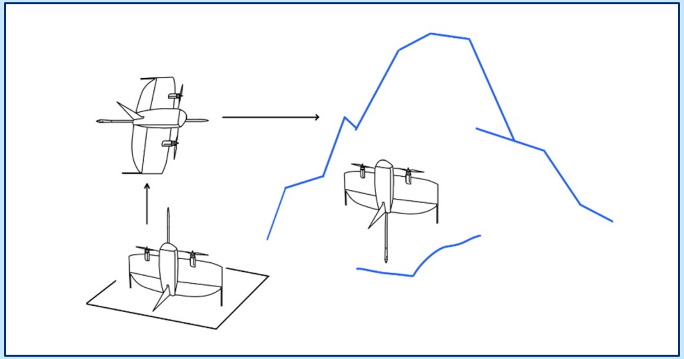
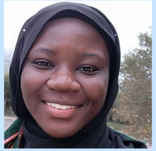
AVATARS

Aerial Vehicles for Avalanche Terrain Assessment and Reporting Systems



Sophie Kruse

Eva Sharman



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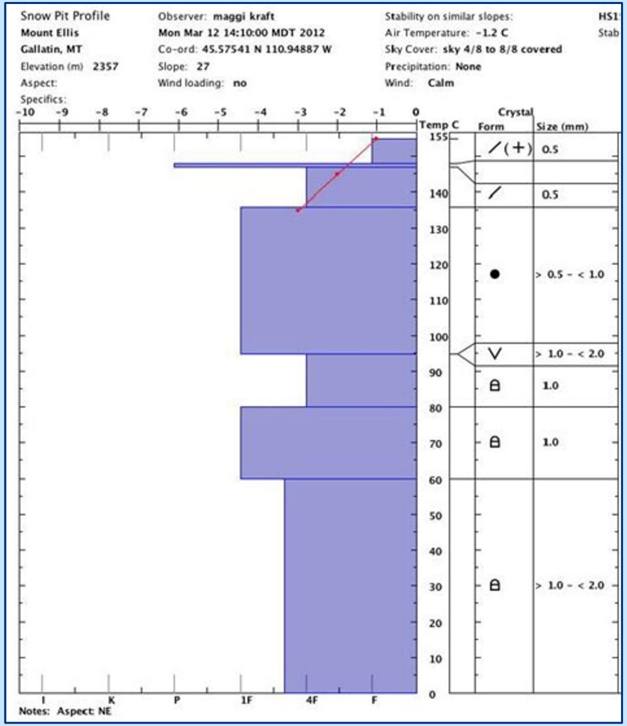
COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

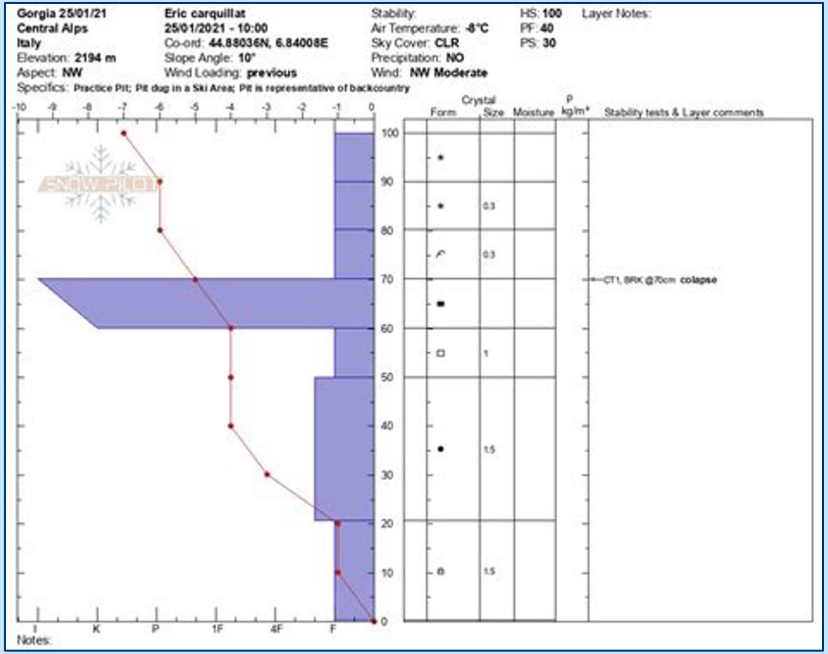
Outline

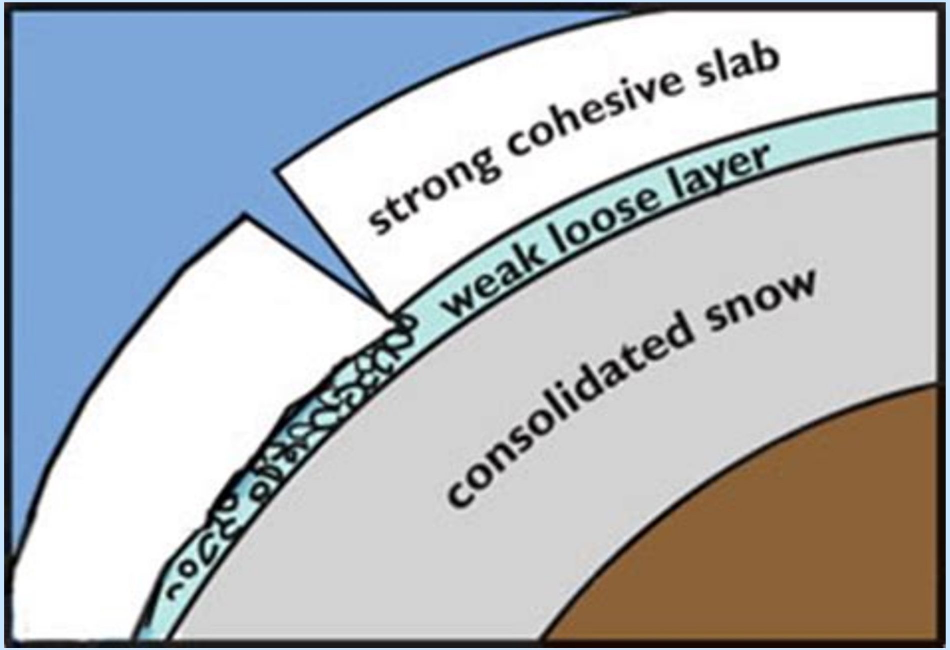
- Avalanche Overview: Science & Current Forecasting
- Emerging Technologies and Proposed System
- Operations and Path to Deployment
- Technology Readiness and Barriers
- Return on Investment
- Conclusion

Profiles & Measurements

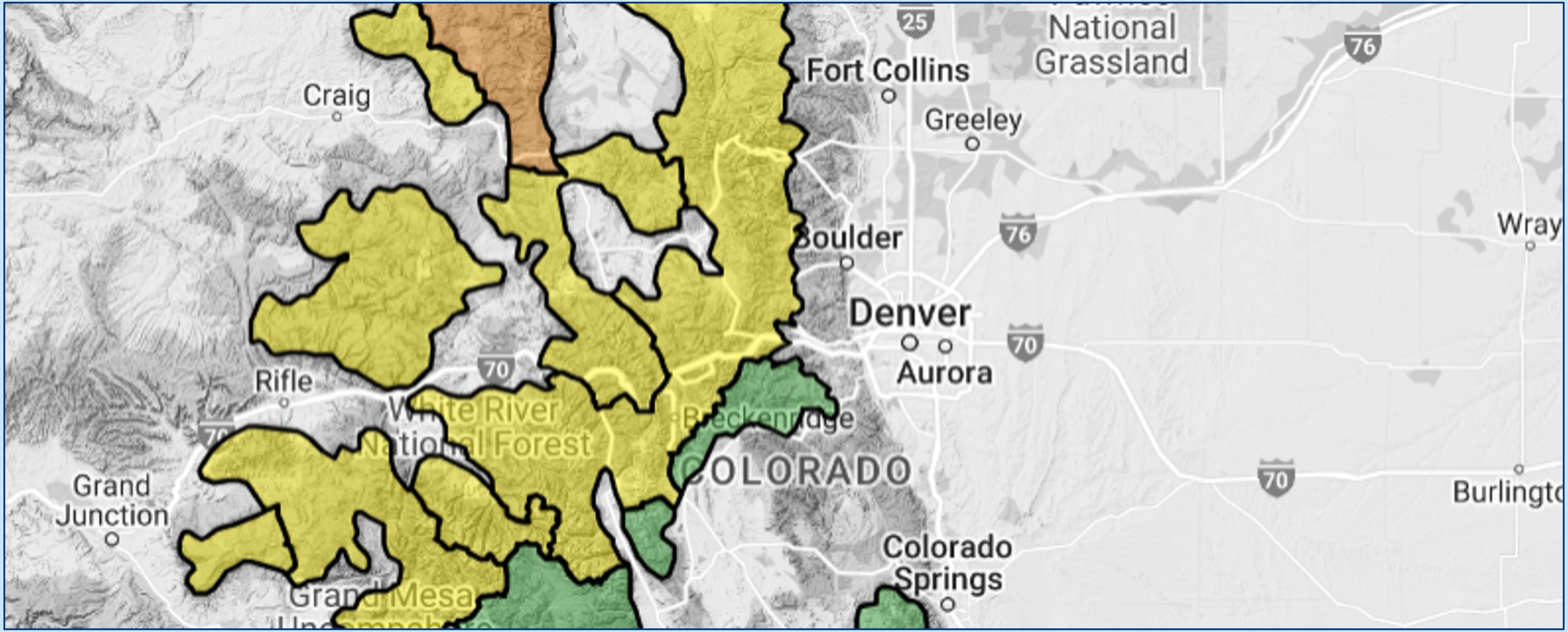


Avalanche Science





Hazard Maps



National
Grassland
Fort Collins
Craig
Greeley
Wray
Boulder
Denver
Aurora
Rifle
White River
National Forest
Breckenridge
COLORADO
Grand
Junction
Burlingto
Colorado
Springs
Grand Mesa
25
76
70

Further Issues

Human Variability

Limited Modeling

Danger for Forecasters

Climate Change Threats

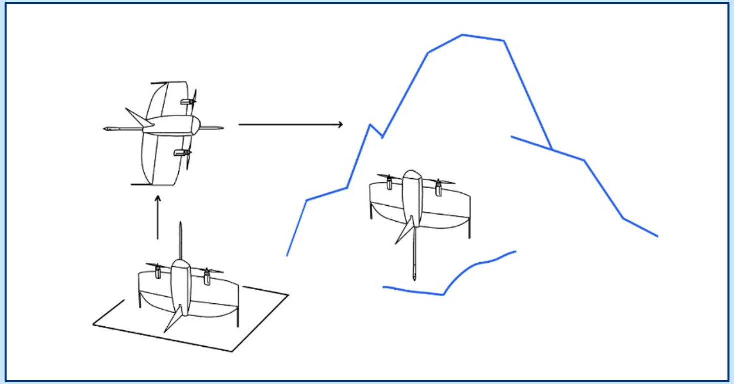
… data is severely limited.

AVATARS

Aerial Vehicles for Avalanche Terrain Assessment and Reporting Systems

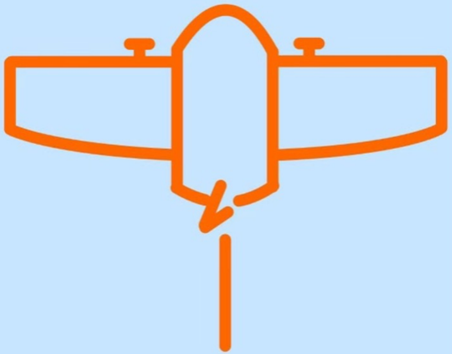
Goals

- *Improve* accuracy and breadth of daily avalanche forecasts
- *Advance* long-term understanding of avalanche science



Key Avalanche Measurements

- Surface and Terrain Conditions
- Snow Profile Data



Integration of a *vertical take-off and landing UAV* with a *sensor-equipped probe*

The Snow Probe

A Digital Penetrometer with Force and Optical Sensor

Credit: Propagation Labs

Choose location

Insert probe into snow

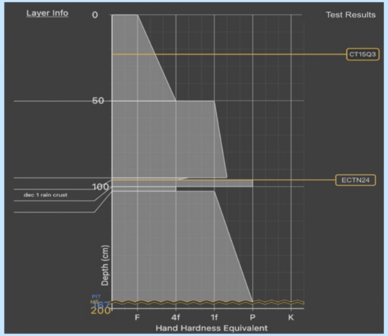
Transmit snow profile readings

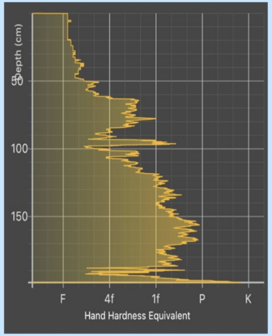
Manual

- Low resolution (100-400mm)
- Subjective
- Point measurement
- Several hours to dig pit

Probe

- High resolution (1mm)
- Objective
- Scalable
- Less than a minute to acquire





Selkirks, British Columbia

- Buried rain crust
- Weak, faceted snow above crust layer
- Consistent across 20+ measurements

Aerial Systems Currently Utilized

Credit: Ben VandenBos, Avalanche Forecaster at the Sawtooth Avalanche Center

Statewide & Regional
Avalanche Centers

↓

Multirotor UAVs for
Avalanche Identification

Limitations

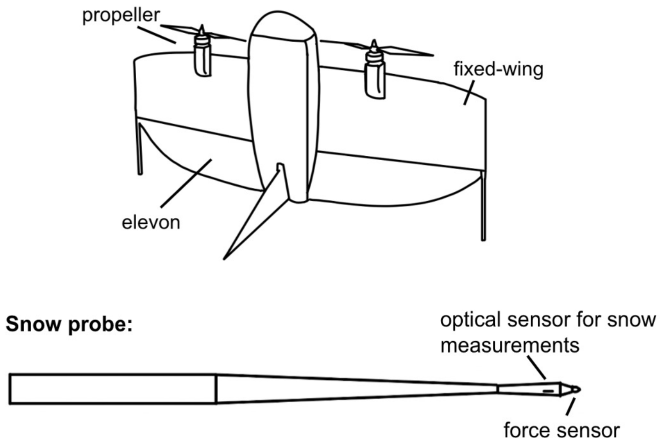
- Aerodynamic Inefficiency
- Short Flight Times
- Limited Range

Credit: Wingtra

Combined System

Proposal

Mount a *deployable probe* on the body of a *Tailsitter UAV*.



"We developed the Snow Scope Probe to *increase* the *speed, accuracy, and objectivity* in which snow profile data can be measured … we see integration with UAVs for use in extreme environments to be a *feasible* and *natural extension* of our mission."

- Garrett Harmsen, Founder of Propagation Labs and Creator of the Snow Scope Probe

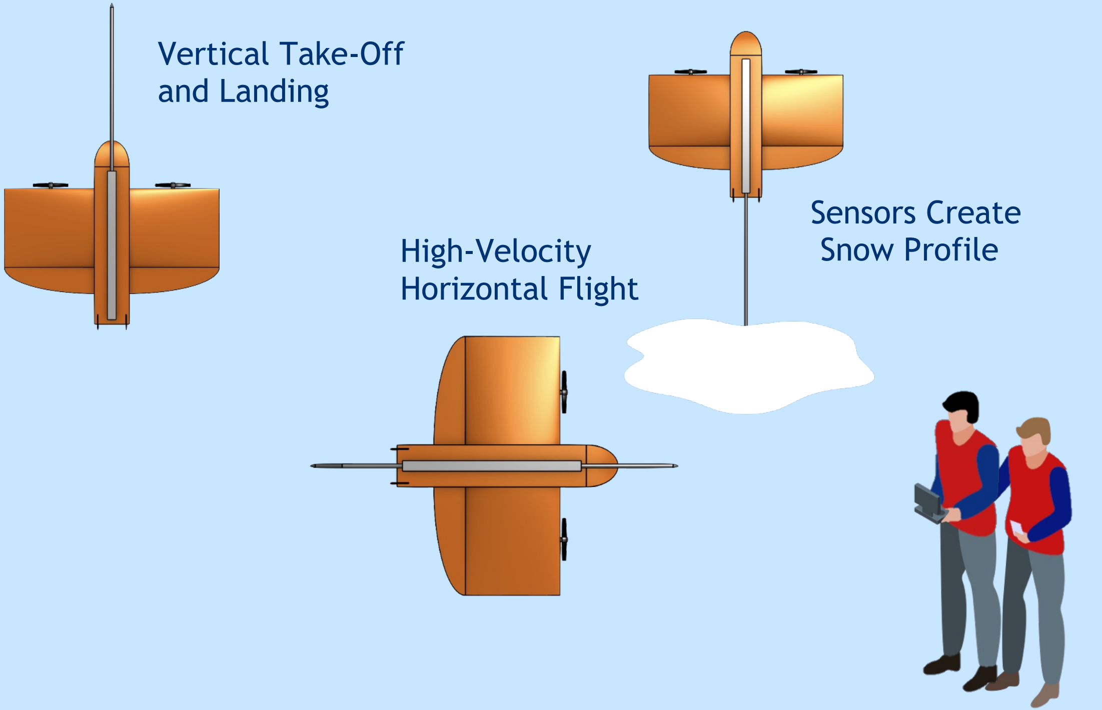
How It Works

Aerial Surveying

Use high-resolution photogrammetry to model *snow depth* and identify *surface markers* of avalanches.

Probe Deployment

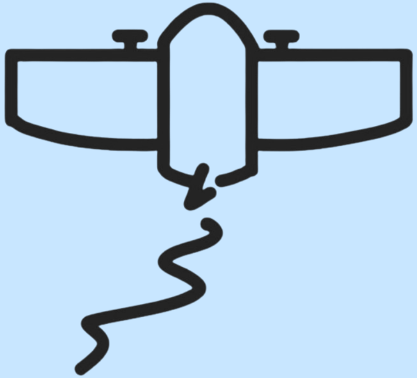
Use deployable probe to gather time-stamped *snow profile data* across slope.



Improvements

- Monitor Inaccessible/Unsafe Terrain — ***35+ mph flight***
- Increase Volume and Accuracy of Measurements — ***300 acres of surveying or 20+ snow profiles each flight***
- Track Change Over Time — ***Model snow depth***
- User-friendly & resilient VTOL — ***Designed for winter conditions***
- Rapid data communication — ***Faster + cheaper than satellite imagery***
- Modular Design — ***Integrate improving technologies***

Planning → Field Deployment → Analysis



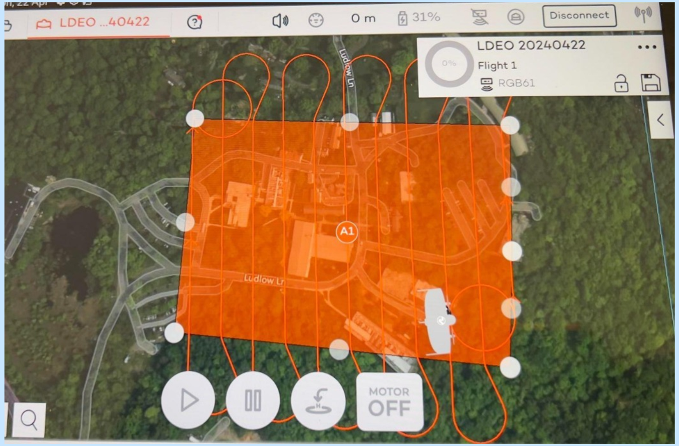
Involvement of Avalanche Professionals

Planning

Identify regions of interest

Choose intended use-case(s)

Develop flight plan



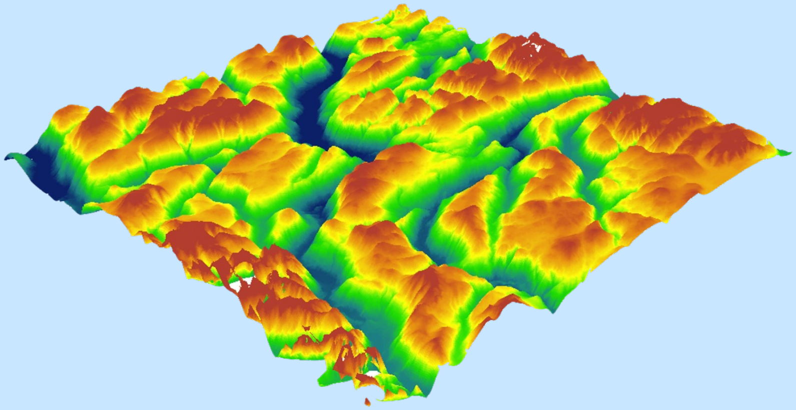
Credit: Lamont-Doherty Earth Observatory

Field Deployment

Aerial Surveying

Summertime and wintertime DEMs

Surface markers

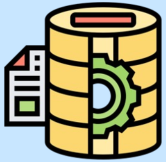


Probe Deployment

20+ profiles across slope

Analysis

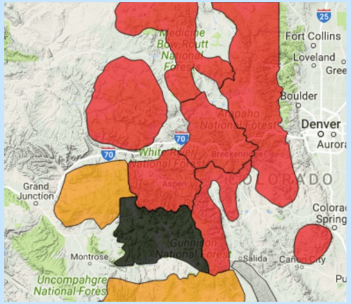
Manage data



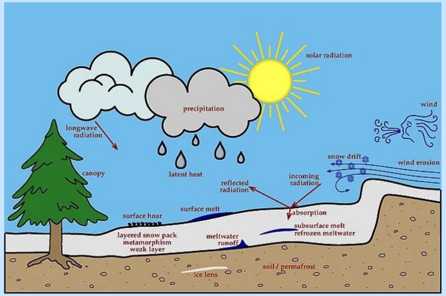
Interpret results

Communicate to the public

Reliable, far-reaching forecasts



Robust models

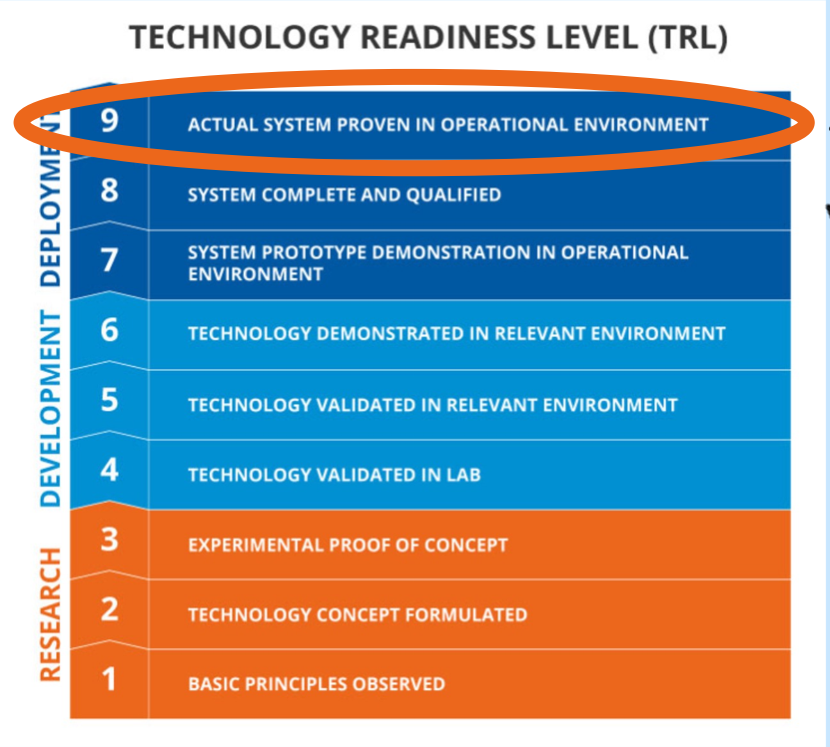


Credit: The Institute for Snow and Avalanche Research, Snowpack Model

Path to Deployment

2025	2026	2027	2028	2029	2030	2031	2032
Prototype Development		System Testing			Preliminary Integration		Full Operational Integration

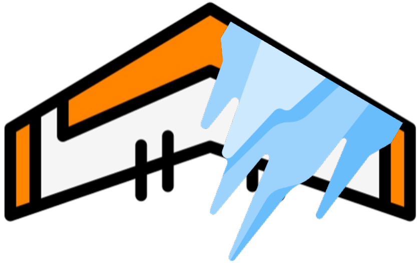
Technology Readiness



Environmental Conditions

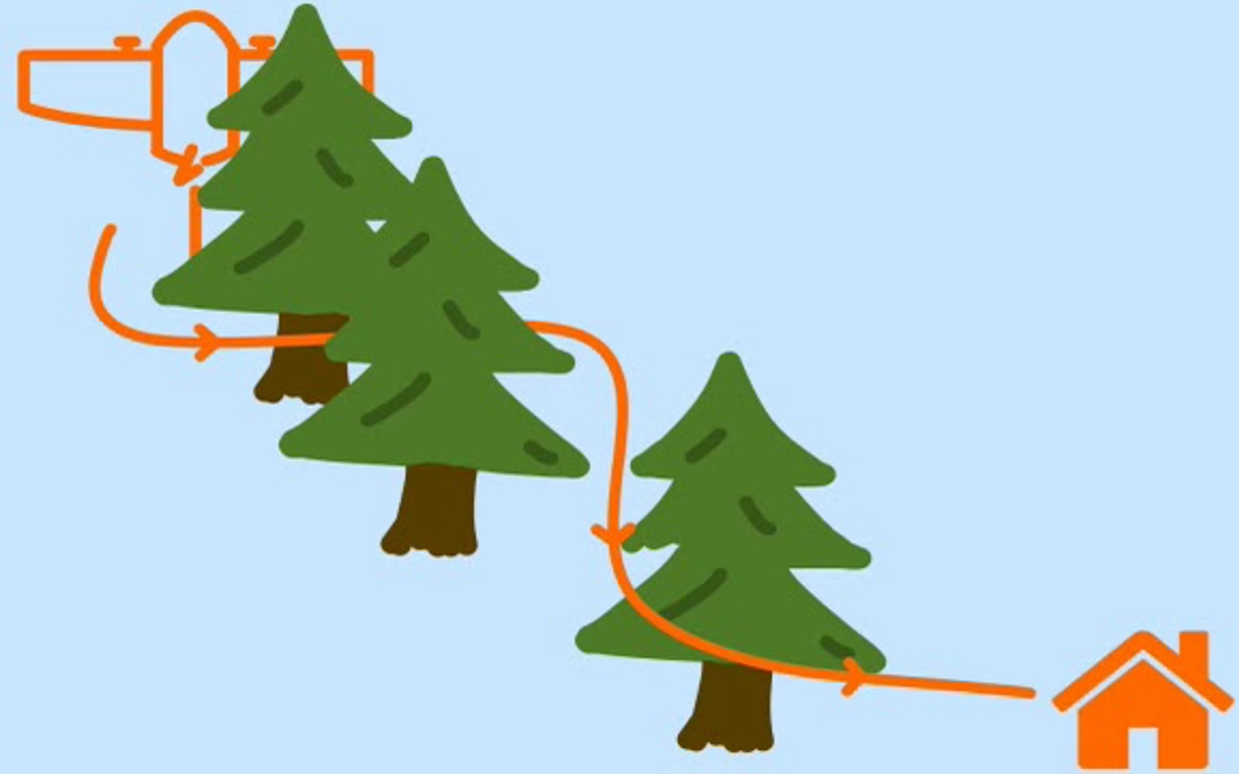
Extreme Weather

Battery Life



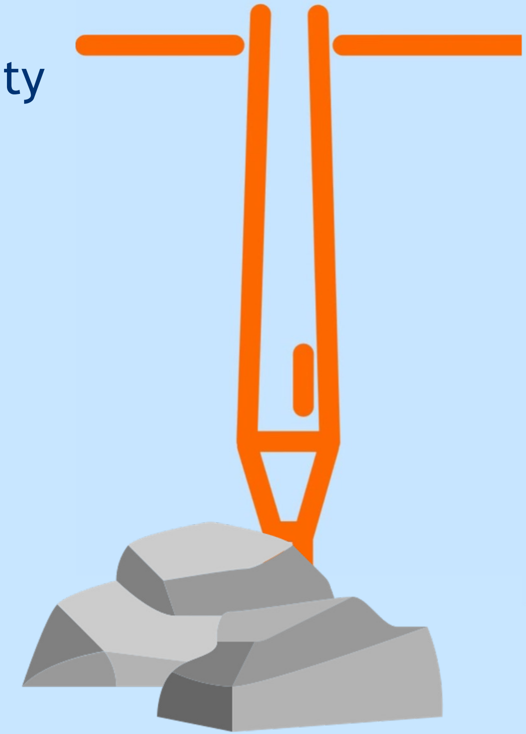
Icing

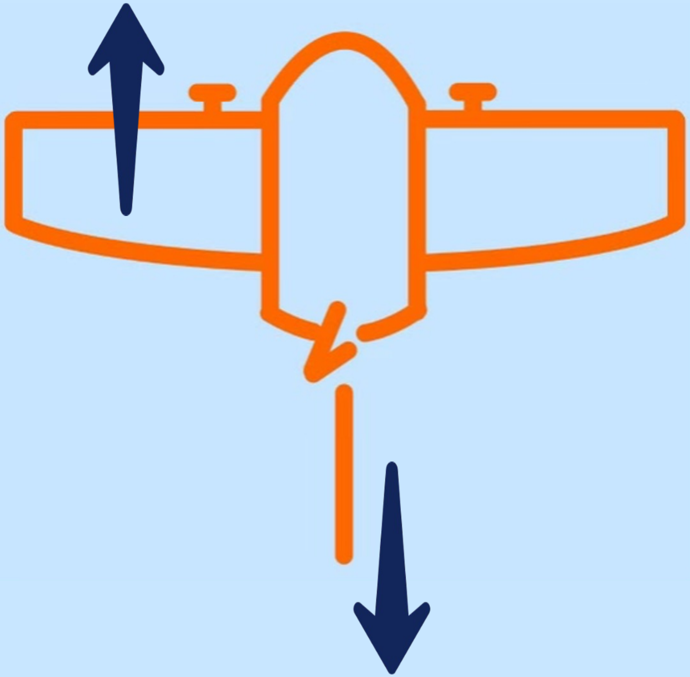
Safety Features



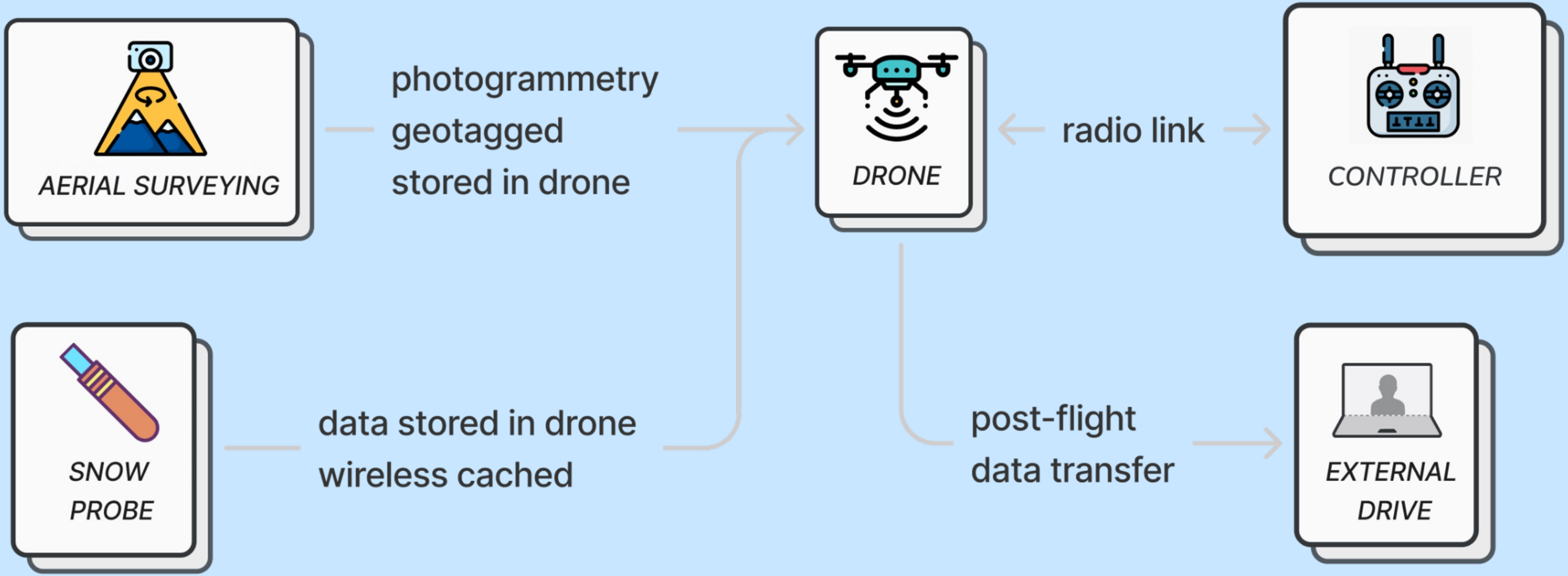
Probe Deployment Risks

- Software for data validity
- Rock and ice layer risks
- Automatic stop system
- Release mechanism

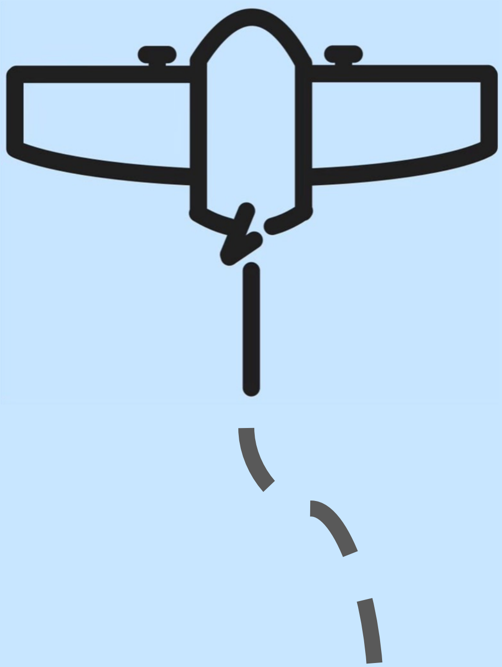




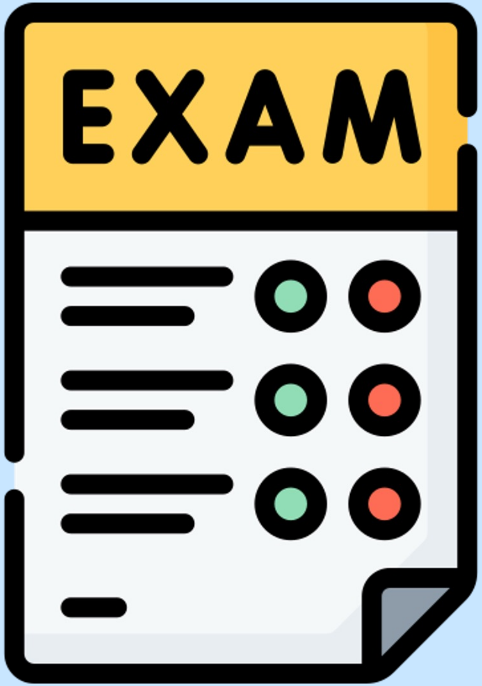
Connection and Data



Flight Logistics



Training



Avalanche Centers

Statewide

CAIC

KEEPING YOU ON TOP
UTAH AVALANCHE
CENTER

Alaska Avalanche
INFORMATION CENTER

Regional

Sawtooth
Avalanche
Center

MOUNT SHASTA
AVALANCHE CENTER

SIERRA AVALANCHE CENTER

CENTRAL OREGON
AVALANCHE CENTER

Barriers to Analyze

Regulations

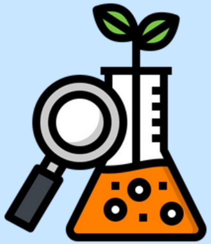
Privacy

Safety

Environment

Acceptance

Return on Investment

Life	Rescue	Injury	Damage	Research
				

Case Study: Colorado

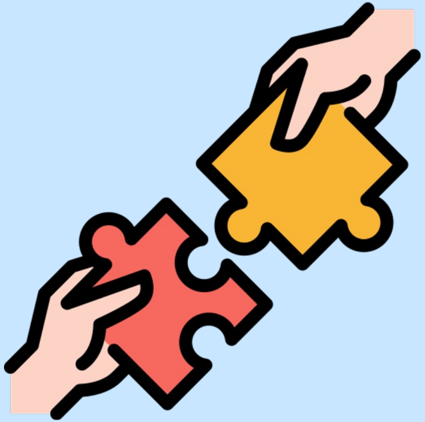
- $2.25 billion in loss of life 1990 - 2023
- 323 avalanche fatalities since 1950
- 816 hours of road closures 2023 - 2024 season
- $525,050 of property damage 1998 - 2023

Funding

Donations

Public Partnerships

Private Partnerships



Why does it matter?