EXPANDING THE CONCEPT OF THE CLIFF CLIMBER ROBOT. K. M. Nebergall, 3137 St Michel Lane, St Charles, IL, 60175, knebergall@gmail.com

Introduction: Challenge Area (16) includes the following: "Low-cost or improved performance in Mars surface mobility, e.g., long-range/fast-rate mobility for lighter rover systems to increase range/radius of mobility for smaller systems, access at or beyond the angle of repose (near vertical or cliff- or crater-wall access, low ground-pressure systems on unconsolidated material), long-range navigation of rovers on the surface of Mars, localization, autonomous, and relative (to/from hub) surface navigation."

The robot proposed in this abstract is an advanced variation on the two-wheeled rappelling cliff-climber that has been the subject of past development. Building on that effort, this variation of the design can swing and twist on its own ropes, traverse laterally left and right across the cliff face, take strike or chip samples, run across the canyon or skylight cave floor, and otherwise dramatically expand mobility to expand scientific investigation while reducing the chance of getting stuck.

Overall Design: Superficially, the cliff-climber design is typical of those experimented with so far. It uses two cables to the cliff edge for lateral stability. It uses two oversized wheels, one on each side, with an instrument platform and motors in the center. It then adds the capabilities listed below.

Steering and Traverse: The wheels may be angled from vertical to horizontal to permit the robot to traverse the cliff laterally rather than simply vertically. This dramatically expands the range of samples and examinations that can be done from the platform in a given traverse down the cliff face. It may also allow the robot to circumnavigate obstacles or hazards.

Swinging and Twisting Capability: The cliff-climber design has the ability to swing or rock on its cables. This gives it the ability to swing in and out of a cavity in the cliff face, or free a cable snared at some level between the climber and the rover. If the climber cables become flipped along the traverse, the climber can also rotate on its center vertical axis to flip back to the correct orientation.

This would also give it the option to "walk" the cables by flipping one side inward and the other outward, then reversing the action. This would be very useful if a cable became snared. A walk could be combined with a wheeled traverse to change the cable position on the cliff face.

There are two mechanical options to give these capabilities, discussed below.

Option 1: Imbalanced Wheels: While nearly every wheel used in locomotion is designed to be as balanced as possible, that is less of a factor with wheels that will be used along a cliff face at low speed. Weights on each wheel would be quickly flipped from the cliff face side to the position 180 degrees away and back again. An accelerometer would determine when a maximum swing is reached and flip the wheels back again. Like a person pumping their legs on a swing-set, this would build or dampen the swing as needed.

Option 2: Extended Wheel Platform: The same functionality as the imbalanced wheel could be designed in with wheels on offset arms similar to the front wheels on the MER, except with the arms themselves used to swing the climber. This would allow variable clearance, and greater clearance if roving the base of the canyon or cave. It would also simplify more risky transitions from horizontal to vertical at the cliff edge. This would add to the safety of the rover by allowing it to park further from the cliff edge. The trade-off is greater mechanical complexity. The offset wheels have no mechanical component to fail, whereas a failure on the part of an offset suspension would dramatically limit mobility.

Thinner Cables and Sleeves: A key dilemma with designing a cliff-climber is the thickness of the cables. If the cables are too thick, the climber may not travel very far, because the cable thickness rather than length will fill the spools. If the cables are too thin, the vehicle risks the lines cutting into the softer parts of the cliff wall or crags and getting caught. The climber design must balance these conflicting demands.

The thinner the cables, the less of a liability it becomes to load the cables on the climber rather than the rover left at the top of the cliff. If the cables are deployed by the climber the cables remain in a relatively fixed position once deployed relative to the cliff face. This dramatically reduces wear on the cables. If the cables are fed by the rover at the top, the cable must scrape the entire cliff face both up and down, increasing the chance of a cut, snag, or tangled line.

To deal with zones where the probe anticipates a sharp edge or slipped line, it may keep several "sleeves" along the cable at the climber side. If an issue is anticipated, the climber may clip a sleeve or a brace on the line before continuing. This would remain locked in place until the ascent, where it would be recovered.

Context Camera/Tail: A context camera and skid or tail wheel would be extended behind the climber and away from the cliff face. This would be rotatable and contain a single small imager with a lens filter divided into strips. Rather than ten filters over a digital camera as on MER, the context camera would have a single filter with ten vertical bands across it. The camera would rotate in increments that would correspond to the width of one of these vertical strips at the minimum distance to the camera. It would be rotatable 360 degrees. This would give imagery in all ten bands to the left, right, and immediately above and below the climber to determine if an interesting sample is within reach of a lateral traverse. It would also provide color imagery of the valley or opposite ravine wall as the descent took place. By keeping the filters and camera as a single unit, the weight, volume, and mechanical complexity is minimized. Also, the climber may aim the tail up and down to give different contexts to these images up or down the cliff face. The tail would allow a counterbalance to the front wheels should the climber reach the bottom of the cliff and attempt short traverses. This context camera would allow navigation in this configuration.

Sampling Capability: For a mission where rock samples from the cliff face are desired, a small flat chisel-like device would be vibrated against the cliff face, with a scoop device mounted directly below it to catch the samples. The chisel may have a window to determine if the sample scoop is sufficiently loaded. The two elements would be clamped together to retain the sample. These elements may be placed like cartridges in a sampling arm. The cutting edge may be part of the arm or the sampler. With the ability of the climber itself to traverse, ascend and descend, swing, and pitch, the arm need only extend, open, sample, close, and swap cartridges. A simple arm allows it to be scaled down in both size and power demands.

Given the ability of the climber to swing into clefts, a second sampler with a ballistic capacity may also be used. This would essentially grab a small core when it came in contact with the cliff face after being swung in. The sampler would extend on a small shaft. Upon detecting contact with the cliff face, a small explosive or spring would drive the sampler into the cliff to gather a sample. It would then be retracted for encapsulation. A back-off plate would dislodge the climber should the sampler become stuck.

Space for Additional Instrumentation: By keeping the core functions of the climber as light and versatile as possible, additional instrumentation packages can be added if appropriate. The question of a hand-lens imager or similar device is left open, along with electrical and thermal conductivity probes, chemical analysis equipment, and so on. This gives the maximum number of science instrument opportunities in the smallest frame possible. A simplified version of this design could be as small as a large coffee cup.

Anchor Option: Depending on the mission, it may be judged appropriate to include an anchor point between the climber and the rover. This would decrease the chance that a slip on the part of either the climber or the rover would cause mission failure or risk. This stabilizer would be a lateral bar with a series of driven spikes along the bottom. This would grab the cliff face. Two loops above that bar would loop the cable one or more times to smooth the action of the descent. The other advantage to this device is that it would allow the rover and the climber to both have a fixed stress point and angle.

Since the anchor would be designed to block movement in a single axis, it could be easily freed from this position and re-used when the descent and ascent were completed. The spikes would lock in at a 45 degree angle, allowing it to simply be pulled out by the rover when the climb was completed.

Rather than being placed at a distance, the anchor bar could be a mechanical drop-bar off the end of the rover. It could simply lower it to the surface and push it into the softer material. Then when the cliff climber is recovered, drive away and raise the platform. The bar and lock could be part of the climber deployment and berthing platform itself.

Using the Cliff Climber to Escape Rover Sand Traps: One problem with the MER rovers was getting stuck in “rover traps” – which is to say thin crusts of hard soil with very soft sand underneath. This hazard trapped both rovers on multiple occasions and cost several months of scientific work. A cliff-climber still attached to the rover could theoretically be used to get away from the sand trap and find traction. It could then assist in pulling the main rover out of the pit.

Alternatively, an issue with a vehicle getting stuck is that the wheels are not only slipping but are trying to climb out of a very steep pit of their own making. A cliff climber could effectively butt against the front of the rover’s wheels and counter-rotate one wheel to dig out the slope. If the anchor bar is mechanically part of the rover, it could use that to push itself out of such hazards.

Prototype Construction: Most if not all elements of this design could be prototyped with a 3D printer, R/C car parts, and hobbyist microprocessors and sensors.