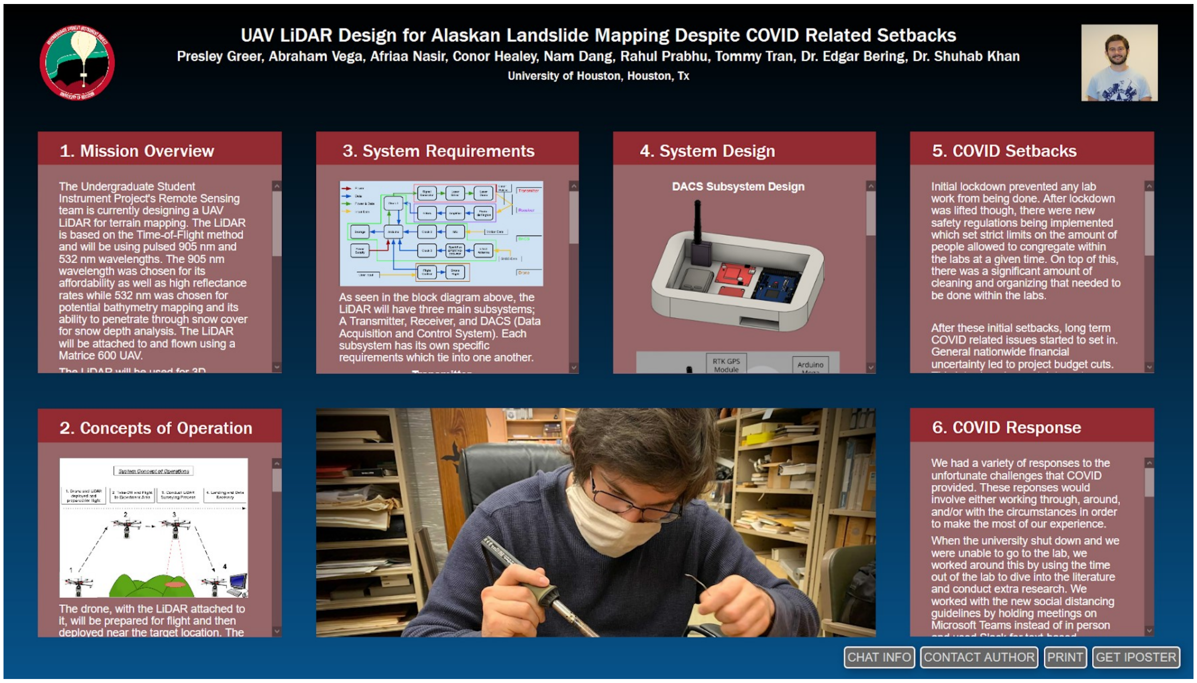
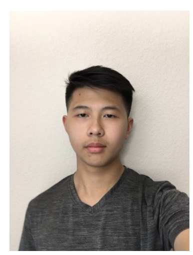
UAV LiDAR Design for Alaskan Landslide Mapping Despite COVID Related Setbacks

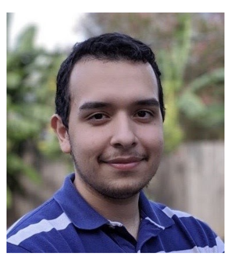


Presley Greer, Abraham Vega, Afriaa Nasir, Conor Healey, Nam Dang, Rahul Prabhu, Tommy Tran, Dr. Edgar Bering, Dr. Shuhab Khan

University of Houston, Houston, Tx




PRESENTED AT:

AGU FALL MEETING

Online Everywhere | 1–17 December 2020

1. MISSION OVERVIEW

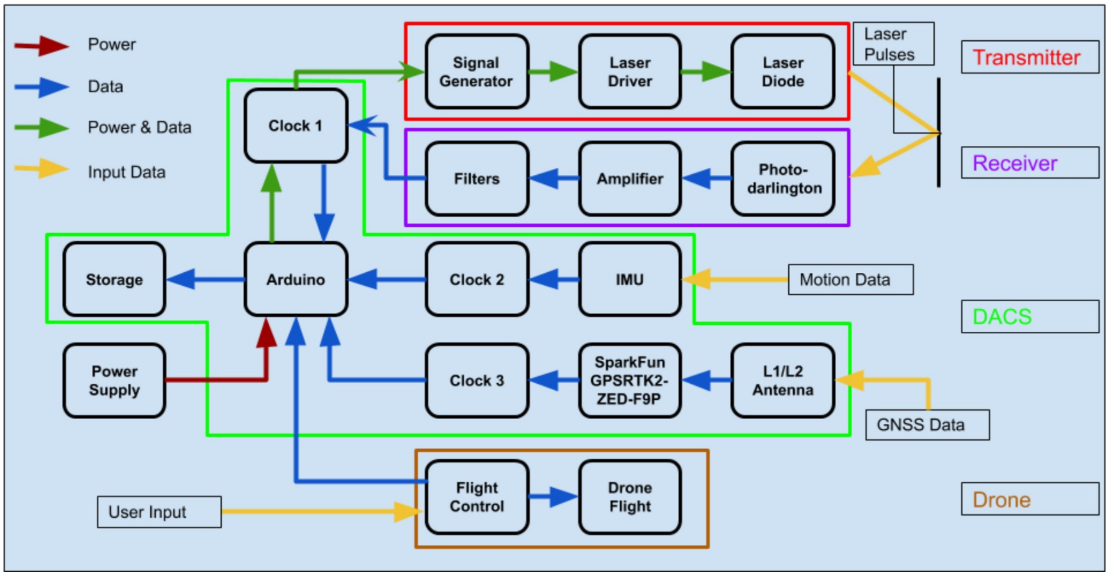
The Undergraduate Student Instrument Project's Remote Sensing team is currently designing a UAV LiDAR for terrain mapping. The LiDAR is based on the Time-of-Flight method and will be using pulsed 905 nm and 532 nm wavelengths. The 905 nm wavelength was chosen for its affordability as well as high reflectance rates while 532 nm was chosen for potential bathymetry mapping and its ability to penetrate through snow cover for snow depth analysis. The LiDAR will be attached to and flown using a Matrice 600 UAV.

The LiDAR will be used for 3D landslide mapping along the Tanana River nearby Fairbanks, Alaska. The goal is to create 3D landslide maps and DEM's with a spatial resolution of 0.3 - 1 m. These maps will then be used to conduct landslide analysis and to study landslide dynamics.

Science Traceability Matrix

USIP Undergraduate Student Instrument Project Remote Sensing Team		Objective #1: Design and build a LiDAR instrument			
		Objective #2: Use the LiDAR to make a 3D map of a landslide			
Mission Objective(s)		To make a dual laser pulsed time of flight LiDAR light enough to be flown by a drone and capable of making terrain maps with up to a 1 meter resolution			
Science Objectives	Measurement Objectives	Measurement Requirements	Instruments	Instrument Requirements	Data Products
What is the probability of landslide failure?	3D Landslide Terrain map	Distance from ground at given moment & position at that moment	LiDAR	_cm Altitude resolution, _ns time resolution, timing of measurements to match up data	Time stamped point cloud
		Positional accuracy above landslide region	SparkFun GPSRTK2-ZED-F9P & OpenLog Artemis	Measure up to 0.01m coordinate precision when RTK enabled. Can receive L1/L2 bands	3D Coordinates, Time
	Determine surface Composition/ geologic environment	Field Observations	Hammer & Shovel	Field work, on ground sample collection	Geologic Samples
		Images	Camera	Centimeter photograph resolution	Photographs
		Relative Reflectance	detector/receiver	Record amount of light reflected vs light used	Reflectance curves/graphs
	Determine vegetation of area	Real & NRI's of Landslide	Camera	~1-10 cm photograph resolution	Photographs

3. SYSTEM REQUIREMENTS



As seen in the block diagram above, the LiDAR will have three main subsystems; A Transmitter, Receiver, and DACS (Data Acquisition and Control System). Each subsystem has its own specific requirements which tie into one another.

Transmitter

The transmitter will emit 905 nm and 532 nm laser pulses. For an unambiguous range of 100 m, the max pulse frequency will be 1.5 MHz.

Receiver

The receiver must be capable of detecting both 905 nm and 532 nm wavelengths. It's optical receiving power requirements can be determined by the LiDAR equation: $P_r = \frac{P_t \rho \mu^2 A_r}{\pi R^2}$

P_r is the power received

P_t is the power transmitted

ρ is the reflectivity of the target

μ is the atmospheric transmission

A_r is the area of the receiver

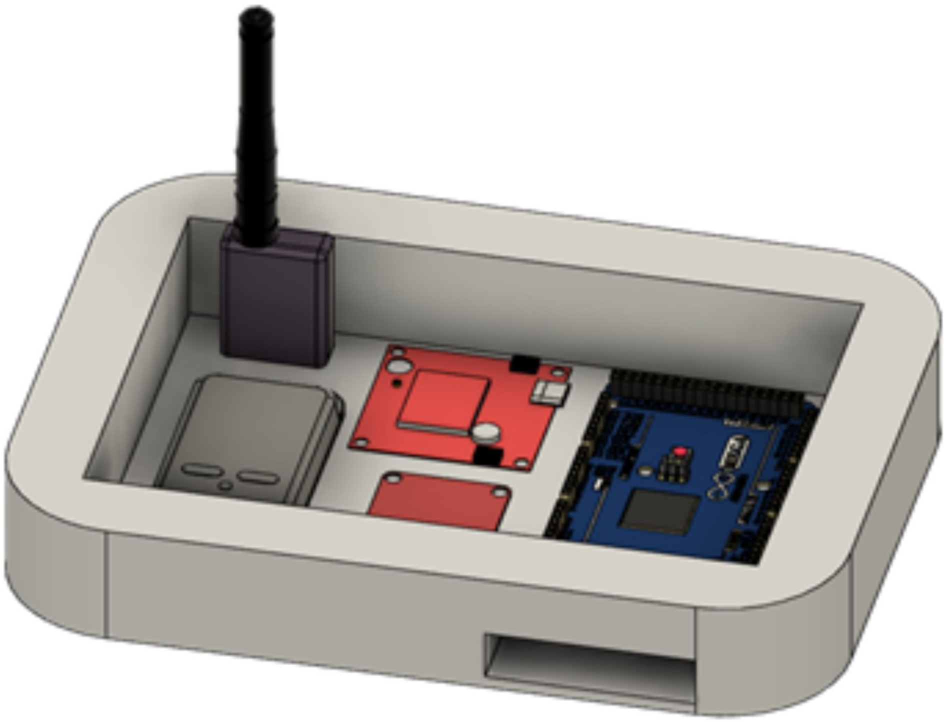
R is the range

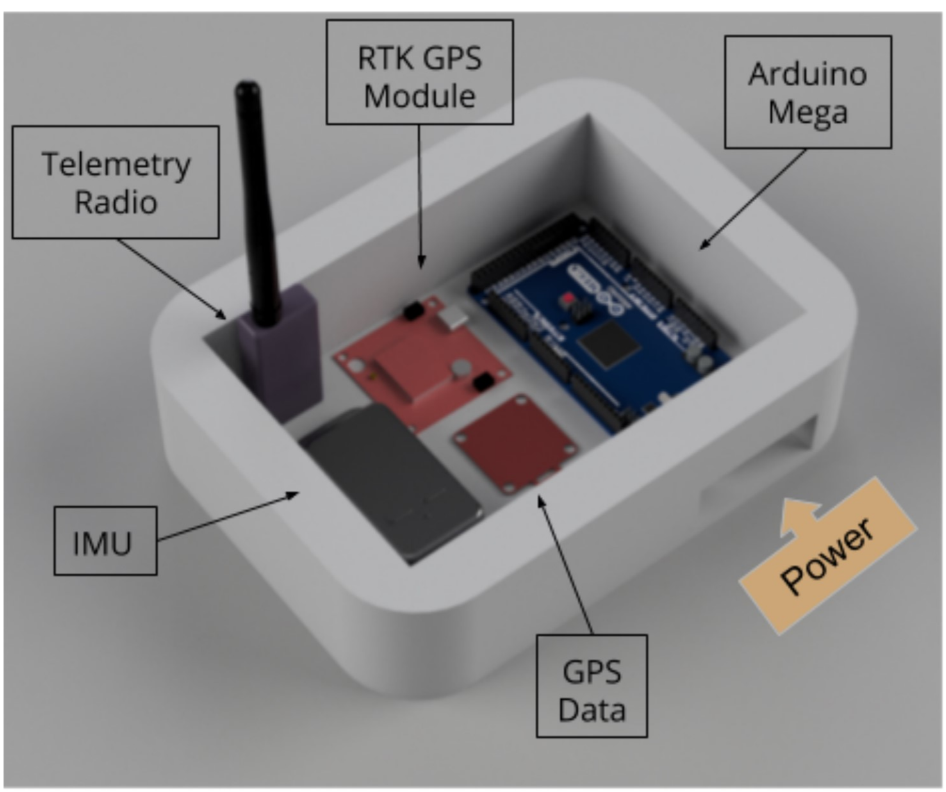
DACS

The Data Acquisition and Control System will keep track of the LiDARs position and orientation with less than 2 cm coordinate accuracy and within 1° orientation accuracy.

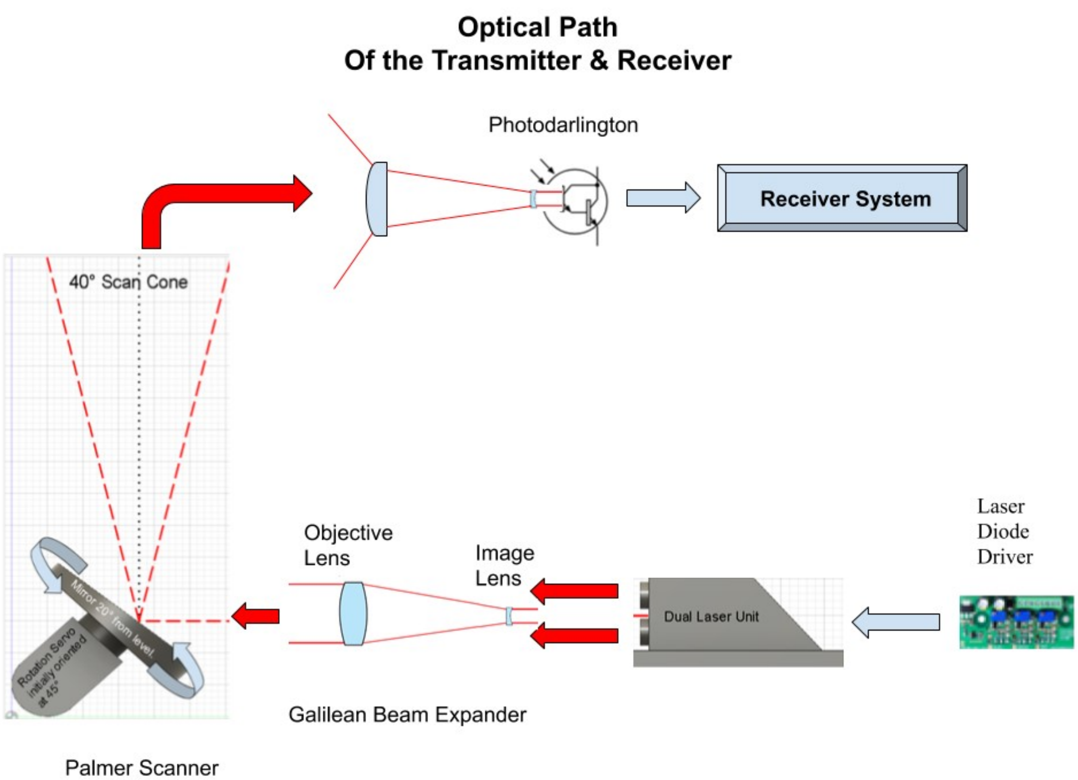
4. SYSTEM DESIGN

DACS Subsystem Design





Transmitter & Receiver Design



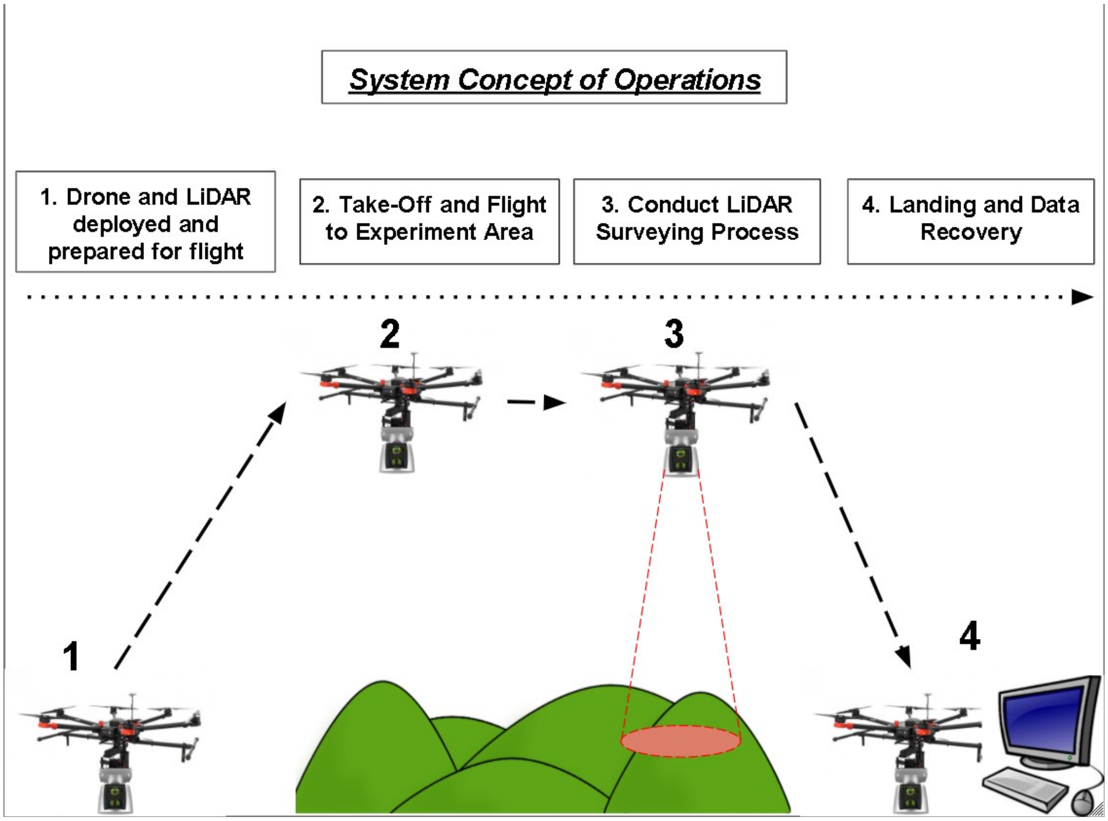
5. COVID SETBACKS

Initial lockdown prevented any lab work from being done. After lockdown was lifted though, there were new safety regulations being implemented which set strict limits on the amount of people allowed to congregate within the labs at a given time. On top of this, there was a significant amount of cleaning and organizing that needed to be done within the labs.

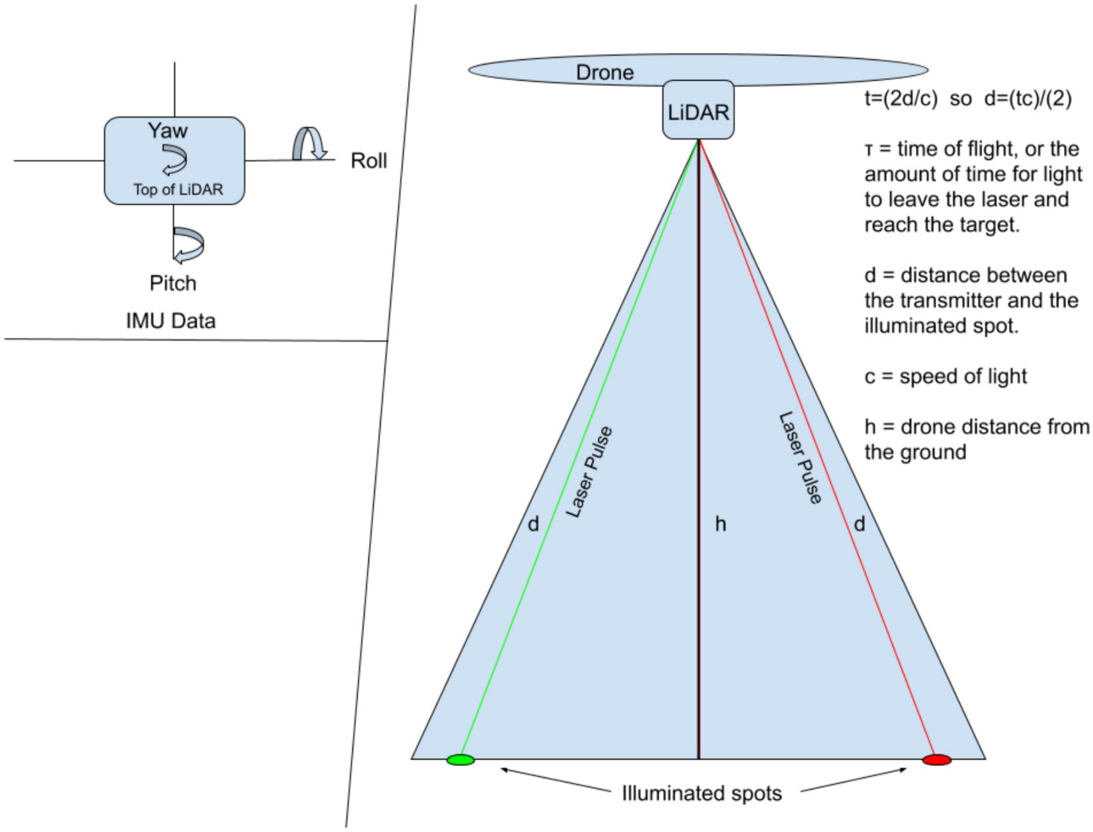
After these initial setbacks, long term COVID related issues started to set in. General nationwide financial uncertainty led to project budget cuts. This introduced uncertainty as to whether we would be capable of even buying the parts required. It's also uncertain if we will even be able to go to Alaska come Spring 2021 due to the potential of another outbreak and interstate travel quarantine requirements.

Living through a pandemic affected everyone's personal lives in various ways. It's safe to say that COVID has provided everyone with an astronomical amount of stress and anxiety. This mental and emotional baggage has caused an understandable loss in moral which has led to a decreased workflow. The social isolation following the cancelation of our in person weekly team meetings adds to that.

2. CONCEPTS OF OPERATION



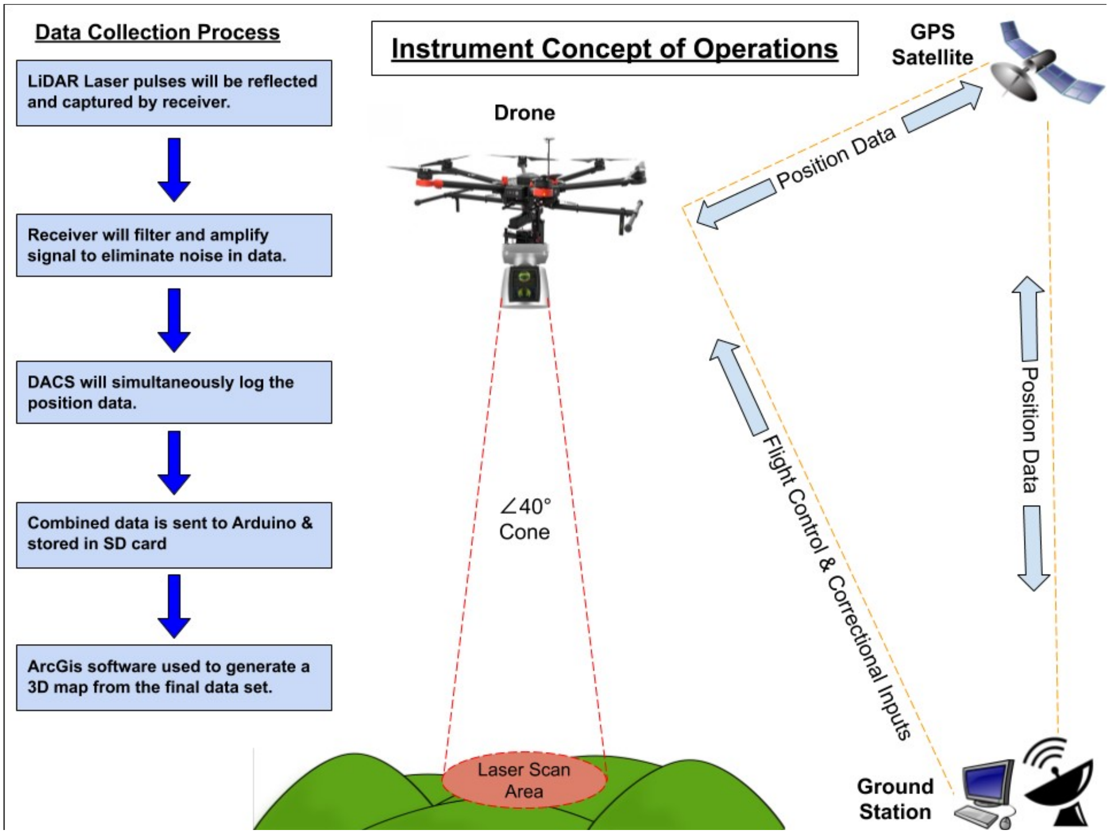
The drone, with the LiDAR attached to it, will be prepared for flight and then deployed near the target location. The drone will then fly the LiDAR over the survey area while the LiDAR fires laser pulses in a circular scan pattern. Once the survey is complete the drone will fly back to the base station and the data will be recovered from the LiDAR.



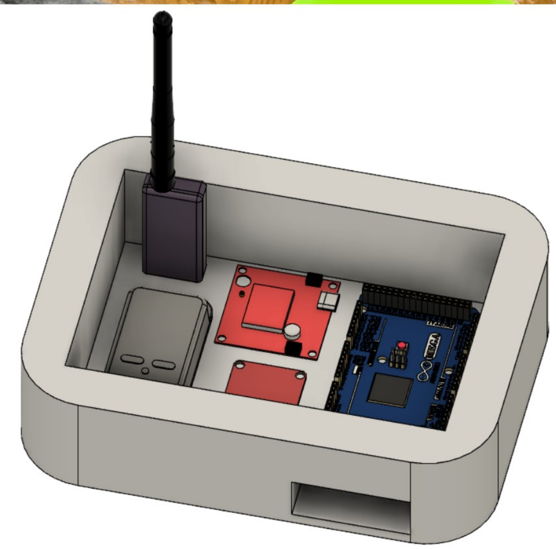
While the LiDAR is being flown over the target location it will be firing two pulsed lasers. The range equation $d = \frac{tc}{2}$ will be used to determine the distance between the transmitter and the illuminated part of the ground where:

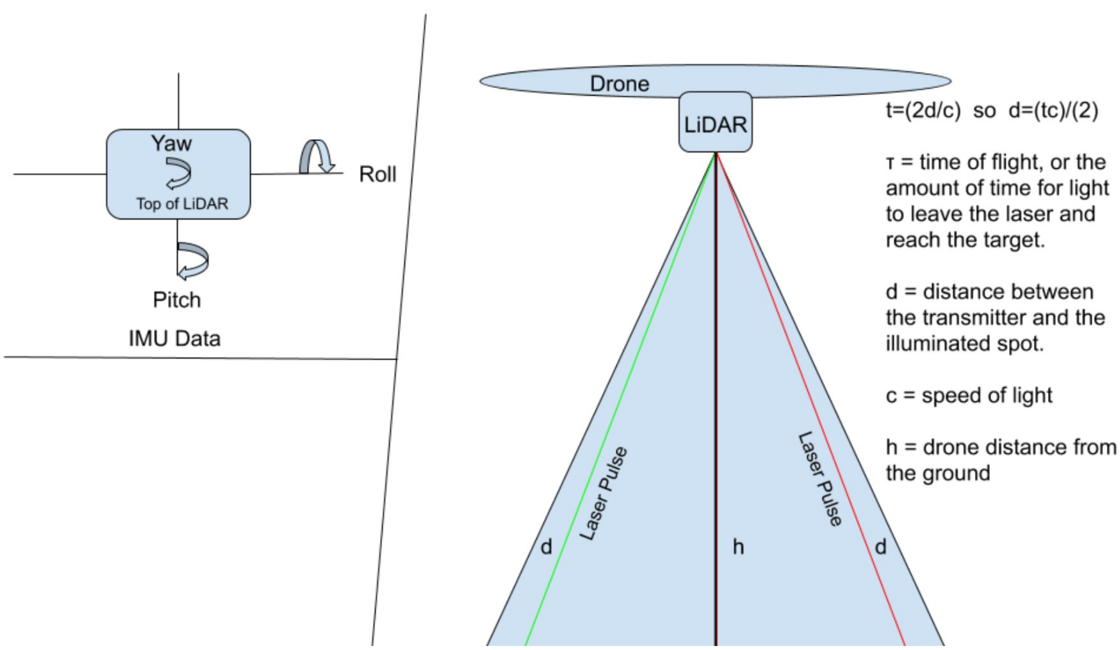
- d is the distance between the transmitter and the illuminated part of the ground
- t is the amount of time for the pulse to leave the transmitter and reflect back into the receiver
- c is the speed of light.

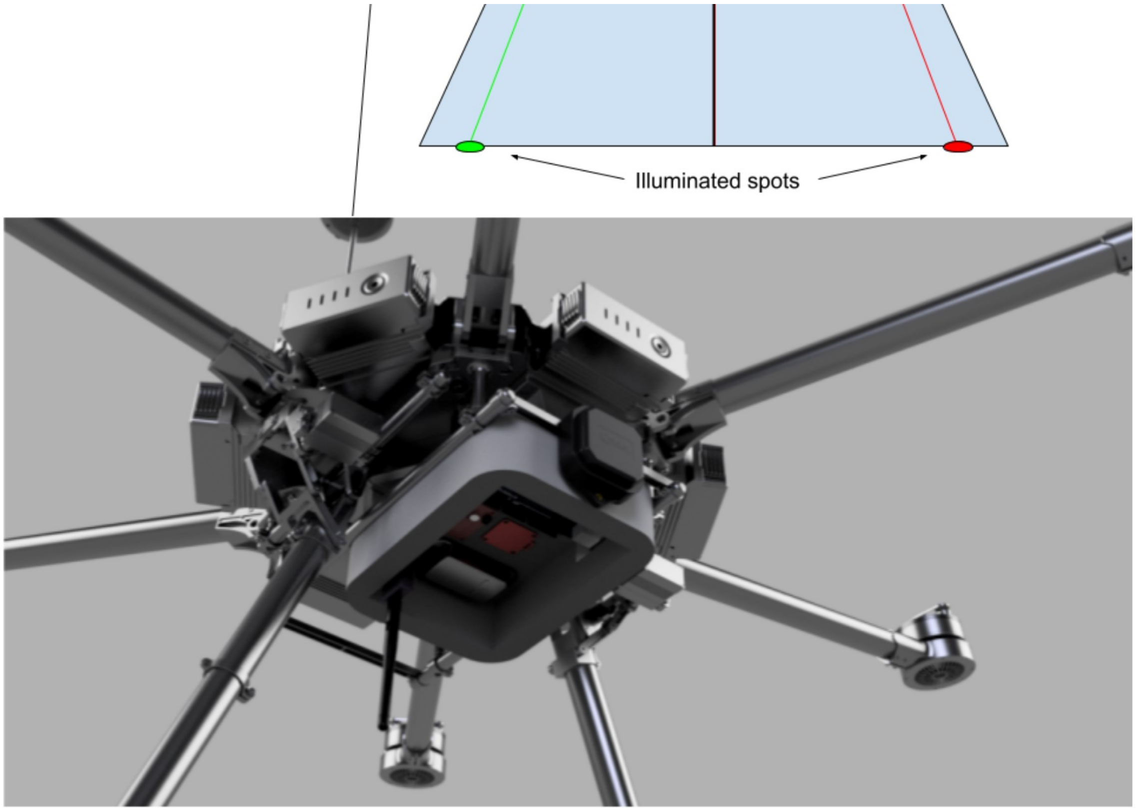
Meanwhile, the IMU (Inertial Measurement Unit) will be recording the LiDAR's pitch, yaw, and roll to correct for orientation.



While the LiDAR is recording the laser pulses and IMU data, the RTK GPS (real time kinematics global positioning system) on the lidar will be receiving positional data from satellites. A ground station with an RTK GPS will also be receiving and generating positional and correction data. The correction data will then be transmitted to the GPS device on the LiDAR. This will provide precise positional data to accompany the laser pulse and IMU data which will all be used to make a point cloud map of a landslide. From there the point cloud can be used to generate a 3D map and DEM (Digital elevation model).




Yaw
Top of LiDAR
Roll
Pitch
IMU Data
Drone
LiDAR
t=(2d/c) so d=(tc)/(2)
τ = time of flight, or the amount of time for light to leave the laser and reach the target.
d = distance between the transmitter and the illuminated spot.
c = speed of light
h = drone distance from the ground
Laser Pulse
Laser Pulse
d
h
d


Illuminated spots

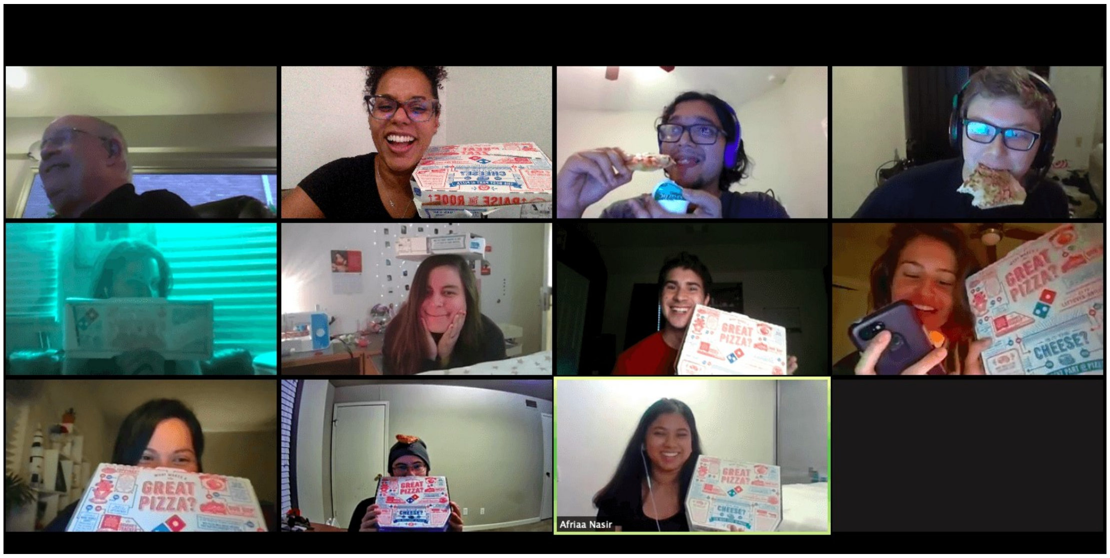
6. COVID RESPONSE

We had a variety of responses to the unfortunate challenges that COVID provided. These reponses would involve either working through, around, and/or with the circumstances in order to make the most of our experience.

When the university shut down and we were unable to go to the lab, we worked around this by using the time out of the lab to dive into the literature and conduct extra research. We worked with the new social distancing guidelines by holding meetings on Microsoft Teams instead of in person and used Slack for text-based communication outside of meetings. When it came down to going to the lab, a lab schedule was made with a limitted amount of people being allowed in the lab at a given time.

Dr. Bering worked through the reduced funding by securing financial support through his network. This has allowed us to begin purchasing parts without worrying that there might be enough funding to complete the project. We still might be unable to go to Alaska come March 2021, but we've decided to work around that by finding potential landslide locations within Texas that can be mapped. We're currently looking into areas along the Balcones Fault.

As far as team moral, an online pizza party was held with all pizza's free of charge. This helped raise everyones spirits. Pictures of the pizzza party can be seen below.


GREAT PIZZA?
CHEESE?
Afriaa Nasir