Assessing Gazex Avalanche Control Effectiveness with Terrestrial Laser Scanning

Proposal to CDOT Research Program
17 June 2015

Principal Investigator:
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University of Colorado, CIRES National Snow and Ice Data Center
Collaborator:
David Finnegan, Research Physical Scientist
US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory

Objective

This project aims to use terrestrial laser scanning (TLS) technology to create snow depth maps in avalanche starting zones for an effectiveness assessment of the new Gazex systems in reducing avalanche hazard in the Loveland Pass (Seven Sisters) and Berthoud Pass (Stanley) highway corridors. Snow depth maps created prior and post Gazex activation will allow the quantification of avalanche areas and volumes, as well as the mapping of snow slabs remaining after control operations.

Background

The spatial distribution of snow depth exerts a strong influence on avalanche occurrence, triggering, character, and potential size. Snow depth also affects snow density, hardness, and weak layer failure. Extreme snow depth heterogeneity is common, especially in wind-affected environments. Avalanche control efforts are often more successful when shallow trigger point areas next to deeper slabs can be targeted with explosives or ski cutting. Control results from permanent installations such as Gazex are optimized when sufficient snow slab has accumulated to create a sizeable release, but before extensive accumulations threaten infrastructure. High resolution snow depth and snow depth change maps from repeat TLS scans can provide quantitative information on snow accumulation patterns for use in avalanche control planning, targeting of explosives, and especially post-control results assessment, and could be used to assess optimal control timing for new operations or installations.

TLS Measurement of Snow Depth

Snow depth is commonly measured by insertion of a ruler into the snowpack, or at in-situ stations via a sonic ranging instrument. Neither method allows safe, repeat, non-destructive, spatially-complete sampling in avalanche starting zones where data are most relevant.

In recent years TLS systems have been applied for mapping of snow-free and snow-covered surface elevations. Subtraction of snow-free from snow-covered elevation models provides high-resolution (decimeter resolution) maps of snow depth or depth change, data products which hold tremendous potential for evaluation of

snow accumulation patterns and operational assessment and planning of avalanche control efforts.

Until recently, TLS surveys have either been limited to short ranges (< 150m range from scanner) due to system wavelength and power, or have required long-duration nighttime scans due to the slow acquisition rate of the scanner and limited detection capabilities at longer ranges. A new TLS system owned by collaborator Finnegan allows unprecedented range and resolution for mapping surface elevation of snow-free or snow-covered terrain. We have employed the Riegl VZ-4000 TLS in snow-covered mountain environments and reliably retrieved decimeter-resolution measurements at ranges over 1 km, with 180° x 60° (horizontal x vertical) field-of-view scans, with durations under 30 minutes. Further, the VZ-4000 uses a 1550nm wavelength laser source, which is eye-safe and therefore safely operated in populated areas. This technology is a potentially revolutionary development for remote measurement of snow depth at high resolutions in complex and hazardous terrain.

Pilot Work To-Date

An exploratory project has been conducted at the nearby Arapahoe Basin Ski Area. This work was conducted on a volunteer basis by the PI and collaborators. In winter 2013/14 a small seed grant from the American Avalanche Association supported data collection in coordination with storm events and avalanche control activity. Initial results are very encouraging, and demand further development. We have documented numerous snow accumulation events, as well as avalanche control activity and results. Figure 1 illustrates a post-control scan, from which we can map avalanche release area, remaining slab (hangfire), and debris volume. Red/pink colors represent snow accumulation since the prior scan (1 week interval), and the white color of the bed surface indicates zero change from the previous scan – that the slides released and ran on the old snow surface – while green/blue colors indicate areas of scour and/or entrainment.

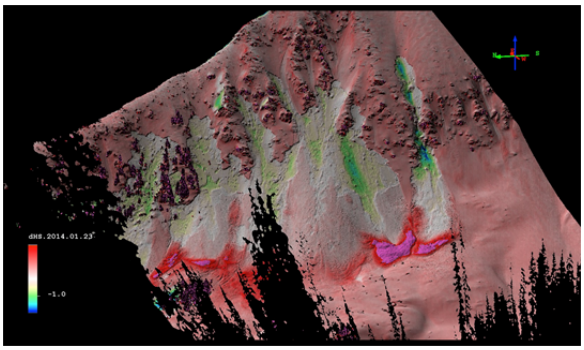

Figure 1. A TLS scan of avalanche activity on the East Wall, Arapahoe Basin, colored by snow depth change from Jan 23 - Feb1, 2013.

Research Plan

Task 1: Conduct site assessments, study feasibility, coordinate workflow and site access details with CDOT/CAIC collaborators

Deliverable 1: Initial scan data images

Task 2: Collect snow-free TLS scans of both sites after construction of Gazex systems.

Deliverable 2: Snow-free elevation point cloud

Deliverable 3: Snow-free bare-earth digital elevation model

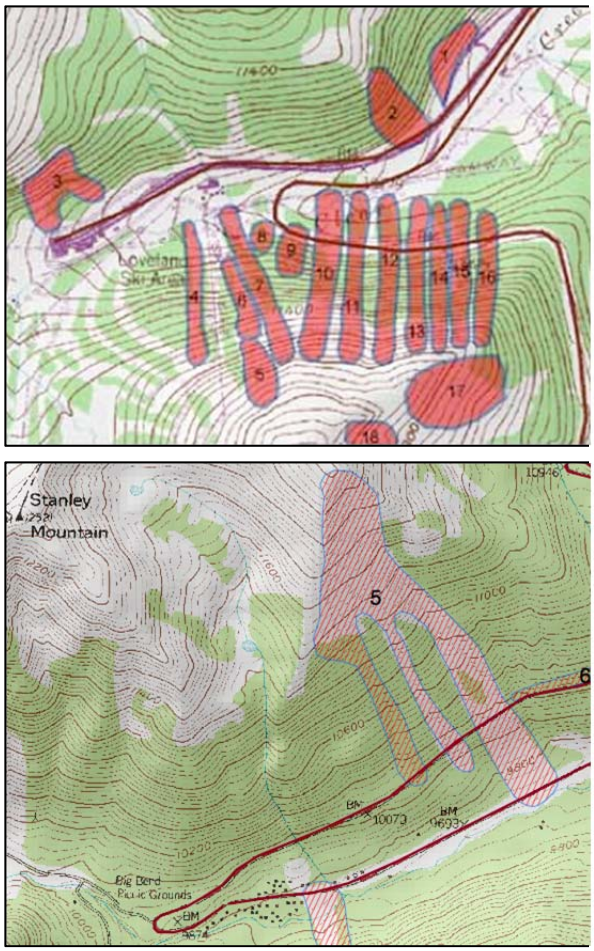

Figure 1. The Seven Sisters (Loveland Pass) and Stanley (Berthoud Pass) study sites. Red polygons indicate avalanche paths to be controlled by GazEx installations, and to be mapped by TLS (maps courtesy *avalanchemapping.org*).

Task 3: Conduct snow-on scans prior to storm events, and pre- and post-Gazex avalanche control operations

Deliverable 4: Pre-control snow depth and storm slab thickness maps

Deliverable 5: Post-control snow depth maps

Deliverable 6: Avalanche area and volume measurements

Field Sites

The proposed work will be conducted at Loveland and Berthoud Passes (Fig. 1). These sites are in high altitude, dry snow, continental environments, characterized by extreme snow depth variability, extensive wind redistribution, and both storm snow and persistent weak layer driven avalanche problems. Gazex remote avalanche release systems will be installed at both sites in Summer 2015. Post-installation TLS surveys will provide snow-free reference elevations for snow depth mapping in subsequent snow seasons.

The survey areas within each corridor allow access to safe scan positions in coordination with CDOT/CAIC personnel. Initial site assessments (*Task 1*) will determine exact scan locations and numbers of scans needed for each site.

Survey Timing and Data Products

Snow-off surveys will be conducted during Summer 2015 to provide a ground reference data set. Actual timing will be flexible to accommodate weather events and construction activity, and scans may be conducted prior to or during Gazex construction to assure snow-free conditions.

Snow-on surveys will be timed to coordinate with loading (storm or wind) events, and with Gazex control activity. Pre-storm scans will establish a snow surface and total snow depth reference data set, post-storm/pre-control scans will allow mapping of storm slab thickness (in addition to total snow depth), while avalanche characteristics and remaining snow slabs (hangfire) will be determined from post-control scans.

Schedule

Project work is planned to commence in Summer 2015, and continue through at least the 2015/16 snow season. Project end date is set at June 2017 to allow for contingencies in snow season 2015/16.

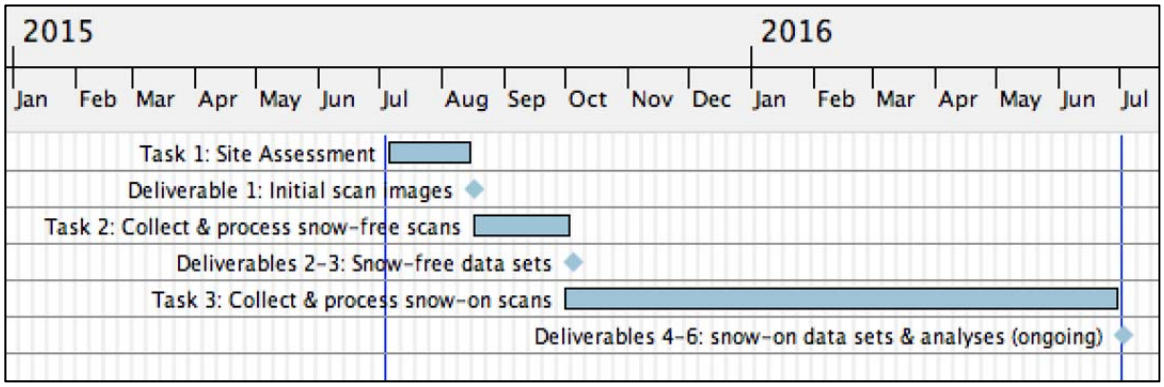

Figure 3: Project timeline.

Facilities, Equipment and Other Resources

Collaboration with Finnegan enables use of the (very expensive) TLS system, developed data acquisition techniques, and specialized processing software, and makes possible this exciting opportunity. Collaboration with CDOT/CAIC personnel provides site access and transportation, and pathways for data product integration with operational avalanche control activities and post-control assessment.

BUDGET JUSTIFICATION

PERSONNEL

Salary for the Principal Investigator is based upon current University of Colorado Boulder academic and staff salary scales. The PI is a Research Associate, and as such is on a research faculty appointment which is not a tenured teaching faculty appointment. The requested level of salary for the PI is 25% time for 10 months. The PI will be responsible for the overall coordination of the project, coordination with collaborators, generation and execution of field planning and data collection, data analysis and post-processing, generation of higher-level data products, and data product delivery and interaction with agency partners.

FRINGE BENEFITS

Fringe benefits are calculated on requested salary per the University's federally negotiated Indirect Cost Rate Agreement, with the Department of Health and Human Services (DHHS). The rate used for the PI is 35.8%.

TRAVEL

Travel funds are requested for the Principal Investigator and collaborator to conduct field data collection, and to attend two conferences: the American Geophysical Union Fall Meeting in San Francisco, CA, and the International Snow Science Workshop in Breckenridge, CO, to present project results. The cost of travel is calculated as follows:

Destination	**No. of Days**	**No. of Travelers**	**Air Fare per Traveler**	**Per Diem: Lodging and Meals, per Traveler**	**Ground Transportation or Vehicle Mileage**	**Abstract and Registration**
Loveland Pass and Berthoud Pass, CO	10	2	N/A	N/A	153 mi/trip @ $0.52/mi	N/A
San Francisco, CA	5	2	$ 500	$280/day	$50/day	$ 510
Breckenridge, CO	5	2	N/A	$194/day	184 mi @ $0.52/mi	$ 510

OTHER DIRECT COSTS

Materials and Supplies:

Other direct costs are included for storage media for management of the large-volume TLS data sets.

Publication Costs:

Publication costs are included for dissemination of results in refereed scientific journals ($2500).

Computer Services:

Other direct costs are included for Computer Services at $250 per year for computer system support, data storage costs, computer and data maintenance services, and computer repair services.

Other:

Funds are requested for computer software and license maintenance at $500 per year.

INDIRECT COSTS

Indirect costs are charged according to the rate agreement specified in the sponsor-generated Request for Proposal, in accordance with prior CDOT and University of Colorado historic research rates. The indirect cost rate for on-campus research is 20% of Modified Total Direct Cost (MTDC), per agreement.

PROPOSED BUDGET DETAILS

Institution: The Regents of the
University of Colorado
572 UCB
Boulder, CO 80309-0572

Title: Assessing Gazex Avalanche Control Effectiveness with Terrestrial Laser Scanning

Principal Investigator: Jeffrey Deems

Duration: 7/1/2015-6/30/2016

	Amount Requested
A. Salaries and Wages	
Principal Investigator: J. Deems	
25% time, 10 months	15,884
Total Salaries and Wages	15,884
B. Fringe Benefits	
PI/RA/PRA/Other: **35.8%** of salary	5,686
Total Fringe Benefits	5,686
Total S/W and Fringe Benefits	21,570
C. Travel	
Domestic:	
Field Work at Loveland and Berthoud Passes, CO:	
10 trips at 153 miles RT mileage	
for personal vehicles,at $0.52/mi	
Field Work Travel Costs	796
2 personnel to AGU	
conference, San Francisco, CA	
RT coach airfare: $500	
Meals/Lodging: $280/day x 5 days	
Registration and Abstract: $450 + $60	
Ground Transportation/Parking: $50/day	
2 trip/yr x $2,660	5,320
2 personnel to ISSW conference Breckenridge	
RT mileage: 184 mi @ $0.52/mi	
Meals/Lodging: $194/day x 5 days	
Registration and Abstract: $450 + $60	
2 trip x $1,576 each	3,151
Total Travel	9,267

D. Other Direct Costs		
1) Materials and Supplies:		
Storage media, portable & hard disks,		500
2) Publication Costs:		2,500
3) Computer Services/Maintenance:		250
4) Other Costs:		
Software and licenses		500
Total Other Costs		500
Total Other Direct Costs		3,750
E. Total Direct Costs		34,587
F. Indirect Costs		
CDOT required Indirect Cost rate: 20.0% of TDC		
Total Indirect Costs		6,917
G. Total Costs		41,504
Total amount requested for one year:	**$**	**41,504**