# Unmanned Ground Vehicles - Design Considerations for Snow and Cold Environments

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It's that time of year when the white stuff falls from the sky across the US, and with it comes lower temperatures. These conditions must be taken into consideration when designing a vehicle for outdoor use.

A few definitions from wikipedia:

Flurry: light, brief snowfall

Snow shower: intermittent snowfall

Light snow: over 1km visibility

Moderate snow: 0.5 to 1km visibility

Heavy snow: less than 0.5km visibility

Blizzard: lasts 3 hours or longer, sustained wind to 35mph, visibility under 0.4

Snow water equivalent: depth of a layer of water that would accumulate in an area, if all the snow and ice were melted in that area

Snow hardness: expressed as a force of resistance to penetration, measured with snow penetrometers (Pytka)

Snow is a 3 phase medium (ice, water, air) and forms a deformable surface where traction decreases because of low friction and rolling resistance increases because of deformation. (Pytka) As temperature increases, snow begins to settle and becomes denser. The main physical and mechanical properties of snow are density, hardness, cohesion, and internal friction. (Blokhin)

Besides the cold, snow can form other hazards, like avalanches, or pose structural problems like buildings collapsing from the weight of the snow. The noise of a vehicle starting up or the shear stress from a vehicle passing could trigger an avalanche. (Diemand) The resulting movement of snow could bury a vehicle, destroy a vehicle by pushing it against an obstacle, or at the very least, cause disorientation from tumbling.

Blowing snow will find a way into compartments that aren't completely sealed, interfere with operation of mechanisms (like robotic arms), and must be melted and drained. (Diemand) As the snow blows across the terrain, it reduces visibility and can interfere with sensor signals. It also can cover obstacles or fill in holes or other obstacles that could lead to navigation problems or loss of the vehicle. Blowing snow that is near its melting point will stick to surfaces like camera lenses, viewing ports, or mechanisms. (Diemand) These will need a heater or cover.

Fog over snow can severely degrade infrared and visible imaging systems. (Diemand)

According to Diemand, ice fog forms when moisture in the air freezes directly to ice crystals around -40C, and occurs in maritime areas or places with open water. It can be produced at warmer temperatures by vehicle exhaust, especially at start-up. The ice fog can obscure vision systems and be a signature control issue for stealth operations, but can be mitigated to some extent by exhaust diffusers or condensers.

Floating ice cover is routinely used to support vehicle traffic. The vehicles must move slower than the critical speed of the ice sheet. The safe speed for 0.3m of ice over deep water is about 7.5m/s or (27km/h) and increases with ice thickness. (Diemand) Do not attempt to cross fast flowing sections. If the air temperature has been above freezing for more than 24 hours, all the ice may be unsafe for travel.

Though it has no affect on actual measured temperatures, windchill strongly affects heat loss. Engines cool faster, exposed parts may not warm up, and components that require heating will need more heat. (Diemand)

Resistance increases and traction decreases as the ground thaws, but mobility may not be greatly affected if the frost depth is sufficient to support the weight of the vehicle.

Navigation is greatly impaired from snowfall because everything is covered. Ford Motor Company is creating high-fidelity three dimensional maps of roadways in an attempt to navigate. Sensors are used to detect people and obstacles. The car's sensors can't see the lane lines, but can see a sign and uses LIDAR to determine the distance from the sign and then deteremines where the lane lines are located. Falling rain or snow can interfere with LIDAR and cameras.

Retrofitting existing vehicles helps, but doesn't solve problems that a specially designed vehicle can solve. Vehicles perform better when designed for the cold. (Diemand)

A chassis with a pivot in the middle allows for better contact when traversing rough terrain and a rigid chassis can provide. (Trautmann)

If a battery is going to fail, the cold will probably bring about its end. This can be a hassle in a parking lot, but could be total failure in Antarctica or on the moon.

(Once again) According to Diemand:

Lead-acid

- vulnerable to freezing when discharged
- do not charge well when cold
- lose power at lower temps

Nicd

- perform better
- unlikely to freeze
- better cranking power
- charge at reduced rate below 15C

NiMH

- higher energy density
- lose more capacity at lower temps
- below 0C charging not advisable

LiON

- little loss at low temp
- charge at normal rate above 0C
- Charge at reduced rate to -30C

Battery cases should be insulated and use waste heat from components. Batteries should be warmed before a significant load is applied.

Cranking a cold engine creates a heavy demand on a battery. Oil becomes too viscous at low temps leading to hard starts and poor engine lubrication, which can be partially solved using engine block and oil pan heaters. Diesel fuel starts to crystallize at low temps and is harder to ignite. Gear lubrication thickens at low temps and can damage gears and axles if acceleration is quick. (Diemand)

According to Titus, problems can develop in the electronics as the temperature changes, including:

- performance can have a gradual or sudden change or could stop working
- MOSFET or CMOS device may operate to -196C and performance might improve
- silicon bipolar transistors stop working around -150C or have such low gain as to be worthless
- semiconductor becomes an insulator around -230C
- devices that dissipate power may have a higher internal temp
- grease in connectors may become solid and insulate connections
- temperature cycling can cause moisture buildup and increase the risk of short circuits
- wire insulation stiffens, can become brittle and fail if repeatedly flexed
- solder can become brittle
- differential contraction of circuit boards

Bekker's Derived Terramechanics Model was formed as a tool for evaluating off-road vehicle mobility. (Laughery) No single vehicle performs at 100% in all conditions. We will look at two main types, wheels and tracks. Mobility on snow is limited by the load bearing capacity of the snow pack. (Pytka) Deep snow reduces mobility due to compaction resistance, dragging of undercarriage parts, and reduced traction. (Diemand) Smaller vehicles with lower ground clearance need lower ground pressure. (Diemand)

Vehicles with tires are more more mechanically efficient and agile but have higher ground pressures.

Things to keep in mind:

- tires inflated in warm areas will lose pressure when cold
- stiff tires can be damaged more easily (Diemand)
- tires can develop temporary flat spots (Diemand)
- When wheel size increases, mass increases in proportion, so, horsepower inputs to overcome wheel inertia must increase or the vehicle's speed will be reduced to a complete stop. (Blokhin)
- wheeled vehicles with low ground pressure can travel over snow less that theh vehicle's ground clearance and less that the radius of the wheels. (Diemand)

Tracked vehicles are less efficient, but have much lower ground pressures.

Things to keep in mind:

- ice or snow gathering in the track assembly could jam it
- the SnoBot vehicle used polycarbonate to reduce snow accumulation in the track assembly (Lever)
- a vehicle with a long track that sinks down in the snow might have a larger turning radius in deep snow (Lever)
- a slight positive trim helps the vehicle move through the snow
- tracked vehicles with a ground pressure less than 7kPa or 1psi are better able to navigate deep soft snow (Diemand)

These are some things to keep in mind when developing a vehicle for snow and cold conditions. Do you know of others?

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