Montana Department of Transportation

2701 Prospect Avenue
PO Box 201001
Helena, MT 59620-1001
www.mdt.mt.gov

Stage 2 - Research Topic Statement

Print Form

RESEARCH PROGRAMS USE ONLY	
RESEARCH IDEA NO:	23-017
DATE OF RECEIPT:	0520/2022
TOTAL MDT COST W/ICAP:	

RESEARCH PROGRAMS

Please submit completed forms via e-mail to MDTResearch@mt.gov. All fields are required, except the last field: XVIII, Sponsor(s). Incomplete forms will not be accepted.

TITLE (required): Drone-enabled subgrade and embankment assessment

TOPIC STATEMENT: Drone-enabled platforms and sensors have sufficiently advanced that they can now provide useful information on geotechnical issues such as unstable soils in pavement subgrades and within embankment fills. This research would deploy multiple sensors to assess dispersive soils and frozen ground at regional and corridor scales for MDT managed roadways.

RELATED RESEARCH SUMMARY FROM STAGE 1:

Unstable soils in pavement subgrades and within embankment fills have a recurring adverse impact that reduces the service life of roadway and drainage assets in eastern Montana. The problematic unstable subgrades and fills result from unique dispersive soil conditions that are associated with weathering of certain bedrock units. As a result of these conditions within the last 10 years, MDT has or is planning to complete reactive subgrade and drainage rehabilitation projects (east of Glendive and near Terry).

The traditional approach to investigating these conditions involves targeted geotechnical programs in known areas of distress once identified by MDT District Maintenance staff. Once this occurs, the embankment and pavement assets have generally deteriorated to the point of requiring an expensive subgrade rehabilitation or reconstruction, in addition to having to repair failed culverts and other drainage features. By having a program that efficiently identifies areas of dispersive soil on a regional basis, MDT could implement proactive interventions that preserve pavement and drainage assets before the asset has reached the end of service life.

The capabilities of unmanned aerial systems (UAS or drones) and the sensors mounted to them have increased in recent years while costs have dropped, and new national regulations for regular commercial operations have made their use more practical. Research demonstrations have shown that drones can be an efficient tool for assessing transportation infrastructure at regional and site scales as part of asset management programs, including for geotechnical assets. A recent project demonstrated the effectiveness of multispectral sensing from a low-cost drone platform at identifying likely dispersive soils areas at a failing embankment near Terry in eastern Montana, using limited fieldwork. Demonstrations in Colorado in 2021 have extended the use of UAS-enabled sensing to unstable slope areas above highways.
The proposed project would deploy multispectral and hyperspectral sensors from drones to wider regional areas of interest to identify and map potentially dispersive soils that can impact the stability of roads and bridges. In addition, the demonstration project can be expanded to improve the areal understanding of frozen ground in northwestern Montana. Multiple sites would be visited to demonstrate the range of conditions where drone-enabled soil assessment methods can provide cost savings and multiply the value of field data collection efforts.

Through this project, MDT would be able to improve the prediction of adverse subgrade impacts from ground conditions, enabling proactive mitigation to occur before more disruptive rehabilitation and reconstruction projects are required.

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RESEARCH PROPOSED:

We are proposing that an appropriate set of drone platforms and sensors be tested and deployed for identifying and mapping potentially unstable subgrade and embankment areas for at least two types of locations in Montana: dispersive soils such as those found near Terry in eastern MT, and frozen ground in northwestern MT. The focus for sensors is hyperspectral, thermal infrared, and multispectral imaging systems, which use multiple, fine-scale bands of reflected natural color and near-infrared light to identify surface features of interest. MDT's recent project for the Terry slide showed promise using a multispectral, tunable drone-based imaging system for identifying likely dispersive soils. Thermal imaging also showed value in helping to assess differences in eastern vs. western facing slopes. Hyperspectral sensors with hundreds of bands from the ultraviolet to near-infrared can now be flown on a practical basis by drones meeting the FAA small UAS definition. Multispectral sensors have become smaller and less expensive, and easier to deploy on smaller, less expensive UAS. These sensors, along with red/green/blue (RGB) high-resolution cameras for creating base maps, would be deployed for this project to map soils of interests at the study sites. In addition the spectral imaging, conventional photogrammetry methods will be used to generate 3D site models of the surveyed locations that can be used to improve visualization and remote understanding of the sites and eventual change detection through any follow-on photogrammetry or lidar surveys.

This research would include a focused set of field demonstrations across at least two seasons, such as spring and fall, to help identify useful differences in soil surfaces at different times of the year. A future phase could extent this past a one year initial phase to understand how changes in soil-specific surface indicators that can be tracked via drone-enabled sensing over longer periods of time. Field data of soil properties, such as moisture levels and cone penetrating testing, could be collected to further correlate this information to observations in the remote sensing data. Drone flights at different times of day (morning/mid-day/late afternoon) are recommended to identify impacts on the outcomes of soil remote sensing. High-resolution ground control (such as better than 3-inch positional accuracy) will be important for useful mapping results.

The results from these multi-sensor field demonstrations will be integrated into a set of geospatial output products made available for project team and MDT use. Merged images (orthophotos) and digital elevation models will be produced for RGB imagery products. Merged multispectral, hyperspectral, and thermal imagery will also be produced. Image classification software, such as eCognition, will be used to create geospatial outputs that identify soil areas of interest (dispersive soils, frozen soils, other soil types) with precise location and area information. These results will be compared to existing and newly collected ground truth data to create error matrices that report on overall and soil type-specific accuracy. The results will be described in a final report with a focus on how the methods and results can be implemented by MDT on a practical basis, including recommendations for potential longer-term analysis.

RESEARCH PERIOD (Time to complete research project.):

This is designed as a one-year project. Recommendations will be made on how a potential second phase could enable a longer-term comparison of how soil characteristics can change over time, including material volume change (loss/ erosion), and how remote sensing can quantify those changes.

IT COMPONENT: Identify if the project includes an IT component (purchasing of IT hardware, development of databases, acquisition of existing applications, etc.). If so, describe IT component in as much detail as possible.

This project will require the use of several hardware and software resources, such as drone platforms, cameras, GPS units, image processing software, GIS software, and the computers needed to process and display geospatial outupts. However, a well-qualified team should be able to provide most of these IT-related resources for the project. New UAS platforms or sensors may be needed by the research team, depending on the released hardware in the coming months. For MDT, the primary IT resources needed will be storage for the drone imagery and geospatial outputs, and typical GIS software (such as ArcGIS or QGIS) to display the mapping results.

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FEASIBILITY, PROBABILITY OF SUCCESS, AND RISK:

A key sign of feasibility is the recent demonstration project funded by MDT that showed how multispectral sensing from a low-cost drone platform could identify likely areas of dispersive soils at a failing embankment near Terry, MT. MDT's 22-16 Literature Search cited 23 relevant examples from the TRID database, four examples from a RIP search, a Research Needs Statement (RNS) focused on increasing understanding of UAS capabilities for addressing infrastructure issues, and another RNS focused on assessing road conditions with UAS. Three of the papers deal specifically with using drones to assess soil stability issues. These papers support that this project will be feasible, with a high probability of success. Work on unstable slopes in Colorado has also shown promise. Continued advancements in drone flight time and sensor capabilities also support a high likelihood of success. FAA rules have been advancing as well, enabling more practical deployment of drones on a practical basis (especially the 2016 "Part 107" commercial UAS rules). Newer rules on operations over people and remote ID, which have begun to come into effect in early 2021 with full implementation in two years, will enable drones to operate in more areas as part of standard operations as well.

The primary risk to project success is that soil characteristics of interest, such as being dispersive or frozen, may not be able to captured by the types of remote sensing that could be deployed for this project. However, the literature survey and recent dispersive soil UAS project reduce that risk. The primary hardware risk is that a drone could fail during operation. However, a recent AASHTO survey showed that drones are now in use by all 50 state DOTs, and accident reports have been few. This risk should not be any different than the risk from existing MDT UAS work.

URGENCY, IMPORTANCE, AND EXPECTED BENEFITS/PAY-OFF: Address urgency, timeliness, and importance of the research. Identify if the research is required for any federal or state initiative or compliance. This section must include a description of how this research will help to meet MDT's mission (i.e., serve the public by providing a transportation system and services that emphasize quality, safety, cost effectiveness, economic vitality and/or sensitivity to the environment).

This research project is designed to help MDT improve the prediction of adverse subgrade impacts from ground conditions, enabling proactive mitigation efforts to occur before more disruptive rehabilitation and reconstruction projects are required. Where the prior reconstruction efforts have occurred or are planned in eastern Montana, the accelerated rates of soil loss and asset deterioration have resulted in more disruptive and expensive reconstruction or rehabilitation projects that exceed $700,000. In these situations, the early identification of dispersive soil conditions could have enabled lower cost interventions such as targeted culvert and drainage repairs and soil amendments to slow the rate of deterioration and ultimately defer the more costly reconstruction projects.

The resulting preservation of existing pavement, drainage, and embankment assets supports MDT's mission having a high-quality, safe, and cost-effective road system that maintains economic vitality, particularly in rural areas of eastern Montana and remote corridors in the northwestern part of the state. Earlier mitigation efforts have the potential to reduce environmental impacts by dealing with problematic slopes before they fail. With MDT having funded this technology as part of an initial project, this research is very timely, and takes advantage of the increased capabilities of drone platforms and sensors. Addressing slope problems can be also be urgent depending on their location, by reducing the likelihood of a more severe failure that unexpectedly removes the road from service.

IMPLEMENTABILITY, IMPLEMENTATION PLAN, AND RESPONSIBILITY: Address the implementability of the expected results from the proposed project. Identify products that will enhance implementation. Identify any known implementation barriers and how these barriers might be eliminated or reduced. Identify MDT office or entity outside of MDT responsible for implementation. Describe initial implementation plan, include timeframe for implementation.

The primary results will be geospatial layers of mapped soil hazard areas that can be used in a risk-informed proactive mitigation plan executed by MDT. The mitigation efforts can range from systematic and focused monitoring in areas with

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low risk, to development of preservation plans for high-risk sections of highway threatened by dispersive and/or frozen ground..
These results will have a high degree of implementability because of the existing mitigation and asset management capabilities of the MDT Geotechnical, Hydraulics, and Asset Management Programs. Implementation will be enhanced through access to geospatial data results with metadata, a project report that describes drone data collection and image processing methods, and meetings with MDT staff to share results and help guide project direction. The project report will also include a framework for using geospatial data in risk-informed geotechnical decision making.
Barriers to implementation could include unfamiliarity with drone processes, negative changes in drone regulations, or public perception of drone use. To help with MDT adopting drone data collection methods, one or more training sessions for MDT staff should be included in the project. Drone regulations appear to be going in the direction of wider, easier implementation based on the FAA, but monitoring of potential new federal, state, and local laws is recommended to evaluate if this is continuing. Public perception of drone use can be mostly positive by explaining how these tools can increase safety and reduce costs, with social media posts and community forums being helpful. Assuming positive project results, the timeframe for implementation can be as soon as the year following the project. If MDT does not want to acquire the needed drone platforms and sensors itself, it can work with a burgeoning drone services industry to have ready access to hyperspectral and multispectral soil assessment methods.

MDT PRIORITY FOCUS AREAS: MDT may, as often as annually, identify priority research focus areas. These focus areas will be listed on http://www.mdt.mt.gov/research/unique/solicit.shtml.

There are currently no priority areas listed on the MDT Research Project Solicitation page.

TOTAL COST ESTIMATE (If the project proposal comes in at a higher cost, it may require further approval and may be delayed.):

Approximately $200,000 for a one year project is a reasonable estimate to develop and demonstrate the project results.

MDT FUNDING SOURCE (If MDT Research, enter SPR): SPR

FUNDING MATCH SOURCE AND AMOUNT: None yet identified.

FUNDING PARTNER(S): None yet identified.

POTENTIAL TECHNICAL PANEL MEMBERS (At this time, individuals do not necessarily need to be identified; rather, MDT offices and outside entities can be named. However, if known, individuals may be named):

The MDT Geotechnical, Pavement, and Hydraulics Programs may all be interested in this project and would be a recommended source of panel members.

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CHAMPION: Must be internal to MDT, feel strongly that the research will benefit the Department, and is willing to chair the technical panel. Note: If a champion is not identified by you or Research staff, this topic statement will not move forward.

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SPONSOR(S) (optional): Must be internal to MDT (Division Administrator or higher) and willing to ensure implementation occurs, as appropriate. If a sponsor is not identified by you or Research staff, this topic statement will not move forward.

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Note: All research topics submitted become public property and submitters are not guaranteed to receive a contract for any work that may result from this topic statement.