Avalanche Mitigation Mission Analysis

AERO 658: UAS Operations

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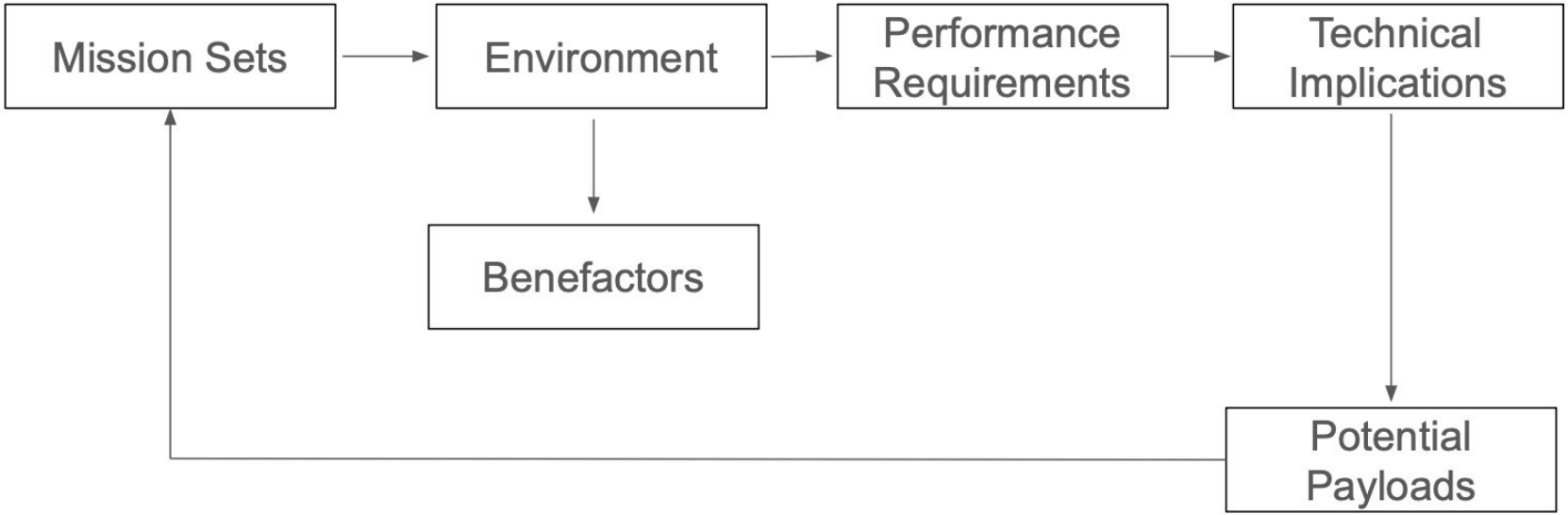
Overview

- Mission description
  - Mission analysis block diagram
- Mission objectives
- Desired data products/results
- Ideal system description
- Realistic system description
- Conceptual mission flow
- Data Reduction/analysis
- Timelines

Mission Analysis Block Diagram



Mission Description/Objectives

Phase 1 - Data collection and analysis

- Gather data to predict avalanche risk and optimize/map payload drop location

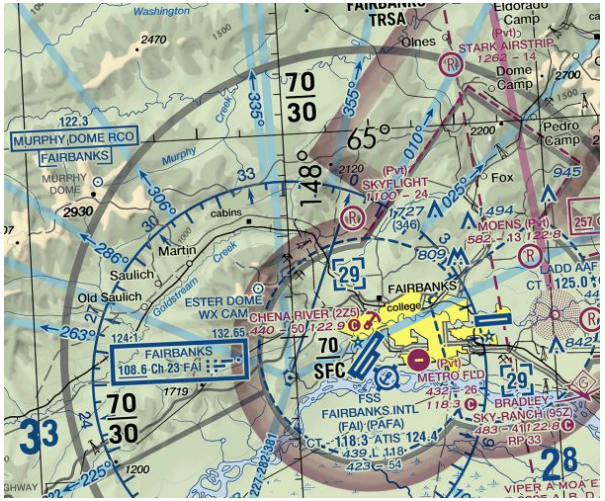
Phase 2 - Trigger controlled avalanche

- Deliver an explosive payload to trigger the avalanche

Environment

Moose Mountain:

- Uncontrolled airspace
  - 10 mi NW of PAFA airport
- Has areas without trees for photographing
  - Total area of approximately 1 square mile
- Weather Conditions
  - Around freezing temperatures and possibly windy



Summary

April 1, 2023 - April 30, 2023

	High	Low	Average
Temperature	49.2 °F	-4.0 °F	20.5 °F
Dew Point	34.8 °F	-11.2 °F	9.5 °F
Humidity	94 %	32 %	63 %
Precipitation	0.29 in	–	–

	High	Low	Average
Wind Speed	15.8 mph	0.0 mph	1.5 mph
Wind Gust	19.0 mph	--	1.6 mph
Wind Direction	–	–	South
Pressure	30.77 in	29.73 in	–

Performance Requirements

- Payload deployment
  - Drone must be capable of carrying 1-2 kg of explosive payload
  - Must be capable of carrying payload housing
  - Other potential components might need to be integrated (receiver and small battery)
- Photogrammetry
  - Drone must be very user friendly
  - 3-axis stabilized gimbal for photos
  - Easily changeable batteries for flight endurance
- Thermal data
  - Drone/sensor suite must record thermal data to be added to locations on modeled map
  - Must store data onboard for further reduction using LabQuest 2 mounted on drone
  - Work in aerial applications and withstand the cold temperatures

Desired Data Products/Results

Data to gather

- Photogrammetric data (photos including time and position information)
- Temperature data (simultaneously recorded with drone position and time)

Desired results

- Elevation map 2D orthomosaic (for detecting areas of avalanche prone slopes)
- Surface temperature 2D orthomosaic
- Combined overlaid map representing avalanche risk

Technical Implications

- Navigation Guidance and Altitude Control
  - Navigation and Attitude Control is important as the drone would need to know where it is at all times to relate sensor data to the location it was taken at
    - Includes visual imagery and snow surface temperature
    - Litchi software records position information and time for after flight analysis
- Communications
  - Litchi software provides real time data link from drone to interface, allowing switching between autonomous and manual flight modes. Full interface gives detailed information about location, telemetry and data collection
- Controls and Autopilot
  - Manual controls will be needed as the drone would be carrying an explosive to avalanche prone areas
  - Use DJI Flight planner to create autonomous flight paths for data collection, export file to Litchi for operations
- Payload
  - Sensor Suite (Inspire 1)
    - Zenmuse X3 camera
    - Vernier Labquest 2 and IR thermometer
  - S1000 will need to carry explosive payload and payload deployment mechanism. May also be required for IR thermometer
- Multi-Vehicle Solutions
  - Multiple drones will be used in this mission each performing unique tasks though will not interact with each other
    - DJI Inspire 1 for data collection
    - S1000 explosive payload deployment
- Launch and Recovery Systems
  - Important to consider environmental effects on drone flight
    - Such include snow covered takeoff and landing zones, high wind environments on mountain slopes, and cold temperature effects on the sensor systems

Ideal System Description: UAS System

DJI Matrice 300 RTK:

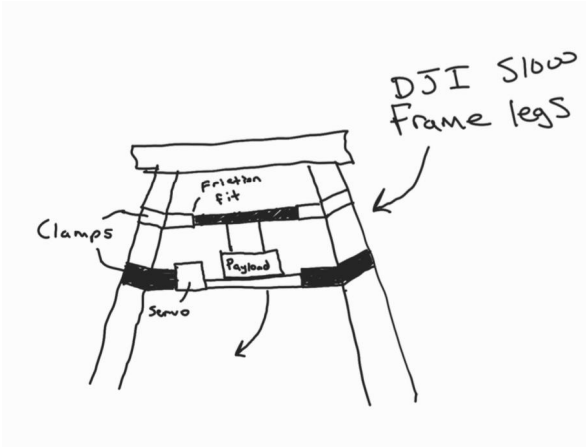
- 55 minutes of flight time
- Service ceiling of 7000 m
- 12 m/s wind resistance
- Maximum of 3 payloads (2.7 kg total)
- Live mission recording: aircraft movement, gimbal orientation, photo shooting
- Advanced flight features and high quality camera (such as Zenmuse P1) provide high-precision data

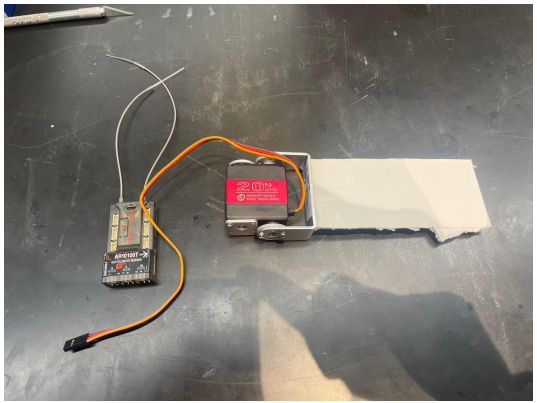
Ideal system description: Payload Deployment

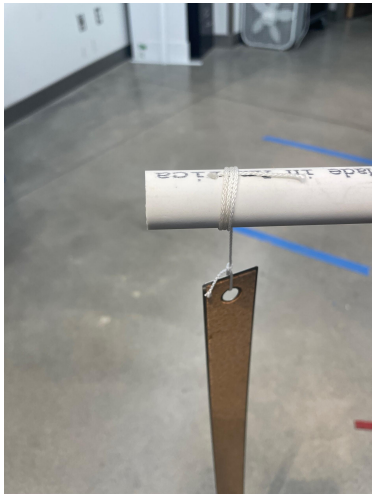
- RC winch to lower and deploy payload
- 3D printed housing to secure payload during flight
    - Attached to S1000 frame legs

Realistic Payload Deployment

- 3D printed parts: Platform, clamps, roller
- 20 kg DSSERVO - RDS3218
- Servo will lower gate for the payload to deploy
- Seperate receiver/transmitter for first iteration
    - Can later be integrated into regular transmitter



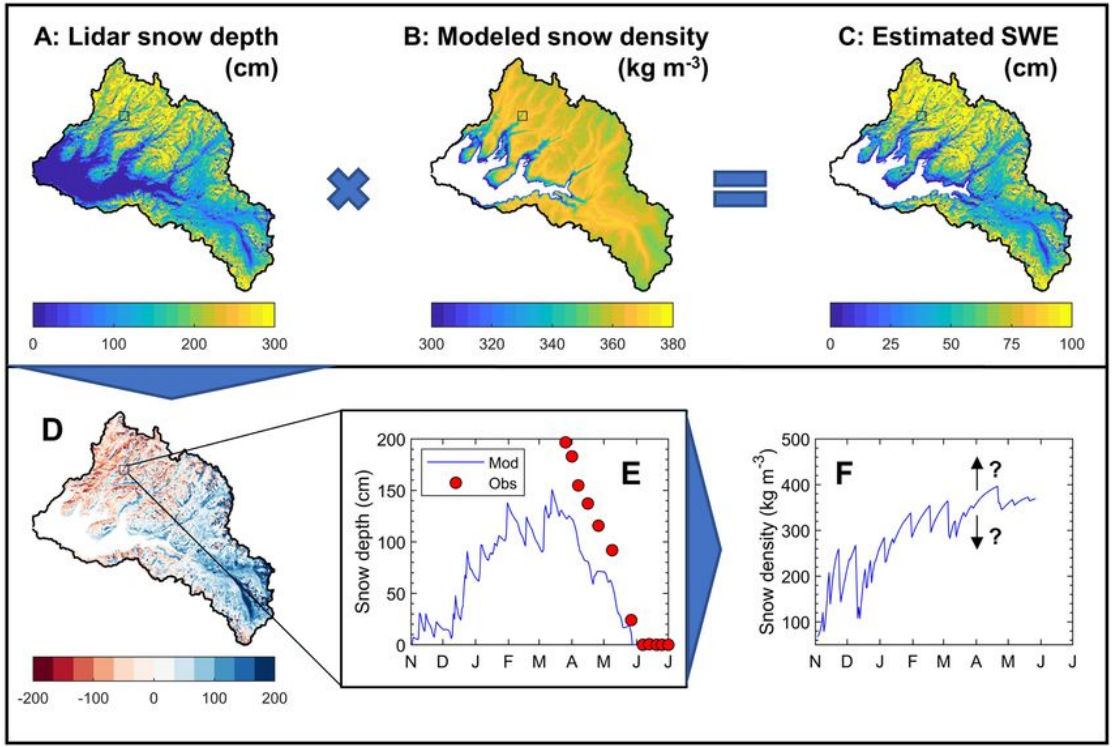




Ideal system description: Snow Depth

- Can detect snow depth and snow layering
- DJI Zenmuse L2, $12,000
  - Dual Payload: LiDAR and Color Visible data
  - 20MP RGB mapping camera
  - LiDAR camera
    - Measures distance to snow and distance to ground
- Compatible with the DJI Matrice 300 Series platforms
- Integrates with DJI data transmissions (live display)

Ideal system description: Snow Depth



Snow Depth Data Collection

- DJI Zenmuse L2 (Expensive)
  - Can detect snow depth and snow layering

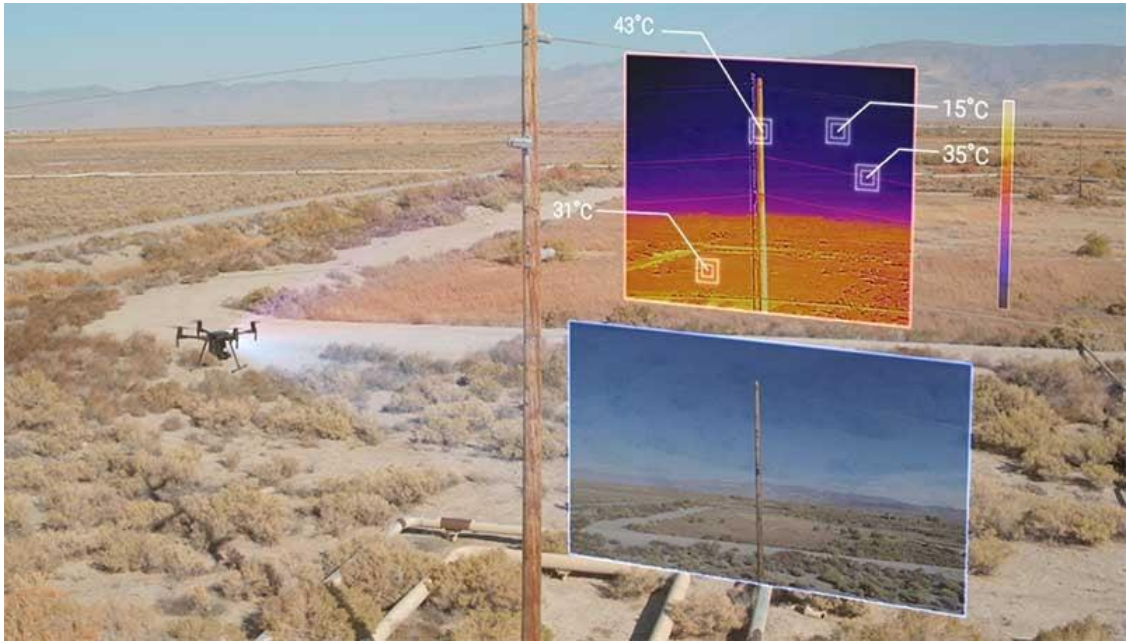
- Single Point Snow Depth Measurement
  - Measure snow depth at single points long UAS path
  - LiDAR cameras with the ability to detect snow depth are also costly

- No cheap alternative that produces required results

Ideal system description: Thermal Imaging

- Can find areas where snow has melted creating unstable snowpack layers
- DJI FLIR Zenmuse XT2, $6,300 - $10,000
  - Dual Payload: Thermal and Color Visible data
  - 4k video camera
  - High-resolution radiometric thermal camera
    - FLIR: Multispectral Dynamic Imaging technology combines the visible light and thermal into one image
- Compatible with the DJI Matrice 600 and Matrice 200 Series platforms
- Integrates with DJI data transmissions (live display)

Ideal system description: Thermal Imaging



Temperature Data Collection

- DJI FLIR Zenmuse XT2 (Expensive)
  - Compatible with DJI drones
  - “Plug and Play”
    - Automatically merges visual and thermal map

- IR Thermometer
  - Spot check temperatures at different locations to find areas where snow has melted creating unstable snowpack layers
  - Temperatures recorded and stored on onboard LabQuest
  - Plot must be overlaid manually

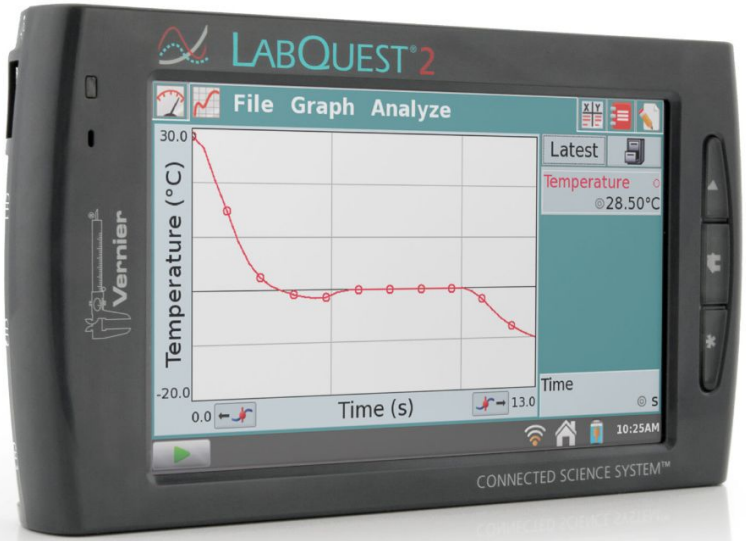
Temperature Data Collection - IR thermometer

Vernier Infrared Thermometer

- Non contact temperature measuring device
- 15:1 distance to spot ratio
- Compatible with LabQuest Pro

LabQuest 2

- Small, portable battery powered device that collects and stores sensor data
- .35 kg weight
- Stored data is recorded against time and can be easily exported and analyzed


LABQUEST 2
File Graph Analyze
Temperature (°C)
30.0
-20.0
Time (s)
0.0
13.0
Latest
Temperature
28.50°C
Time
10:25AM
Vernier
CONNECTED SCIENCE SYSTEM™


Vernier IR-BTA
MEAS

Visual Data Collection

- DJI Inspire 1 Default built in camera
- Zenmuse X3
  - Visual imagery of snow surface to create 3d map
    - 4K Video, 12MP
    - Find slope angles of the snow

- For best results of image quality
  - 60% - 70% forward overlap
  - 20% - 40% lateral overlap

DJI S1000 - Advanced stability octocopter

- Total weight: 4.2kg
- 15 min hover time at 9.5kg
- Easy assembly and transportation
- Adequate room for payload attachment
- Max takeoff weight of 11kg
- Expensive and difficult to fly, requires trained pilot
- Operating temperature: -10 to 40 C
- Max Speed 16m/s
- High Wind resistance

DJI Inspire 1

DJI inspire 1: Small multi-rotor UAS

- Weight with battery: 2.935 kg
- Flight time: 18 minutes per battery
- 4 batteries total
- Operating temperature: -10 to 40 C
- Easy to operate
- Minimal payload attachment points
- 22mph max wind speed resistance

Realistic System Description/Potential Payloads

- Payload deployment: DJI S1000
  - 3D printed deployment mechanism will be attached to the S1000
- Photogrammetry mapping: DJI Inspire 1
  - 3-axis gimbal and camera for taking photos/videos
  - Map the pitch of varying slopes to identify high risk areas within 30-38 degrees
- IR Thermometer and LabQuest 2
  - Spot check temperatures at different locations to find areas where snow has melted creating unstable snowpack layers
  - Map surface areas that have been heated by the sun and pose higher risk
- LiDAR
  - No cheap alternative that produces required results

Mission Software - Photogrammetry

Flight Planning

- DJIFlightPlanner

Flight Operations

- Litchi

Data Analysis

- DJIAfterFlight

Photogrammetry/Mapping

- iWitnessPro V4, Drone Deploy, ArcGIS

DJIFlightPlanner (Autonomous Flight Planner)

- Adjust critical imaging parameters: camera sensor, flying height, ground speed, forward overlap, side overlap, ground pixel size & imaging frame rate
- Puts you in complete control over your photogrammetric aerial survey mission & ensures full coverage over the area of interest
- Export file format can be imported directly into Litchi (for Android & Apple iOS) for flying. So then with a single-button press, you can make your drone take off, fly the mission, and safely land again after having automatically captured all the required images (DJI, 2024)
- Compatible with DJI Inspire 1 and S1000

DJI Flight Planner - Workflow

PLAN THE AREA

Draw a polygon or import (as a KML file) your area of interest over streaming background maps

SELECT YOUR SENSOR

Choose your DJI drone model from our wide range of supported models (with more to come)

SELECT SETTINGS

Select flight-specific parameters such as altitude, ground sample, image overlap, ground speed, etc. The software automatically adjusts each variable to meet your needs.

OPTIMIZE THE PLAN

Tweak the settings to give most efficient route and best coverage using the real-time on screen graphic output

TIDY UP

Remove any unwanted flight lines / stations by simply selecting and deleting them on the screen

EXPORT THE RESULT

Save the flight plan ready to use in Litchi (flight control software)

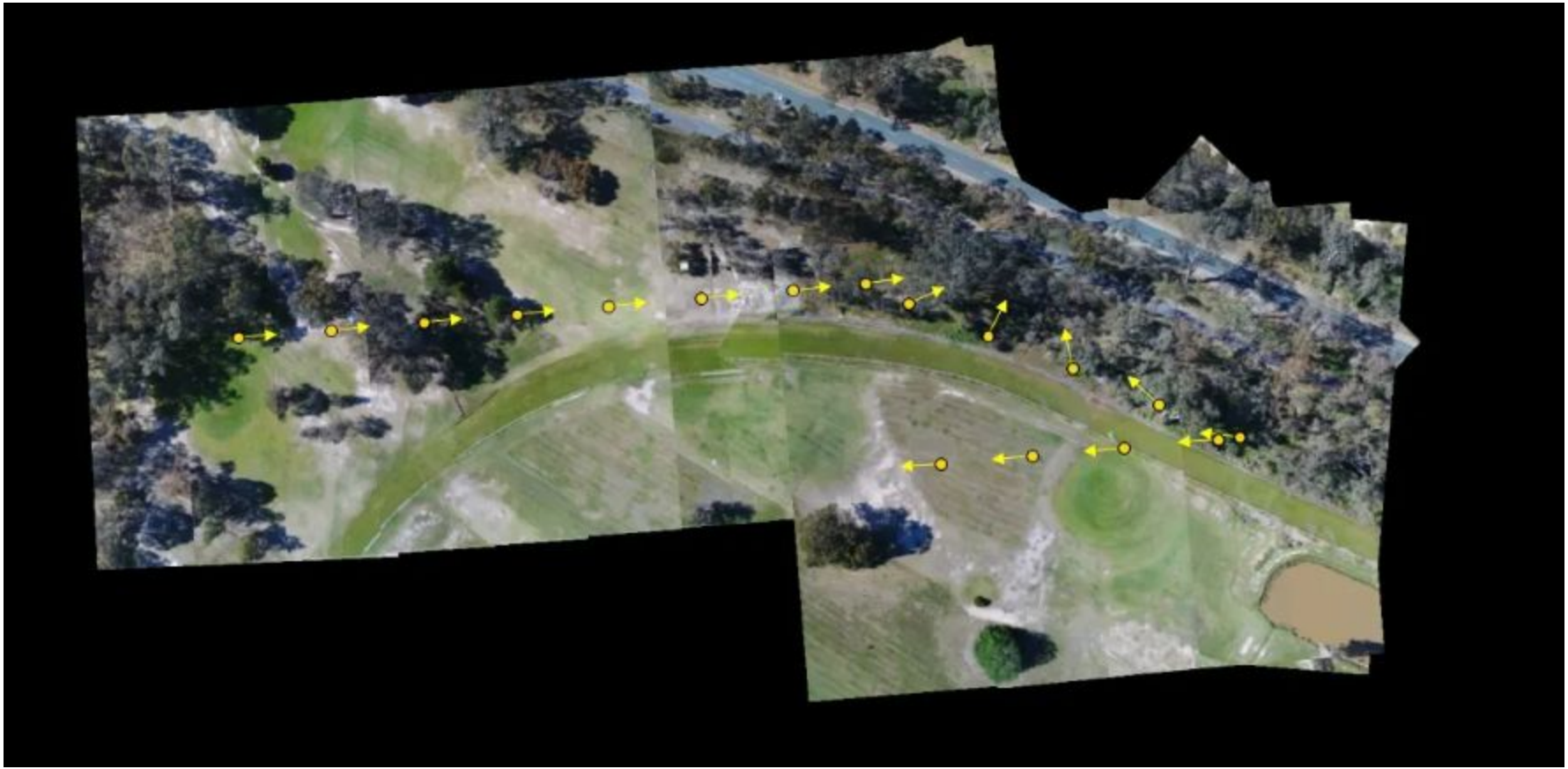
Litchi (Operations Interface)

1. **Flight Modes**: Use this dropdown to change the flight mode.
2. **Radar**: Shows the position of the aircraft relative to the operator's mobile device (Android only).
3. **Flight Telemetry**: Shows altitude relative to take-off elevation, distance from home point to aircraft and speed on all axis. In Follow mode, the distance between the mobile device and the aircraft is shown.
4. **Show/hide small view**: Tap to minimize the size of the small view. Tap on the small view to switch the map and video views.
5. **Aircraft**: Shows the aircraft location on the map. Tap to add a Waypoint or Point of Interest at the aircraft location.
6. **Mobile Device**: Shows the mobile device location on the map. Tap to add a Waypoint or Point of Interest at the mobile device location.
7. **Home Point**: Shows the home point location on the map. To set a new home point, drag this marker to another location. You must be flying in order to move the Home Point.
8. **Photo/Video Switch**: Use to change the camera mode.
9. **Take Photo/Record**: Tap this button to take a picture while in photo mode. Tap to start and stop recording while in video mode.
10. **Gimbal Pitch Indicator**: Shows the current position of the gimbal tilt. Top is +30° above horizon, bottom is -90°. Tap on this indicator to toggle between bottom and top gimbal positions.
11. **Zoom to Mobile Device**: Tap to zoom the map to the current mobile device location.
12. **Unlock Map Orientation**: By default the map is oriented towards North. Tap to have the map rotation continuously adjusted to match your mobile device's position relative to north.
13. **Camera Settings**: Tap to open camera settings.
14. **Mode Switch Button**: Tap to change the flight mode or to log in to your Litchi account.
15. **Satellite Count**: Shows the number of satellites that the aircraft is locked onto.
16. **RC Battery/Virtual Joysticks**: Shows the remaining remote controller battery percentage. When connected to a drone without remote controller, tap to show/hide the virtual on-screen joysticks.
17. **Battery Status**: This bar shows the status of the aircraft battery. The part in red represents the battery required to go home.
18. **Aircraft Status**: Shows the current aircraft flight status.
19. **Uplink**: Shows the strength of the remote controller uplink signal. For Mavic Mini 1 and Mini SE, the flight mode (Normal/P,Sport,Cine) is displayed in this location, tap to change the flight mode.
20. **Downlink**: Shows the strength of the video downlink signal.
21. **Aircraft Battery**: Shows the remaining aircraft battery percentage.
22. **General Settings**: Tap to show general settings.

DJIAfterFlight (Data Analysis)

Some powerful features of DJIAfterFlight include:

- display vector data from the flight itself including positions & look-angles for each image
- turn on/off the streaming background map (internet required) and change map layers
- display image thumbnails (when yaw/pitch/roll information present)
- display a single piece of EXIF information on screen for every image at once
- show pointing arrows for flight direction at time of each image capture
- show individual image footprints (when yaw/pitch/roll information present)
- ability to search for specific metadata by typing
- copy selected image file(s) to a new folder
- ability to export EXIF, XMP and specific DJI metadata in a highly customizable text file format
- customize on-screen display (display colors, etc)
- ability to export all EXIF/XMP metadata in a variety of file formats including tab-delimited text, .csv comma-separated values, XML format & also JSON format
- show/hide various on-screen elements to help generated screengrabs for reports etc
- quickly review imagery on-site before leaving to ensure nothing has been missed
- extremely fast to load data and user-friendly interface for data manipulation & viewing
- compatible with imagery from any source where GPS information is stored in the image headers
- sort and colour-code the display based on user-selectable metadata [coming soon]
- compare *planned* aerial missions from DJIFlightPlanner with *actual* captured data using DJIAfterFlight [coming soon]
- plus more !



iWitness Pro V4

- Fast and robust automated photogrammetric processing of networks of 10s to 100s of images and many 1000s of object points, from multiple cameras.
- Fully automatic multi-image network orientation and 3D measurement of both targeted and untargeted objects
- Employs red retro-reflective or black & white coded targets and provides automatic determination of the coordinates of any targeted feature point
- Produces 3D measurement of targeted points to an accuracy of an order of magnitude better than with manual image referencing
- In targetless orientation and 3D point determination, *iWitnessPRO-V4* uses a SfM approach with rigorous photogrammetric orientation to produce a 3D point cloud covering the object or scene being measured, the point density being dependent on the texture content of the imagery
- Fully automatic camera calibration, both via targets and targetless, as well as on-the-job self-calibration
- Support for Ground Control Points (GCPs) typically from GPS or other traditional surveying methods
- Well suited to combined automatic and manual measurement for optimal feature point determination
- Robust and reliable error detection through on-line, automatic data processing
- Flexible generation of planar facet-based photo-textured 3D models
- Best-fit geometry functions and flexible measurement of curves and lines for export to CAD

Other photogrammetry software options:

DroneDeploy - offers flight planning, operation, and mapping

PixPro, ArcGIS - uses photogrammetric data to generate 2D orthomosaics and 3D models

Conceptual Mission Flow: 3D Mapping

- Charge batteries for DJI Inspire 1
- Transport drone to test location (currently Moose Mountain)
- Take photos of the terrain, varying the angles and altitudes
- Perform data analysis
- Use data to create maps of target area detailing avalanche risk
- Select an optimized drop location

Conceptual Mission Flow: Payload Deployment

- 3D print deployment mechanism
  - Clamps, payload platform, lowering mechanism
- Securely attach to the legs of the S1000 drone
- Test lowering mechanism in lab without S1000 being powered
  - Does the hatch open without issue?
  - Does the payload successfully detach from the S1000
- Test fly S1000 drone with payload deployment

Data Analysis

- Photogrammetry mapping: DJI Inspire 1
  - Identify areas where the slope angle matches those where an avalanche is expected to occur
- IR Thermometer
  - Identify areas where the snow has melted leading to create weak snowpack layers that can lead to slab avalanches
- Use real time position data from temperature flight to overlay temperature data onto 2d orthomosaic from photogrammetry

Timeline

- Week 1
  - Draft mission analysis (Friday March 29)
  - 3D print housing for payload (and create representative 3D printed payload)
- Week 2
  - Final mission analysis (TBD)
  - Draft mission operation plan (Friday April 5)
  - Flight test Moose Mountain
- Week 3
  - Attach S1000 payload and lab test
  - Conduct S1000 flight test
- Week 4
  - Likely last week for potential flight tests, payload testing
  - Use software to create 3D model of Moose Mountain region
- Week 5
  - Final mission operation plan (Monday April 22)
    - Final team briefings will be the same week
  - Team video, complete any remaining tasks

Questions?