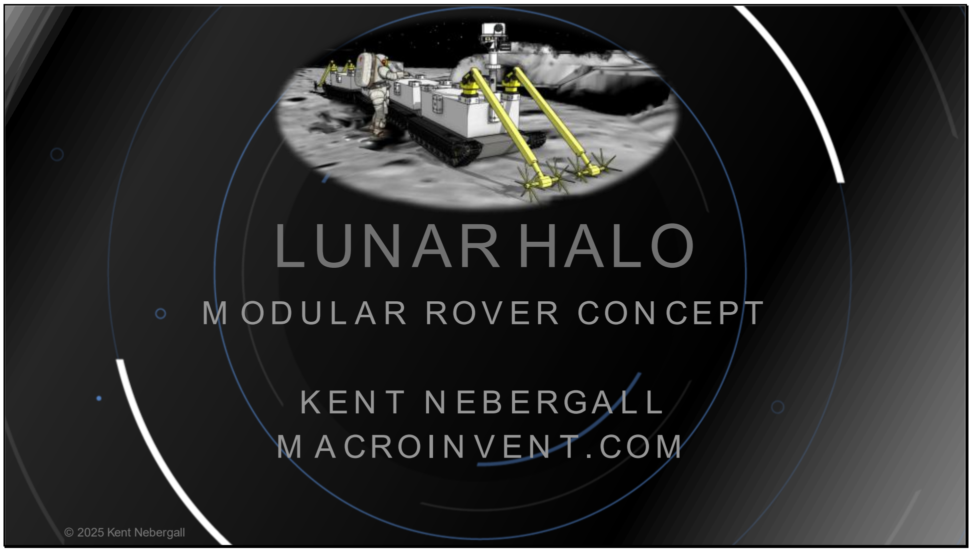
Slide 1



Hi everyone.
This is a rover concept I invented to help astronauts at the Lunar South Pole, which can be adapted to Mars.

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ABSTRACT

Modular Rover Technology for Human Outposts

In late 2024, I won a $20K NASA prize for designing a rover that could do science and light industrial work in the moon's permanently shadowed craters. The rover design draws from over 100 years of polar exploration engineering and Mars rover situations. I created a modular solution that could work in nearly any unknown terrain, while being field-maintained by astronauts. The result was called Lunar Halo.

While designed for the moon, this rover concept is ideal for crossing the Martian dust fields that trapped the Spirit rover, climbing the steep slopes that caused Perseverance to backslide, and exploring in lava tubes with poor lines of communication. It can do both exploration and light industrial hauling within and beyond human outposts. It's essentially the sure-footed burro to accompany the pressure-suited prospectors of the new frontier. The rovers are small enough to fit through a human airlock for maintenance but can be locked together into crawler platforms for transporting larger equipment.

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In late 2024, NASA ran a pair of competitions called Find Me on the Moon. The first was a low-tech navigation aid for the astronauts at the lunar poles that didn't require electricity. The other was to design a machine to bring samples back from the bottom of Shackelton Crater at the lunar South Pole.

I entered both competitions and to make a long story short I got honorable mention in the navigation one and grand prize in the polar exploration one. So, $250 for my massive two-month navigation design and twenty grand for a month of thoughts on polar rover design.

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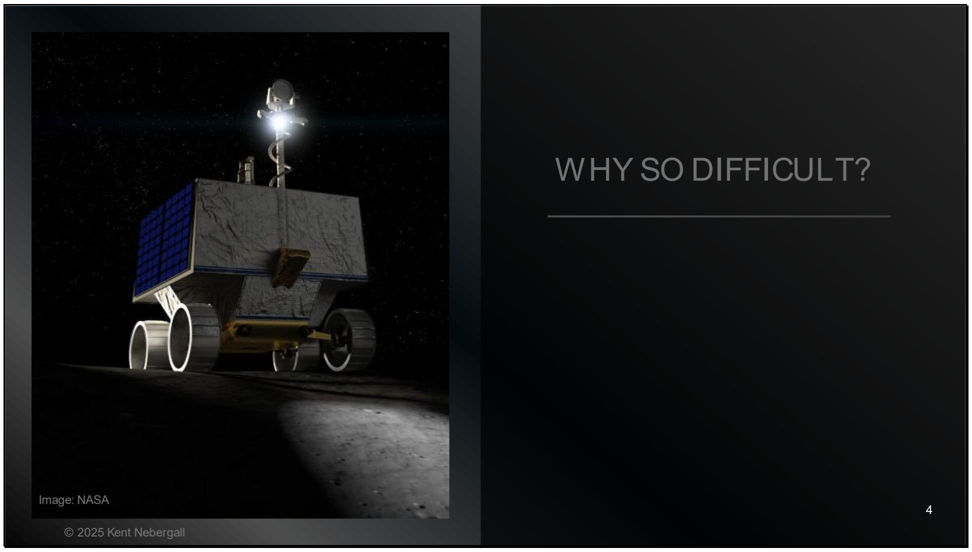

NASA had a private contractor build Viper to explore this crater, which went overbudget, got cancelled last year, then got reinstated and will fly in two years. But take a close look at that suspension before we continue.   It's actually a bit better than it looks. The wheels have treads a bit like a paddle wheel boat and it can theoretically slide on its belly if it bottoms out, or raise the suspension.

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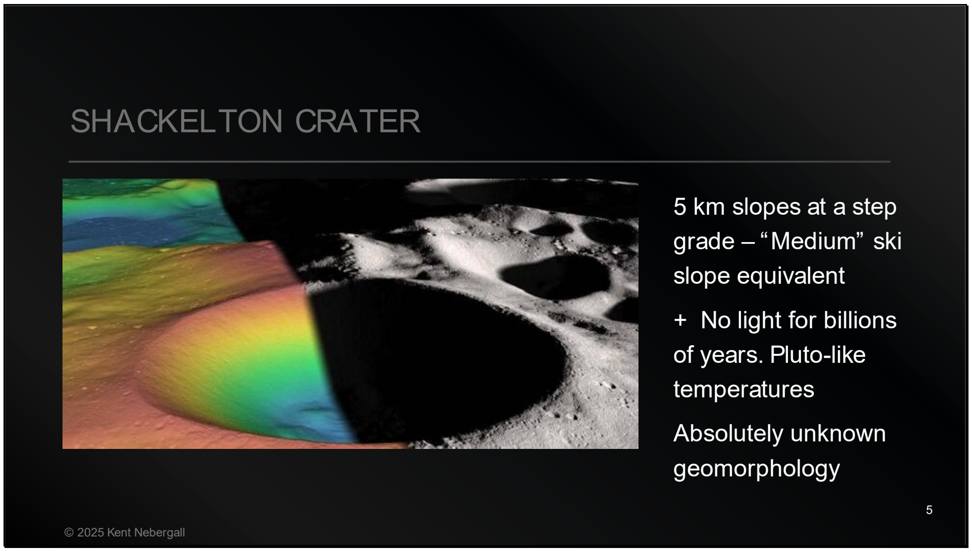

First off – here is the slope a rover has to go down. At an average of 25 degree incline, it’s the equivalent to a medium difficulty Ski run. Low gravity will make traction into the surface far less effective.
There hasn’t been light or heat much above the temperature of Pluto in billions of years. So the geomorphology and surface properties are unknown.

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Secondly, even baked-out lunar regolith is a lot like snow in that it's fluffy and slick until it's compressed. It's nasty on joints with metallic, glass, and oxidized mineral grit to chew up any seals and joints on your vehicle. Note that material properties tend to change in near-cryogenic conditions. It's barely cold enough for high temperate superconductors to work, but even modest waste heat from a vehicle will quench that out.

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So that's a lot of options. But we don't carry them all at once.   The rovers would be sent to the moon with sets of accessory kits.

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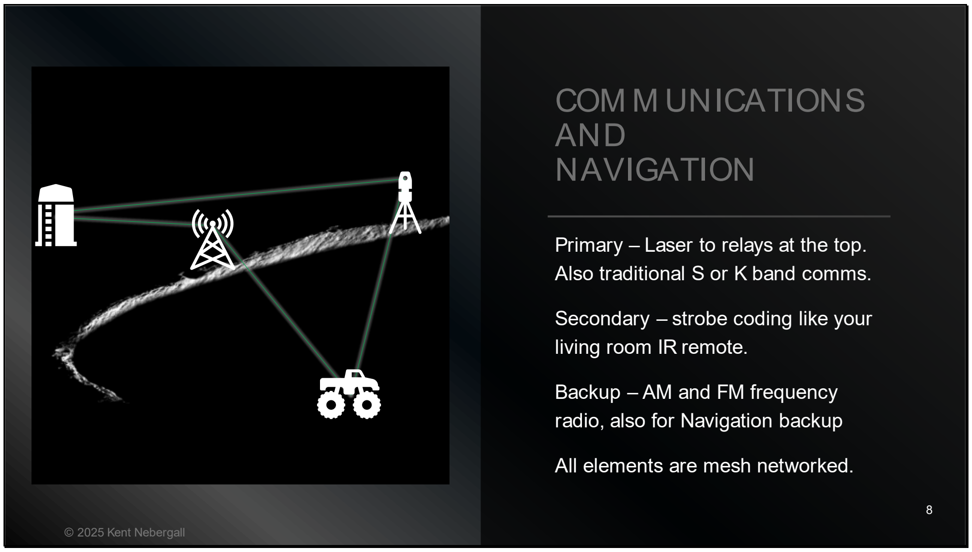

Several relays on the rim of the crater could beam and receive data and also be navigation beacons for the rovers.

The advantage of a dark zone is that you could send short data bursts over long distances with a simple encoded strobe light. You wouldn't even have to see the rover – you'd just have to have the rover and the relay from the rim of the crater see the same ground around the rover. Direct lasers can send high speed data. For backup, AM and FM frequencies can be used for basic navigation, like aircraft on Earth with ADF and VOR systems. The use of two different longer frequencies would minimize radio shadows. And all these elements would be mesh networked across several devices.

From a Mars perspective, we are using something similar at MDRS to send data live to crews at any distance from the Hab. This can also be adapted to lava tubes on either the moon or Mars.

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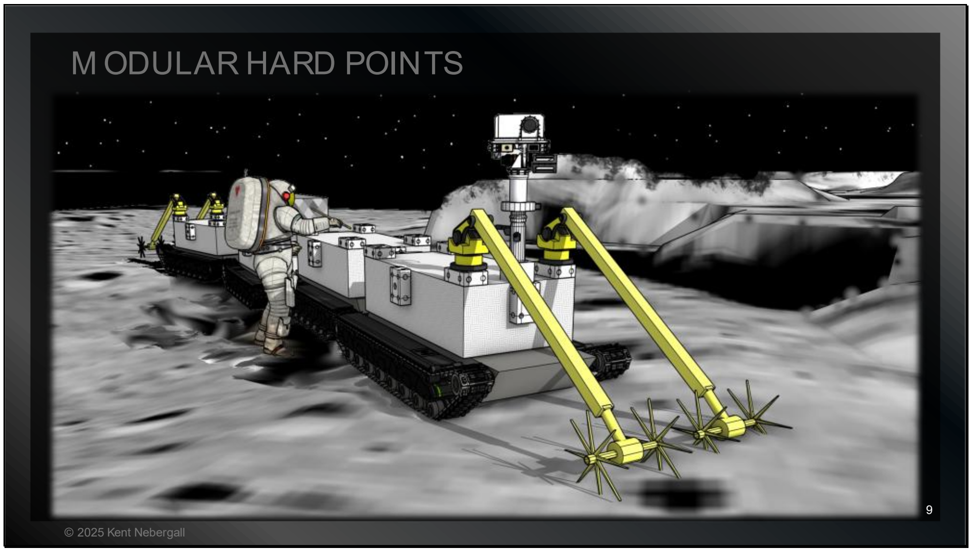

The rover has modular hard points to mount these accessories when needed. Picture a lunar base with several rovers and a set of tool kits that let the crew attach roll cages, outriggers, or other equipment, depending on the mission. The same hard points can carry cargo, battery packs, mining gear, experiments, and so on. They could even carry crew a bit like a small ATV.

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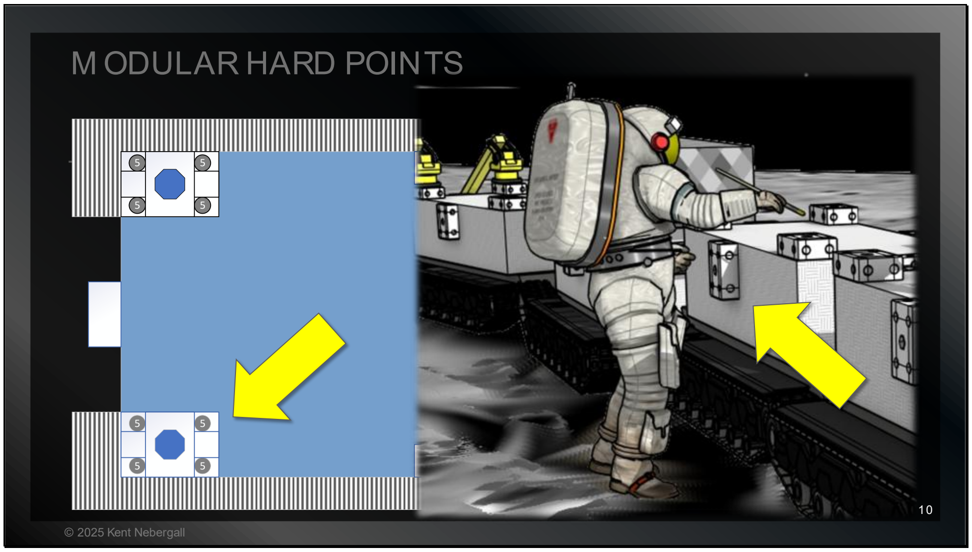

The hard points can transfer loads, but also data and power. They are a bit like the hard points on the outside of the ISS that let the Canadarm 2 move from point to point like an inchworm to access different parts of the station structure. They are strong enough to link the cars in the land train or mount small bulldozer blades and other light construction equipment.

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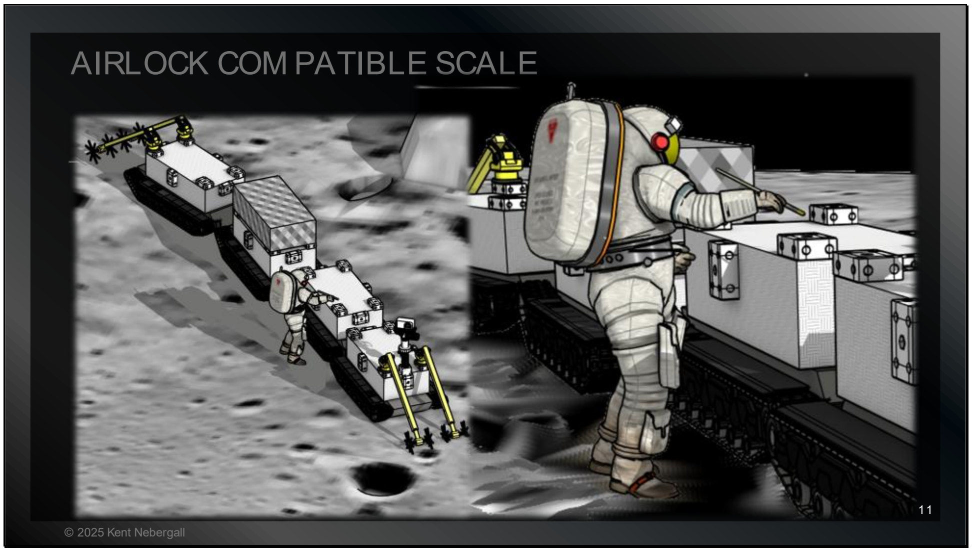

The rovers are also small enough that they could be carried through an airlock designed for humans. They are basically the size of a small desk. This allows them to be brought into a shirtsleeve environment for deeper maintenance work.

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For the record, THIS is what we use on earth for steep ski slopes. And that's in Earth gravity. So what have we learned in 100 years of polar exploration using motorized vehicles?

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Here was our first big failure. This is the 1937 Antarctic Snow Cruiser. It was designed to cross Antarctica while carrying a small biplane on it's back to allow the crew to map the terrain ahead of and around it photographically and plan routes through the unknown. It was designed based on data from an earlier expedition that said the snow could withstand a certain level of vehicle weight. So they built it to be half that weight load.
Unfortunately, the math that said that tires need a much higher load wouldn't exist for another fifteen years. It was actually ten times the weight allowed. It made it three miles before becoming a stationary control tower for the aircraft.

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In the 1960s, R. G. LeTourneau was working on a solution for pulling logs out of swamps and invented the land train. These were later used to build the distant early warning radars in Alaska, Canada, and Greenland. They spread the load out over dozens of electrically driven wheels powered by a central generator.

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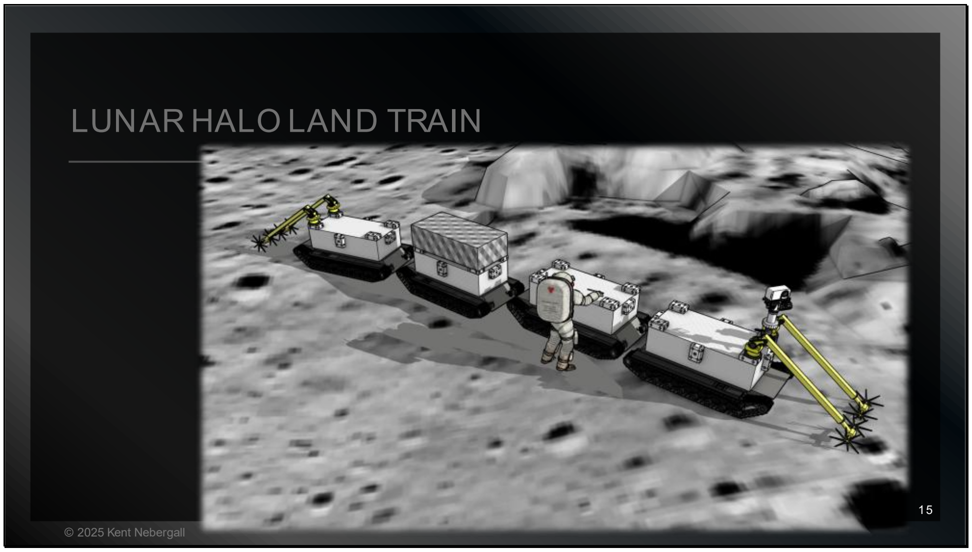

So my design is also a land train. Except with caterpillar tracks to manage the load even more broadly on completely unknown terrain.
But even that might not be enough, or not enough all the time.

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We want contingency systems to keep from tumbling down-slope. An average slope of 25 degrees over a five kilometer course means that some spots will be even more difficult than that. And remember, you have to get back out again.

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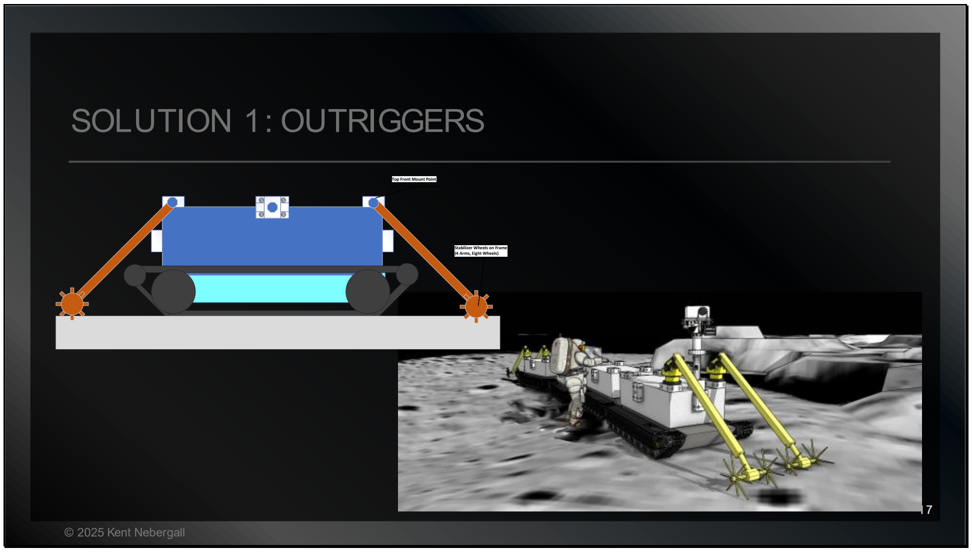

So the first solution was outriggers, a bit like a sea kayak. Note the pins on the wheels. These are designed to give exactly the same weight load as the rover itself, so if the pins sink into dust, the rover will too. This prevents a situation like the "rover traps" that eventually took out the Spirit rover on Mars. The terrain was stable until the full weight of the rover was on it, then it fell through a crust into a soft talc-like dust that was very difficult to escape. The outriggers would be tied to an AI vestibular system to reach and grab the ground if needed. The pins would also measure any tiny lateral force indicating a slide.

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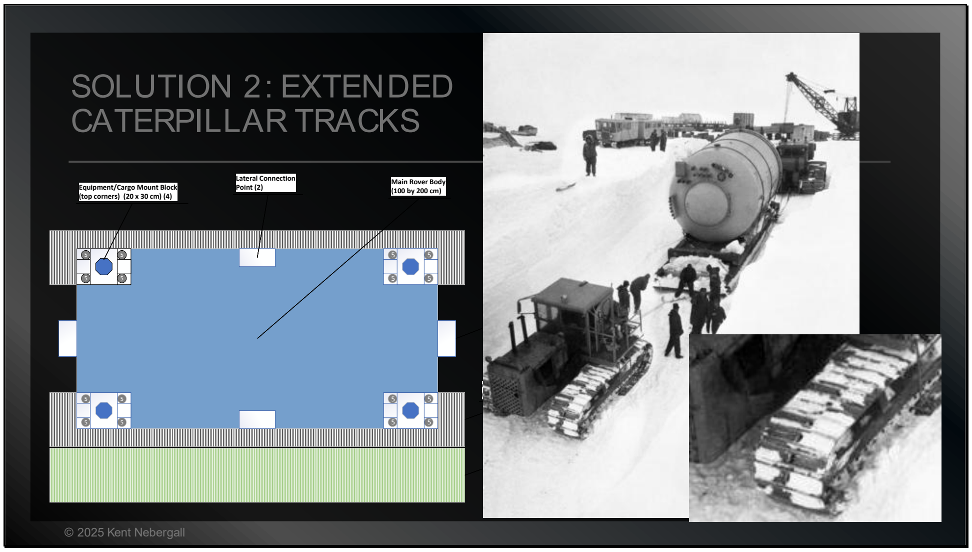

Also note this is a human-tended rover, so we can add new components in the field. The diagram is a top-view of the rover with the green part showing a bolted-on set of extensions to each tread of the caterpillar tracks. This was based on a similar issue when the Thule air base in Greenland sent an expedition to the polar cap, and couldn't climb the mountains even with conventional tracked vehicles. So they went back to base, welded on extensions, and it worked from then on.

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Another possible option would be to feed out a cable behind the rover. The reel for the cable would be on the rim of the crater and added to as it was used up along the way. This could be put on stands like a ski lift and used to stabilize vehicles on ascent and descent. The last car of the land train could include a take-up real to keep the slack in the system minimized.

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As a last resort, we may include the equivalent to a snow anchor that could be dropped as a contingency into the dust and hope it snags on a rock. We could intentionally plant them ahead of steeper drops and repel of them with that cable system I mentioned, provided we can set up a special trailer that can install poles to keep the cable off the ground and put the cable back into the slats after the rover passes. A bit like a cable car mechanism, but with a release and connect system.

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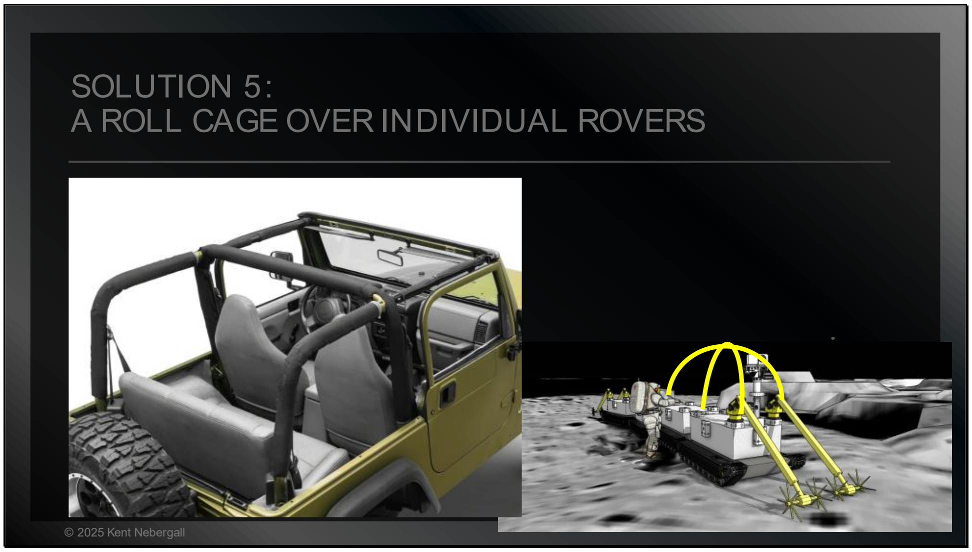

Of course, everything could fail. The name Lunar Halo was coined because the original concept involved a high roll cage in case it tumbled down slope that would ensure it would try to land on it's treads once it came to a rest. A bit like the Weeble toys toddlers play with. The roll cage also is a great place to mount lights, cameras, and communication gear.

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So what does this mean for Mars exploration?

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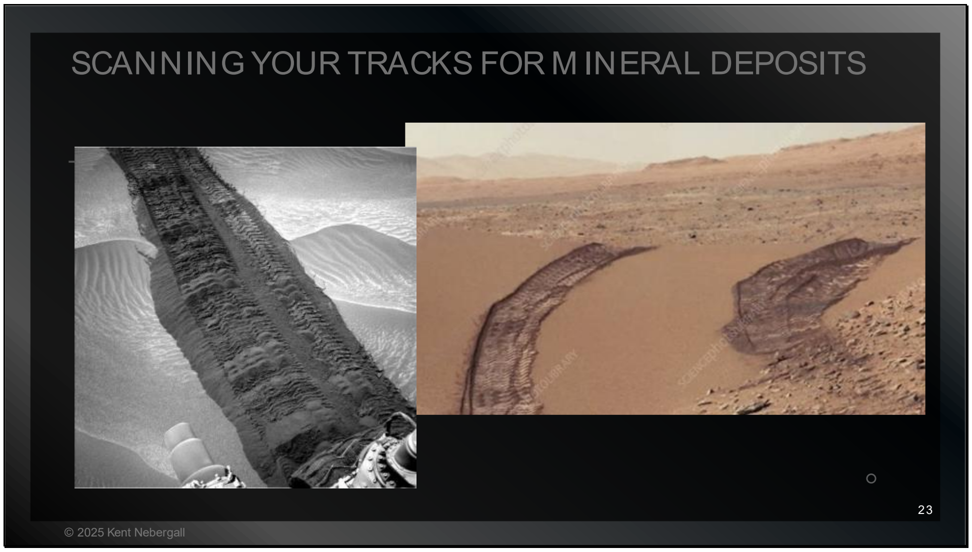

Another trick the system uses is inspired by the Mars rovers. A camera system scans the tracks behind the rover with AI. This looks for any exposed minerals automatically, as well as ground compression by the tracks to determine the load capacity of the surface at any location where the rover has been. This becomes part of a science data pool on the geology around the outpost.

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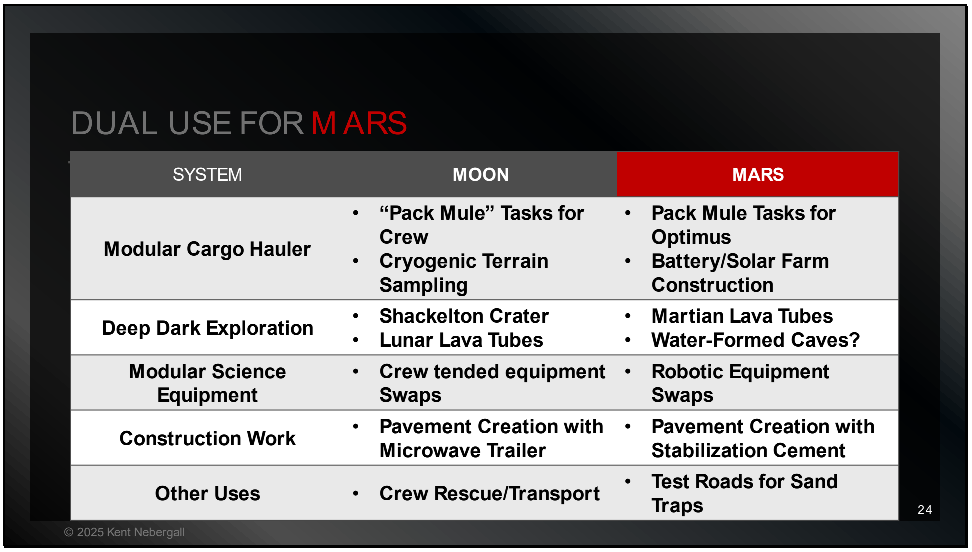

So what does that have to do with Mars? Well, it can be a good pack mule for carrying burdens for both humans an Optimus style robots when setting up solar arrays and other equipment. With the mesh network systems, we could also use them to explore lava tubes on both the moon and Mars. We could also use them for construction in both locations, and test long traverse routes for sand traps and so on prior to committing larger vehicles.

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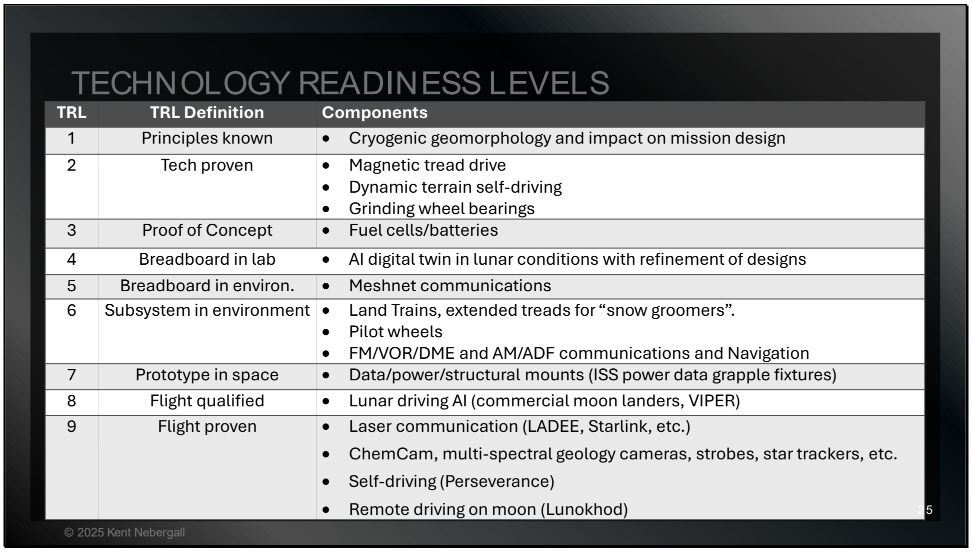

TRL	TRL Definition	Components
1	Principles known	• Cryogenic geomorphology and impact on mission design
2	Tech proven	• Magnetic tread drive • Dynamic terrain self-driving • Grinding wheel bearings
3	Proof of Concept	• Fuel cells/batteries
4	Breadboard in lab	• AI digital twin in lunar conditions with refinement of designs
5	Breadboard in environ.	• Meshnet communications
6	Subsystem in environment	• Land Trains, extended treads for "snow groomers". • Pilot wheels • FM/VOR/DME and AM/ADF communications and Navigation
7	Prototype in space	• Data/power/structural mounts (ISS power data grapple fixtures)
8	Flight qualified	• Lunar driving AI (commercial moon landers, VIPER)
9	Flight proven	• Laser communication (LADEE, Starlink, etc.) • ChemCam, multi-spectral geology cameras, strobes, star trackers, etc. • Self-driving (Perseverance) • Remote driving on moon (Lunokhod)

Most of this is based on existing technology, though a few bits about how a vehicle will interact with the permanently frozen surface are complete unknowns. So I hope Viper can lower that threshold and succeed. Many of these systems are based on existing hardware already flown to the moon and Mars.

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Thank you! Any questions?

