MULT 25-604 – Aerial Precision: 3D Reality Capture and GIS Integration with Drone Technology

Project Proposal

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October 11, 2024

Executive Summary

This document provides a definition of the scope, work, and deliverables for the Aerial Precision project sponsored by GeoDecisions and commissioned by Virginia Commonwealth University to use photogrammetry and LiDAR data to create a viewable map product that may be used by the company to make informed decisions and aid in the development process. Herein are the methods by which the project shall be completed and the limitations that have so far been identified that may limit the design process, and the alternatives that may be used to circumvent those constraints. The problem statement gives a detailed look at the process as a whole and some background information that will be helpful to understand the project and the overall process that will be taken to fulfill the project requirements. The problem statement provides a detailed overview of the project, including background information necessary to understand the project's goals and the process to meet its requirements. The following section presents the design requirements, including the goals and objectives, and then identifies specifications and constraints that will help narrow the feasible design options. Relevant codes and standards crucial to the project's execution are also detailed. The document then defines the scope of work throughout the project lifecycle, outlining the deliverables that will be provided to the sponsor, key milestones to ensure the project stays on schedule, and the resources needed to meet these deliverables. These resources may need to be acquired or purchased during the project timeline. Overall, this document is a jumping-off point to provide the sponsor with a clear definition of what is intended by the project team and what may be expected as the project progresses.

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Section A. Problem Statement

In order to make the most educated decisions about infrastructure projects, visualization of the structure and its spatial data are crucial. Visualization is needed in consulting and design analysis to provide customers with a visual representation of the actual structure in the field and to make the most informed decisions based on the most up to date information. GeoDecisions, a division of Gannett Fleming focused on delivering geospatial technology and data to its customers, has sponsored this project through Virginia Commonwealth University to design and prepare a process to use drone technology to make three dimensional models of worksites in order to fulfill this mission.

While many tools exist already to do much of the photogrammetric and geospatial processing, the project sponsor seeks a way to bring all of these tools together into a streamlined, efficient, and replicable process that spans from collecting the raw data in the field using LiDar and geolocation-embedded aerial imagery to processing it through a GIS system and then displaying that data through the chosen set of tools in an easily deployable and accessible online platform. This may then be used either within the company as a way to analyze projects and sites or as a way to provide information and insight to its clients. This project seeks to streamline this process and provide the most efficient means of taking it from the data collection stage to the data display stage. As GeoDecisions is an ESRI Partner, the incorporation of the ESRI software suite in as much of the design process as possible is a major focus in order to expand the capability of the tools that are already available and preferred by the company [5].

The first portion of the project will be dedicated to determining the appropriate hardware for use with the project. This will include determining which type of drone, sensors, and other materials will be needed in order to collect the appropriate type and amount of data needed for successful runs of the process being designed. This includes both photogrammetry and LiDar data, both of which will be assessed for their benefits and drawbacks as well as for the method by which the data is formatted, processed, and visualized in the context of a GIS system. LiDar data has already been used in the planning, maintenance, and design of projects across many industries including surveying, construction, and highway development [3]. Photogrammetry shares many of these use cases and also contributes a greater ability for creating maps due to its photorealism and color [4].

The next stage of the project will then take the data collected and determine the best way to preprocess the data before it is imported into the GIS software suite. This will include the extraction of the data from the chosen hardware and ensuring it is in the appropriate format before importing it into the next stage, which will be the integration of the data with the ESRI suite. This will include learning and researching the capabilities of ESRI's products, specifically the ArcGIS line of products including ArcGIS Pro and ArcGIS Online, as well as some of the extensions and geoprocessing tools that may assist in the execution of the project goals. Alternatives for these software components exist, including QGIS as an open source GIS software and other paid tools that run cloud-based photogrammetry, but because all of this software is already in use by the client and accessible to them, the ESRI suite will be the best option for the deployment of this project [1]. It also provides all tools within one suite, whereas two or three may be required from different developers if using an alternative that would likely make the project less cohesive and more complicated. This will be a major component of the work and will lead into the next stage, creating a view of the data for the end user.

Creating ways to visualize the collected data in an easy to understand and useful manner will be the component of the project most visible to the end user. Many possibilities for displaying the data exist, but in order to stay within the ESRI software system at the request of the sponsor and it already being integrated with the software being used for the processing stage, ArcGIS Online will be the target platform for creating a viewer for the data. Other alternatives would have included creating a custom web interface likely with server functionality, which would have exceeded the scope and purpose of the project and would have been too lengthy to do in contrast to what is already available through ESRI. Another would be using another proprietary alternative such as GeoSolutions MapStore, but would have run into similar complications with compatibility and would cost more money than using what is already available to us [2].

Once the process from drone data to a viewer is complete, the project will move to document the best methods developed during the prototyping stage in order to provide a technical plan of operation (TPO) to the sponsor to create replicable results that can be applied in the day to day operations of GeoDecisions. After creating the plan of operation sample data that has been processed and put into a viewer will be provided as well to aid in the proof of concept and provide anyone seeking to replicate the results with the same data to test the system with.

While many companies face the challenge of learning how to use and integrate this new technology into their workflow, GeoDecisions is seeking to better utilize the tools already at their disposal to incorporate the visualization from data retrieved through drone technology into their offerings to their customers and in their own decision making process. By completing this important work, the project will deliver a streamlined process that makes the development of this type of insight more accessible to the company and will allow them to offer drone data comparable to and competitive with others in the geotechnical industry to place them at the leading edge of consistent drone integration into geospatial projects.

Section B. Engineering Design Requirements

The design requirements for this project focus on creating a drone-based system capable of collecting photogrammetry and LiDAR data, processing it into 3D models, and displaying it via a web-accessible interface, such as ArcGIS Online. Key constraints include the drone's ability to carry the necessary sensors, process data into compatible formats like .las and DEM, and integrate with existing hardware within the sponsor's budget. The workflow must be optimized for efficiency and thoroughly documented to ensure replicability, all while adhering to federal, state, and local regulations.

B.1 Project Goals (i.e. Client Needs)

This project aims to produce an efficient, repeatable workflow for producing detailed 3D models of structures and worksites and making them available in a web interface. The completed workflow will integrate with existing tools that the sponsor prefers, with data collection performed by an aerial drone with sensors for photogrammetry, LiDAR, or both. Documentation is a key component of the final project, as it will allow the sponsor to reproduce results at sites beyond the sites flown in support of the design and development of the initial models.

- Design and implement a drone-based system for collecting photogrammetry data, and explore options for integrating LiDAR data into the system.
- Determine optimal processing workflow to translate collected data into 3D models within a web-accessible environment.
- Produce the completed model in a geolocated virtual environment, along with a functional interface for viewing and interacting with the model.
- A Technical Plan of Operations, or the documentation of how to run the workflow
- Provide a framework, or exploration of the possibility, of additional computer vision or machine learning enhancements on top of the processing framework or interface.

B.2 Design Objectives

Based on the project goals, the completed design must achieve a number of clear, measurable objectives. Among these are the physical objectives of the drone system and any integrated sensors, as well as the process objectives that will detail the workflow of how the system operates. The major objectives of this project are listed below:

- The drone will carry the necessary payload to collect GPS, photo, LiDAR, and kinematics data.
- The drone and payload will be specified within the budget of the sponsor, or use existing hardware in order to stay within budget and provide requested functionality.
- The workflow will be developed within an industry-standard application, and be optimized to the extent possible in order to reduce flight and processing time.

- The documentation will be specific and detailed, providing all steps necessary to recreate the results of the original collection run(s) and subsequent model(s) from this project.

B.3 Design Specifications and Constraints

In order for the proposed data collection system and documentation to meet the objectives above, there are a number of considerations that need to be accounted for, especially considering the need for the completed project to integrate with an existing digital environment. Chief among these specifications and constraints are the *Functional constraints*, like the ability to collect sponsor-specified data and complete the processing in a timely manner, the *Cost and Manufacturing constraints*, like part or sensor availability, and the *Data and Interoperability constraints*, like ensuring the system can be structured within existing tools or frameworks.

- The design must be able to carry sensor payload (camera and/or LiDAR unit) along with any onboard data storage/processing needed for a minimum of 20 minutes (*Functional*)
- Data collected must include geolocation information (GPS) in order to properly encode photo and/or LiDAR data (*Data*)
- Data must be processable into .las file types (LiDAR) or digital elevation models (DEMs) of either digital surface model or digital terrain model (DSM, DTM) type (*Data*)
- Design must integrate or accept input from the existing drone as specified by the sponsor [DJI Mavic Air] (*Functional, Interoperability*)
- Documentation should be complete to the point that no further resources are required (aside from hardware) to reproduce results at different sites (*Functional, Maintenance*)
- Design must not interfere with other aircraft, radio signals, and their reception/transmission, and any law enforcement or emergency services, per Federal Aviation Administration, Federal Communications Commission, and Virginia State codes and regulations (*Functional*)

B.4 Codes and Standards

FAA Part 107:

Sets standards and establishes guidance regarding FAA Remote Pilot Certification, operational limitations, and airspace restrictions.

Virginia Code § 15.2-926.3 (Local Government Regulations):

Local governments in Virginia are allowed to regulate drone use in specific areas. Therefore, if you are flying in a certain city or county, check the local ordinances for any additional restrictions.

Section C. Scope of Work

This project will develop a streamlined process for collecting, processing, and visualizing drone-based photogrammetry and LiDAR data to enhance decision-making for infrastructure projects. The scope of work includes identifying the appropriate drone hardware and sensors, collecting and preprocessing the data, and integrating it with the ESRI ArcGIS suite for geospatial analysis. The final stage will focus on building an accessible ArcGIS Online viewer for stakeholders to visualize and analyze 3D models of work sites. Deliverables include a technical plan of operation and a proof-of-concept dataset for replicable use, along with the Capstone-specific items like the abstract, project posters, and formal report.

C.1 Deliverables

The following deliverables will be provided to ensure a comprehensive and replicable process for the drone-based mapping system, from data collection to visualization, along with supporting documentation and a representative dataset. Although the majority of the deliverables are determined by the sponsor, there are also posters, abstracts, and project reports that all Capstone projects must include. These deliverables will serve as key outputs of the project to facilitate future use and analysis by the sponsor.

- Technical Plan of Operation (TPO): Detailed process for replicating data collection, processing, and visualization, including implementation of the modeling process from start to finish.
- ArcGIS Online Viewer Template: Example setup for displaying 3D models of collected data.
- Sample Data: Data set used for testing and replicating the modeling process.
- Code and Tools: Any custom code or tools developed during the data optimization and workflow process.
- Completed Data Collection Run(s): Collected and processed data displayed in a web portal.
- Final Project Report: Comprehensive report summarizing the project's methodology and results.
- Posters, Flyers, and Presentation Materials: Visual materials for project dissemination.
- Project Proposal and Timeline: Initial project scope and timeline for execution.
- Bi-weekly Updates and Weekly Status Reports: Regular updates to track project progress.

C.2 Milestones

The project can be broken down into a number of milestones that correspond to both project objectives and deliverable deadlines. Each milestone builds off the progress of the previous ones, and the timeline established (Appendix 1) should be reflective of the overall pace of the project, despite being an informed projection and not a strict schedule. Any changes to the project scope, deliverables, and milestones should be thoroughly discussed and mutually agreed upon by all parties, and documented and justified in detail.

- Startup/Kickoff: Make introductions as a full team to establish the *team contract*, general meeting schedule, and rough scope of the project.
- Initial Research: Meet with sponsors and determine the needs, wants, and expectations of the finished design. Begin researching in order to specify the project and create a *project proposal*.
- Design I: Select sensors, drones, and other hardware. Gain access to ESRI suite and begin determining what tools will be needed to process data.
- Design II: With sample dataset, display projection of real-world geometry in ArcGIS, begin web portal access research
- Design III: Develop interim workflow based on results of sample data processing, and *finalize design* for data acquisition system.
- Design Documentation: Provide finalized documentation of the design, and detail completed work on the *Fall design poster*.
- Design Reporting: Document the final project design in a formal report as a guideline for implementation during the Spring semester.
- Pre-Implementation: Finalize data collection and preprocessing workflows as needed, and perform setup of digital tools and environment for data collection.
- Implementation I: Determine test location, develop flight plan and best practices, refine limitations and guides for location survey in general.
- Implementation II: Perform test flight, collect results, and verify data entered into ESRI ArcGIS tools behaves as expected for pre-processing. Further, refine pre-flight workflow.
- Implementation III: Derive 3D models from processed flight data based on established design, and place models in a representative virtual environment.
- Final Implementation: Provide *web portal access* to the model in a user interface, allowing time for layout and function refinements.
- Finalized Documentation: Taking into account previous notes and revisions, produce a *technical plan of operation* that details the process from hardware selection to environment viewing.
- Presentation of Results: Produce and display the *project abstract* and *final poster*, and present them to peers and stakeholders for evaluation.

C.3 Resources

Resources for the project will be provided almost entirely by the project sponsor, GeoDecisions, as they are the primary stakeholders. We will specify a variety of hardware and software requirements that we expect to work best in this application. However, the final decision of what equipment to use is based on company resources, preferred systems, and familiarity. Expected resources include:

- ESRI ArcGIS Suite - Data processing and visualization tool for GIS data.
- A Drone with high definition camera, and the ability to integrate further sensors (LiDAR).
- Computer resources for data processing, flight planning, and other data tasks.

- IDE for software development, including Python and necessary dependencies.
- Virtual environment for building models and implementing processing code.
- Any data provided by the sponsor that can be used to implement into ArcGIS.
- A LiDAR sensor is to be integrated into the drone and be used in the implementation phase.

ESRI ArcGIS suite is being provided as the core tool for our implementation of the project. It will be used to convert and link the data from the drone and LiDAR sensors into photogrammetry data. This tool was chosen because it is easily accessible, and is used by GeoDecisions, which will provide us with a license to use the software. For our drone on the other hand, we are given a drone from GeoDecisions mentioned previously; however, we are recommending the use of DJI Matrice 300 RTK for its various features and easy integration software into ArcGIS. Another possibility would be the DJI Mavic 3 Enterprise, which is similarly designed with a high-spec camera and the ability to expand function with other payloads. The drones, while both excellent choices for a full-featured drone mapping system, are priced outside of the budget range, and since we are given a drone to use already, we could use the funding to choose a better LiDAR sensor.

For the LiDAR choice, originally, it was expected that the LiDAR of choice would be YDLIDAR G4 since it was easy to use and cheap to purchase. However, after some research and design changes, there were two options to replace it with, Livox 360 and Unitree 4D LiDAR. Both are very capable and easily integratable onto a drone system. Another design decision was the availability of these choices and since the Unitree LiDAR was available at the time of ordering, we decided that it would be the best option to include in the project as well as its wider range of detection compared to its competitor, Livox 360.

As for an IDE, it is recommended that we use a universal IDE that can be accessible to anyone who is trying to replicate the process. For example, VScode is a great example of a universal IDE.

Section D. Concept Generation

The design concepts explored in this section are divided among potential options for hardware, processing software, and display options. Three alternatives are provided for each, with a small description of how each of the alternatives impacts the design overall.

The two major components of hardware for the project are the drone, which typically includes the camera and the Lidar sensor. These are the two options for creating three-dimensional models that will be explored by the group to be able to determine a workflow, although for simplicity the photogrammetry option is favored more by the sponsor for its ease of use, ability to provide colored data, and the fact that it has been implemented previously by other divisions of the company. For the drone, one option is the Mavic Air 2. The sponsor already has a model of that drone that they are comfortable with using, and it would allow the project team not to have to buy that drone. Another drone option includes the DJI Phantom series, which is larger and would be able to carry a larger payload and is still within the consumer-range budget. Other higher-end options exist including the Matrice or Inspire lines of drones by DJI, but they are quite expensive compared to the others and for our purposes would not provide a very significant advantage. There are also the DJI Mini series of drones which are on the cheaper range of the DJI line, which would work very well for photogrammetry as well, but would not be able to support the load whatsoever of a Lidar sensor. For Lidar sensors, the two options considered were the Livox Mid-360 and the Unitree 4D LiDAR L1RM, both of which provide similar functionality, and Livox comes with a proprietary Livox Viewer in order to be able to visualize the data. Both options come with a software development kit (SDK) which would be used to process the data after it is collected.

For processing software, a decision needs to be made out of the many varieties of geospatial software on which would be best to use. Because the sponsor, GeoDecisions, is an ESRI partner, the ESRI suite of tools including ArcGIS Pro is a very viable option for the processing of the data once it is produced, and it is able to be combined with other ESRI software packages as well that the sponsor is able to provide. An alternative to the ESRI suite is QGIS, a free and open source software that provides geospatial processing similar to ArcGIS. Naturally, this would seem to be a good option if ArcGIS was not available through the sponsor. ArcGIS includes its own photogrammetry suite called ArcGIS Reality. There is a tool called Pix4D that provides similar photogrammetry functionality that would serve as an alternative as well.

In terms of displaying the data once it has been processed, the two major options would be to use something proprietary or to create a viewer from scratch. Creating a viewer from scratch, while it would provide the most flexibility, would be difficult to implement for someone in the company looking to create a quick model and detracts from the goals outlined by the sponsor for the project. The alternative, using proprietary software, would partially depend on the software suite chosen to do the processing. ArcGIS provides ArcGIS Online as a way to publish data that has been processed in their software suite, and that was the method preferred by the sponsor because their company prefers to use it and has done so with their other projects.

Section E. Concept Evaluation and Selection

The process of evaluating design concepts involves a systematic approach that ensures an objective, data-driven selection of the most suitable option. A Decision Matrix, also known as a Pugh Matrix, was utilized to compare and assess the performance of multiple design concepts against established selection criteria. The criteria used for evaluation included Performance, Cost, Safety, Reliability, and Risk, each of which was assigned a weight to reflect its relative importance in achieving the project objectives. The design concepts considered were the **DJI Mavic Air + Unitree 4D LiDAR L1RM**, **DJI Matrice 300 RTK + Ouster Velodyne VLP16**, and **DJI Mavic 3 Enterprise + Custom LIDAR**. Each concept was scored according to its ability to meet the criteria, with raw scores transformed into weighted scores based on the importance of each criterion. The inclusion of the Unitree 4D LiDAR L1RM in Concept 1 marked a significant enhancement from the original YDLIDAR G4, offering greater precision, higher uptime, and reduced risk, albeit at a higher cost. This change led to an increase in the overall total score for Concept 1, reflecting a more robust and reliable design choice. The Decision Matrix not only facilitated a rational comparison between alternatives but also minimized bias in the selection process, ensuring that client needs, regulatory constraints and operational efficiency were all accounted for. By providing quantifiable justification for design selection, the process builds confidence in the chosen concept and aligns the project team and client on a unified path forward. Table 1 shows the decision matrix for choosing between these designs based on a weighted factors of each criteria.

Table 1 Decision matrix for design concepts

Criteria	**Design Concept A (DJI Mavic Air + Unitree 4D LiDAR L1RM)**	**Design Concept B (DJI Matrice 300 RTK + Ouster Velodyne VLP16)**	**Design Concept C (DJI Mavic 3 Enterprise + Custom LIDAR)**
Performance	85	95	85
Cost	80	60	70
Safety	90	90	80
Reliability	85	95	85
Risk	80	85	75
Total Score	83.75	85.25	79.25

Since the sponsors have already provided us with the Mavic Air, this cuts down the cost of buying a new drone for the concept of the project and allows us to use the available resources. Furthermore, The Unitree 4D LiDAR used has a better overall score in terms of visibility and readability. Hence why it was chosen as a design concept and a criterion.

Section F. Design Methodology

This section details the iterative design process used to evaluate, improve, and validate the drone-based mapping system. The methodology integrates computational modeling, experimental testing, and client validation to ensure the final design meets all specified objectives and client needs.

F.1 Computational Methods

Computational tools play a vital role in evaluating and iterating on the design of this drone-based mapping system. The methods employed include:

GIS and 3D Model Processing

- ArcGIS Pro: Primary software for integrating photogrammetric and LiDAR data, performing geoprocessing, and creating 3D models.
- Data Formats: Input datasets include LiDAR data (.las files) and photogrammetry-derived DEMs (DSM and DTM). Outputs are assessed for accuracy using built-in geostatistical tools in ArcGIS.
- Boundary Conditions: For photogrammetry, overlapping imagery with 60-80% forward and side overlap ensures complete and accurate reconstruction. LiDAR processing involves ground point filtering and vegetation removal to create digital terrain models (DTM).

It is assumed that weather and lighting conditions during data collection are optimal, minimizing noise in photogrammetry and LiDAR datasets. Post-processing tools exist to help denoise data.

Modeling and Simulation

- Drone Flight Path Simulation: Tools like DJI Flight Simulator or mission planning software are used to optimize flight paths and sensor coverage.
- Payload Balance: Using electronic measurement techniques, center of gravity will be maintained before and after installation of sensor payload.

F.2 Experimental Methods

Experimental testing ensures that collected data meets specifications for geolocation accuracy, coverage, and model quality.

Field Testing

- **Drone Testing Setup**: Test flights conducted at designated locations simulate actual worksite conditions. GPS accuracy is evaluated by comparing drone logs with ground control points (GCPs) represented by team member phones.
- **Sensors**: Both photogrammetry cameras and LiDAR are tested for resolution, point density, and range.
- **Test Environment**: Urban and rural environments are selected to evaluate the system’s robustness in varying conditions.

Data Validation

- **Control Data**: Ground truth data, such as measurements from surveying tools, validate LiDAR-derived models and photogrammetry DEMs.

Testing Equipment

- Drone with sensor payload for flight tests.
- GPS devices (smartphones) for GPS data accuracy validation.
- Surveying or measuring equipment for physical data accuracy validation.

F.3 Architecture/High-Level Design

The workflow architecture comprises the following stages:

Data Collection:

- Drone missions are planned with specified flight paths and sensor configurations.
- Data formats (e.g., .jpeg for photogrammetry, .las for LiDAR) are determined based on ArcGIS compatibility.

Data Preprocessing:

- Image alignment and stitching in photogrammetry tools (e.g. Drone2Map).
- LiDAR data preprocessing includes noise filtering and terrain classification.

ArcGIS Integration:

- Data is imported into ArcGIS Pro for geospatial processing and 3D modeling.
- Metadata ensures traceability, including timestamps, GPS coordinates, and sensor settings.

Web Deployment:

- Final 3D models are published to ArcGIS Online, allowing users to interact with models through a web viewer.

F.4 Validation Procedure

The validation procedure ensures that the final design meets the sponsor's needs and adheres to design objectives. Our sponsor is planning to provide a dataset from one of their client worksites for our final presentation and validation, so we can prove the process on a dataset as similar to real conditions as possible. Our aim is to have the Data Preprocessing and ArcGIS Integration stages completed using sample data collected by team members in order to smoothly and rapidly integrate the provided data for validation.

Client Review and Demonstration

- **Timeline**: Validation is scheduled for **mid-April**, with preliminary results (TPO, test datasets) shared by **late March**.
- **Demonstration**:
  - A live demonstration of a processed dataset is presented in ArcGIS Online.
  - The Technical Plan of Operations (TPO) is reviewed to ensure replicability.
- **Feedback Capture**:
  - Record **interview notes** during the demonstration to document client suggestions.
  - Allow the client to explore the web viewer and observe interactions, noting pain points or feature requests.

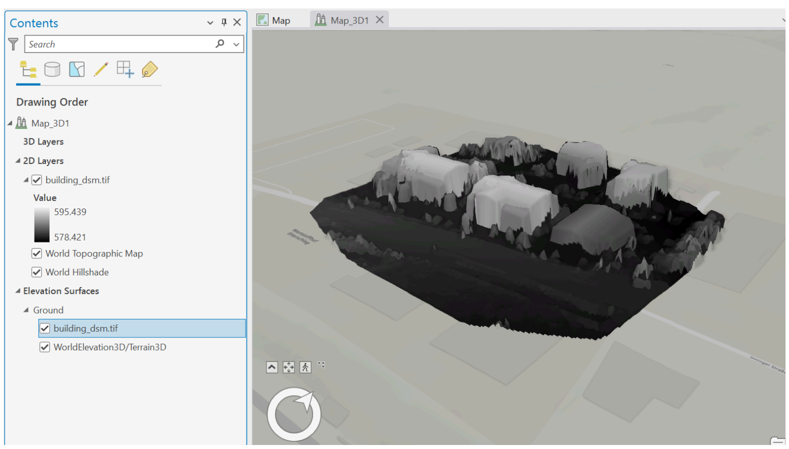
Metrics for Validation

- **Usability**: Assess the web viewer for load times, navigation ease, and clarity of data presentation.
- **Accuracy**: Compare final 3D models to ground truth data, ensuring geolocation accuracy meets specifications.
- **Workflow Efficiency**: Document the time required for each stage of the workflow, aiming to meet or exceed established benchmarks.

Section G. Results and Design Details

In preparation for defining a streamlined process for bringing data from the collection stage to a display on ArcGIS online, the team began with understanding the methodology and tools that ArcGIS provides for data that has already been prepared. The first process explored was a model created from photogrammetry.

An online pre-processed model was found that provided downloadable formats of the completed model. This model was then imported into ArcGIS in order to create a layer. The first attempt at this used a *.obj* file, which did not allow for the proper placing of the model onto the correct coordinates. After further research, it was determined that using a DSM (Digital Surface Model) would allow for the data to be properly placed in the correct location, as well as for easier processing into a three dimensional model. The drawback of the raw DSM model is that it does not contain the image data natively, so an image was overlaid on the model in the viewer just to display the capability. The following photos show first the DSM placed in ArcGIS Pro and then it displayed in an ArcGIS Online viewer with a photo overlaid.

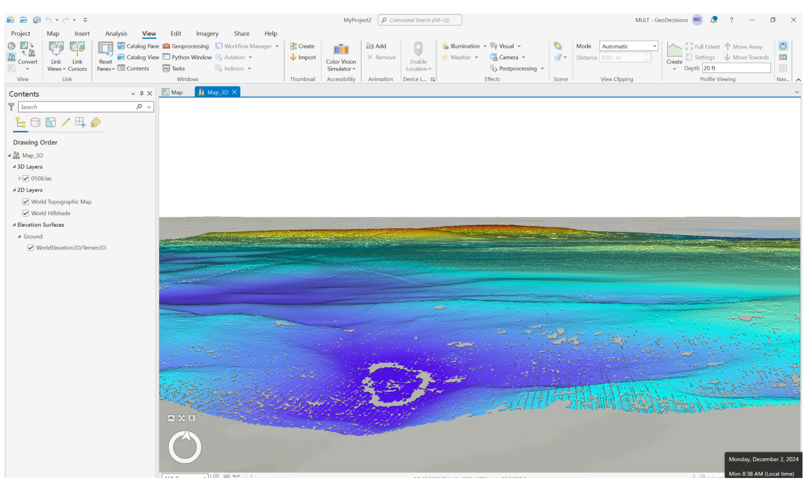


Screenshot G1

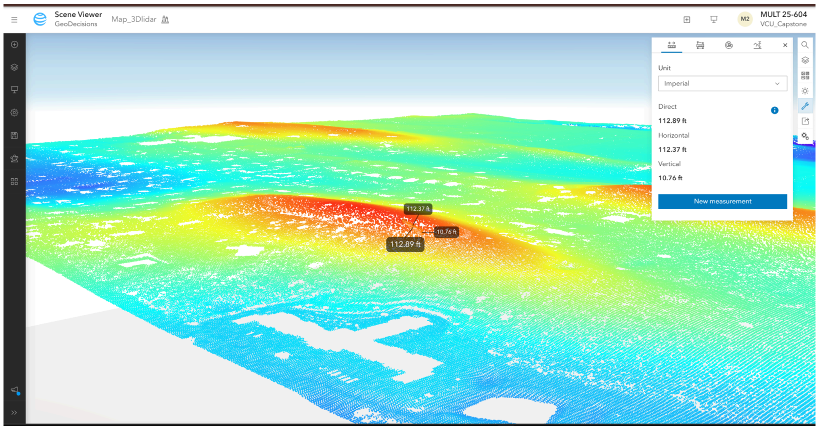
Screenshot G2

While the latitude and longitude coordinates are correctly placed when converting to ArcGIS Online, it seems that the projection is not interpreting the z-axis values correctly, which is something that will be explored further in order to fix the issue. It is also something that may be solved when access to ArcGIS Reality is granted, as we will not be using random models but ones that were crafted by the team from the beginning. The biggest limitation for this process at the moment is not being able yet to create our own models through ArcGIS Reality, which will create *slpk* (scene layer package) layers in the software that will include both the DSM model that will produce the spatial layout and the photographs that will overlay it in a way that is realistic, instead of the overhead image as in screenshot G2 above.

The other process explored was the Lidar data, and a Lidar dataset was found online with a *.las* file extension. That was also imported into ArcGIS Pro in order to process and view the data. The following were produced, the first in ArcGIS showing the Lidar data and its relation to the default hillshade and the second showing the data being displayed in ArcGIS Online.



Screenshot G3



Screenshot G4

In screenshot G3, it is clear that the Lidar data follows well the contours of the ground and is displaying well in the scene, which means that to that point, we have a good process defined. The data moves well to ArcGIS Online, except that the z-axis values again get distorted and the model ends up high in the air. This is again just a projection issue, and will be something that will be worked on as the project progresses. Screenshot G4 also shows the use of the measurement tool that is by default enabled in the scene viewer, and something that will be useful in custom scenes and maps as we work more closely on the ArcGIS Online side of the project. The Lidar data that is used here covers a much larger area than what will be used during the project, and has less complex shape, which will be other considerations as we begin doing our own scans with the Lidar. The team has also been doing preliminary scans with the Lidar during the familiarization process over the last bit of the semester while it has been in the team's possession, but the process is still in its infancy and is not yet ready to be imported into ArcGIS.

Section H. Societal Impacts of Design

H.1 Public Health, Safety, and Welfare

The drone component of the project is perhaps the most applicable to health, safety, and welfare concerns. Because drones do come with a small level of risk, there is always the chance that something could go wrong during flight and end up injuring someone. While legal precautions aim to eliminate some of these concerns, the operator must remain wary of people in the nearby area and must not put the drone at risk of hurting someone. Beyond physical injuries, drones have some privacy concerns that might impact public well-being, as well as sometimes being loud and disruptive when flown around people. Any flights must do their best to reduce those impacts.

H.2 Societal Impacts

Because Geodecisions works with many clients who have projects that are providing benefits to the public through infrastructure and production, the project has a societal impact in providing the purveyors of these publicly used projects the best geospatial information that photogrammetry and Lidar are able to provide within the ESRI scope. They will have the ability to use the information gained through replications of the process defined by this project to make informed decisions that will make their projects more safe and more beneficial to the public.

H.3 Political/Regulatory Impacts

There are few policy impacts that may result from this project, save any that may come from the benefit that this process may have in advising regulatory agencies or legislators through GeoDecisions' relationship with its clients. All applicable drone and photography laws will be strictly adhered to by anyone involved in the project.

H.4. Economic Impacts

The nature of producing this detailed process was to provide a method for GeoDecisions to most effectively communicate its geospatial data to its clients in a way that allows them to visualize and make informed decisions about projects that they are working on with the firm. In this way, the results of this project will be able to be implemented into the workflow of members of the GeoDecisions staff to work with clients and help to make the best and most informed business decisions. It will also provide a relatively cost effective way to produce imagery through the use of smaller hardware such as drones that can be operated by someone within the company rather than to have to contract out with an aerial photography firm that may charge a large amount of money and that would need to be paid for each project. This allows employees within Geodecisions to produce their own aerial maps and three dimensional models whenever it is necessary, which is a financial benefit to the company.

H.5 Environmental Impacts

The design process by its nature has little physical development, but there are still impacts that the overall project may contribute to the environment. Because many of Geodecisions' clients are in infrastructure, and these projects are outdoors and must be implemented within the physical natural environment, the insights that will be provided through use of the completed process will be able to help the clients make informed decisions that will be in the best interest of natural preservation and that will allow projects to be seamlessly integrated with their surrounding nature. One thing that a user of the process must be conscientious about is the flying of the drones and the potential impacts that can have on wildlife in the areas around where the drone is being operated.

H.6 Global Impacts

Photogrammetry and Lidar data are already collected and processed at a global scale in order to create depictions of the earth and to provide geospatial information to users both professionally and personally. As this project expands on some capabilities that are already available and implemented, the resulting documentation from the project will provide detailed explanations and instructions on how to use the specific toolset defined by the sponsor to create such representations of data. Furthermore, Geodecisions serves clients at the federal, state, and local government level and in the power and energy, transportation, and water utilities sectors. With clients in such a broad array of industries and at different levels of government, this project will provide the company an effective and optimized method to serve these clients using the methodologies that have been developed and condensed into the Technical Plan of Operation. This will allow the company to provide a consistent product and representation of their projects to their various stakeholders and a uniform method of collecting and retrieving data for different clients.

H.7. Ethical Considerations

Photographic content naturally elicits thoughts about personal information being digitally stored and recorded, and the ability of drones to maneuver around buildings and populated areas are also something to consider. Photography of individuals when collecting data for a run through the pipeline should be kept to a minimum and avoided unless they explicitly consent to being in the photographs. This applies to panoramic photographs as well. Drone flying for the purposes of collected photographs and imagery for the pipeline should be done with proper discretion and regard for the people and buildings in the surrounding area. Drone flying should only be conducted for the explicit purposes of creating the model and should not be used recreationally when conducting a site survey. Proper licensing and certification should be used when flying drones. Any people in the area of the flight should be informed of the reason for the drone and the area covered if it poses a significant disturbance of privacy or safety. Data maintained in the GeoDecisions ArcGIS accounts and for site surveys should only be shared with the relevant parties so that no trade or industry confidential information is able to be obtained by a third party. Caution should therefore be used when displaying created models or other data to someone not involved in the project.

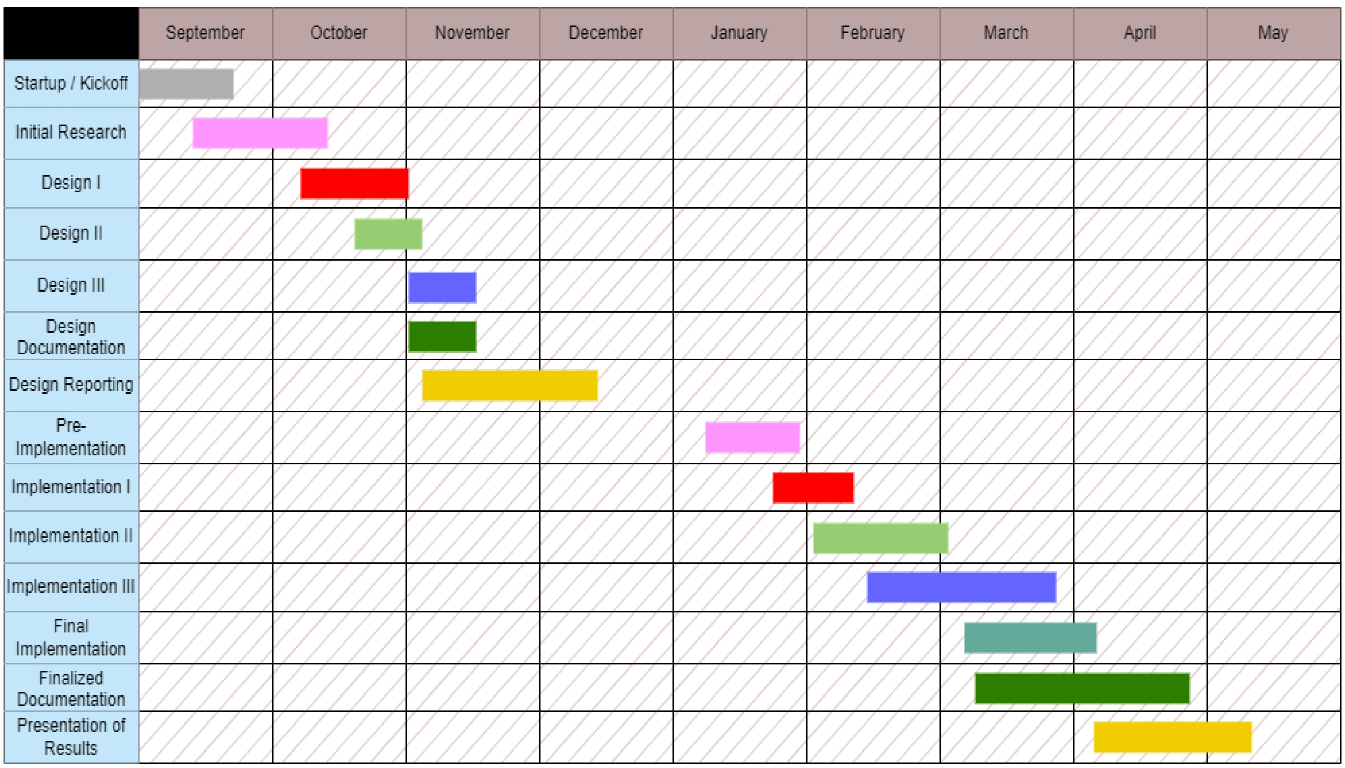
Section I. Cost Analysis

Cost Breakdown of the Project

Item	Count	Cost
Unitree 4D LiDAR L1 RM	1	$309.00
	TOTAL:	$309.00

Appendix 1: Project Timeline

Here's a Gantt chart that outlines a rough timeline for the project. This Gantt chart can be subject to change depending on the design and implementation of the project. It specifies over which period of time each phase of the project should be completed and ensures that the project is progressing as it should over its duration. This is meant to keep the team on track and to give a rough estimate of when certain tasks should be completed to be on track with submitting the project and deliverables in an appropriate time frame.



Appendix 2: Team Contract (i.e. Team Organization)

MULT 25-604 – Aerial Precision: 3D Reality Capture and GIS Integration with Drone Technology

Team Contract

Prepared for

Matt Merrill

GeoDecisions

By

Adil Adil

Grady Beck

Colin Drake

Nathan Germain

September 4, 2024

Contents

Step 1: Get to Know One Another. Gather Basic Information.

Team Member Name	***Strengths each member bring to the group***	***Other Info***	***Contact Info***
Adil Adil	Circuit Design, Programming, Problem Solving, Time Management, Work Ethics, Leadership, Task Allocation, Drone Experience	VCU Makerspace Certified, FSAE Experience	adila2@vcu.edu
Grady Beck	Programming, Drone Experience, GIS Experience (ArcGIS), Time and Resource Management, Work Ethic, Communication	Computer Science Student	beckgm@vcu.edu
Colin Drake	Communication, project management, results-driven, prototyping, programming	VCU Makerspace Certified	cdrake3@vcu.edu
Nathan Germain	Problem-solving Some experience in FPGAs and embedded design, Logistics	VCU Makerspace Certified	germainnt@vcu.edu

Other Stakeholders	***Notes***	***Contact Info***
Faculty Advisors (Yuichi Motai, Tamer Nadeem)	Dr. Motai is the ECE advisor. Dr. Nadeem is the CS advisor.	ymotai@vcu.edu tnadeem@vcu.edu
GeoDecisions (Matt Merrill)	Senior Technical Solutions Director	mmerrill@geodecisions.com

Step 2: Team Culture. Clarify the Group's Purpose and Culture Goals.

Culture Goals	***Actions***	***Warning Signs***
Openness about deadlines and objectives	- Be transparent about progress, especially if deadlines are close - Be willing to schedule time for critical tasks, even when inconvenient	- Team members do not respond to requests for progress updates - Vague scheduling conflicts without reason/justification
Responsive communication and professional decorum	- Requests for input and scheduling are replied to in a timely manner - Team members assume positive intent, and constructively address interpersonal issues	- Team member provides deliverables with little time to integrate and bug check - Not replying to group messages within a reasonable time
Collaborative engagement	- Divide and delegate tasks fairly, let each other work to our strengths - Help one another where applicable, and make an effort to understand the work of others	- Hogging drone flying time - Regularly delegating work to others without producing personal results
Informal gathering and teambuilding	- Find time to meet where project work isn't the priority - Engage in common interests, study other classes, gripe about work, etc.	- Repeatedly finding excuses to avoid informal gatherings
Standards and uniformity	- Documentation and communication are to be formatted in a standard fashion to promote professionalism	- Comic Sans - Arial

Step 3: Time Commitments, Meeting Structure, and Communication

Meeting Participants	*Frequency* *Dates and Times / Locations*	*Meeting Goals* *Responsible Party*
Students Only	As Needed, On Discord Voice Channel	Update group on day-to-day challenges and accomplishments
Students Only	Every Wednesday Evening, on Discord and every Monday in person after faculty update meeting (below)	Actively work on the project and update any documentation we have or need (everyone participates)
Students + Faculty advisors	Will meet on Monday at 3:30pm in ERB 2308	Update the faculty advisors and get more information about certain aspects of the project.
Project Sponsor	Once a Month, Either over Zoom or in person	Determining Project expectations and goals, requirements, and feedback. Each team member is responsible for being present for meeting

Step 4: Determine Individual Roles and Responsibilities

Team Member	*Role(s)*	*Responsibilities*
Adil Adil	Systems/Mfg Engineer	✔ Leads design and fabrication process. ✔ Test any Hardware manufactured.
Grady Beck	Financial Manager	✔ Budgets project funds and handles financial records. ✔ Encourages responsible use of funds and materials.
Colin Drake	Project Manager	✔ Develops schedule and project agenda. ✔ Maintains and promotes a positive environment within the group. ✔ Provides point of contact to outside parties as needed.
Nathan Germain	Logistics Manager	✔ Coordinates use of reserved space, and storage space. ✔ Collaborate with the team and faculty to allocate resources and plan events.

Step 5: Agree to the above team contract

Team Member: Colin Drake	*Signature:* ____________
Team Member: Grady Beck	*Signature:* ____________
Team Member: Nathan Germain	*Signature:* ____________
Team Member: Adil Adil	*Signature:* ____________

References

[1] University of Pennsylvania. "GIS Resources: Geographic Information Systems (GIS)." Penn Libraries. Accessed September 29, 2024. https://guides.library.upenn.edu/c.php?g=475370&p=3254298.

[2] GeoSolutions Group. "MapStore Technologies." Accessed September 29, 2024. https://www.geosolutionsgroup.com/technologies/mapstore/.

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