# 3D Mapping of Glacier Moulins: Challenges and lessons learned

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## Context & Motivations

- Deploying robots in the cryosphere is still an open problem [1], and is a crucial source of data collection and analysis, essential for understanding problems such as climate change.
- Dante was the first robot successfully deployed in a remote hazardous setting, an Alaskan volcano [2], demonstrating feasibility
- Prior deployments have shown the hazardous conditions surrounding surveys within glaciers [3, 4] and have highlighted the potential of robotic platforms in monitoring changes.

## Experimental platform

- We designed and developed a measurement platform capable of sustaining significant forces caused by various extreme motions and collisions that can occur in extreme environments.
- The platform is built to record data from sensors needed to perform localization and mapping using a Raspberry Pi 4B.
- Data is then post-processed to complete the localization and mapping and evaluate its performances.
- To ensure no pollution is left on-site if anything breaks, a safety net was installed on the platform, thin enough not to cause any occlusions.

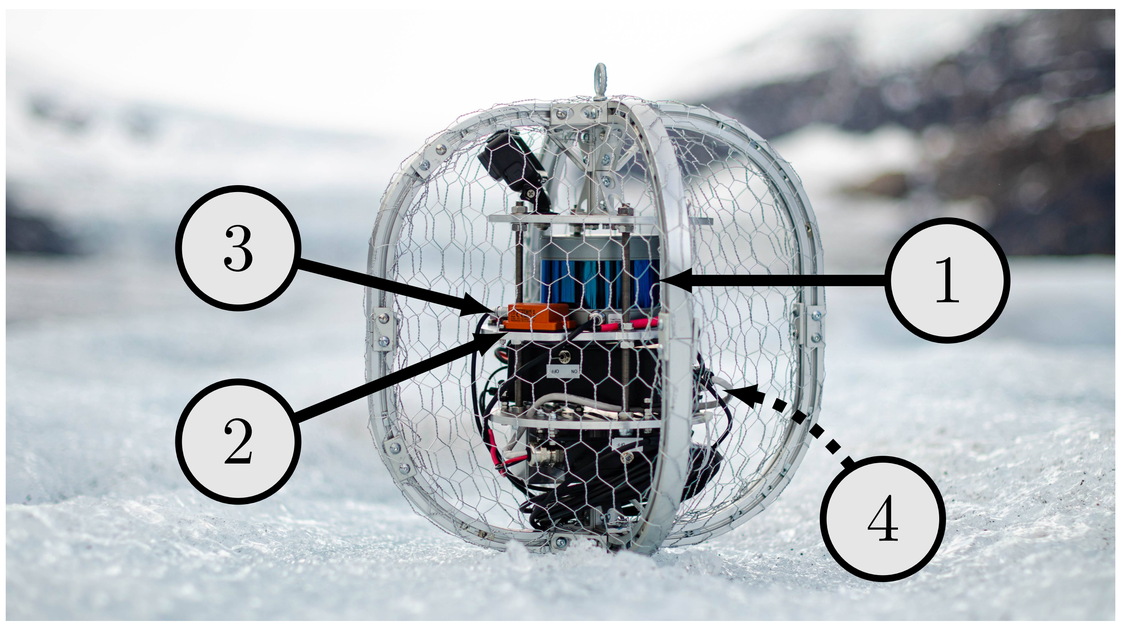


Figure 1: Data gathering platform with which sensor measurements were recorded to perform 3D localization and mapping, equipped with a lidar Robosense RS-16 (1), an Xsens MTi-10 IMU (2), a Vectornav vn100 IMU (3, behind the Xsens MTi-10) and a barometric pressure sensor DPS310 (4, on the other side of the platform).

## Challenges and lessons learned

- **Extreme environments** lead to:
  - erratic weather conditions necessitating rugged equipment and dedicated specialized equipments,
  - stringent safety measures and extreme conditions that add additional stress on your body and mind.
- **Preparation** is key:
  - thorough and tested experimental and validation procedure are necessary,
  - spare equipment is crucial, everything that can break will break.

## Results

- Lidar and IMU measurements enabled us to compute 3D mapping and localization of the experimental platform throughout its slow descent in the moulin.
- Experiments were conclusive, but only low quality maps were obtainable.

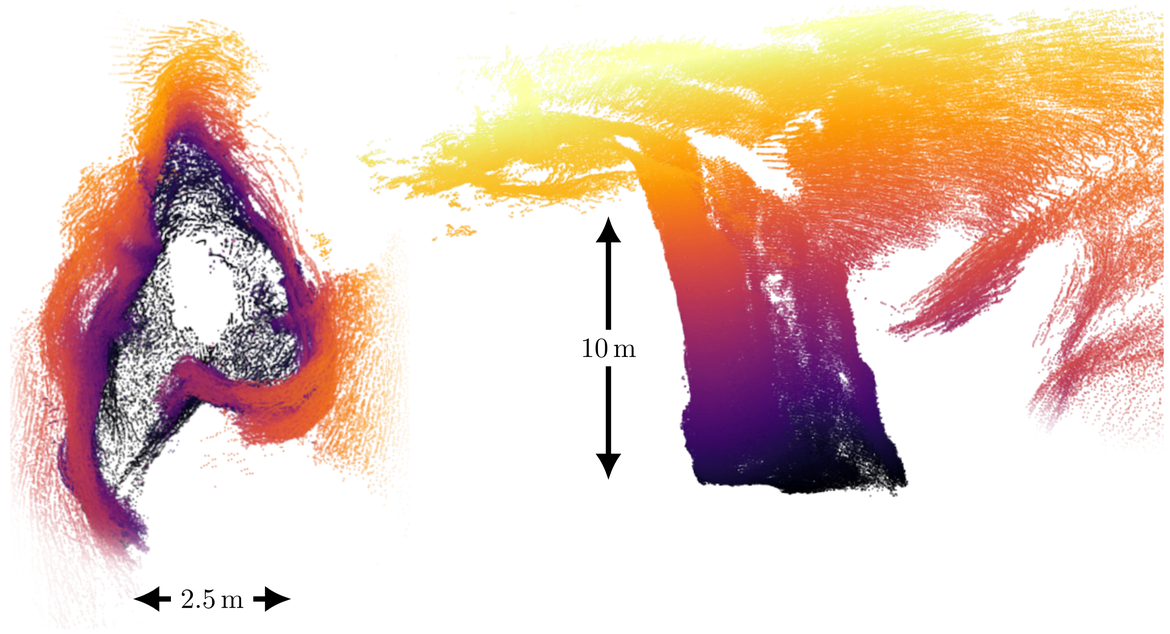


Figure 2: Map result (colored by elevation) from the moulin experiment. Left: top view; Right: Side view. The lack of features in the moulin makes the mapping of such environments challenging.

- Lack of features led to:
  - under-constrained and degraded registration solutions,
  - lower quality maps,
  - lower quality information about the surveyed environment.
- Addition of barometric pressure information can help gain constraints.

## Experiments

- **Ice canyon**:
  - Low difficulty experiment.
  - The platform rolled down an ice canyon while recording sensor measurements.
  - Environment with enough constraints and easy access to quickly validate the impact of ice and various factors on the platform.
- **Glacial moulin**:
  - Low feature environment.
  - The platform is initially lowered down the moulin while recording sensor measurements.
  - Ultimately, the platform was thrown in the moulin to record measurements through extreme motions such as free fall.

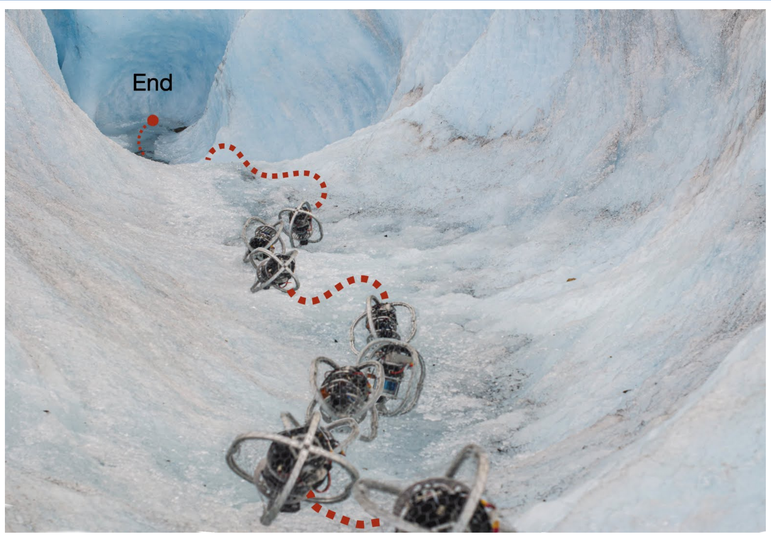


Figure 3: The experimental platform rolled down a 30 m ice canyon.

Figure 4: The experimental platform was lowered in a glacial moulin, mapping its surroundings.

## Future works

- **Increase mapping performances and robustness** through fusion of information from several sensors.
- **Use an atmospheric pressure sensor** to better constrain the elevation drift.
- **Improve the experimental platform** to increase its robustness and versatility.

## Acknowledgments and References

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