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MODEL OPTIMIZE CONTROL

C-UAS
CENTER FOR UNMANNED AIRCRAFT SYSTEMS

Optimized Infrastructure Monitoring

3D Modeling in Complex Environments

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Project Overview

Optimized Infrastructure Monitoring

Since 2013…

- Maximize model resolution
- Evaluate workflow impacts
- Optimize flight path
- Collect field data
- Simulate anomaly detection
- Model long linear infrastructure

Present…

- Model complex environments

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Italy Earthquake Modeling

Link to Italy Model: http://prismweb.groups.et.byu.net/PL/App/#%2F/

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Intelligent Multiscale Targeted Monitoring

debris blocking road
medium interest area

failed retaining wall
high interest area

intermediate foliage
low interest area

damaged houses with unknown structural integrity
high interest area

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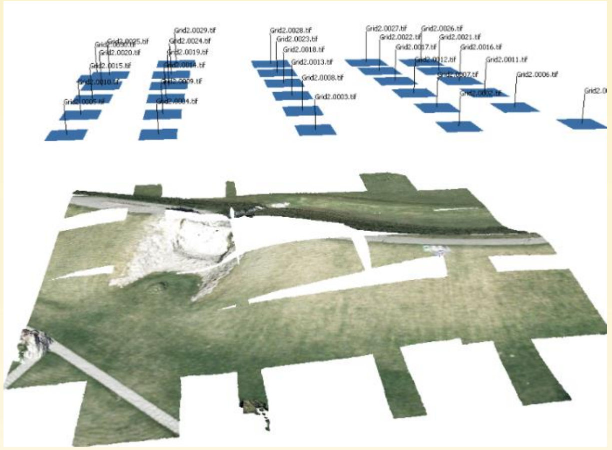
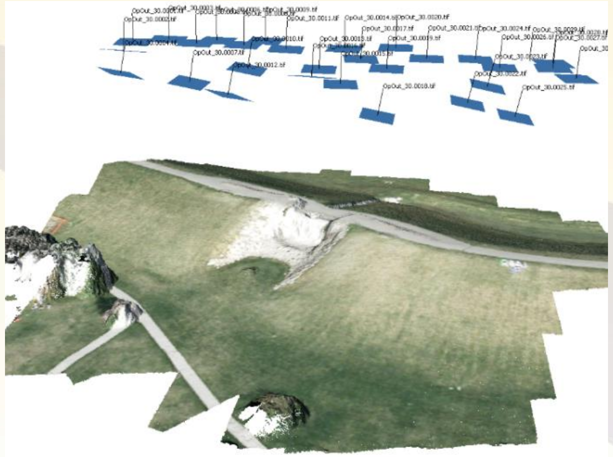
Optimized Flight Planning Validation

Simulated Flights - 2015



Grid Flight

Accuracy: 10 cm



Optimized Flight

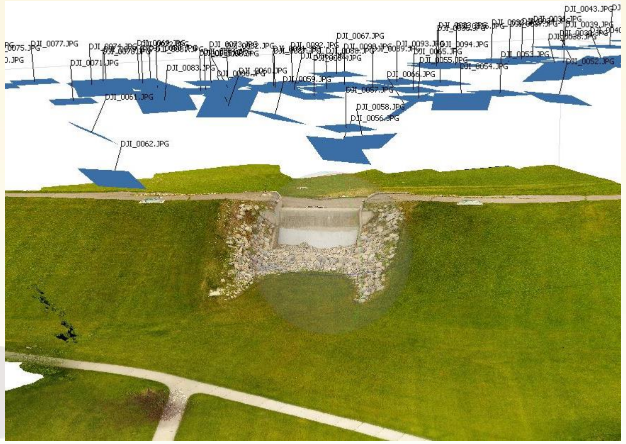
Accuracy: 3.8 cm

+62%

Physical Flights - 2016

Grid Flight

Accuracy: 14 cm



Optimized Flight

Accuracy: 8.4 cm

+40%

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With Pictures from DJI Phantom 4.

Close Up Flights

- Initially created holes
  - Bad input elevation data effects multiplied by close flights
  - Minor problems with algorithm view angles
- Solutions
  - Add a dome to the initial elevation data
  - View angles fixed

North Salt Lake Landslide

- Largest optimized flight yet!
  - 600x400 ft
- Fixed hole problem
- Initial elevation model pre-dated landslide
  - Mitigated with an added mound on the initial model to add dimension
- Future Work:
  - Change detection
  - Iterative model refinement study

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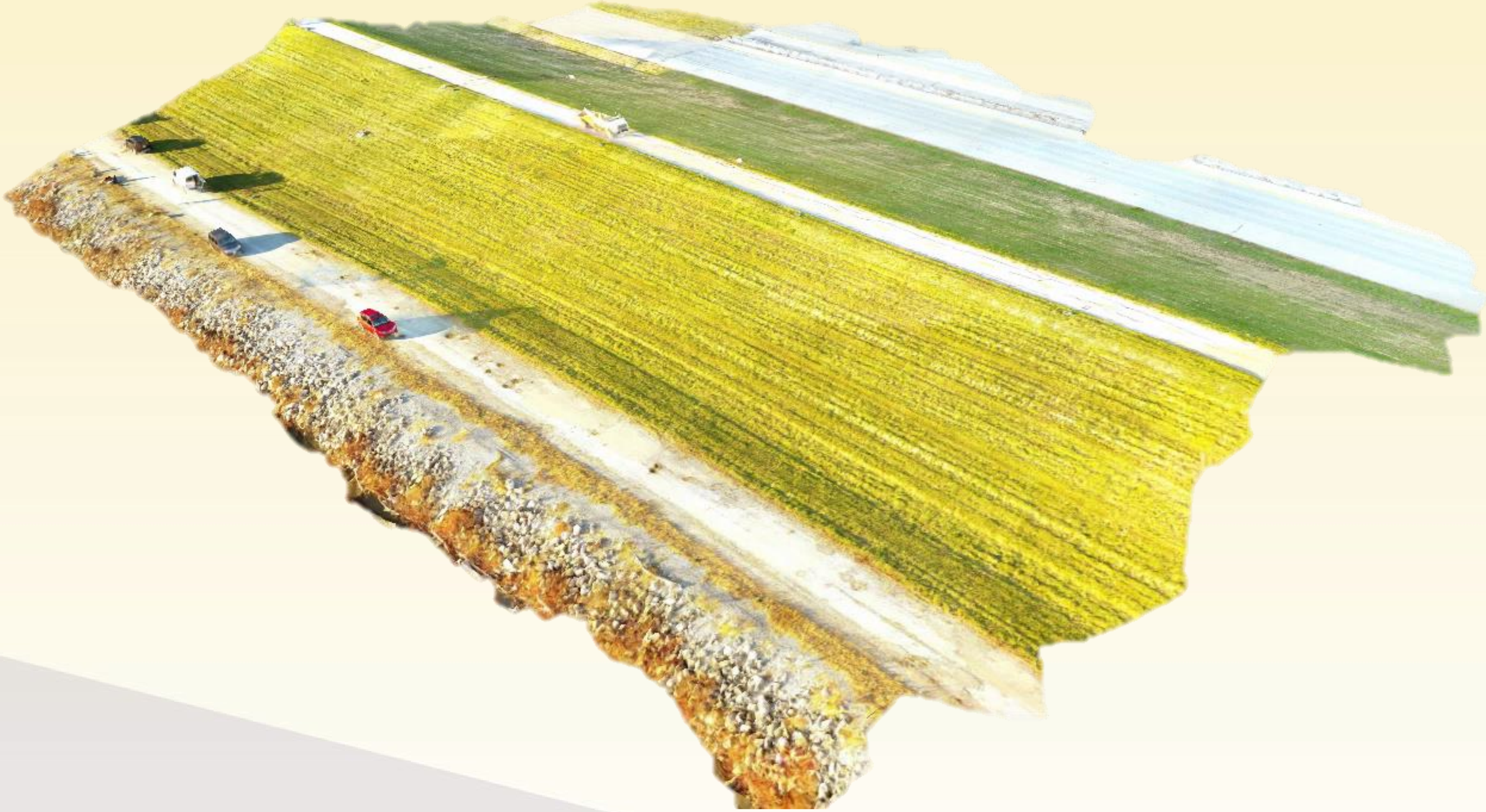
St. Louis Levee

- Large and small UAVs
- Heavy lift platform and DSLR camera (piloted)
- Optimized path (fully automated)



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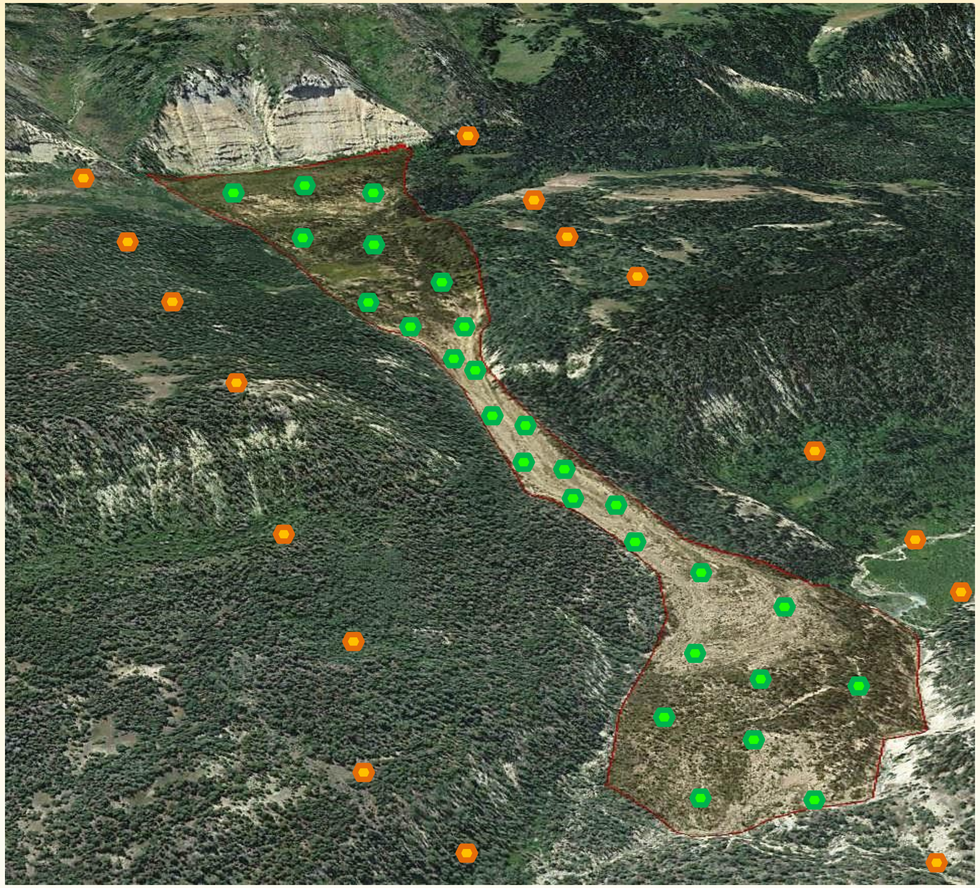
Future Work: Change Detection Study

- Intelligent multiscale targeted monitoring
- Repeated flights over 4-6 months
- Field validate with precise ground surveys
- Evaluate use of longer term static ground control
  - Simplifies repeated inspections



1.3 mile landslide in Sanpete, UT

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Indoor Flights

- Millions of miles of pipeline and other enclosed long linear infrastructure
- No current method for navigating a UAV autonomously through an enclosed linear environment

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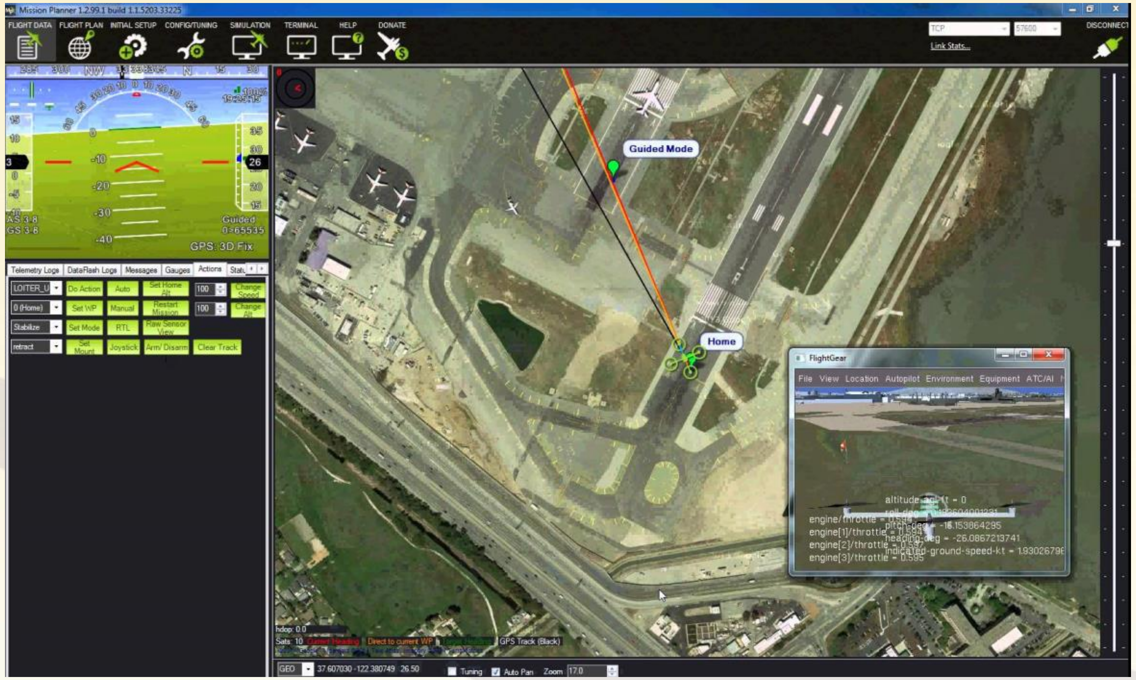
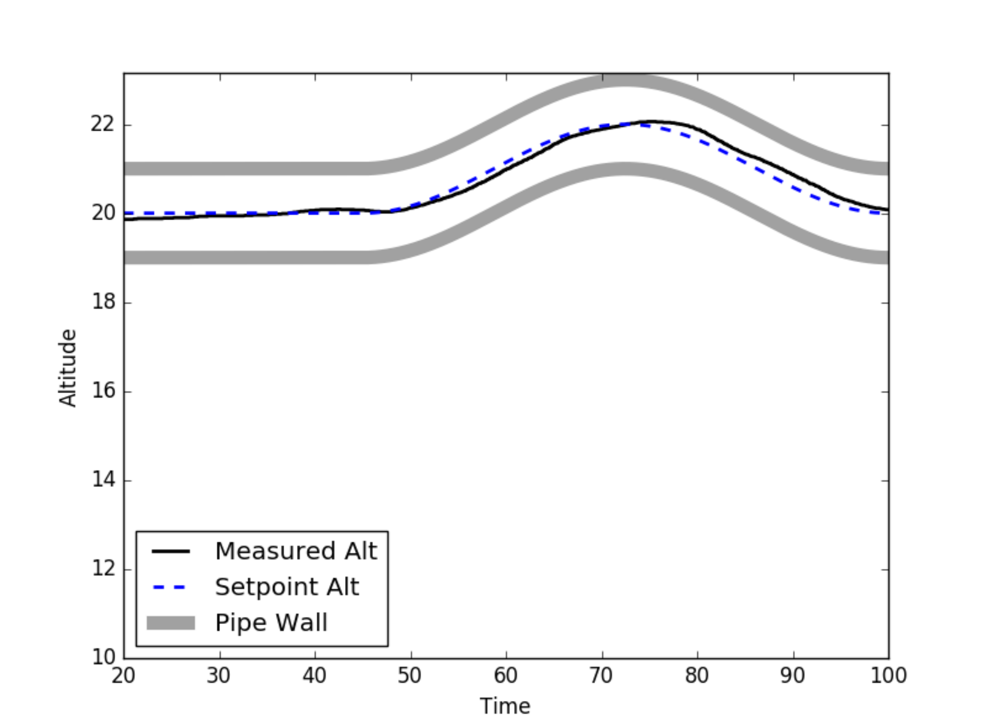
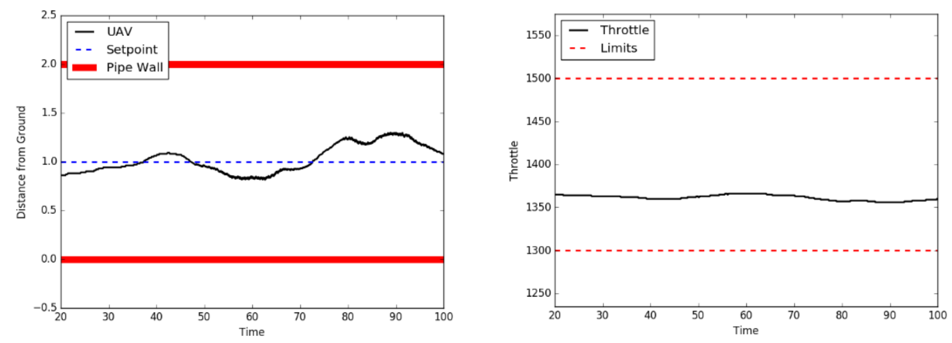
Proof of Concept

Arducopter Software-in-the-loop Simulator:







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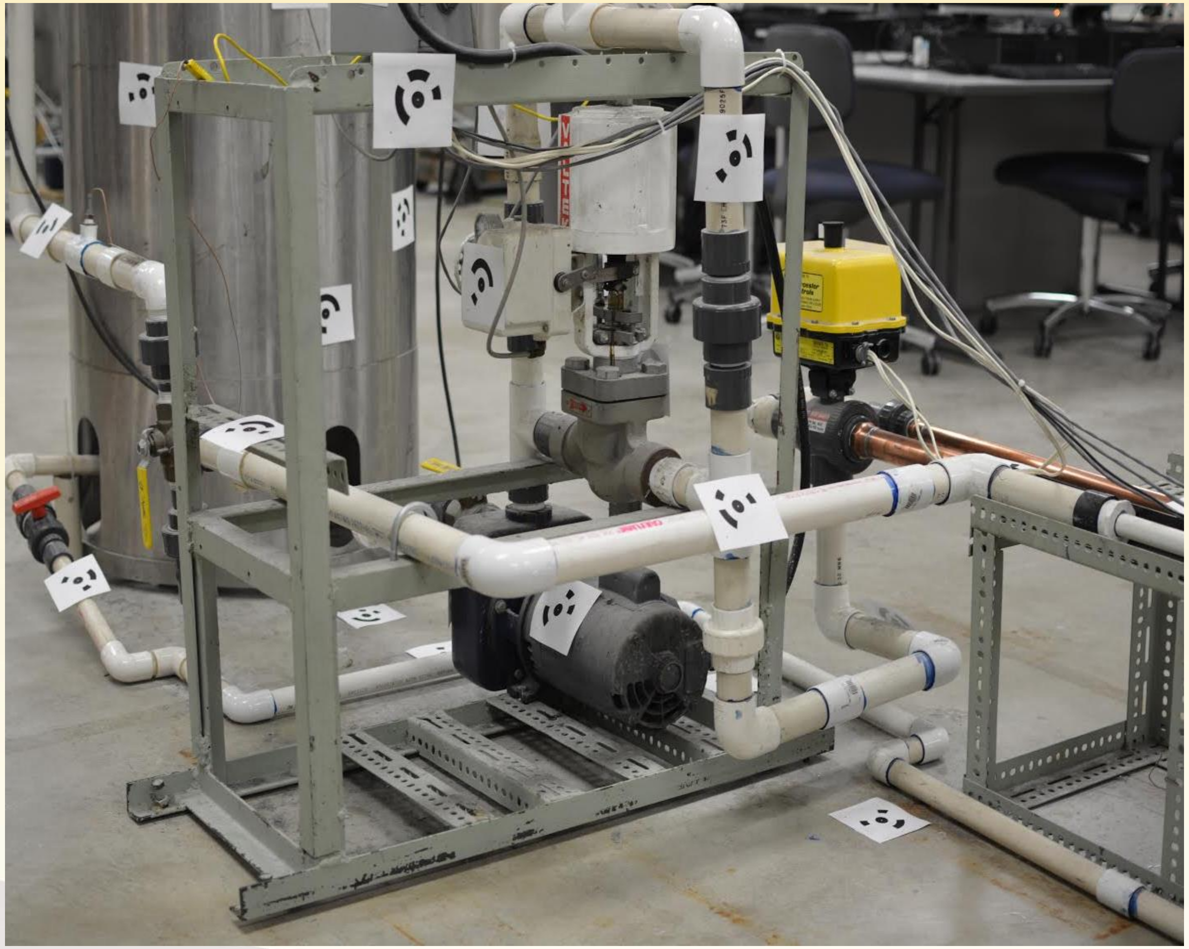
Combined Photogrammetry & LiDAR

- Optimization done in Summer 2016
- Lab scale equipment
  - Flow controller
  - Pumps and meters
  - Pipes and tanks
- Varied surfaces
  - Shiny metallic surfaces
  - PVC Piping



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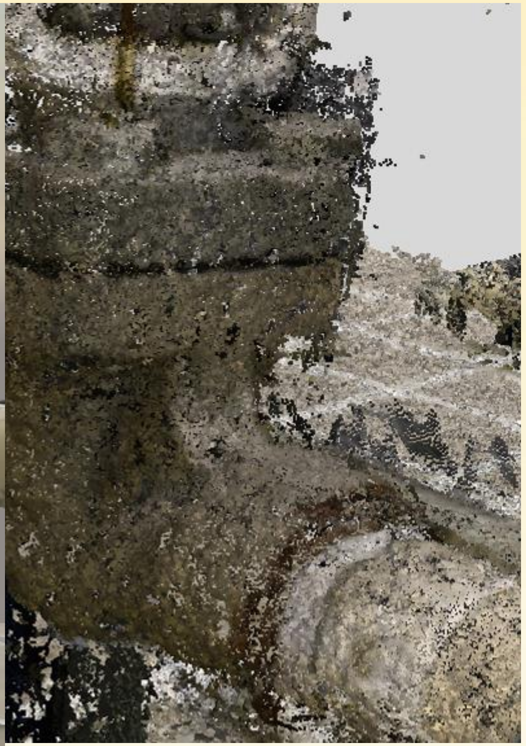
Complex Structure from Motion



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Online 3D Model Gallery

https://goo.gl/DrMsK9

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Going Forward

- Complete thorough change detection field study
- Intelligent multiscale targeted monitoring
- Continue indoor long linear inspection work moving to 2D
  - Physical 1D test flight
- Simulated iterative model refinement study

QUESTIONS?!

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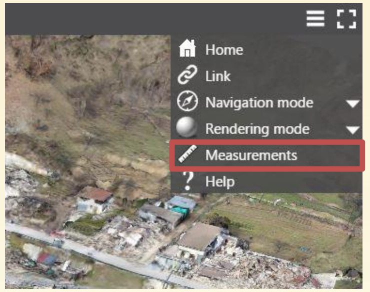
Measurable 3D Models on Your Smartphone

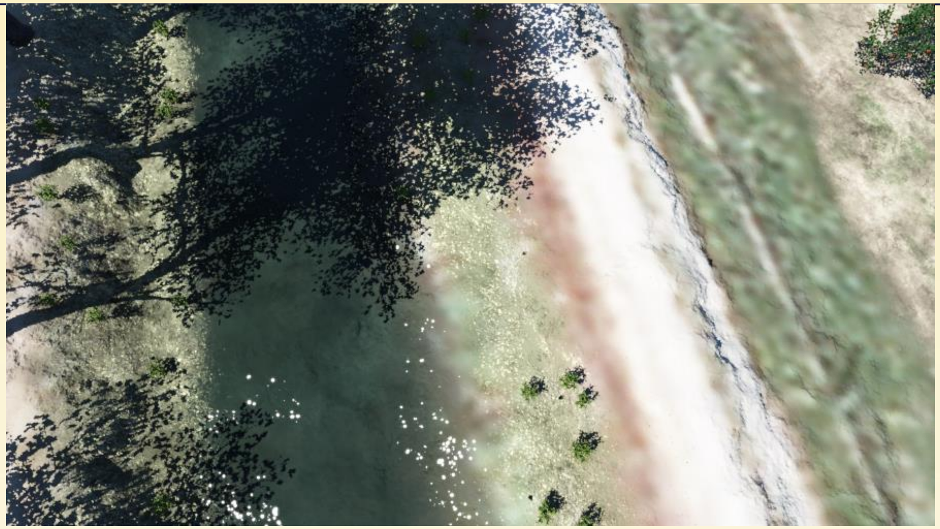
- Task: Calculate the volume of the boulder



8.5m x 6m x 3.5m = *180m*^{3}

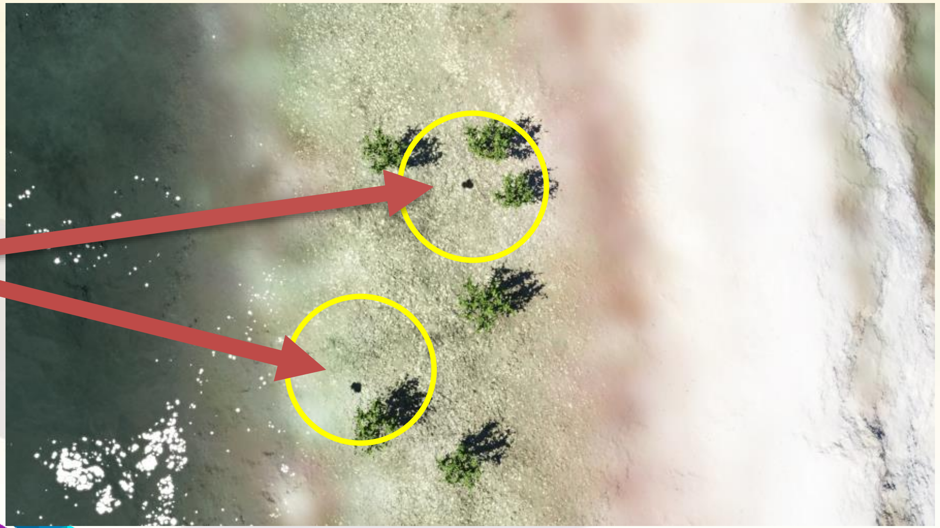
Hole Detection

90 m



11 m

3 inch diameter holes



4 m

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Advantages of Flying Closer

- Small objects visible at closer range
- Increased model knowledge ensures no spot will be missed
- Maximize coverage for 2D change detection
- Smaller (safer and cheaper) UAV's
  - Example: Japan Earthquake model
- Can see beneath objects

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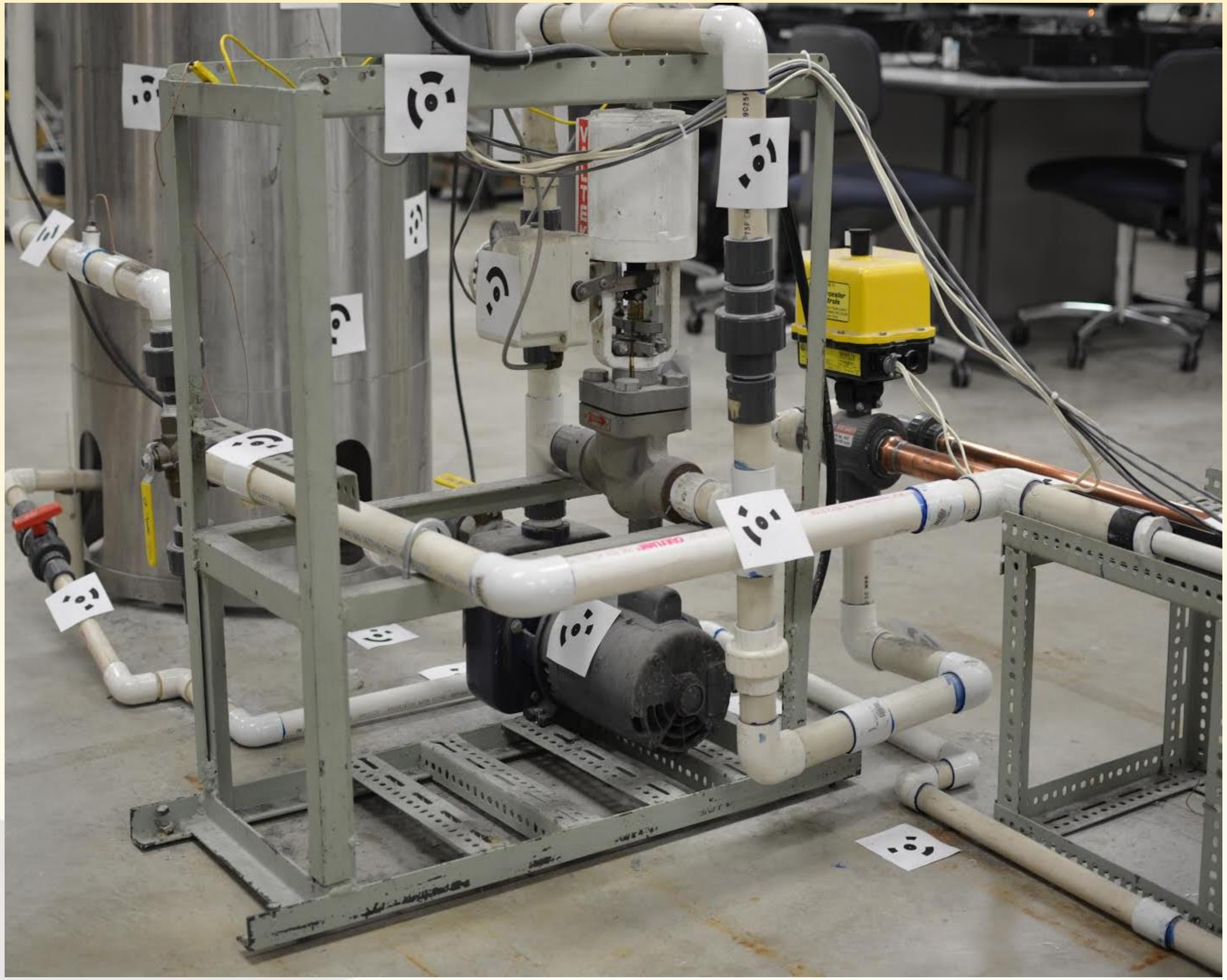
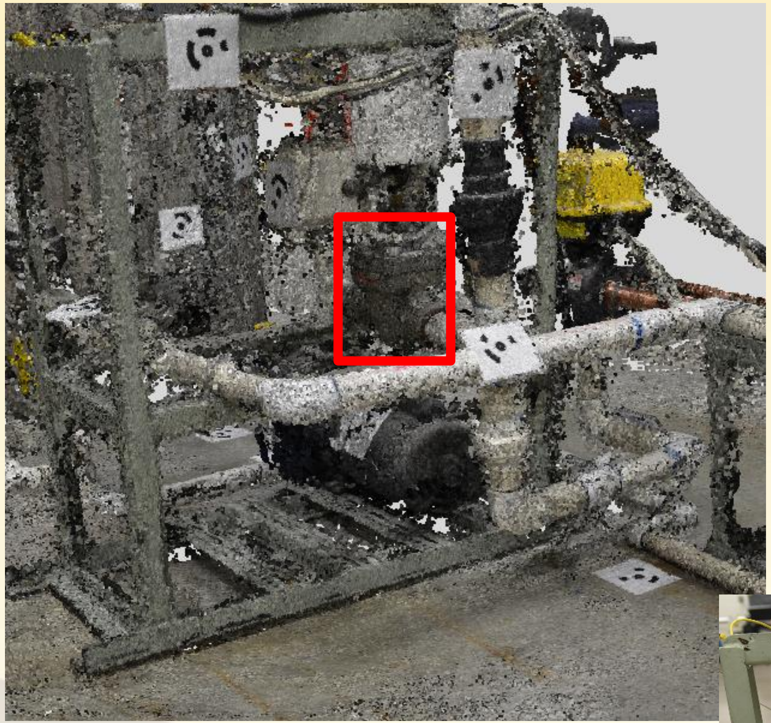
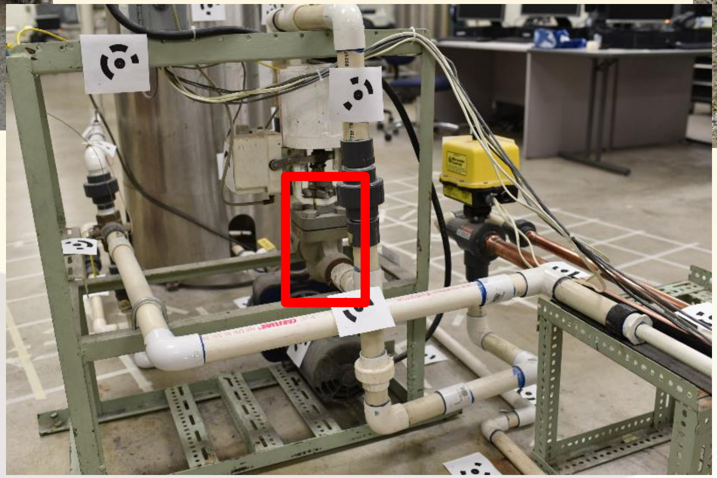
Test Case

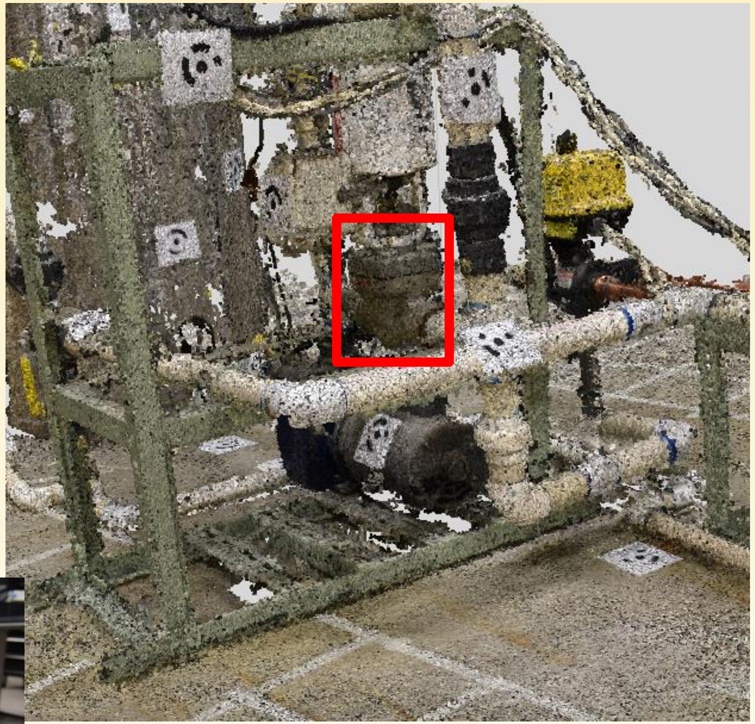
- Lab scale equipment
  - Flow controller
  - Pumps and meters
  - Pipes and tanks
- Varied surfaces
  - Shiny metallic surfaces
  - PVC Piping



Initial Results







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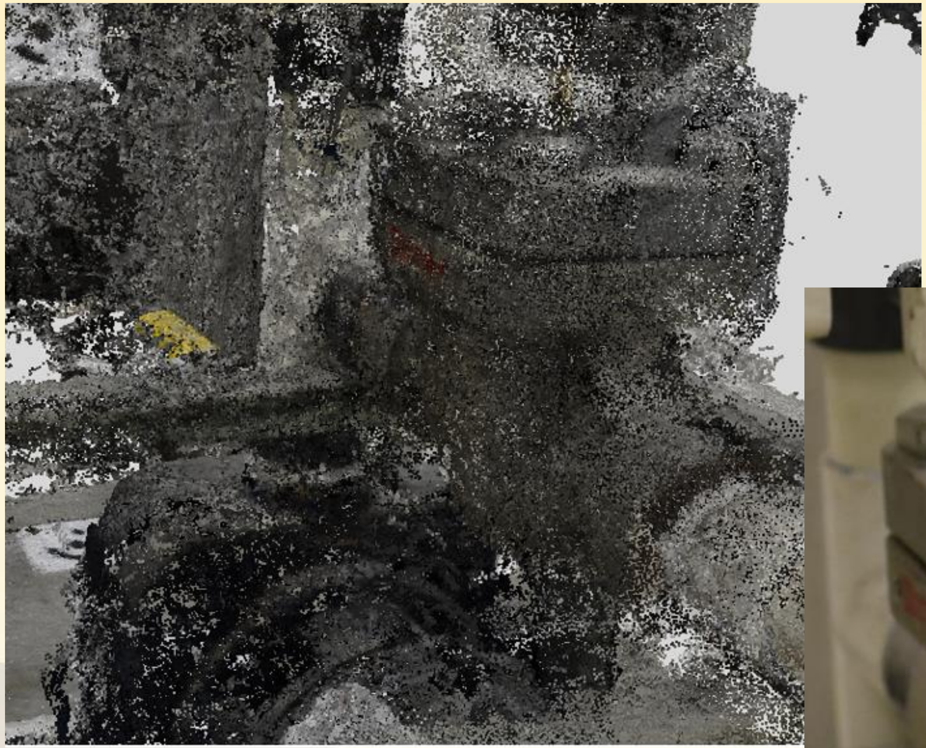
Complex Structure from Motion



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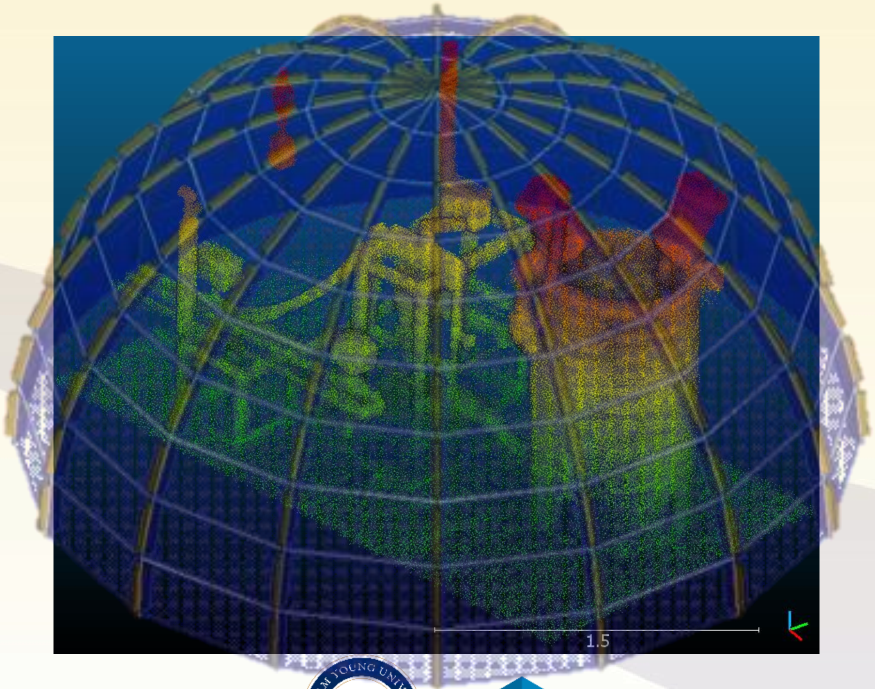
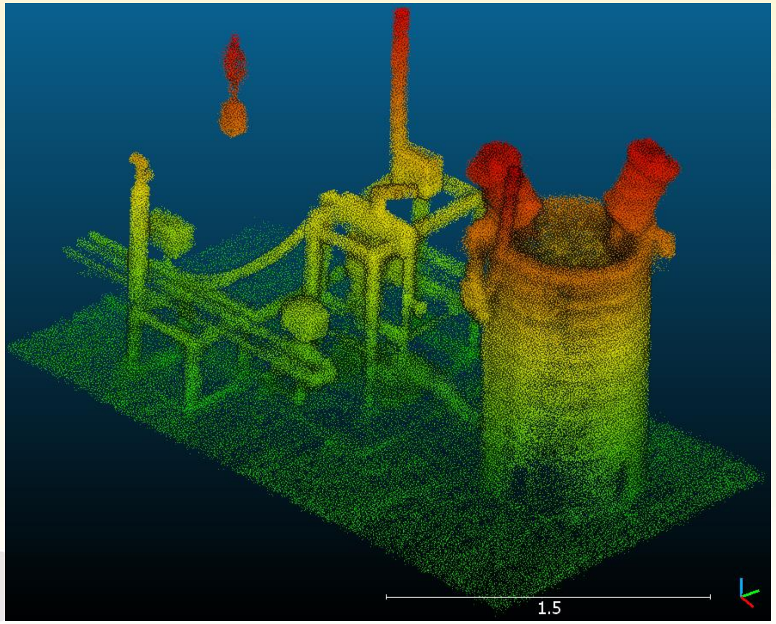
General vs Modeled

- Two methods of optimization

- Unknown system/anomaly
  - Bubble method



- Known system/anomaly
  - New method with blocked cameras



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Application Study 1

- Steinaker Dam – Vernal, UT
- Already have a good model
  - Want to match with a smaller system and camera
- Change detection application
  - Flown 2 years ago
- Verification of optimized flight paths

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Application Study 2

- Highline Canal – Payson, UT
- Long linear application
- Some obstructions
  - Pipes
  - Bridges
  - Trees
- Modeling of detected anomalies

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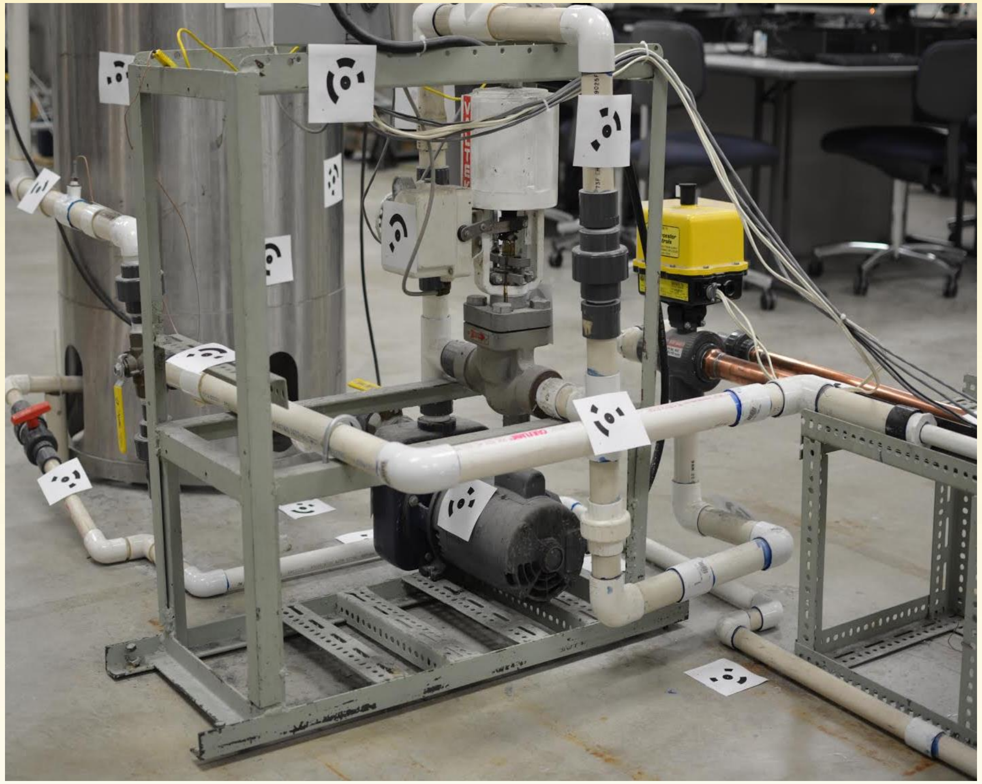
Application Study 3

- Most Complicated System
  - Significant amounts of blocking
- Pictures within the key targets
- Added difficulty from reflections
- Depth of view problems
- Explore alternate methods
  - 2D change detection
  - Object recognition



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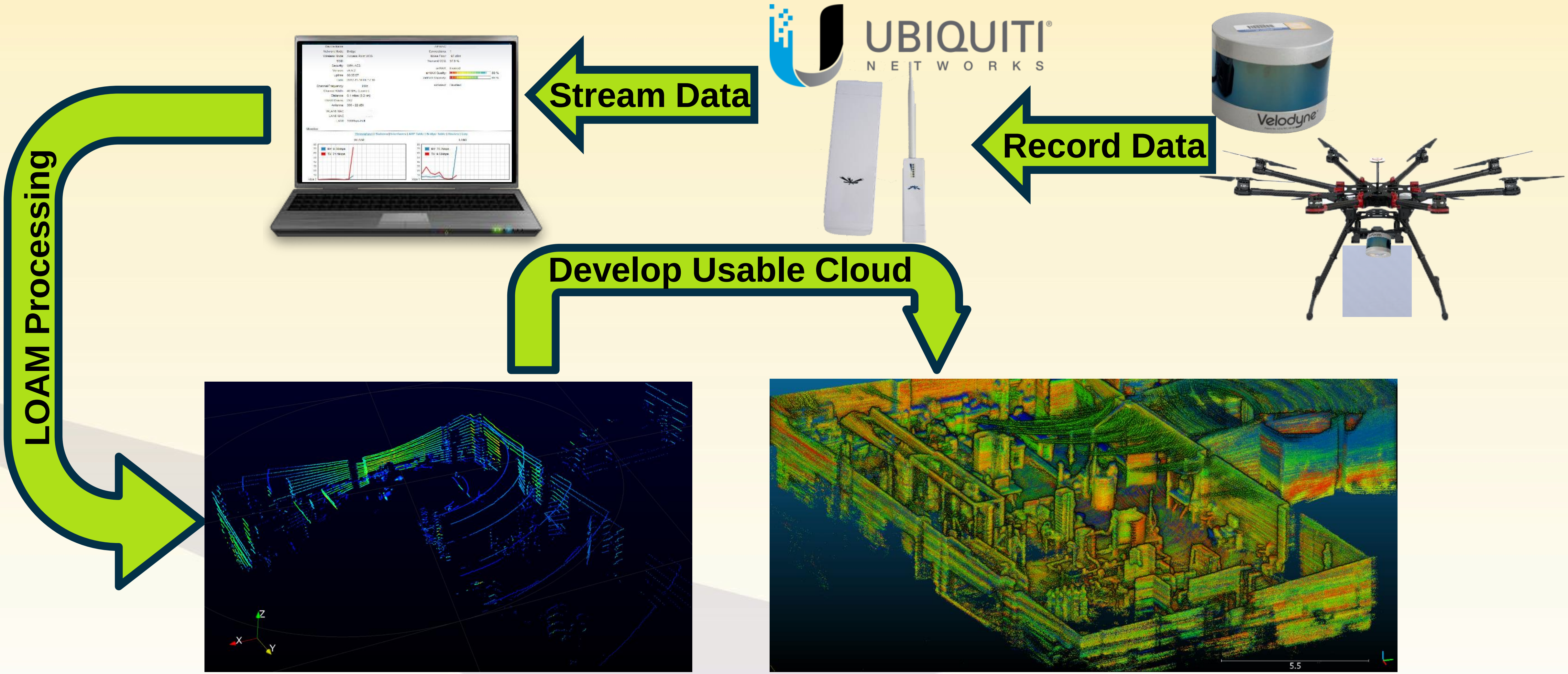
Workflow



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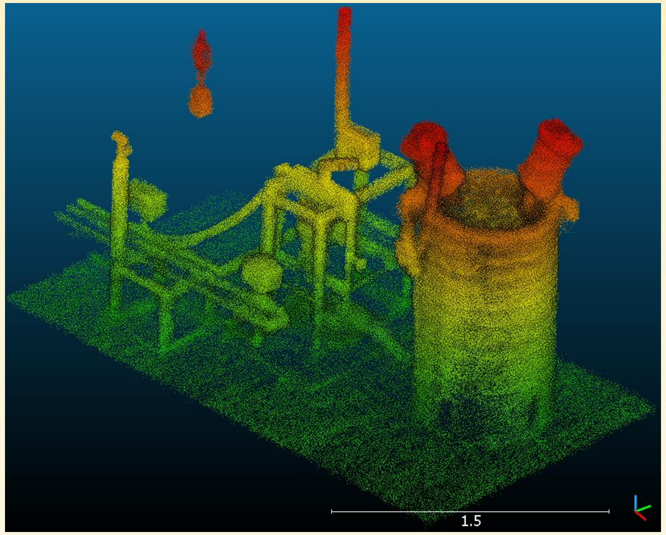
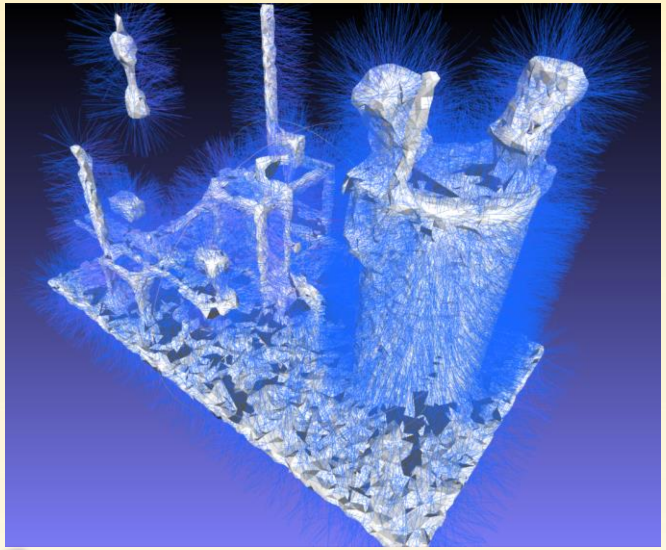
Workflow (part 2)

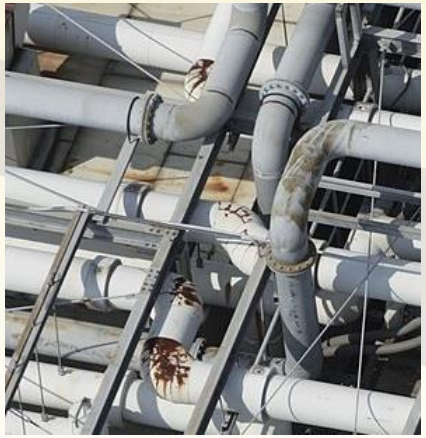


Generate Mesh



Optimize Flight Path

Detect Corrosion



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Initial Conclusions

- Feasible picture locations successfully determined and optimized
- Optimized waypoints reduced pictures by 50% while improving coverage
- Model knowledge increased coverage by ___
- Lidar significantly more accurate for model creation
- Focus issues magnified when in close proximity