Amphibious Robot For Reclamation Work On Soft Tailings Deposits

Nicolas A. Olmedo | President & Founder | Nov 2017
Develop technologies to reduce the cost, risk, and difficulty of working in the world’s toughest environments
Safe mine waste (tailings) management requires continuous environmental monitoring

- It is difficult and expensive.
- Current approaches may put workers at risk.
- Few areas are accessible with traditional technology.
Unmanned systems offer:

- Health and safety
- Productivity
- Operational efficiency
- Cost savings
- Risk reduction
Mobile Robots for collecting samples:

- Access oil sands tailings deposits with a crust (15 kPa)
- Drill a hole through the crust
- Deploy a tailings sampler up to 1.7m
Mobile Robots for Terramechnics based soil parameter estimation:

- Instrumented a wheel to measure state and loading
- Drove over deformable terrain and collected measurements
- Estimated cohesion & internal friction angle of the soil
Mobile Robots for Terramechnics based soil parameter estimation:

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\[ W : \text{Normal load} \]
\[ DP : \text{Drawbar pull} \]
\[ T : \text{Torque} \]

Shear stress:
\[
\tau : \begin{cases} 
\tau_1 & (\theta_m < \theta \leq \theta_1) \\
\tau_2 & (\theta_2 \leq \theta \leq \theta_m) 
\end{cases}
\]

Normal stress:
\[
\sigma : \begin{cases} 
\sigma_1 & (\theta_m < \theta \leq \theta_1) \\
\sigma_2 & (\theta_2 \leq \theta \leq \theta_m) 
\end{cases}
\]

\[ \omega : \text{Angular speed} \]
\[ v : \text{Ground speed} \]
\[ \theta_1 : \text{Front contact angle} \]
\[ \theta_2 : \text{Rear contact angle} \]
\[ \theta_m : \text{Angle of maximum stress} \]
\[ z : \text{Sinkage} \]
\[ r : \text{Wheel radius} \]
Robotic Manipulator for Terramechnics based soil parameter estimation:

- Developed a robotic manipulator to control slip of a wheel
- Control normal loading on an instrumented wheel
- Estimated cohesion & internal friction angle of the soil

\[ \tau(\theta) = (c + \sigma(\theta) \tan \phi)(1 - e^{-r/k(\theta_1 - \theta - (1-s)(\sin \theta_1 - \sin \theta))}) \]

\[ \sigma(\theta) = \left( \frac{kc}{b} + k\phi \right) z(\theta)^n \]

\[ s = \begin{cases} 
(r\dot{\theta} - v)/r\dot{\theta} & r\dot{\theta} > v : \text{accelerating} \\
(r\dot{\theta} - v)/v & r\dot{\theta} < v : \text{decelerating} 
\end{cases} \]
High Resolution Vane Shear Test Tools

Specifications with No 4 Spring:

- **Angle resolution:** 0.009 deg
- **Spring Sensitivity:** 0.0046 Nm/deg
- **Torque resolution:** 0.00004 Nm
- **Torque Range:** 0 – 1 Nm

For a 2.5 cm D (H = 1D) Vane

- **Stress Resolution:** 0.001 kPa
- **Stress Range:** 0 – 30.5 kPa
Our goal:

- Amphibious robots for tailings monitoring
- Reduce costs of survey
- Eliminate risk to workers, do not require an operator
- Access to all types of deposits
- Instrumented to collect reliable data and samples anywhere, anytime
• Collaboration with University of Alberta

• Laboratory testing on treated MFT (CFER, EKS)

• Deployed terramechanics sensors and undisturbed surface samplers
Field Trials

- Collaboration with ConeTec
- Moved on treated tailings (teleoperated)
- Deployed a cone penetrometer

CST-AR1 Traversing centrifuged oil sands tailings deposit
Field Trials
Field Trials
Challenges

- Difficulty turning on hard ground
- Limited payload capacity (30kg)
- Limited depth (2m)
- Requires operator
Key features of AR2

- 40% larger
- Increased payload capacity (100kg)
- 4 “wheel-drive”
- Tool deployment up to 4m
- Payloads:
  - seedlings planter,
  - seed broadcaster,
  - wick drain deployment system
Seedlings Planter

- 100 kg capacity, 324 – 540 seedlings
- 6 belts to drop seedlings at 25cm spacing

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<th>Value</th>
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<tr>
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<td>Seedling Capacity (Willows)</td>
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<td>Seedling Capacity (Grass)</td>
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<td>Rows</td>
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<tr>
<td>Row Spacing</td>
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Seed Broadcaster

- Material capacity: 55L
- Maximum spread width 6m

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<td>Material Capacity</td>
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<td>Maximum Spread Width</td>
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<td>Typical operating conditions</td>
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<td>Base Model Vendor</td>
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Wick Drain Payload

- Feeder capacity 3 (extendable to 12)
- Maximum install depth 3.7m
- Maximum install speed 8.5 cm/5
- Custom anchor plates for soft material

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<tr>
<td>Feeder Capacity</td>
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<td>Expandable to 12</td>
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<tr>
<td>Maximum Install Depth</td>
<td>3.7m</td>
<td>Typical operating conditions</td>
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<tr>
<td>Maximum Install Speed</td>
<td>8.5 cm/s</td>
<td>Typical operating conditions</td>
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<tr>
<td>Typical Install Speed</td>
<td>2.0 cm/s</td>
<td>As tested</td>
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<tr>
<td>Typical Install Time</td>
<td>3 min</td>
<td>As tested, per wick drain</td>
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WICK DRAIN PAYLOAD
Environmental monitoring

- Tool deployment for collecting water samples and mud samples
- Vegetation sampling
- Vane shear test tools
- Bathymetric surveys
• Robotic systems can be used for environmental monitoring of challenging environments.
• Amphibious robots are required to access harsh terrains to deploy instruments, collect measurements and samples.
• Collaborations between operators, service providers, research institutes, and other technology developers are required to introduce automation that improves industrial operations.
• Dr. W. Wilson and Dr. N. Beier for their technical support and guidance.

• Oil sands tailings operators and service providers that have supported the development of the technology and field trials.
Contact

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Meet The Team

Nicolas A. Olmedo  BSc, EIT, PhD Candidate – President

Jamie Yuen  MSc, EIT – VP Finance & Operations

Stephen Dwyer  MSc, EIT – VP Engineering

Michael Lipsett  PhD, PEng – Senior Advisor
### Comparison of Monitoring Solutions

<table>
<thead>
<tr>
<th></th>
<th>Manned Boats</th>
<th>Large Manned Barges</th>
<th>RC Boats</th>
<th>CST Rovers</th>
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<tbody>
<tr>
<td><strong>Unmanned</strong></td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td><strong>Access to harsh terrains</strong></td>
<td>NO</td>
<td>SOME</td>
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<td><strong>Cost</strong></td>
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<td>$</td>
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