

## High Definition Laser Scanning

The most effective survey method available today for location of complex or inaccessible features.



## Part 1: Introduction to LiDAR and Point Clouds

## Laser Scanning (or LiDAR)

### Light Detection And Ranging

### 3 Traditional Types of LiDAR:

#### 1. Aerial LiDAR

(aka Resource-grade LiDAR)

Described in terms of Quality Levels:

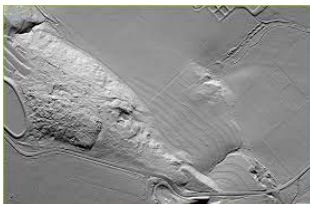
QL1 = 3-8+ points/square meter  
QL2 = 1-2.9 points/square meter  
QL3 < 1 point/square meter

US Forest Service online training:

[http://www.fs.fed.us/eng/rsac/lidar\\_training/](http://www.fs.fed.us/eng/rsac/lidar_training/)



### Examples of Aerial LiDAR:



### 3 Types of LiDAR:

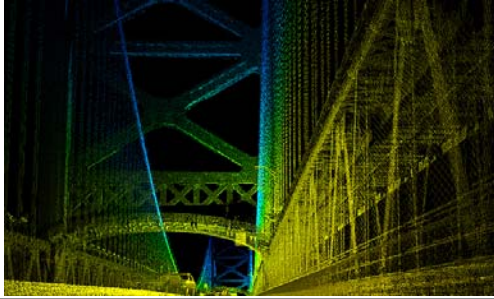
#### 1. Aerial LiDAR

(aka Resource-grade LiDAR)

#### 2. Mobile LiDAR

(scanner on moving vehicle or train)



**Example of Mobile LiDAR:****3 Types of LiDAR:**

1. Aerial LiDAR  
(aka Resource-grade LiDAR)
2. Mobile LiDAR  
(scanner on moving vehicle or train)

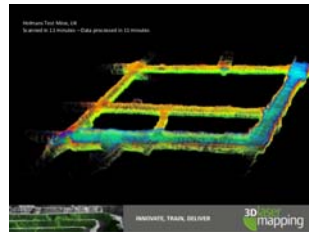

**3. Terrestrial LiDAR**  
**= High Definition 3D Laser Scanning**

(what we'll focus on today)

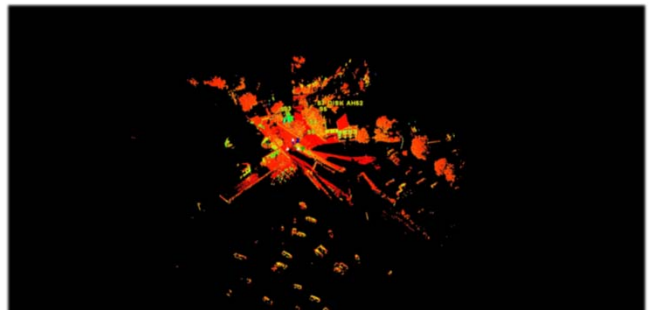
- 50K – 2 million laser measurements per second
- (Typ.) Range capability up to 300+ meters (approx. 1000+ ft)
- Survey-grade accuracy for each measurement

**3\*\* Types of LiDAR:**

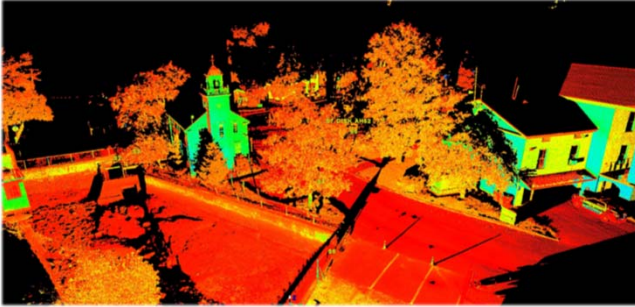
1. Aerial LiDAR  
(aka Resource-grade LiDAR)
2. Mobile LiDAR  
(scanner on moving vehicle or train)
3. Terrestrial LiDAR = High Def. 3D Laser Scanning


**(4) Hand-held scanners**  
 (applications in confined spaces such as mine tunnels)
**LiDAR produces a Point Cloud****So... What is a Point Cloud?****Start with One Scan**

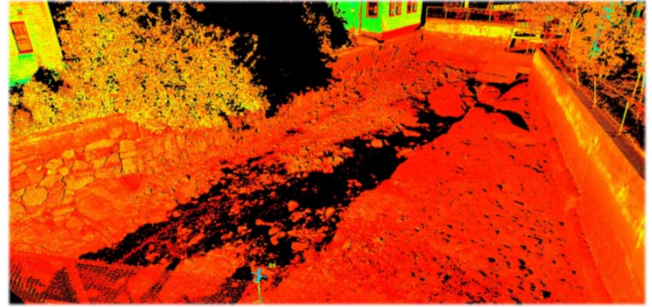
A Point Cloud is a collection of "survey points" where each point is a stored return (X,Y,Z coordinate + intensity value) from the scanner's laser.



Zoom in a little on previous image...



Zoom in a little more on previous image...



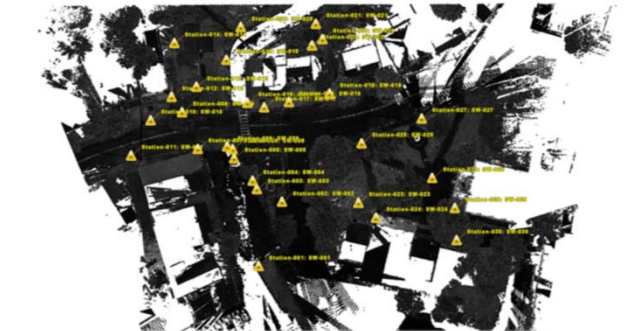
And we begin to see individual "points" in the point cloud...



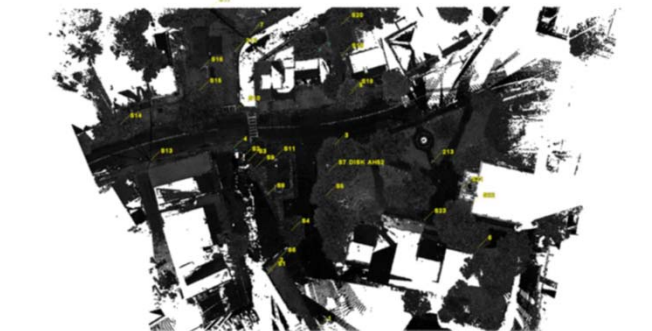
Then Combine Several Scans Together...



And integrate each individual scan into one combined "point cloud"



I combine those scans together using survey control points they share...





We combine those scans together using survey control points they share...



And the software we use to process the scans show how well it all fits...

Zoom in on registration report for Scan-to-Scan, sorted by error size (top)

Type	Status	Weight	Error	Error Vector
Coincident Sphere - Sphere	On	1.0000	0.015 ft	(0.012, 0.010, -0.001) ft
Coincident Sphere - Sphere	On	1.0000	0.013 ft	(-0.003, -0.012, -0.003) ft
Coincident Sphere - Sphere	On	1.0000	0.011 ft	(0.011, 0.004, 0.002) ft
Coincident Sphere - Sphere	On	1.0000	0.011 ft	(0.010, 0.004, 0.001) ft
Coincident Sphere - Sphere	On	1.0000	0.011 ft	(0.007, -0.007, 0.005) ft
Coincident Sphere - Sphere	On	1.0000	0.011 ft	(-0.003, -0.011, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.011 ft	(0.008, -0.007, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.010 ft	(0.008, -0.004, 0.004) ft
Coincident Sphere - Sphere	On	1.0000	0.010 ft	(-0.009, 0.004, -0.004) ft
Coincident Sphere - Sphere	On	1.0000	0.010 ft	(0.006, 0.007, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.010 ft	(0.006, -0.007, 0.004) ft
Coincident Sphere - Sphere	On	1.0000	0.010 ft	(0.007, 0.007, 0.001) ft
Coincident Sphere - Sphere	On	1.0000	0.010 ft	(0.008, -0.005, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.010 ft	(0.007, 0.000, 0.006) ft
Coincident Sphere - Sphere	On	1.0000	0.009 ft	(0.004, -0.008, 0.002) ft
Coincident Sphere - Sphere	On	1.0000	0.009 ft	(0.009, -0.001, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.009 ft	(-0.001, 0.009, 0.002) ft
Coincident Sphere - Sphere	On	1.0000	0.009 ft	(0.006, 0.006, -0.002) ft
Coincident Sphere - Sphere	On	1.0000	0.009 ft	(-0.008, 0.003, -0.002) ft
Coincident Vertex - Vertex	On	1.0000	0.009 ft	(-0.008, -0.002, -0.002) ft
Coincident Sphere - Sphere	On	1.0000	0.009 ft	(0.003, -0.008, 0.001) ft
Coincident Sphere - Sphere	On	1.0000	0.009 ft	(0.002, -0.008, 0.000) ft

Zoom in on registration report for Scan-to-Scan, sorted by error size (bottom)

Coincident Sphere - Sphere	On	1.0000	0.001 ft	(0.001, 0.000, -0.001) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(0.001, 0.001, 0.000) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(-0.001, 0.000, 0.001) ft
Coincident Sphere - Sphere	On	1.0000	0.001 ft	(-0.001, 0.000, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.001 ft	(0.001, 0.000, 0.001) ft
Coincident Sphere - Sphere	On	1.0000	0.001 ft	(0.001, 0.000, 0.000) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(0.001, 0.001, 0.000) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(0.000, -0.001, 0.000) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(0.000, 0.001, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.001 ft	(0.000, 0.000, 0.001) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(-0.001, -0.001, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.001 ft	(0.001, 0.000, 0.001) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(0.000, 0.000, 0.001) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(-0.001, 0.001, 0.000) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(-0.001, 0.000, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.001 ft	(0.001, 0.000, 0.001) ft
Coincident Sphere - Sphere	On	1.0000	0.001 ft	(0.001, 0.000, 0.000) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(0.000, 0.000, 0.000) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(0.000, 0.000, 0.001) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(0.000, 0.000, 0.000) ft
Coincident Vertex - Vertex	On	1.0000	0.001 ft	(0.000, 0.000, 0.000) ft
Coincident Sphere - Sphere	On	1.0000	0.001 ft	(0.000, 0.000, 0.000) ft

Zoom in on registration report for Scan-to-Control (sorted by error)

5521 (FOR IMPORT 27-AUG-2018 - CONTROL ONLY).TXT - Notepad

```

File Edit Format View Help
1, 3035263.958, 852073.4382, 7.301, MAGS
2, 3035334.059, 852027.189, 7.496, HUBS
3, 3035463.846, 852113.876, 12.056, MAGS
4, 3035472.129, 852001.702, 9.876, MAGS
5, 3035517.233, 852135.9036, 12.62057, MAGS
6, 3035333.875, 852259.9887, 14.50547, MAGS
7, 3035595.634, 852033.2655, 9.59764, HUBS
212, 3035579.885, 852015.8565, 9.5383, MAGS
213, 3035434.028, 852220.022, 13.64829, MAGS
57 DISK AH52, 3035434.65, 852103.3923, 11.166, DISKF-1053
510, 3035515.867, 852011.5738, 10.386, DISKF-1165

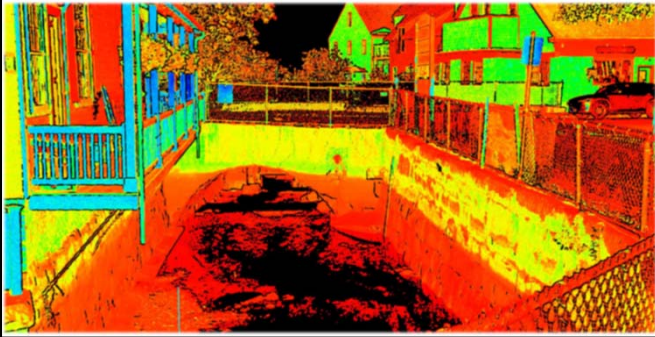
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Constraint ID	ScanWorld	Status	Weight	Error	Error Vector
5521	5521 (FOR IMPORT 27-AUG-2018 - CONTROL ONLY).TXT (Levelled)	On	1.0000	0.020 ft	(0.006, -0.012, 0.015) ft
510	5521 (FOR IMPORT 27-AUG-2018 - CONTROL ONLY).TXT (Levelled)	On	1.0000	0.020 ft	(-0.012, -0.001, -0.009) ft
5	5521 (FOR IMPORT 27-AUG-2018 - CONTROL ONLY).TXT (Levelled)	On	1.0000	0.018 ft	(-0.003, 0.018, 0.003) ft
213	5521 (FOR IMPORT 27-AUG-2018 - CONTROL ONLY).TXT (Levelled)	On	1.0000	0.015 ft	(0.009, -0.011, 0.004) ft
57 DISK AH52	5521 (FOR IMPORT 27-AUG-2018 - CONTROL ONLY).TXT (Levelled)	On	1.0000	0.014 ft	(0.011, 0.000, -0.007) ft
212	5521 (FOR IMPORT 27-AUG-2018 - CONTROL ONLY).TXT (Levelled)	On	1.0000	0.013 ft	(0.013, 0.002, 0.002) ft
7	5521 (FOR IMPORT 27-AUG-2018 - CONTROL ONLY).TXT (Levelled)	On	1.0000	0.012 ft	(0.008, 0.004, -0.003) ft

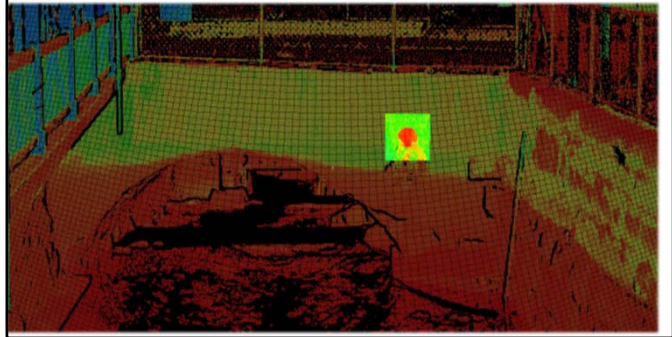
We can "slice" parts of the cloud to view in 3D...



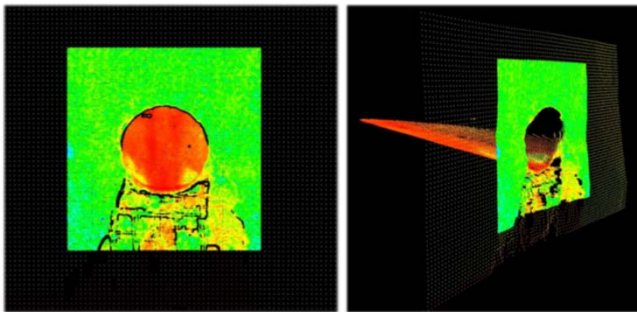
We can select the density of the scan coverage within each scan setup



We choose different density/resolution to suit different purposes...



Example of getting pipe size & invert elevation from higher-res scan window



## Part 2: Applications in Topographic & Construction Surveys

Accurate and safe surveys of complex and/or inaccessible features



2.2 - Building Surveys  
"Snow Pump Station"  
Nashua, NH

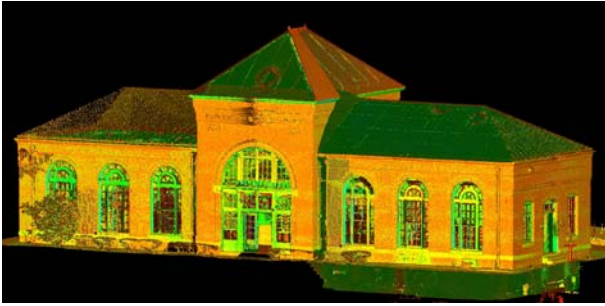
Delivered:

3D CAD Solid  
Models

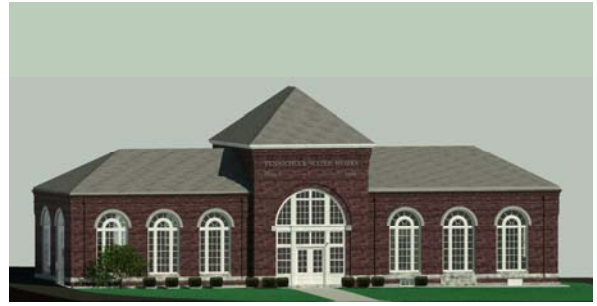
(exported from  
Revit Models)



Building Survey – for 3D Modeling in Revit – can support BIM



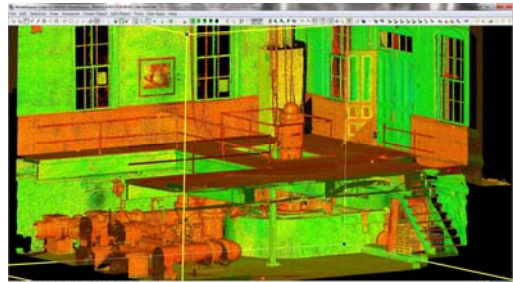
Building Survey – for 3D Modeling in Revit



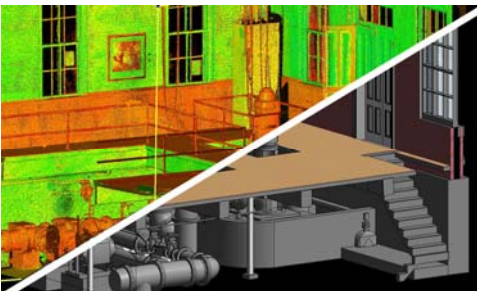
Building Survey – for 3D Modeling in Revit



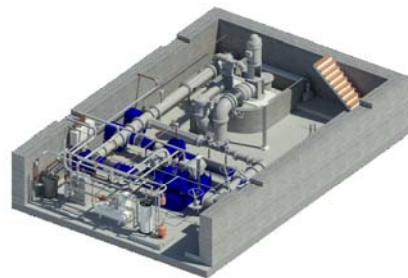
Building Survey – for 3D Modeling in Revit



Building Survey – for 3D Modeling in Revit

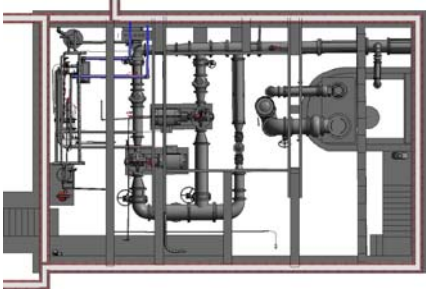


Building Survey – 3D Modeling in Revit





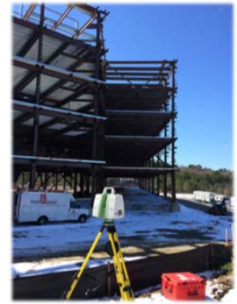
### Building Survey – for 3D Modeling in Revit



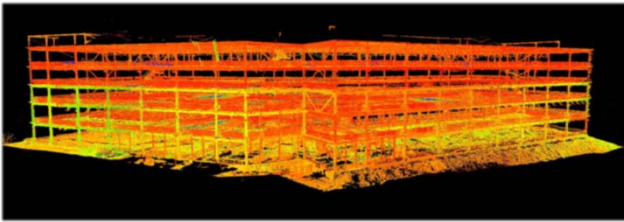
### 2.3 - Steel Plumbness Surveys Millipore Office Building Burlington, MA

Delivered:

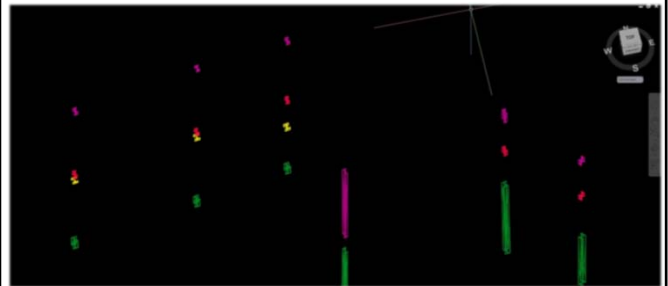
Column Plumbness Report



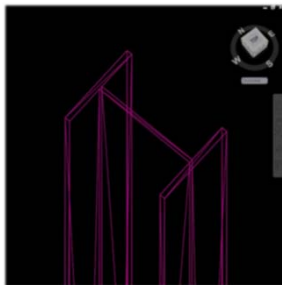
### Millipore Office Building - Burlington, MA



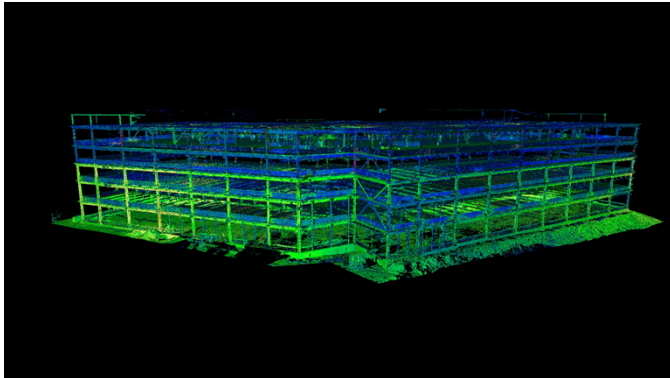
### Millipore Office Building - Burlington, MA



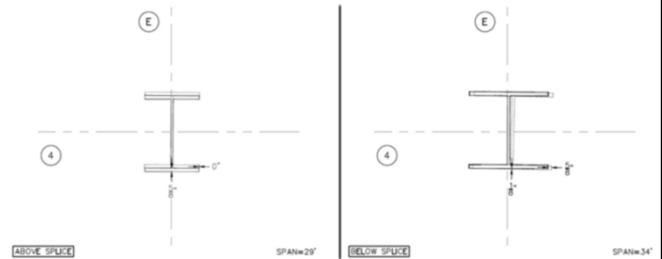
### Millipore Office Building - Burlington, MA



Video fly-through of site



Millipore Office Building - Burlington, MA



## 2.4 – Flatness Surveys (Elevation Maps)

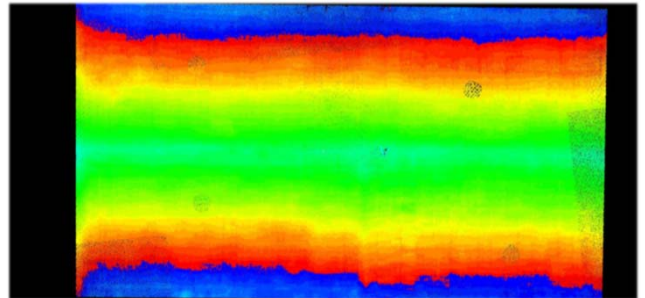
Delivered:

“Elevation Map” in heat-map format

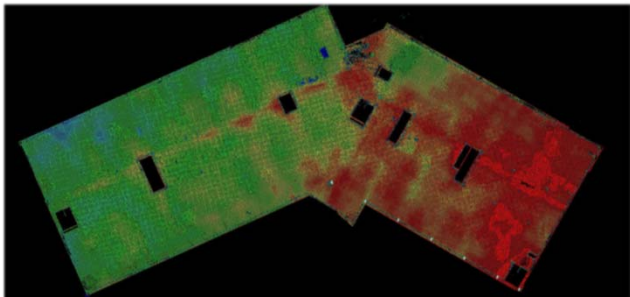
CAD surface



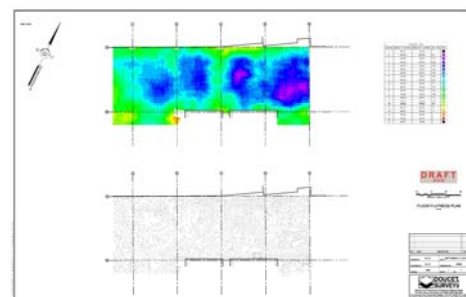
UNH Field Hockey Field – Durham, NH



Office Building – Burlington, MA

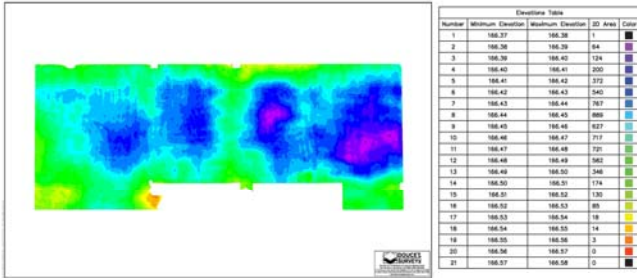


Parking Garage





### Parking Garage –



### 2.5.1 – Difficult & Dangerous Places

Ledge Face: approx. 62' high at highest point, 1000 linear feet to survey



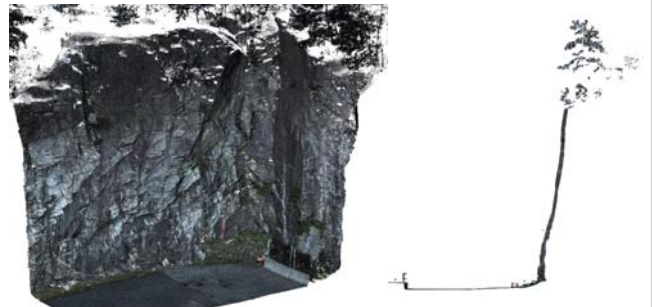
### 2.5.1 – Difficult & Dangerous Places

Ledge Face: approx. 62' high at highest point, 1000 linear feet to survey



### 2.5.1 – Difficult & Dangerous Places

Ledge Face: approx. 62' high at highest point, 1000 linear feet to survey



### 2.5.2 – Difficult & Dangerous Places

Electrical Substation



### 2.5.2 – Difficult & Dangerous Places

Electrical Substation



**2.5.2 – Difficult & Dangerous Places**  
**Electrical Substation**



**2.5.2 – Difficult & Dangerous Places**  
**Electrical Substation**



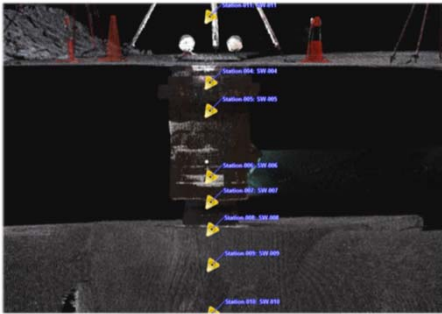
**2.5.3 – Difficult & Dangerous Places**  
**Confined-Space Vault with College Brook flowing through it (UNH)**



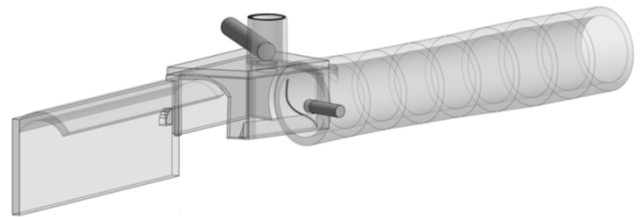
**2.5.3 – Difficult & Dangerous Places**  
**Confined-Space Vault with College Brook flowing through it (UNH)**



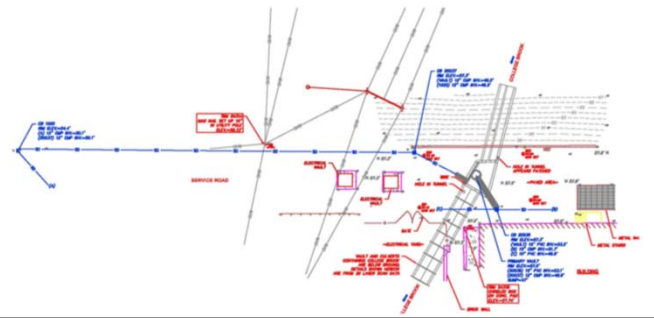
**2.5.3 – Difficult & Dangerous Places**  
**Confined-Space Vault with College Brook flowing through it (UNH)**



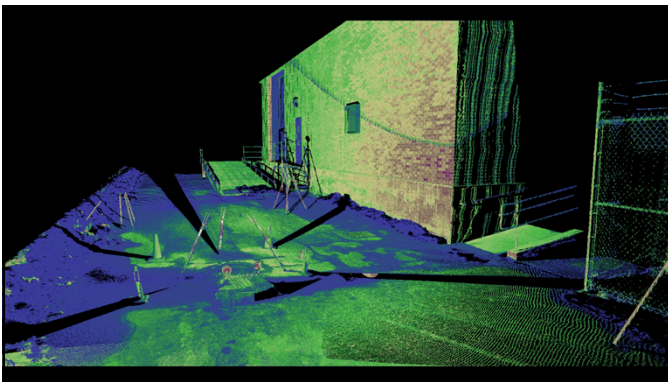
**2.5.3 – Difficult & Dangerous Places**  
**Confined-Space Vault with College Brook flowing through it (UNH)**



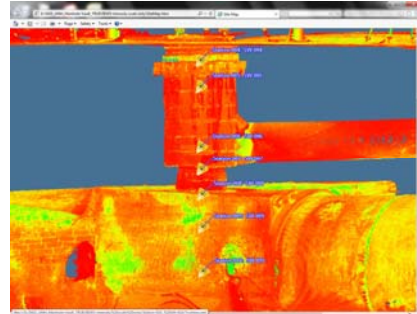
**2.5.3 – Difficult & Dangerous Places**  
**Confined-Space Vault with College Brook flowing through it (UNH)**



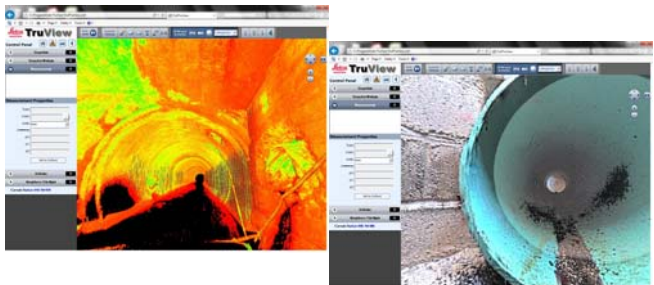
Video fly-through of site



Sidebar: Leica TruView – free downloadable app



Sidebar: Leica TruView – free downloadable app

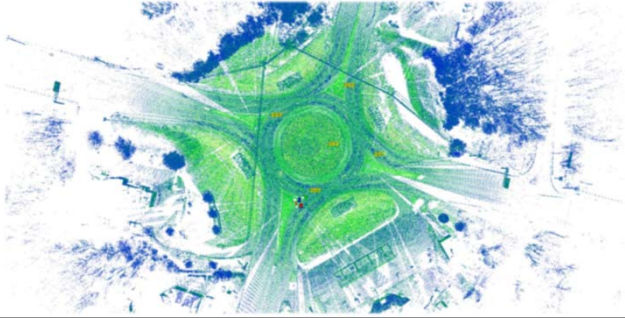


**2.5.4 – Difficult & Dangerous Places**  
**Lee Traffic Circle (Rotary) – Lee, NH**

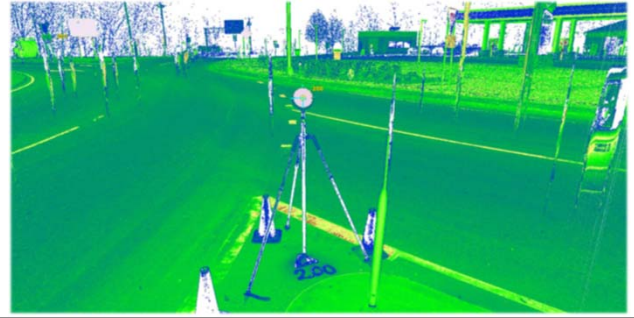




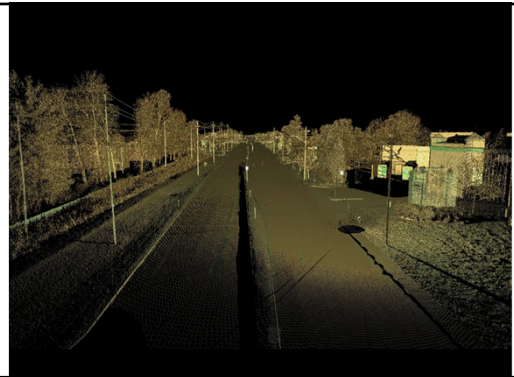
2.5.4 – Difficult & Dangerous Places  
Lee Traffic Circle (Rotary) – Lee, NH



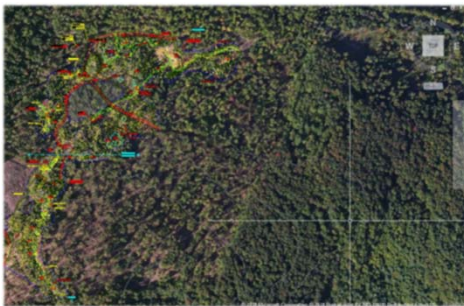
2.5.4 – Notice the “static” or “noise” from passing vehicles...



Video fly-through of another roadway  
Broadway Ave – Salem NH  
Scanned November 28, 2016



2.5.5 – Difficult & Dangerous Places  
Pike Hill Mines, Corinth VT



2.5.5 – Difficult & Dangerous Places  
Pike Hill Mines, Corinth VT



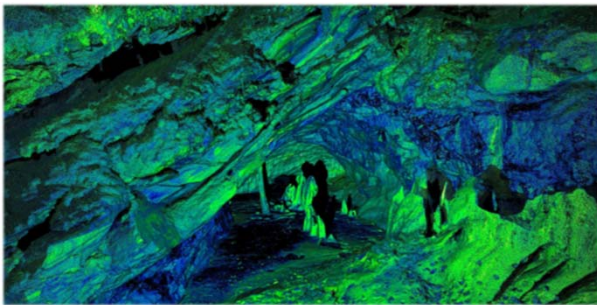
### 2.5.5 – Difficult & Dangerous Places Pike Hill Mines, Corinth VT



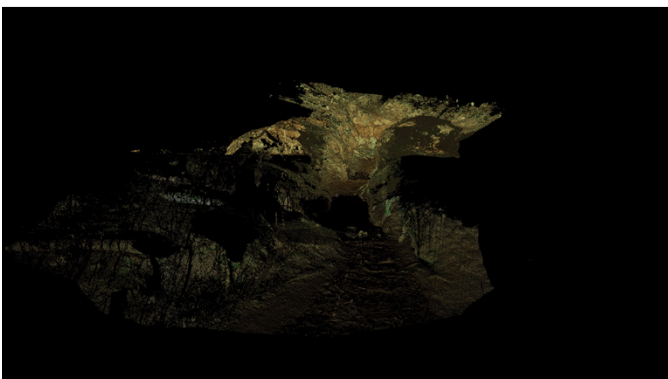
### 2.5.5 – Difficult & Dangerous Places Pike Hill Mines, Corinth VT



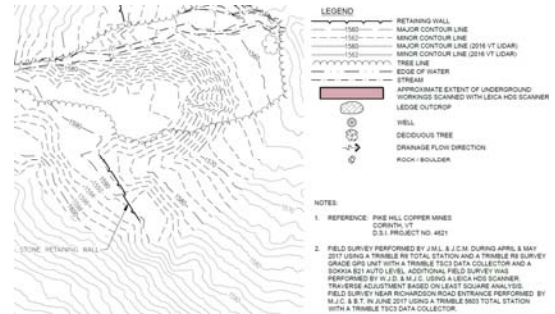
### 2.5.5 – Difficult & Dangerous Places Pike Hill Mines, Corinth VT



### Video fly-through of one of the mines



**Sidebar:**  
**Combination of Conventional Survey , Aerial LiDAR, and 3D Laser Scanning**



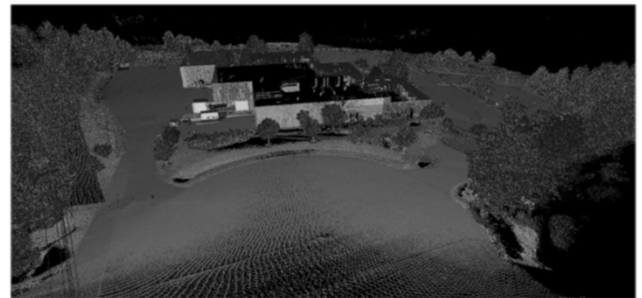
**Let's take a short break**

## **Part 3: Applications in Boundary Surveys**

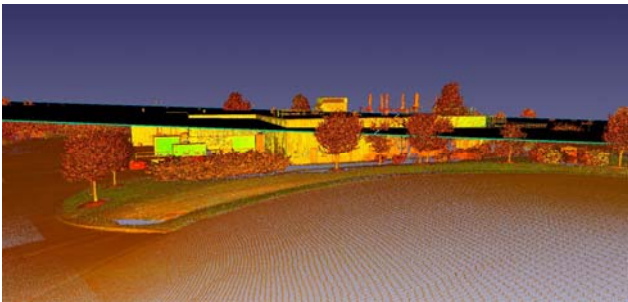
**3.1.1 – ALTA Issues**  
Avigation Easement – Technology Drive, Lebanon, NH



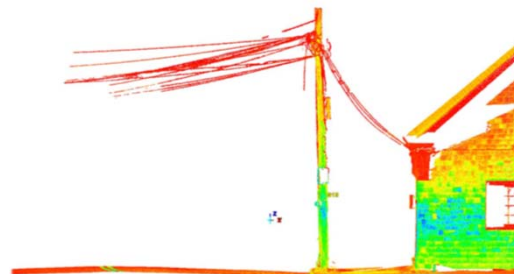
**3.1.1 – ALTA Issues**  
Avigation Easement – Technology Drive, Lebanon, NH



**3.1.1 – ALTA Issues**  
Avigation Easement – Technology Drive, Lebanon, NH

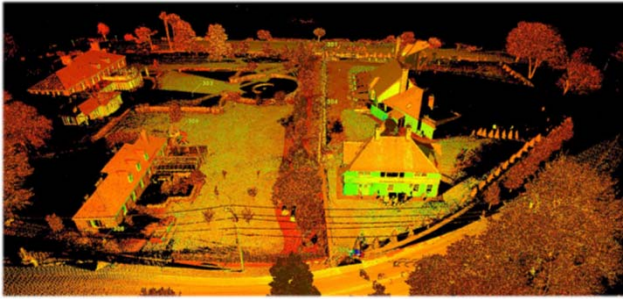


**3.1.2 – ALTA Issues**  
Utility Poles near property lines

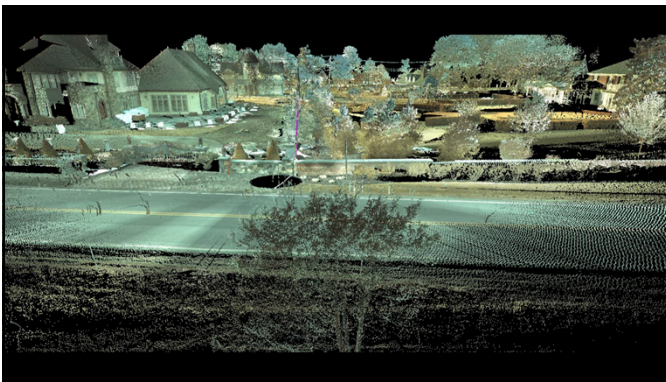




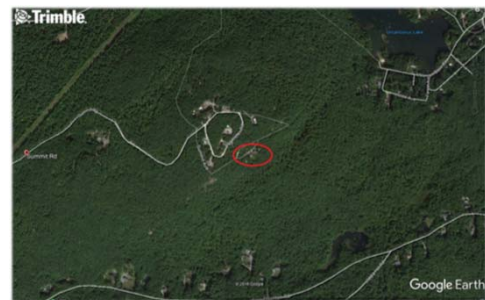
### 3.2.1 – Boundary Surveys Illustrating the property line for the masses...



Video fly-through of the site –  
magenta line is along property line



### 3.2.2 – Boundary Surveys Illustrating extent of trespass, helping with “Beware of the Dog” issues...



### 3.2.2 – Boundary Surveys

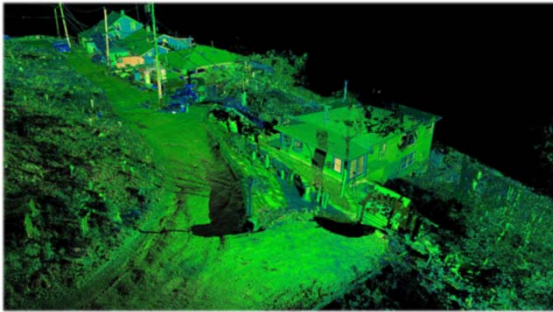


### 3.2.2 – Boundary Surveys Illustrating extent of trespass, helping with “Beware of the Dog” issues...



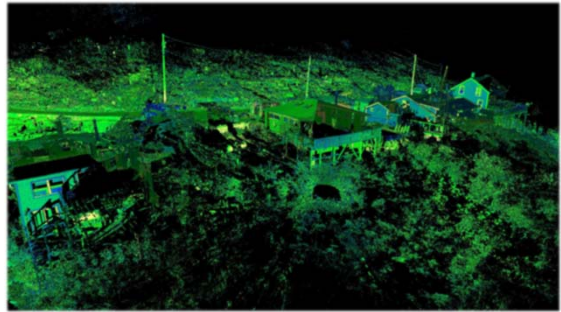
### 3.2.2 – Boundary Surveys

Illustrating extent of trespass, helping with “Beware of the Dog” issues...



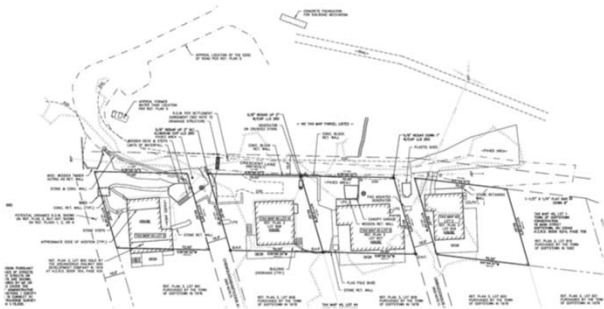
### 3.2.2 – Boundary Surveys

Illustrating extent of trespass, helping with “Beware of the Dog” issues...



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Illustrating extent of trespass, helping with “Beware of the Dog” issues...



### 3.2.2 – Boundary Surveys

Illustrating extent of trespass

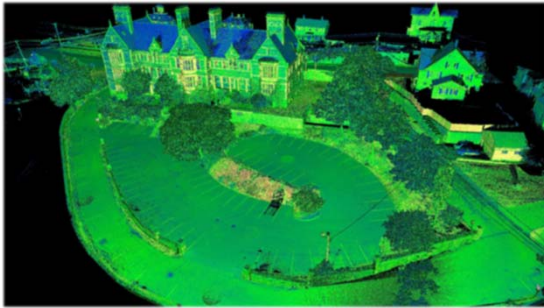


## Part 4: Range of Deliverables

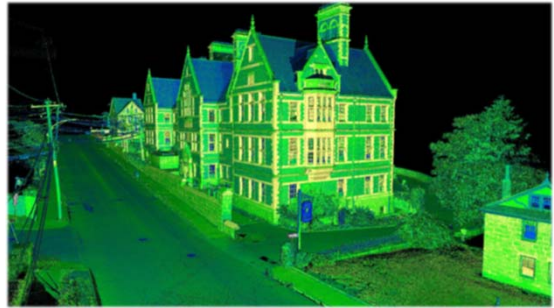
### 4.1 – Point Cloud (only) as a deliverable



4.1 – Point Cloud (only) as a deliverable



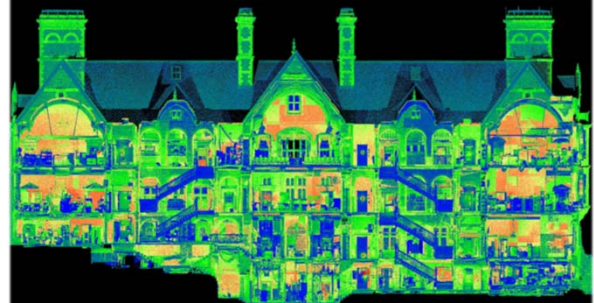
4.1 – Point Cloud (only) as a deliverable



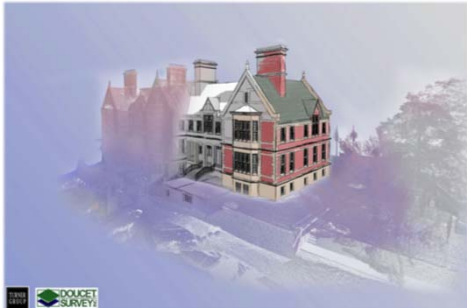
4.1 – Point Cloud (only) as a deliverable



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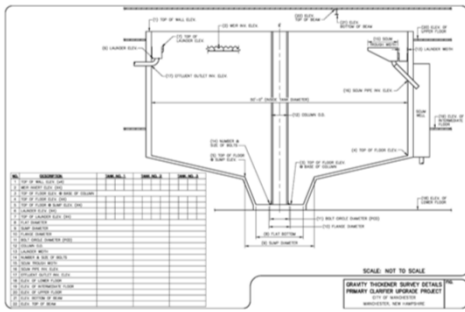


4.1 – Excel spreadsheet only (not a common deliverable)

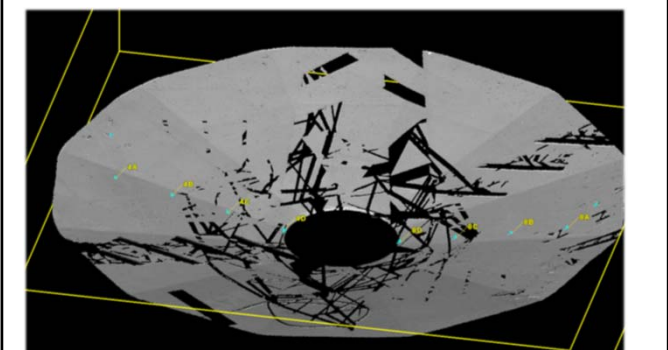
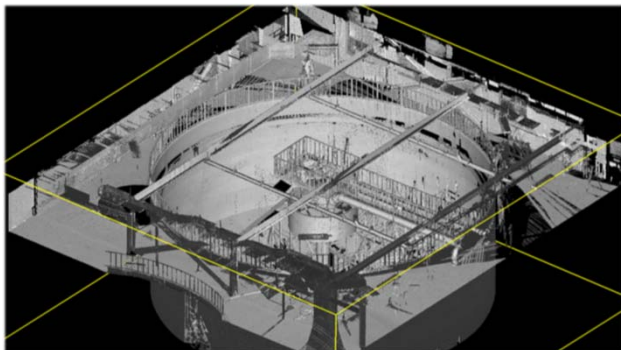
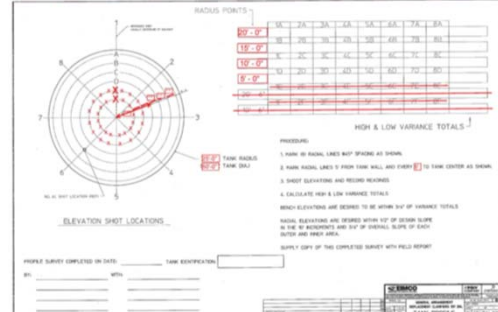




## 4.1 – Excel spreadsheet only (not a common deliverable)

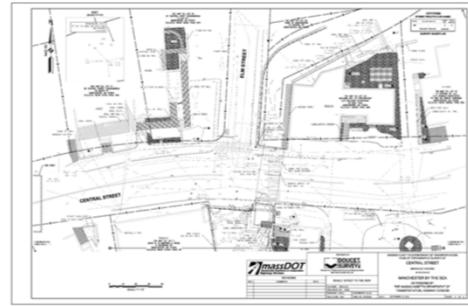


## 4.1 – Excel spreadsheet only (not a common deliverable)

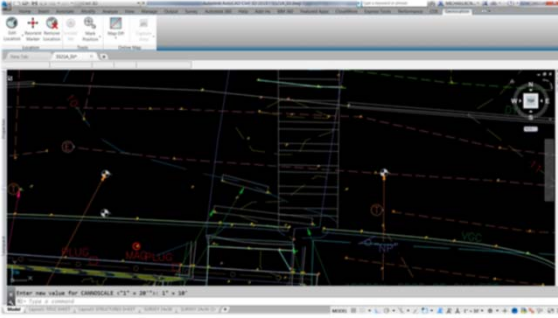


[illegible]

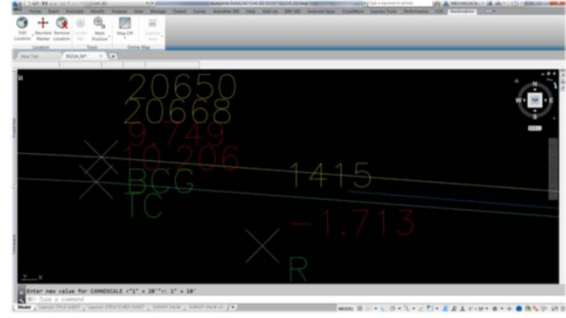
### 4.3 – Autodesk Civil 3D Drawing (our most frequent deliverable)



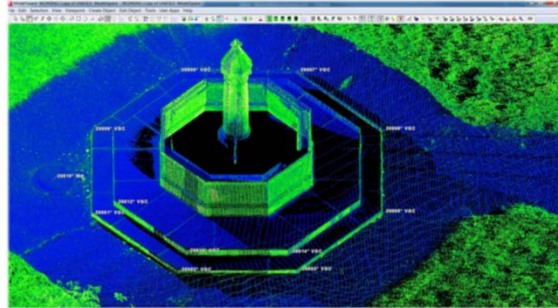
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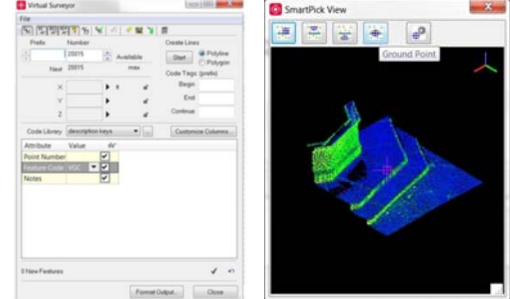
### 4.3 – Autodesk Civil 3D Drawing (our most frequent deliverable)



### 4.3 – Autodesk Civil 3D (use Leica Cyclone Virtual Survey Points)



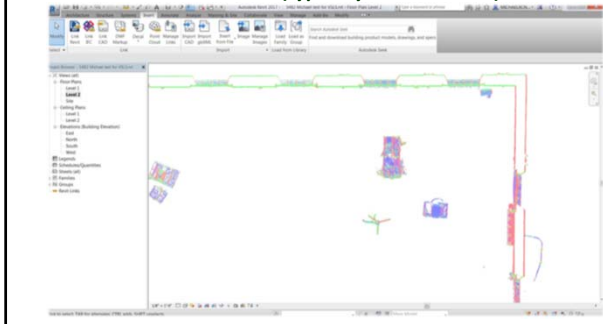
### 4.3 – Autodesk Civil 3D (use Leica Cyclone Virtual Survey Points)



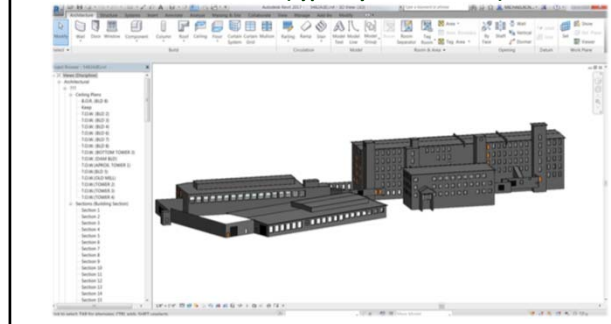




#### 4.4 – Autodesk Revit Model (typically for Architects)



#### 4.4 – Autodesk Revit Model (typically for Architects)



#### 4.4 Autodesk Revit Model Bement Covered Bridge Bradford, NH Built in 1854

Delivered:

Existing Conditions plan in  
CAD

3D model of timbers

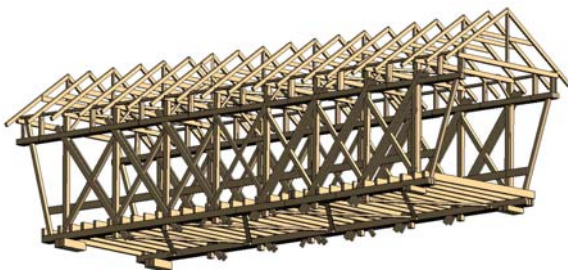
2D plan & profile views



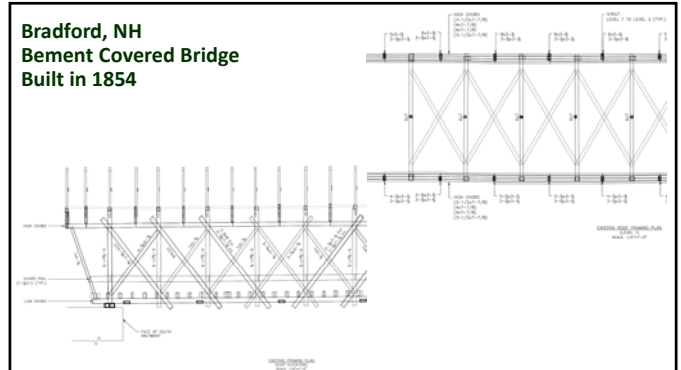
#### Bradford, NH Bement Covered Bridge Built in 1854



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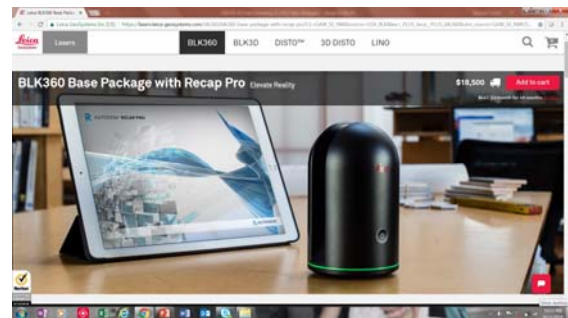
## 4.5 Leica TruView Files as a deliverable

## 5. Costs

### 5. Costs

1. Hardware
  - A. Scanner
  - B. Targets/Spheres
  - C. Additional Server to store data
2. Software
  - A. Cyclone (for example) to manipulate scan data
  - B. Cloudworx for Civil 3D
  - C. Edgewise (for example) for auto-extraction & modeling
3. Training

### 5.1 Hardware Costs – huge variability in \$ and capability



### 5.1 Hardware Costs – huge variability in \$ and capability



### 5.1 Hardware Costs – will almost certainly need extra server

Recent scan project with 30 scans, no images: 36GB

Recent scan project with 100+/- scans, no images: 133GB

## 5.2 Software Costs

### Leica Cyclone Subscription Software

5308150	Cyclone Subscription base (1yr).	\$	60
	Cyclone Subscription (1yr)		
	- Base product for Cyclone module subscriptions.		
	- Must be ordered with at least one module Option.		
5308151	Cyclone BASIC Option (1yr Subscription)	\$	810
5308152	Cyclone REGISTER Option (1yr Subscription)	\$	3,190
5308153	Cyclone SURVEY Option (1yr Subscription)	\$	3,190
5308154	Cyclone MODEL Option (1yr Subscription)	\$	5,420
5308155	Cyclone IMPORTER Option (1yr Subscription)	\$	820
5308156	Cyclone SERVER-Client Option (1yr Subscription)	\$	420
5308157	Cyclone SERVER-Base Option (1yr Subscription)	\$	830
5308158	Cyclone PUBLISHER Pro Option (1yr Subscription)	\$	3,760
5308159	Cyclone REGISTER 360 Option (1yr Subscription)	\$	2,050
5308160	Cyclone TruView PUBLISHER Option (1yr Sub)	\$	2,050

Thank you for your interest!

