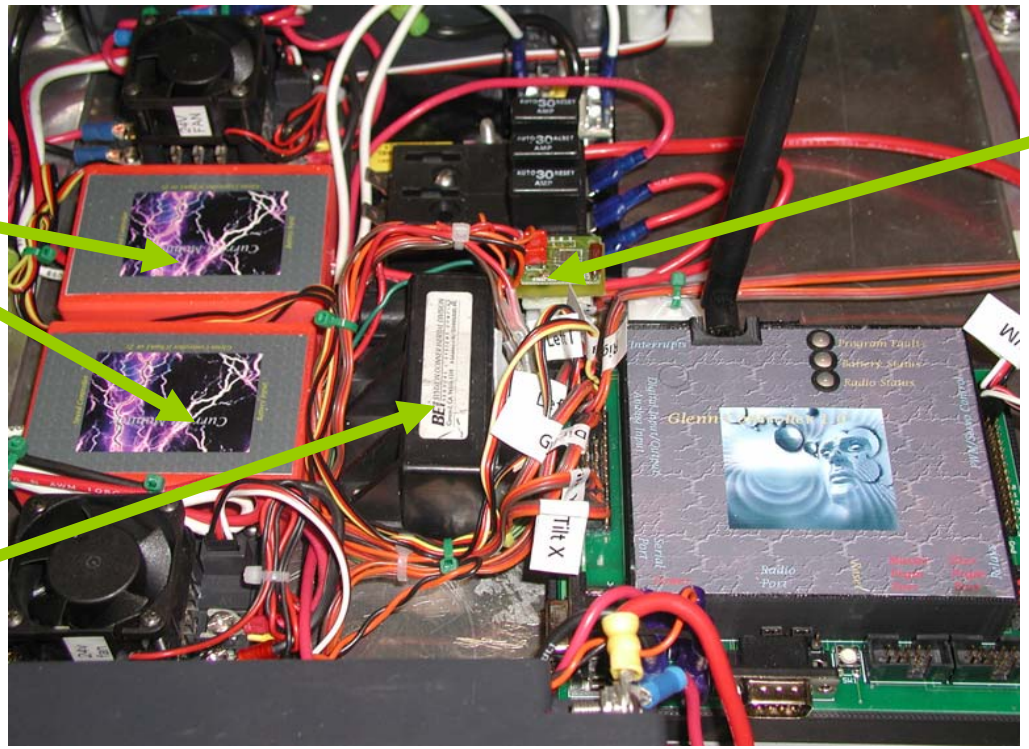
Telecommunication through the radio link is achieved by one of two user interface methods.

- A Labview control interface allows two-way transfer of data. Consequently, sensor, motor and battery parameters can be monitored and recorded while commands are simultaneously transmitted to the controller.
- A modified PlayStation hand held control provides the convenience of mobility.

Sensors onboard Cratos

Motor Current Sensors

Solid-state gyro



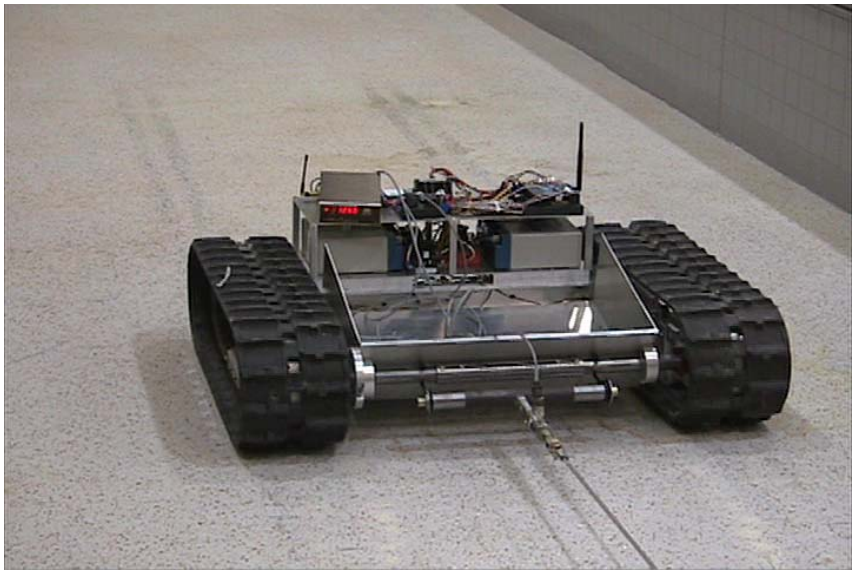
Accelerometer for x & y tilt

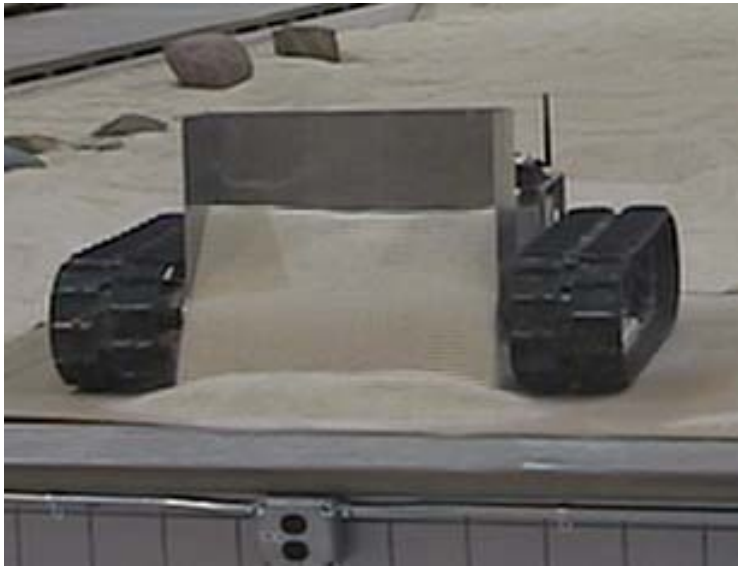
Wheel encoders with quadrature outputs (not pictured)

A variety of sensors can be interrogated using the controller. The flexibility of the I/O lines allows for 10-bit analog signal conversion, digital input/output, external interrupts, edge and level triggered counters, variable frequency square-wave signal generation and PWM output.

Cratos Tests

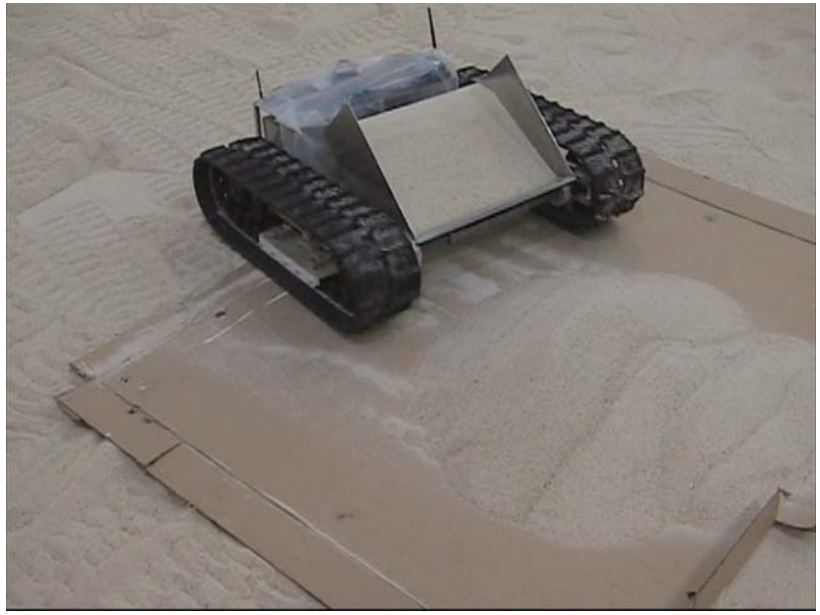
- Drawbar pull
  - On panted concrete in W2
    - Empty, F= 102lbs
    - Additional 150lbs, F=202lbs
  - In SLOPE sand simulant
    - Empty, F= 120lbs
    - Additional 150lbs, F= 170lbs
- Bucket typical load
  - Mass of load ~50lbs (No a full bucket)
- Seven bucket test
- Side slope test
- Trenching/berming test
- Ramp building

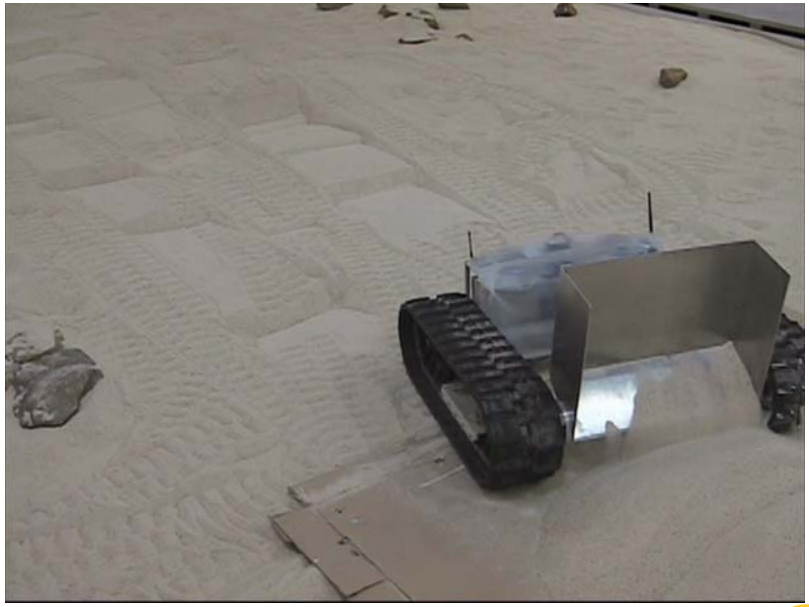




Some example cases for Cratos

- 1 MT O2 Production using Carbothermal
  - Kg regolith per day total 36.8 kg
  - Deliveries per day per vehicle 3
  - Load per delivery 23 kg
- 10 MT O2 Production using Carbothermal
  - Kg regolith per day total 351 kg
  - Deliveries per day per vehicle 16
  - Load per delivery 23 kg
- 1 MT O2 Production using Hydrogen Reduction
  - Kg regolith per day total 415 kg
  - Deliveries per day per vehicle 18
  - Load per delivery 23 kg





Conclusions and Future work

Conclusions

- Cratos scale vehicles can deliver the quantities of regolith required to support significant oxygen production
- Cratos can dig trenches and berm
- Cratos can build a ramp

Future work

- Automate the system Cratos should be more automated
- Develop dumping mechanism to dump back and down
- Concentrate on compacted regolith excavation