Decision Support Tools for Mobility Analysis over Snow, Ice, Frozen/Thawing Ground

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Issue

• The US Military has been fighting in the desert for the last 20 years.
• We have adversaries with well known capabilities in northern climates.
• New technologies need to be adapted to terrains unique to the far north for mobility superiority
**Snow, Ice, Frozen/Thawing Ground, Peat, Vegetation**

**Snow**
- Traction decreases
- Additional resistance and plowing forces
- Need to decrease weight and pressure
- Deep snow can obscure obstacles
  - Cannot “see” them
  - Could float over them

**Ice**
- Decreased traction
  - Climbing, braking, cornering
  - Very slippery when wet
  - Very slippery with light snow cover

**Lake & river ice**
- Strength varies with thickness and temperature
- Moving loads cause waves under ice
- Predicting safe ice crossings
- Removing river ice to place a bridge

**Freezing & Thawing Soil**
- Very strong when frozen
- Very slippery and weak when thawed (water doesn’t drain)
Seasonal Mobility Assessments in Northern Regions

Characterize terrain/vehicle interactions

Develop vehicle models

Validate mobility models

Analyze physical terrain conditions

Construct terrain database

Predict speed maps

Vehicle Models

Terrain Models

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Dynamic Cold Regions Terrain Variables

- Snow cover characteristics (covered area, depth, density)
- Temperature
- Precipitation
- Frost Depth
- Freeze/thaw cycles
- Wind speed
- Wind direction
- Humidity
- Soil moisture
- Soil temperature
Snow cover likelihood in MARCH
Based on GlobSnow 1 km Snow Extent product
From optical remote sensing (AVHRR, MODIS, VIIRS)

Example: Global Snow Cover Area (SCA)

Statistical estimates of Snow Water Equivalent (SWE) used to estimate snow depth and density
Example: Sea ice extent January to April 2018

Source: http://nsidc.org/data/seaice_index/archives
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Generate Summer Terrain Parameters:

- Elevation
- Land Usage
- Soil Type
- Soil Moisture

Satellite Imagery

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Generate Winter Terrain Parameters:

- Frost Depth
- Snow Density

Satellite Imagery

- Wetland
- Forest
- Mountain
- Water
- Urban

Snow Depth
Example Results: Seasonal Impacts for Tracked Vehicle

Speed Maps

Speed Range (kph)
- 50 – Max Speed
- 30 – 50
- 15 – 30
- 5 – 15
- 0 – 5
- Water

- In winter frozen ground improves vehicle mobility
- Not able to traverse peat soils unless frozen
- Greatest speed limiter is snow-covered slopes
Example Results: Seasonal Impacts for Light Wheeled Vehicle

Speed Range (kph)

- 50 – Max Speed
- 30 – 50
- 15 – 30
- 5 – 15
- 0 – 5
- Water

- Sufficient mobility during summer and winter, but not spring thaw
- Vehicles cannot traverse peat unless frozen
- Greatest speed limiter is wet soil and snow-covered slopes
Example Results: Different Vehicles in Winter

- High slopes have greater impact on speed in winter
- Peat soils are now frozen so vehicles can traverse safely

Speed Range (kph)

- 50 – Max Speed
- 30 – 50
- 15 – 30
- 5 – 15
- 0 – 5
- Water

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Summary: Seasonal Mobility Assessments Process

Climatology Analysis → Terrain Data Acquisition → Snow & Ice Cover → Frost/Thaw Predictions → Terrain and Vehicle Characteristics

Speed Maps → NATO Mobility Modeling

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Similarities in The Search for an Arctic Landing Zone (LZ)

19 April 2009 MODIS imagery

Resolute Bay

Gascoyne Inlet

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Phoenix Compacted Snow Airfield Engineering Design

First Landing, Nov 2016

Compacted Snow Airfield:
• First wheeled snow runway since Russians in 1950s
• Heaviest wheeled aircraft on snow, ever!
• >500,000lbs, 160 psi tires
Matching Similar Ecotypes: Atmospheric, Terrain & Biological Conditions
Next Steps:
Entry and Sustainment in Complex, Contested Environments

1. Develop new ways to generate terrain data using remote assessment
2. Quantify/Incorporate uncertainty in results
3. Automated tools for terrain file generation
4. Evaluate/validate results for current vehicle fleet
5. Incorporate deep snow, over-snow and other winter surfaces
6. Add capabilities for peat and highly organic soils
7. Add vegetation effects on terrain strength and mobility

Multinational terrain data sharing agreements!
NG-NRMM and High-fidelity Modeling:

1. Cold regions terrain mechanics (snow, ice, frozen/thawing ground, peat and organic soils, heavily vegetated ground)
2. Implement results into high-resolution mobility models
3. Sensor performance models for cold terrains
4. VANE, ANVEL, plus OpenSource software

**NATO: AVT 248: Next-Generation NRMM (Standards)**

**NATO: AVT-ET-194: Assessment and Tools for Mobility of Autonomous Military Ground Systems**

From: J. Durst, Dissertation Defense, March 4, 2019
Next Generation Combat Vehicle: Autonomy in Cold and Challenging Terrain

If the autonomous vehicle can’t sense it, it can not effectively maneuver.

1. Artificial Intelligence/Machine Learning (AI/ML) using stand-off sensing data for terrain assessment
2. AI/ML for vehicle performance prediction in cold terrain
3. Autonomy and control in extreme environments
Seasonal Impacts on Mobility: Conclusions

- Seasonality has significant impacts on mobility, especially in austere, off-road environments.
- Accurate representation of terrain conditions is essential for robust mobility predictions.

Next Steps
- Future vehicle technology needs to be adapted for terrain unique to northern regions:
  - Revive deep and over-snow vehicle capability
  - Address S&T gaps
  - Apply new M&S techniques
  - Develop autonomous capabilities