SPARC @ CAST-AIL

SPatial Archaeometry Research Collaborations

sparc.cast.uark.edu

Multi-scalar 3D documentation.

Linking up ALS, TLS, and Object Scanning.

W. Fredrick Limp, Rachel Opitz, Katie Simon, Adam Barnes,
Malcolm Williamson and Jack Cothren
Center for Advanced Spatial Technologies
University of Arkansas Fayetteville

Outline

- Very brief review of key aspects of technologies
- Compare and contrast capabilities and features
- How to decide
- Sources of more info
- Questions

Focus … acquisition and analysis of HDSM data

- HDSM
  - – High density survey and measurement
- Technologies involved
  - – Airborne photogrammetry
  - – Airborne LiDAR
  - – GPS (esp) high resolution
  - – Terrestrial “laser” scanning
  - – Terrestrial photogrammetry

Focus …acquisition of spatial data

- Airborne photogrammetry
- Airborne LiDAR
- GPS (esp) high resolution
- Terrestrial LS and related
- Terrestrial photogrammetry

Landscape

Site

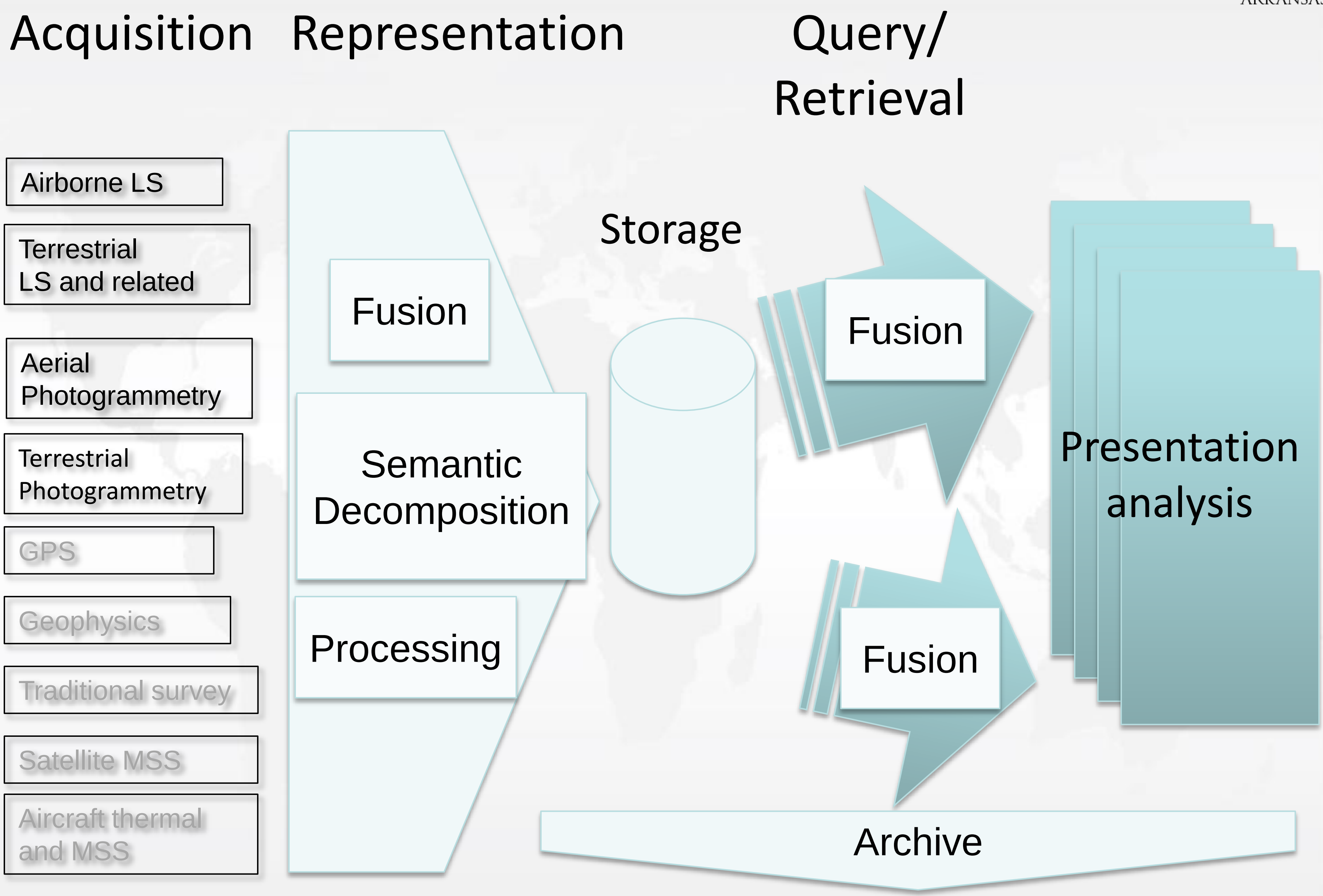
Structure

Feature

Object

A single (class of) tool(s) is not adequate

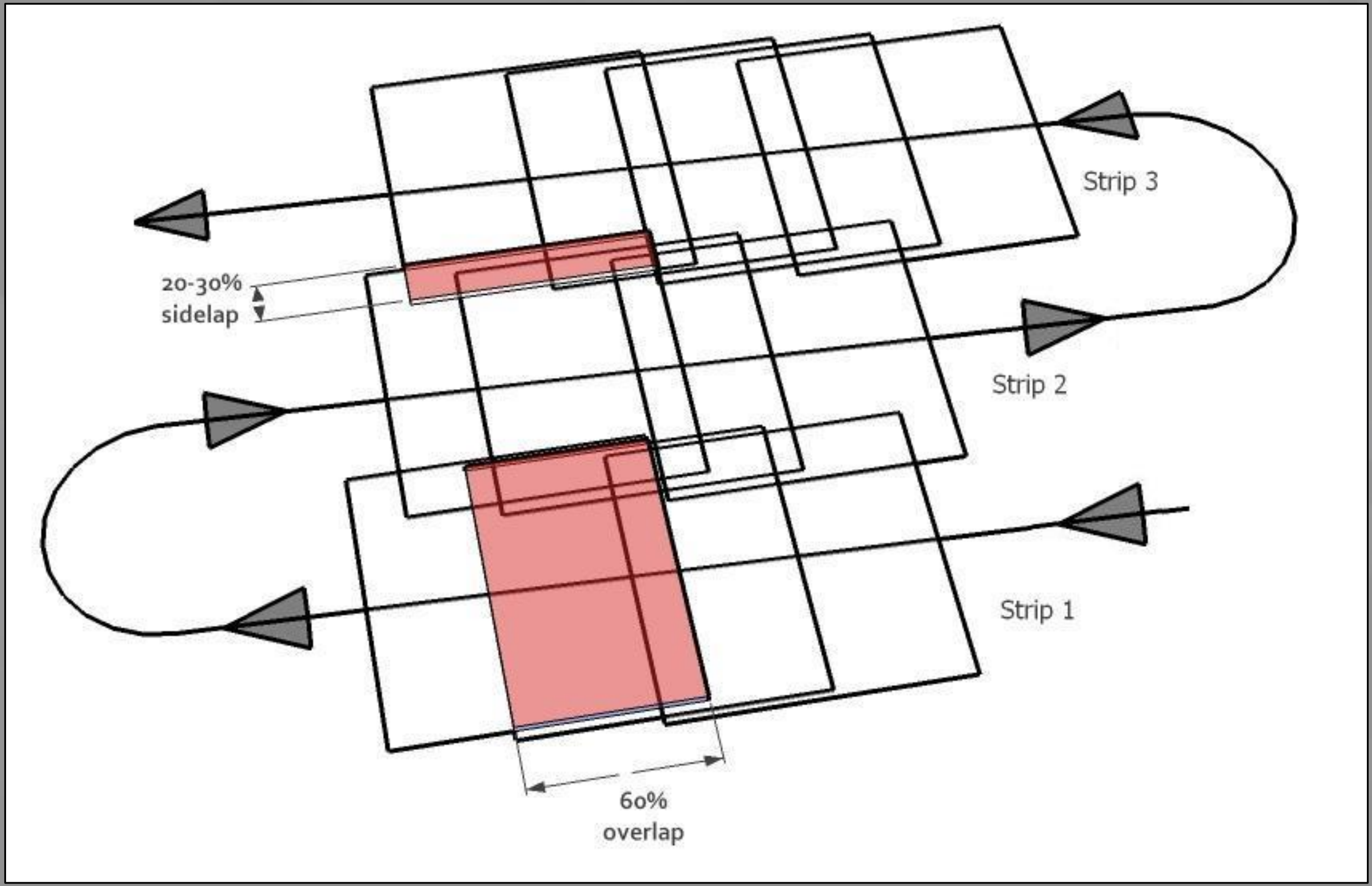
- One environmental factor does not define a healthy ecosystem
- One technology does not define a healthy **digital ecosystem**
- Need integration of technologies of:
  - Representation
  - Capture – data acquisition
  - Measurement
  - Etc..
- ALL are needed



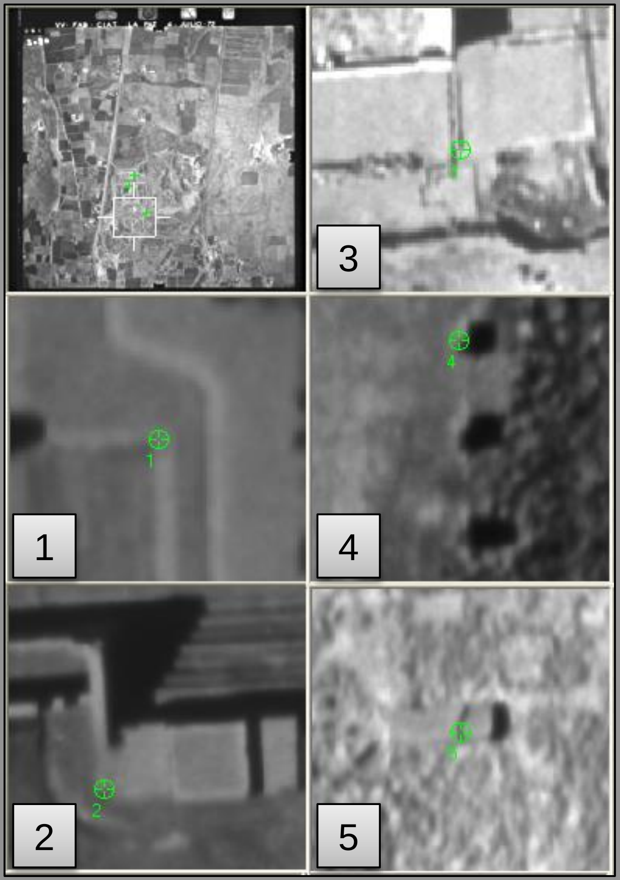
W. F (Fred) Limp
SPARC Webinar
January 2014

AERIAL PHOTOGRAMMETRY

Aerial Photogrammetry



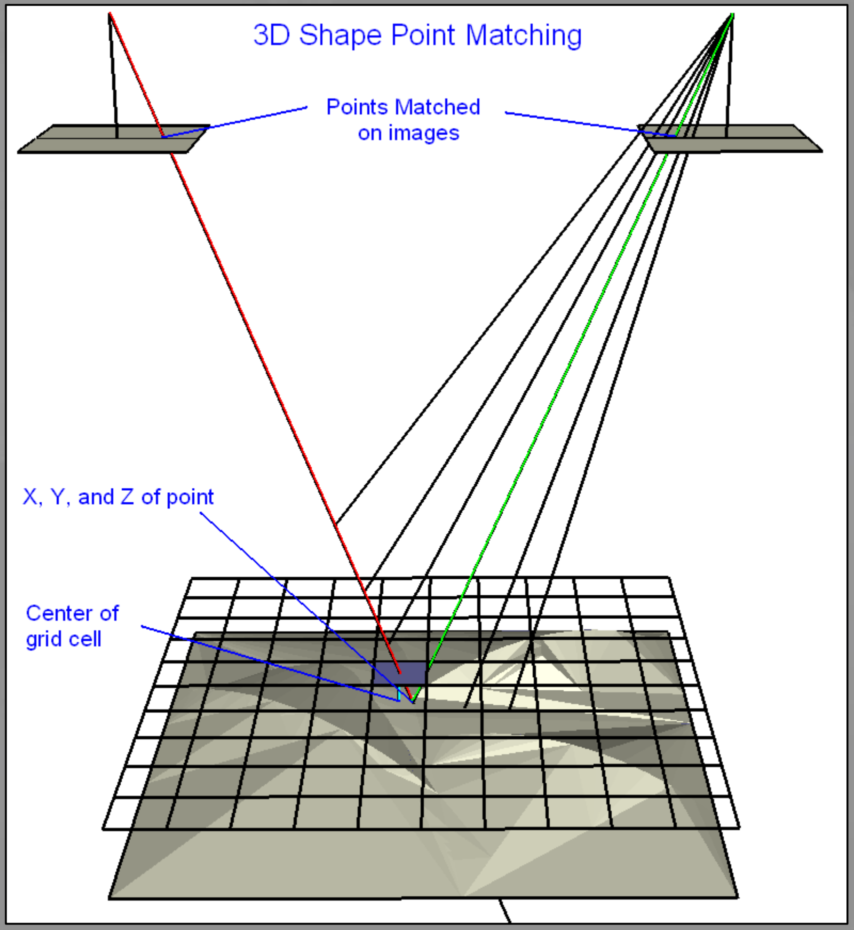
Basic Requirements



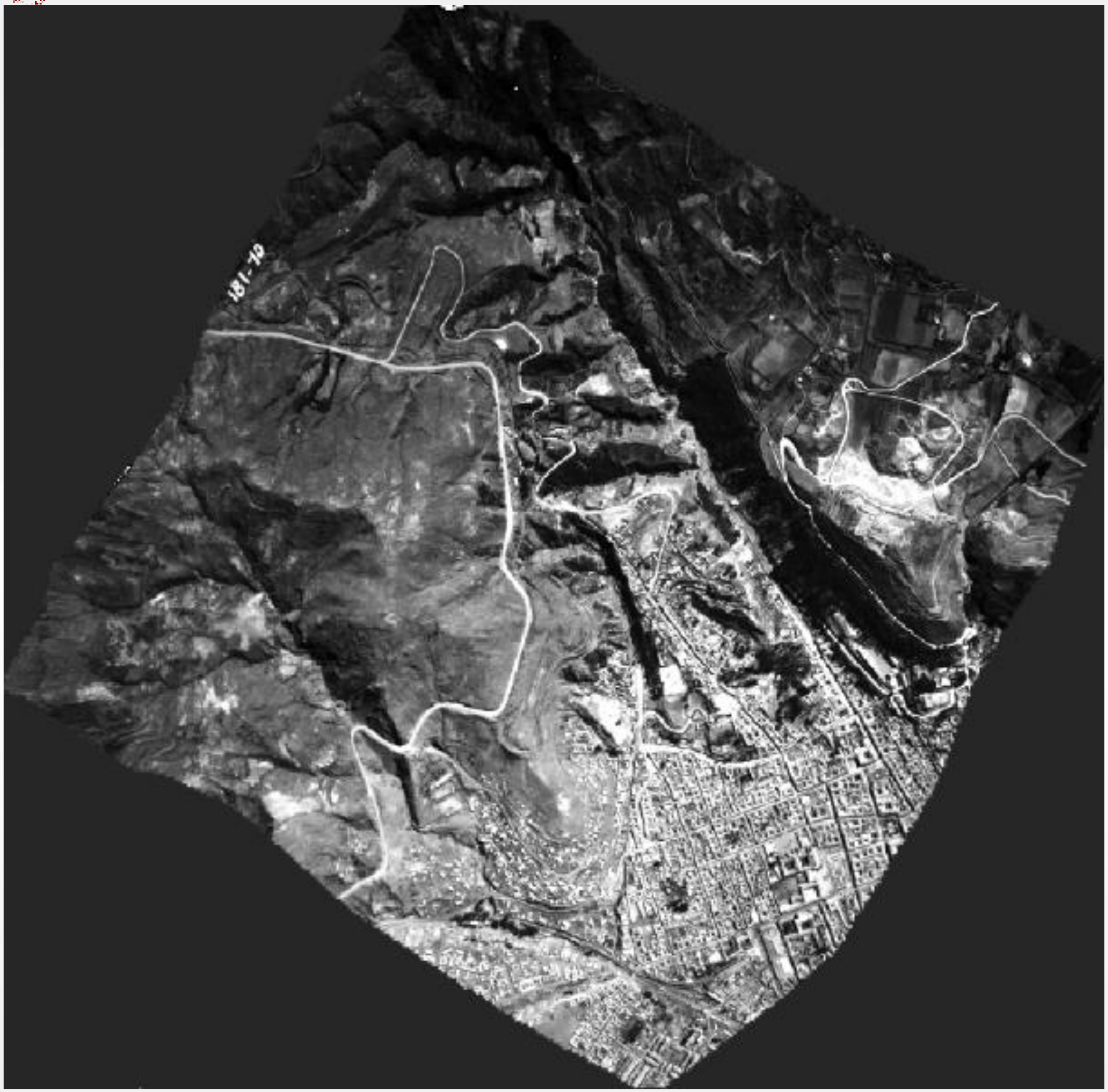
- Stereo (overlapping images)
- Ground Control Points (GCP)
  - Photo identifiable
  - Know real world coordinates

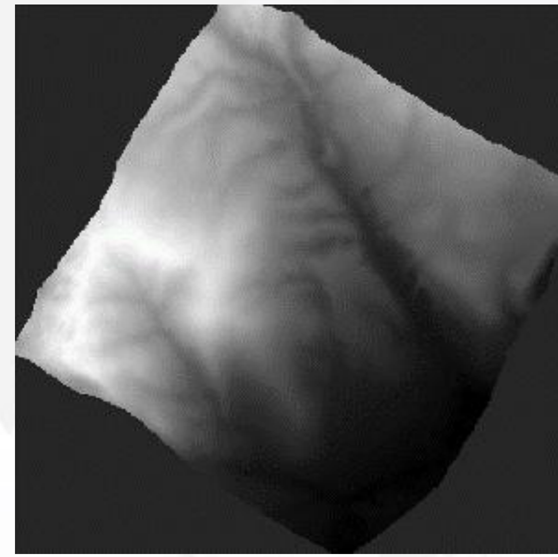
ID	X	Y	Z
1	798.70	774.70	-12.186
2	756.55	797.13	-9.691
3	629.10	732.95	-10.588
4	803.86	635.33	5.112
5	1018.66	696.55	-9.504

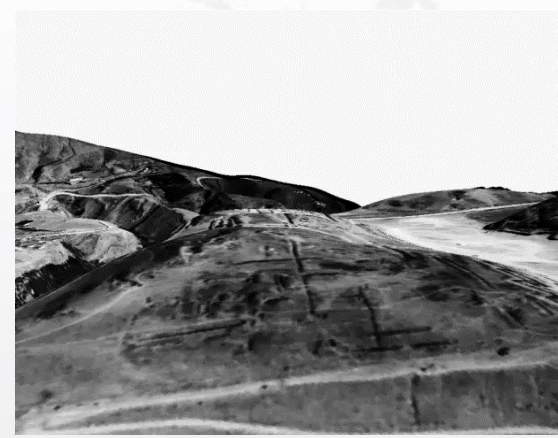
Automated 3D point extraction



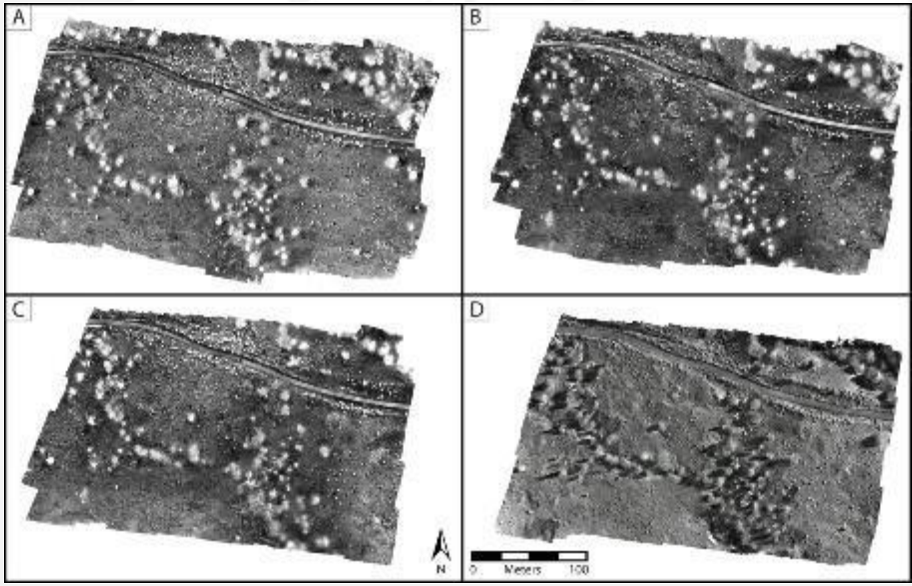
Cuzco 1970 photography

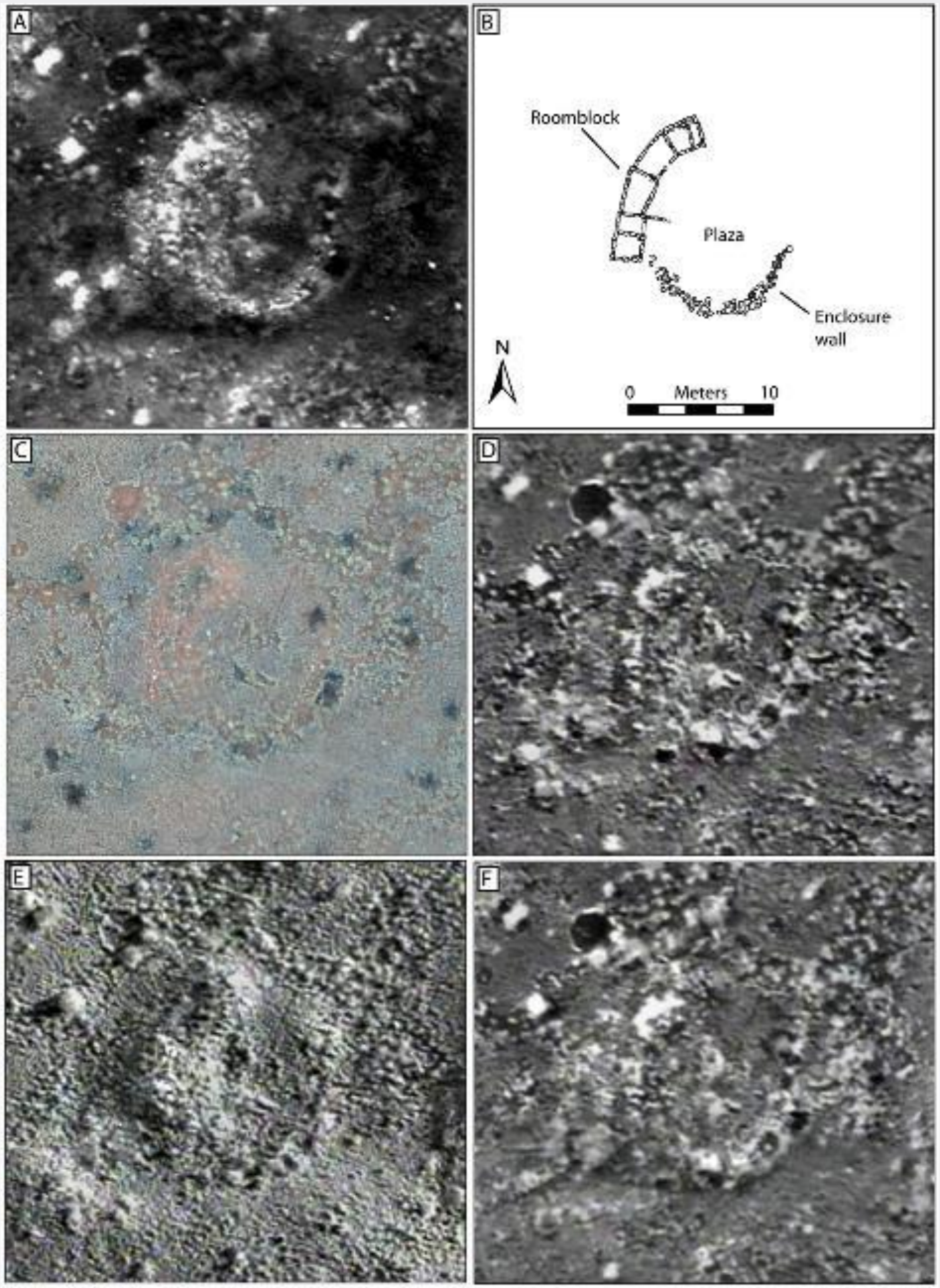






UAVs as platform …



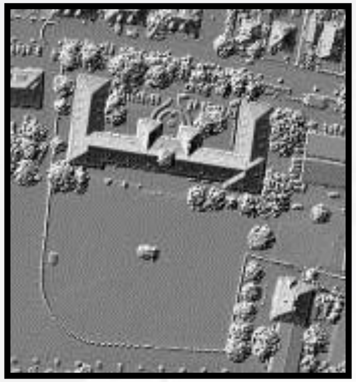


Contact Jesse Casana
jcasana@uark.edu

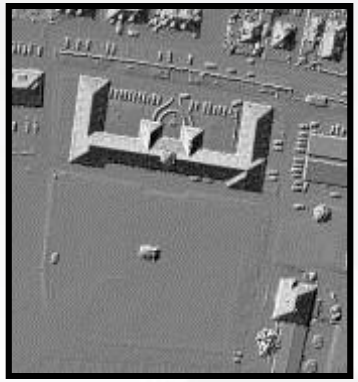
AERIAL LIDAR

ALS 50

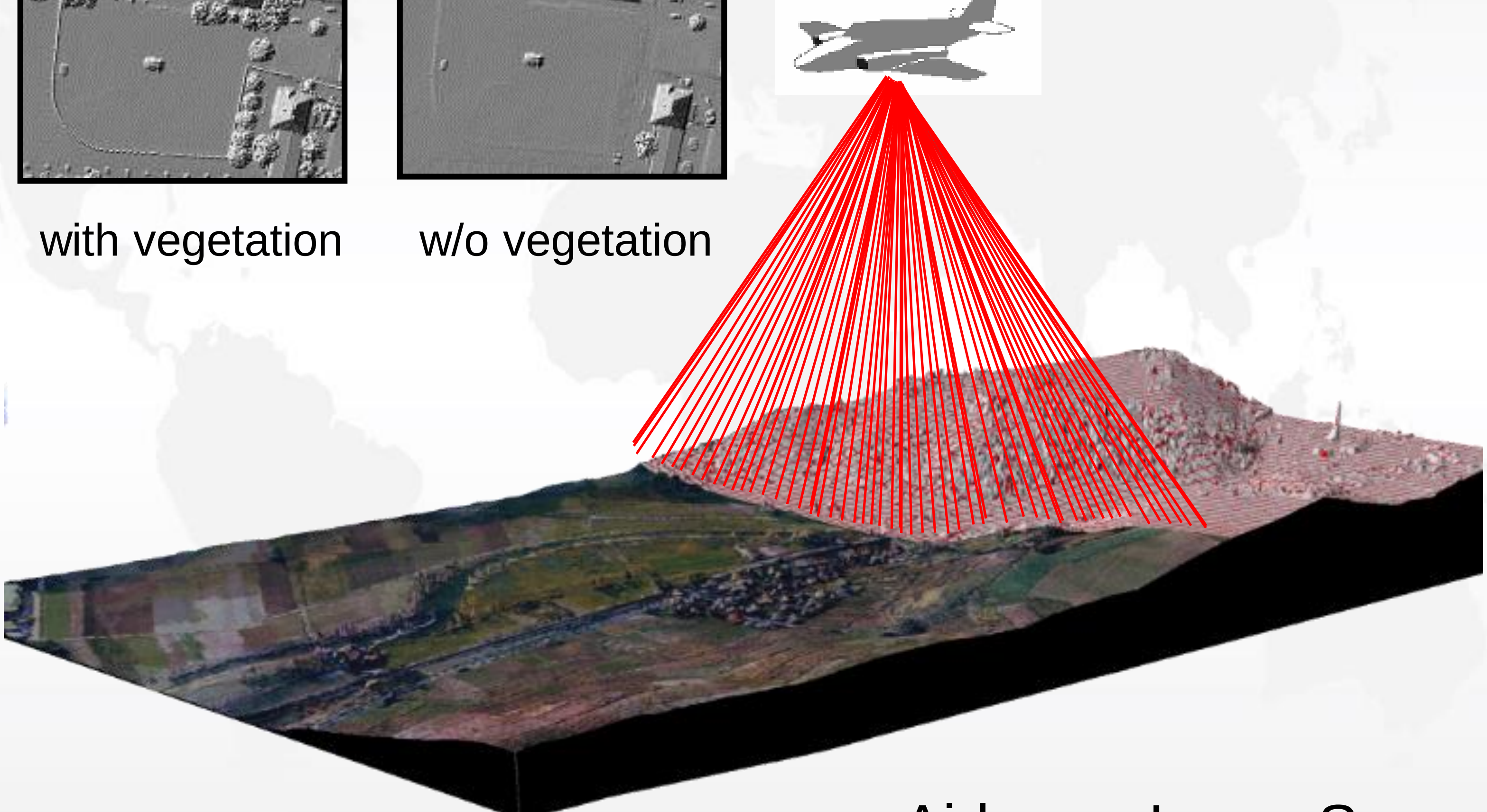
Leica Geosystems



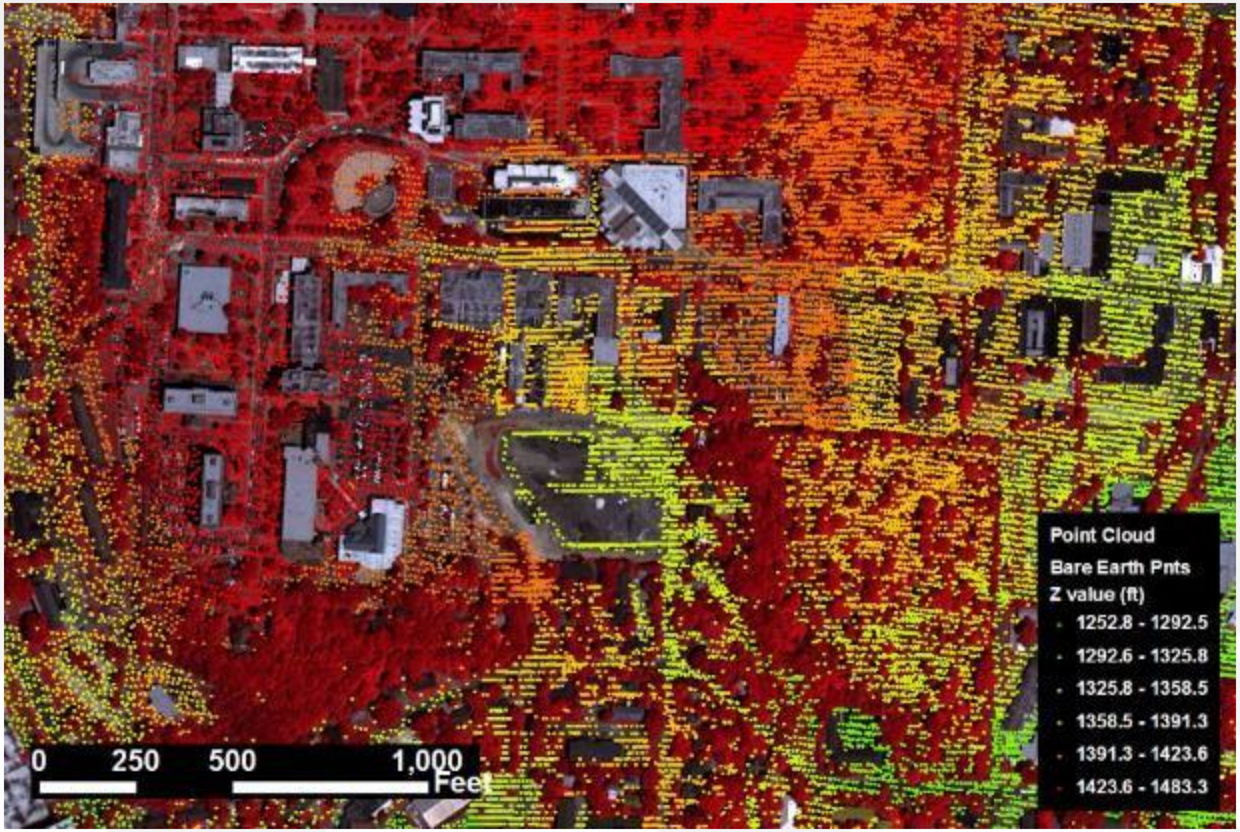
with vegetation

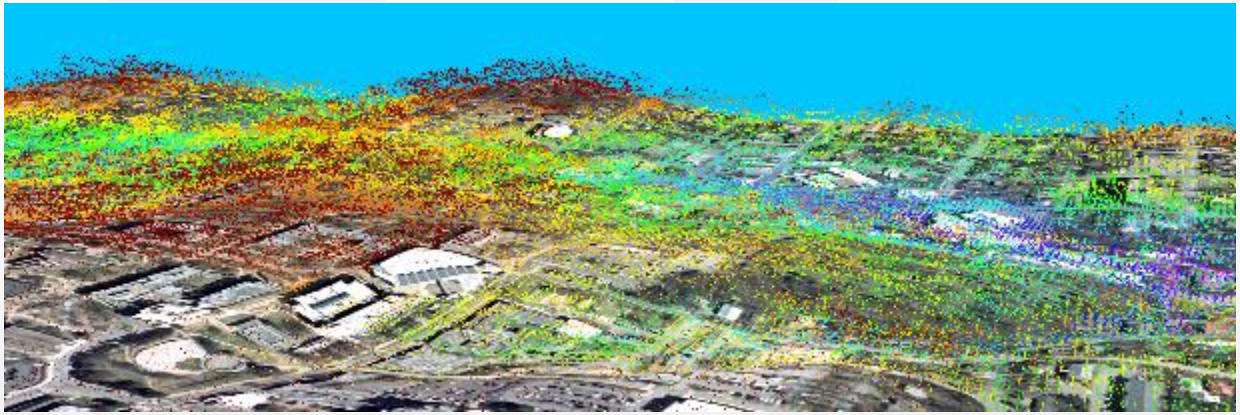


w/o vegetation

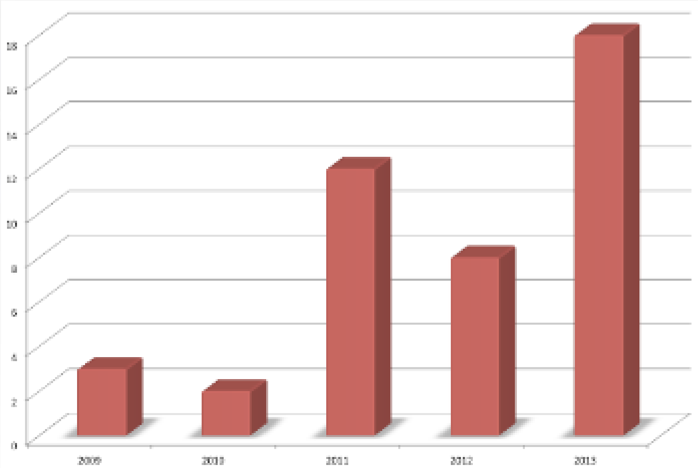


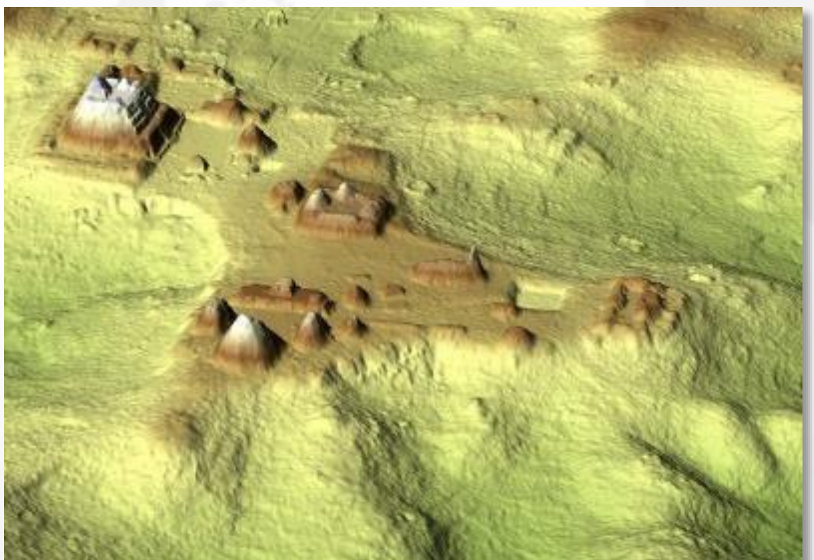
Airborne Laser Scanning


Point Cloud
Bare Earth Pnts
Z value (ft)
1252.8 - 1292.5
1292.6 - 1325.8
1325.8 - 1358.5
1358.5 - 1391.3
1391.3 - 1423.6
1423.6 - 1483.3
0 250 500 1,000
Feet

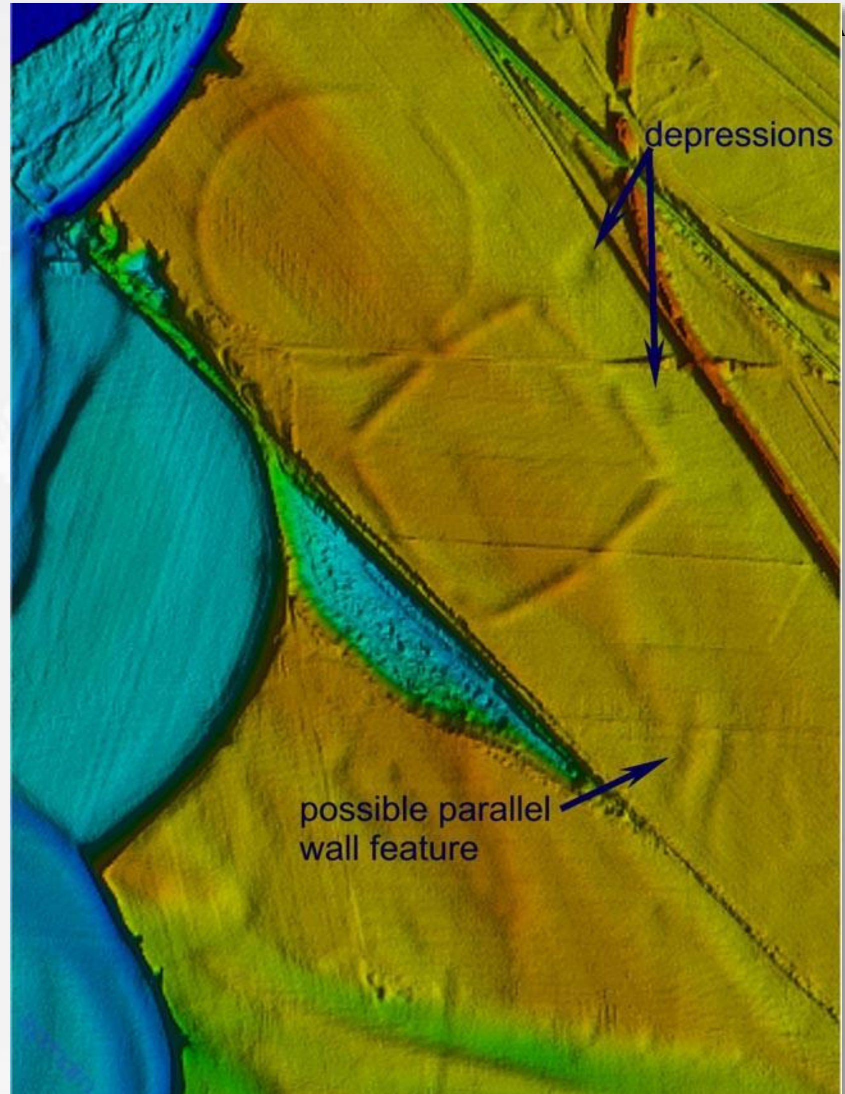


LiDAR Articles in JAS





Caracol Archaeological Project
PNAS 2012 Chase et al



Ohio Archaeology
Romain and Burks 2008

QUESTIONS?

HIGH RESOLUTION GNSS

W. F (Fred) Limp
SPARC Webinar
January 2014

GPS common in archaeological survey

- Mapping grade (single channel – L1) code based autonomous systems
  - Routinely provide under 3-4 m capabilities
  - Modest cost
  - Rapid acquisition times
  - DGPS solutions
    - Improve results to (up to) decimeter accuracies
- High resolution capabilities via RTK
  - Dual L1 and L2 carrier
  - $10-20K+ in cost – complex to configure
    - Base and rover
  - Rapid acquisition after initialization
    - Point occupations of a few seconds
  - Common to achieve < 5 cm precision (H and V)

GNSS developments

- Near term (now)
- Much larger satellite constellations
  - GPS, GLONASS, Beidou ….
- RTK network (PP-RTK)
  – Less complex than base/rover
  – Wide area coverage
  – Fast initialization
    - Under 10 sec
- Precise point positioning
  – Dual frequency receiver
  – Access to real-time satellite correction data

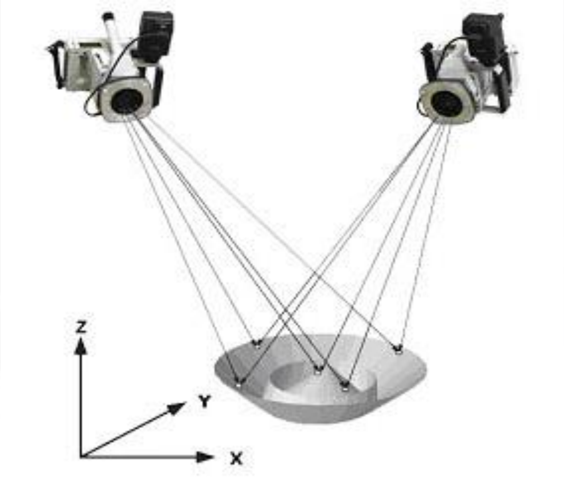
Next developments …

- L2C (Block IIRM and later)
  - Civilian moderate and long codes on L2
  - Support dual channel code based systems
  - Removal of ionospheric delay
  - Faster acquisition
- L5 (Block III satellites)
  - Much stronger signal (+2x)
  - Improved code/signal structure
  - Capabilities in challenging settings
    - Under tree canopy
    - High relief
    - Urban
    - Indoors?

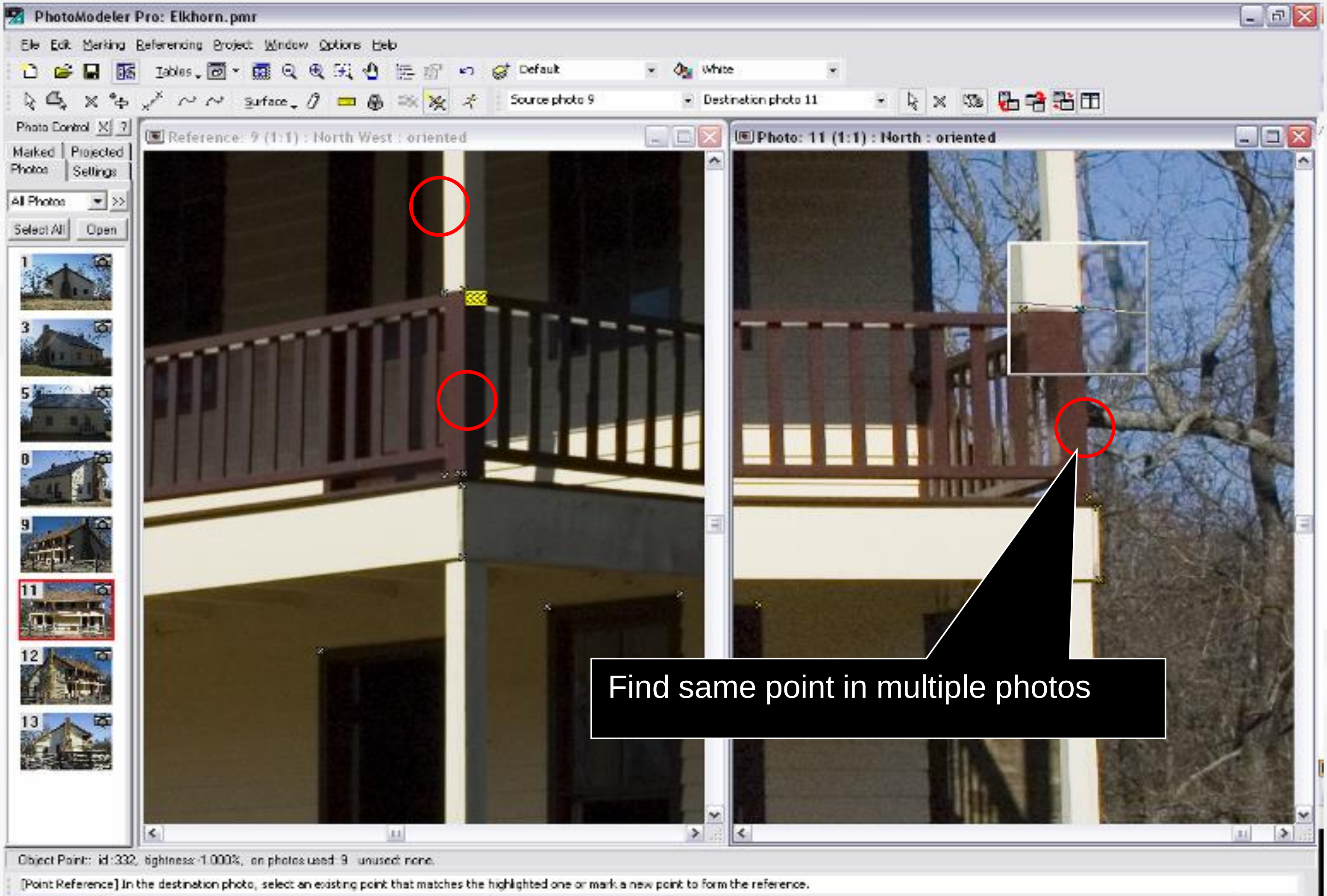
TERRESTRIAL PHOTOGRAMMETRY

AKA “Close-range” photogrammetry

Photography at El Zotz

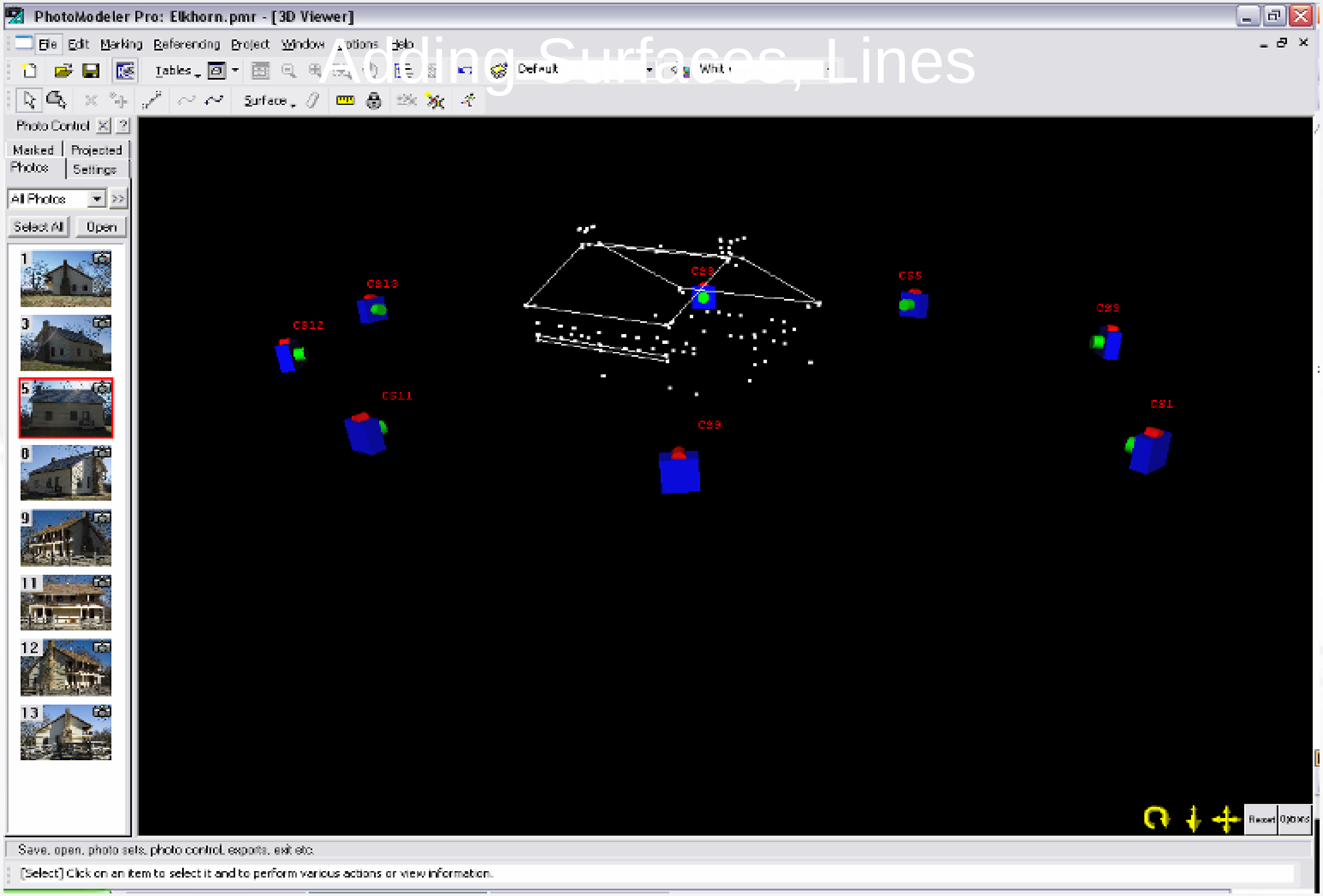



Add/Remove Photographs
Photos in
Z:\PERI_images
Photos in project
1
3
5
8
9
11
12
13
>>
<<
All >>
All <<
Change directory...
OK
Cancel
Help



Use multiple photos that show same areas

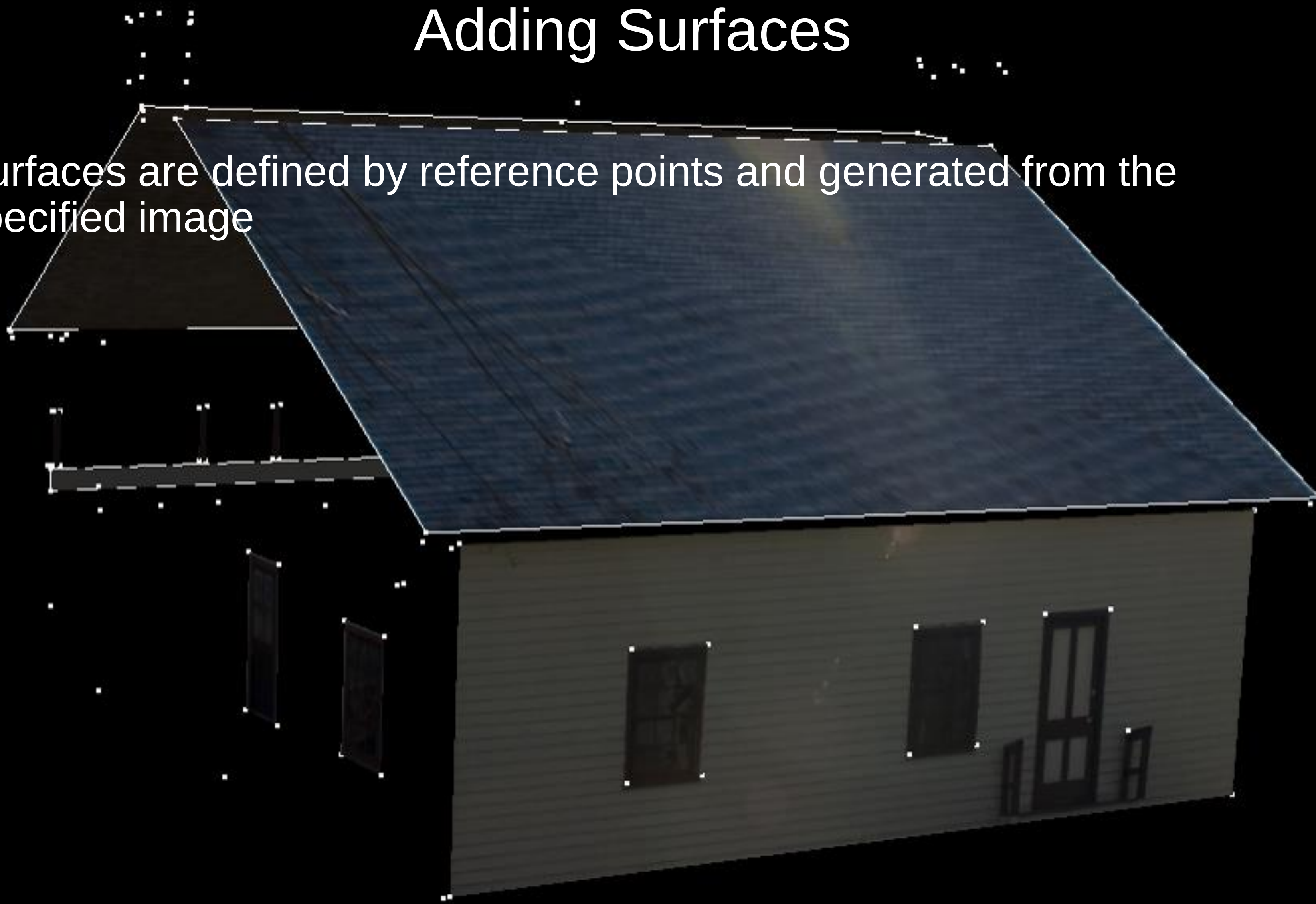
“old way” … Manually link the same location in multiple photos



Camera location and parameters automatically calculated

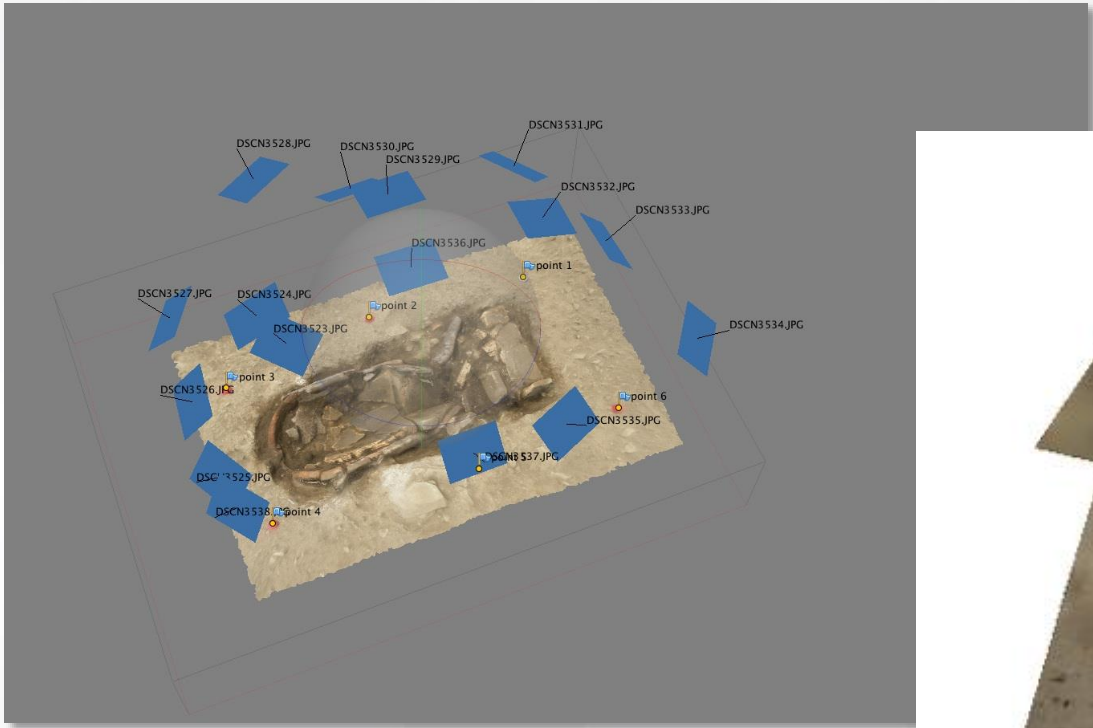
Adding Surfaces

Surfaces are defined by reference points and generated from the specified image



Problems w/ multiple images

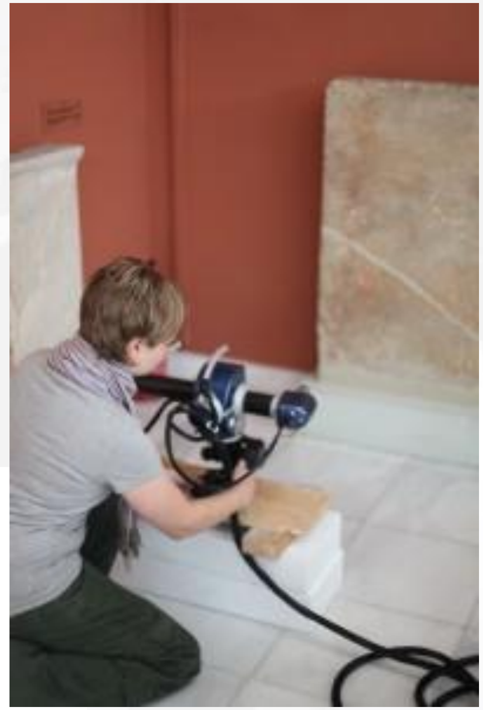
Automatic camera orientation



QUESTIONS?

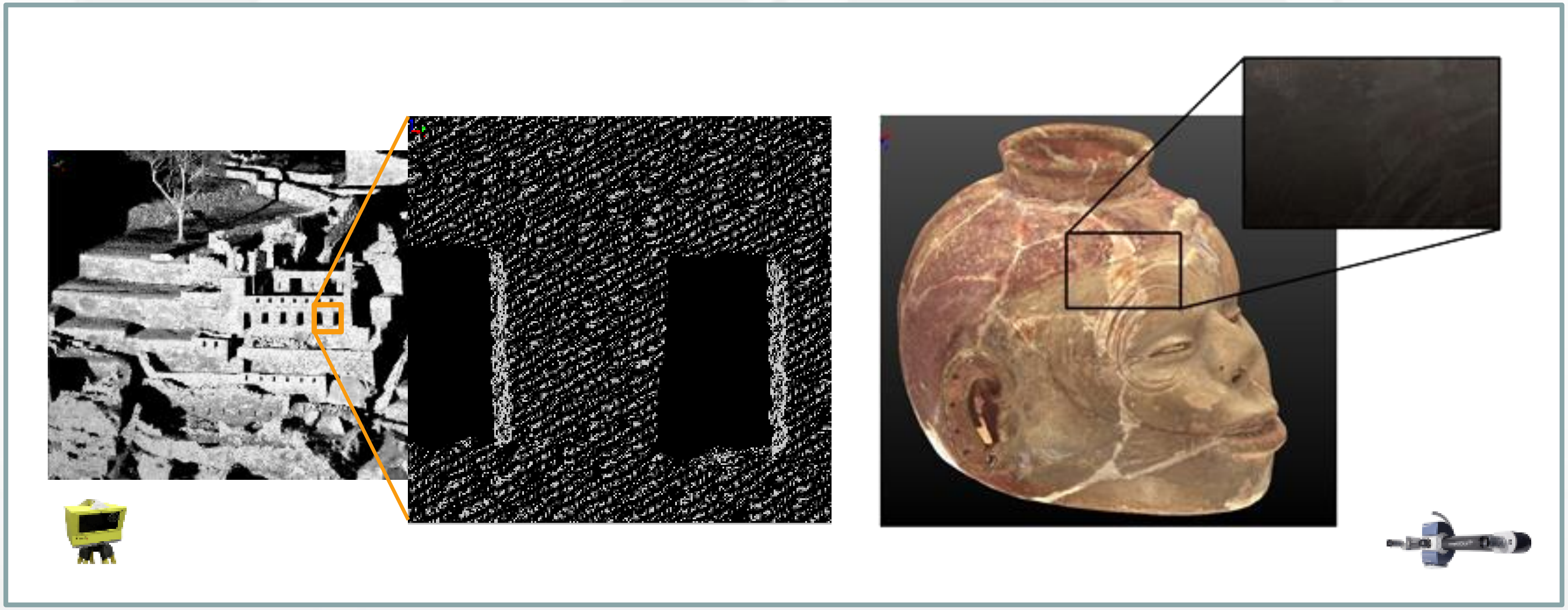
TERRESTRIAL "LASER" SCANNING

Terrestrial “Laser” Scanners



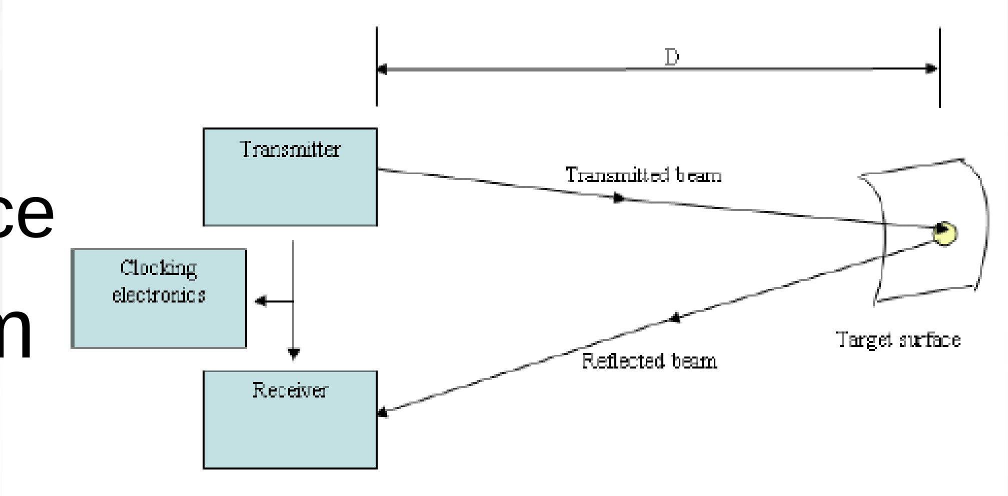
3D Scans:

- *A digital representation of an object consisting of hundreds of thousands to millions (or more) of precisely measured X, Y, Z (and often RGB) coordinates collected with a 3D scanner*



Time of flight

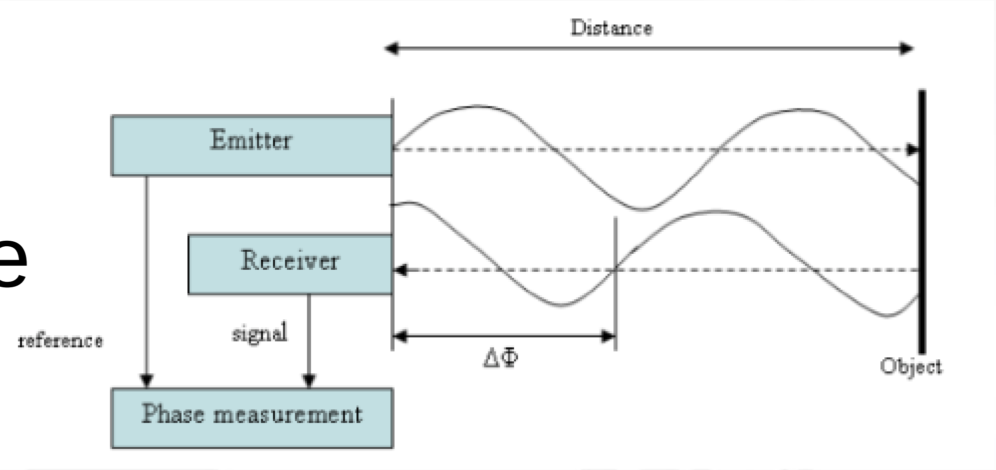
- System sends out laser pulse
  – Times its return
  – Determines distance
- Precise mechanism increments pulse horizontally and vertically to determine angles to locate pulse in x, y, and z



Graphic: 3Driskmapping.org

Phase comparison

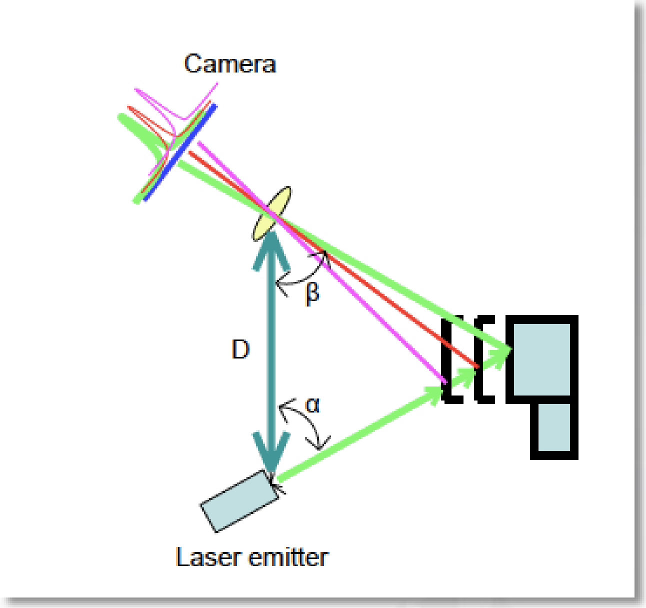
- Sends out pulse
- Transmitted wave and received wave properties are compared using signal processing methods to determine distance traveled



Graphic: 3Driskmapping.org

Triangulation

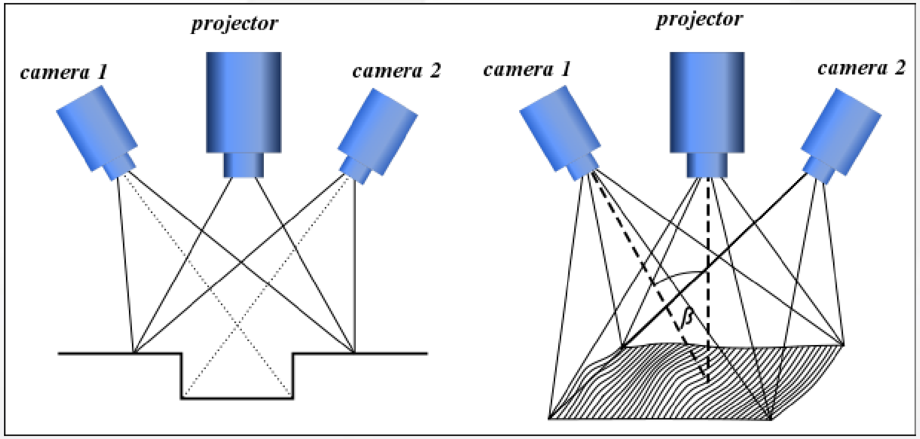
- Sweeps laser "line" across surface
- Receives at a separate (precisely located) CCD camera surface
- Using geometry of CCD and laser determines the parallax of line locations



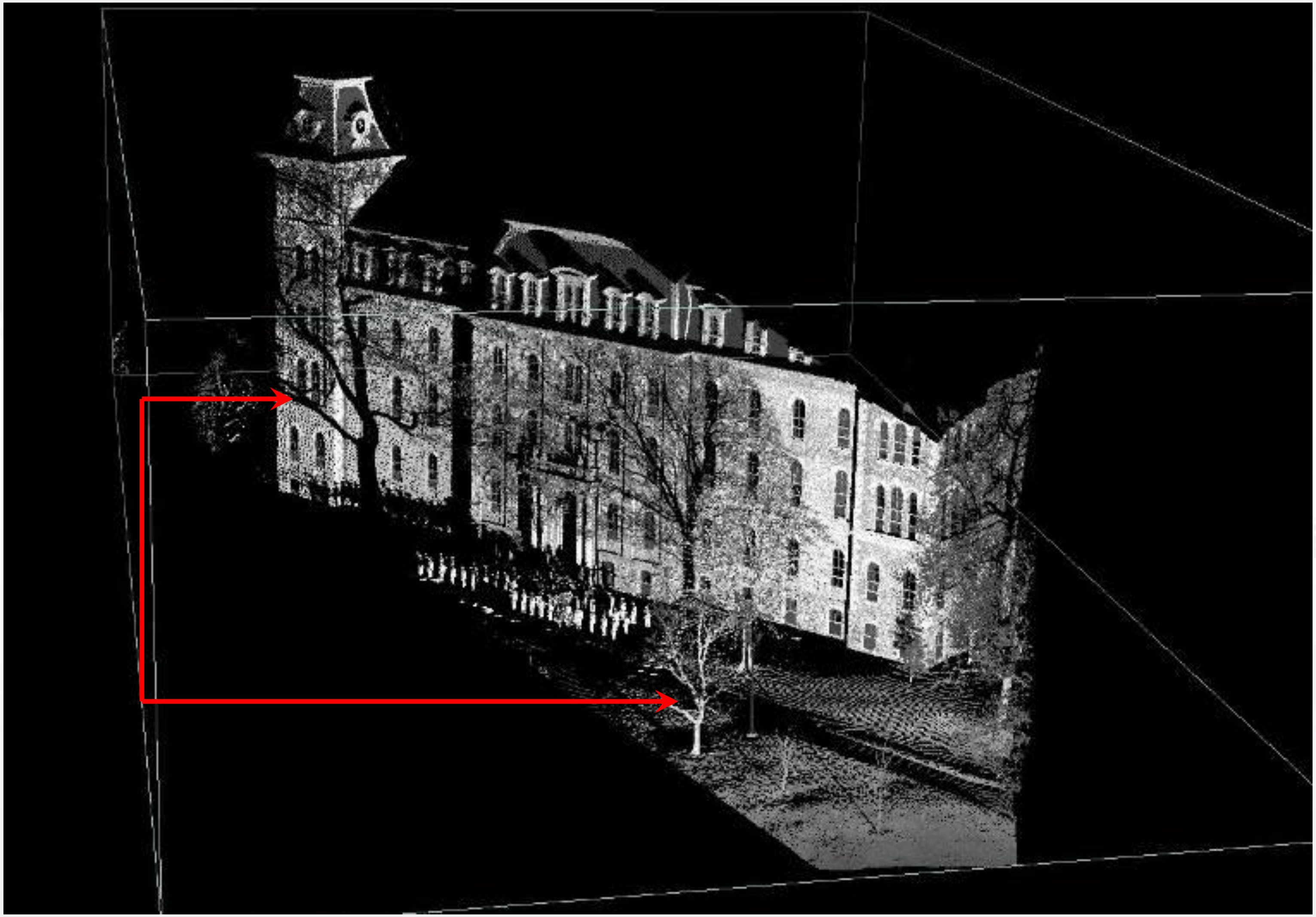
Graphic: 3Driskmapping.org

White light/Fringe Projection

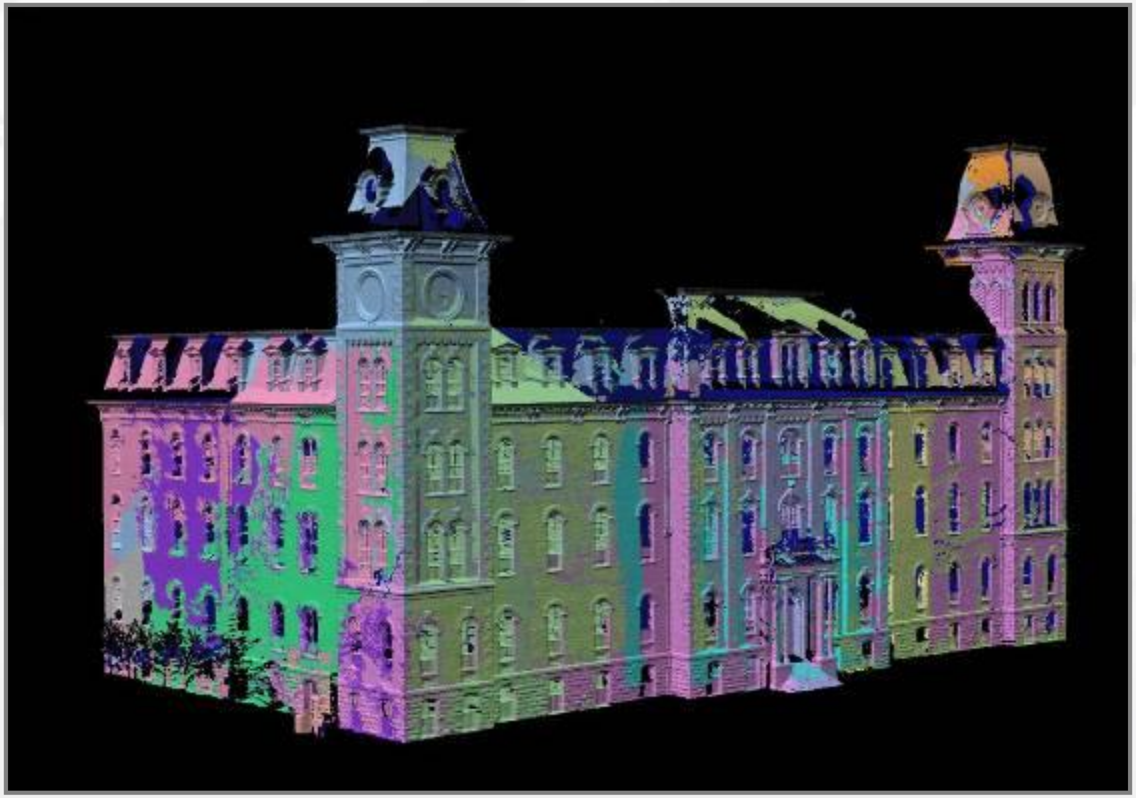
- A type of triangulation system
  - Projects a pattern (fringes) onto an object
  - Sensor takes multiple images and uses images to triangulate 3D coordinates
  - High resolution – 10s of micrometers



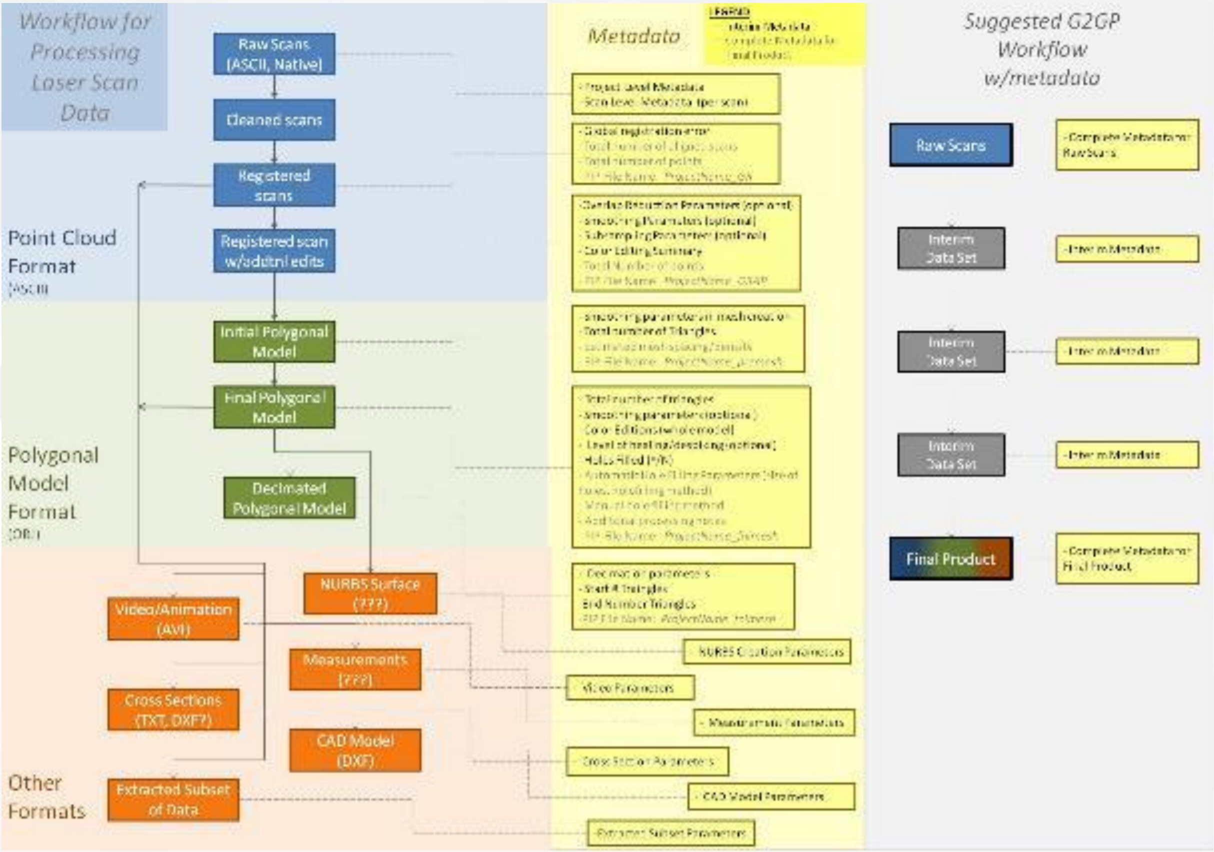
Laser “moves” across surface like a tight flashlight



Aligning the individual scans (each color is a separate scan)



Laser scan workflow and metadata



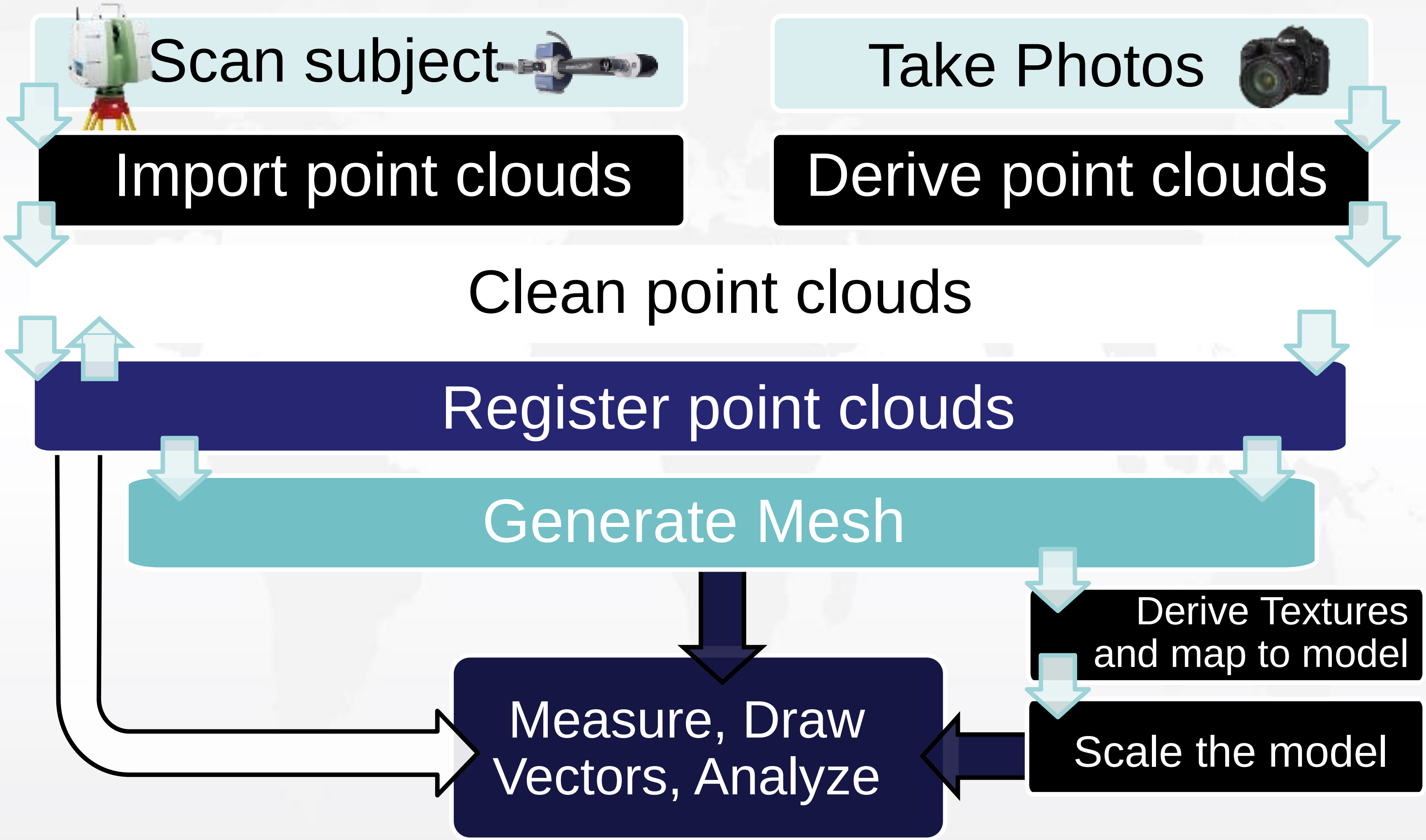
http://guides.archaeologydataservice.ac.uk/

Element	Description
Project Name	Name of the project
Name of monument, survey area, or object	Name of object, monument, or area scanned
Monument/Object Number	The ID number or code, if applicable, of the object or monument
Survey Location	Exact location of survey with complete address and/or coordinates
Survey Date(s)	Dates(s) of survey
Survey Conditions	The overall weather trend during survey (sunny, overcast, indoors, etc.)
Scanner Details	Details of the instrument(s) with serial number(s) and scan units
Company/Operator Name	Details of company and/or scan operator
Control data collected?	If yes, then list control_file_name.txt.
Turntable used?	Yes/No
RGB data capture?	If yes, then specify whether: - Internal or external? - Was an additional lighting system used? If yes, then provide a brief description of the lighting system.
Estimated Data Resolution	The estimated data resolution across the monument or object.
Total Number of Scans in Project	Total number of scans
Description of final datasets for archive	What datasets will be archived (include file names if possible)
Planimetric map of scan coverage areas	If applicable, then provide the image name.
Additional project notes	Additional notes
Images from survey	Optional, if yes, then provide the image file names

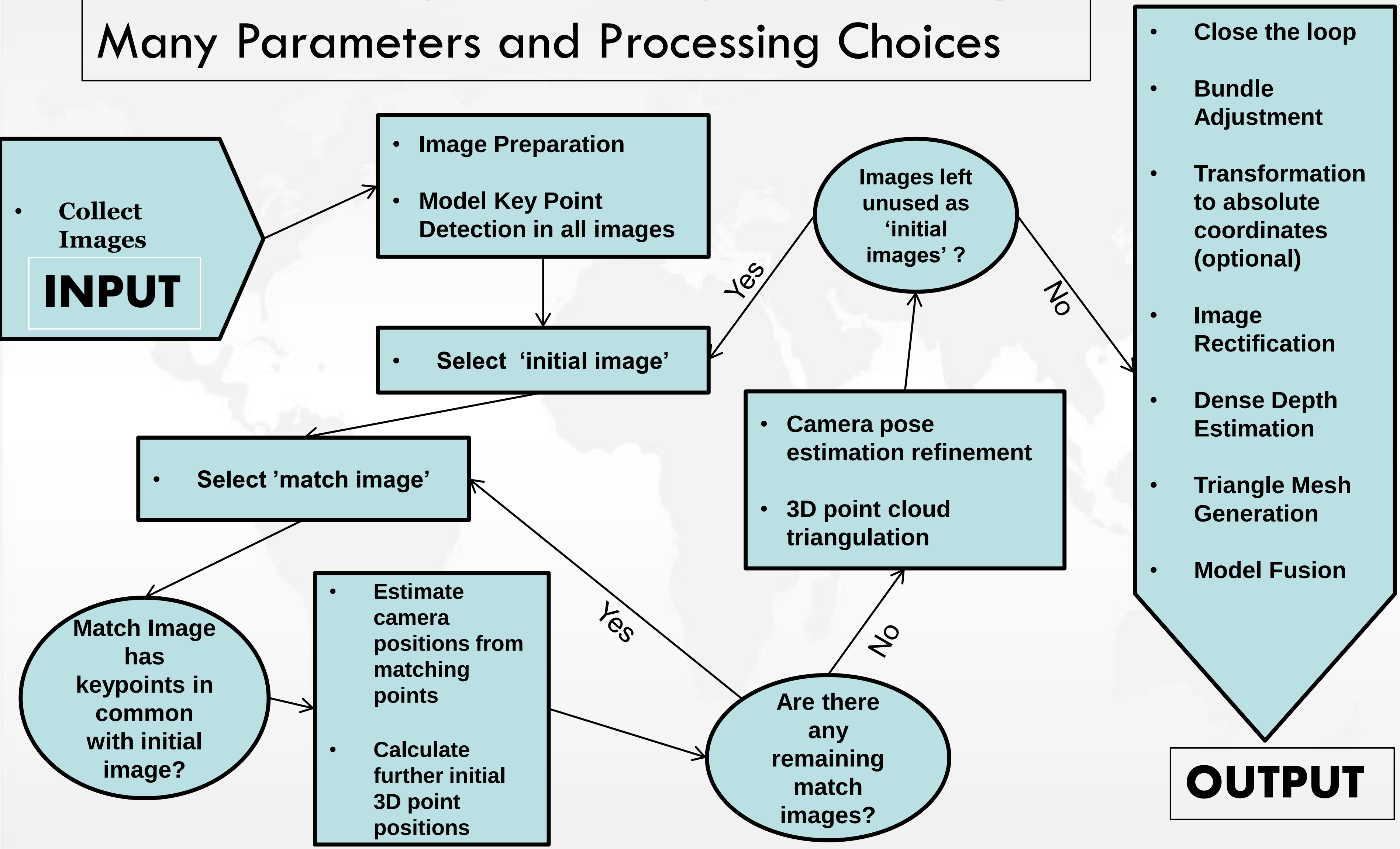
Example of Project Metadata

http://guides.archaeologydataservice.ac.uk/g2gp/LaserScan_Toc

General 3D Data Pipeline



Close-Range Photogrammetry:
Many Parameters and Processing Choices



Key Issues

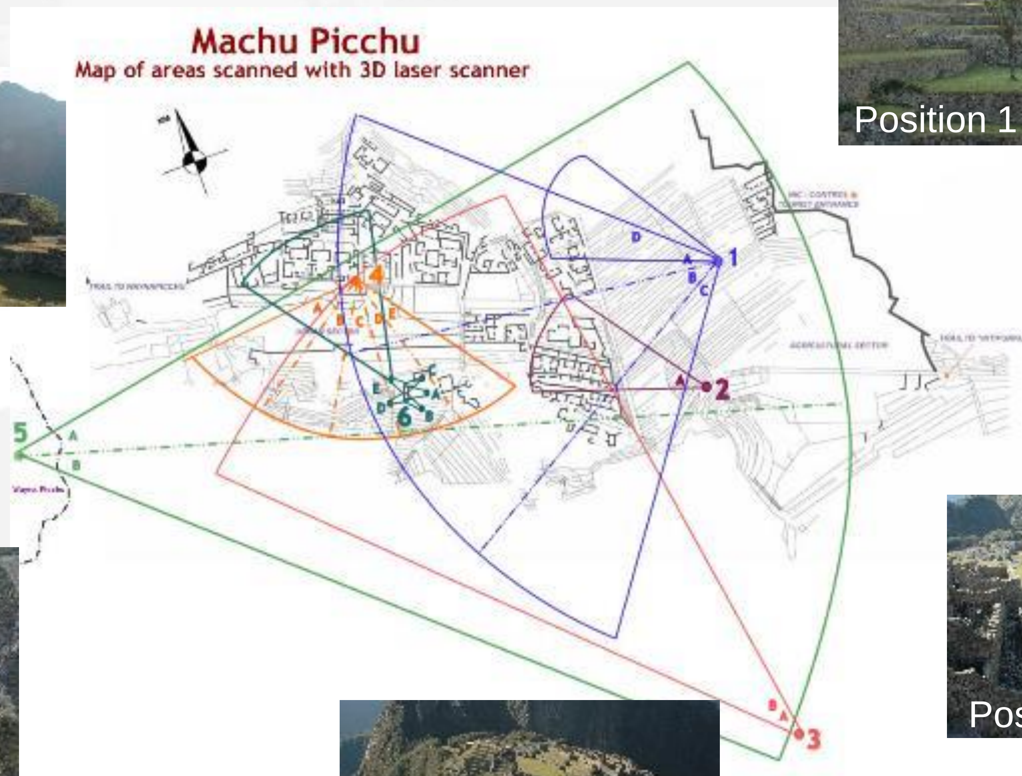
- Data collection
  - Access
  - Reflectance
    - Surface
    - Angle
  - Resolution
- Processing
  - Time
  - Computing
- Reporting

Data Collection

- Access


Position 1


Position 4



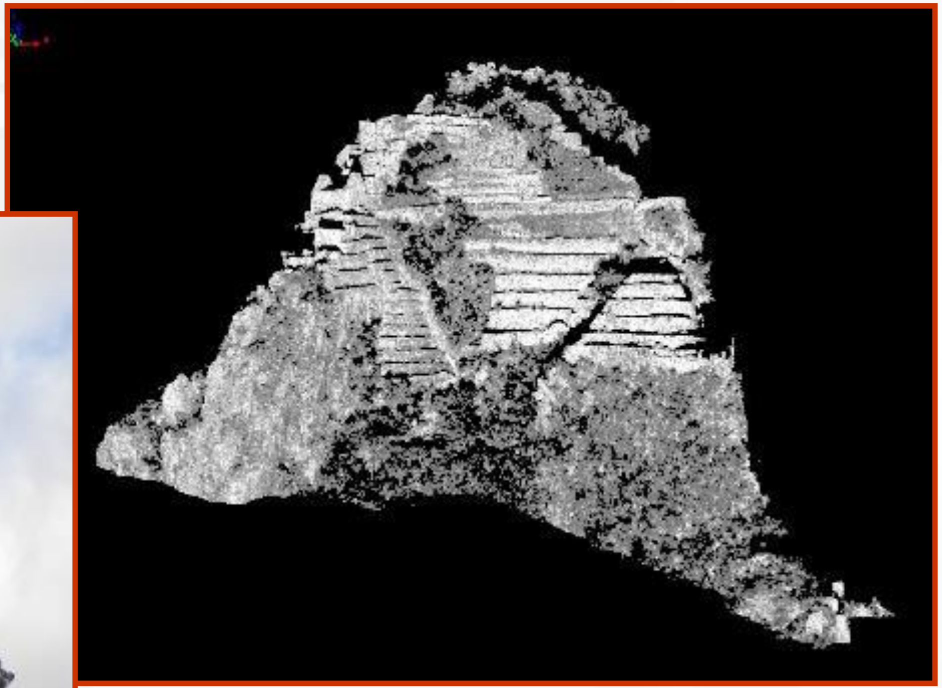

Position 2


Position 5


Position 3

Data Collection

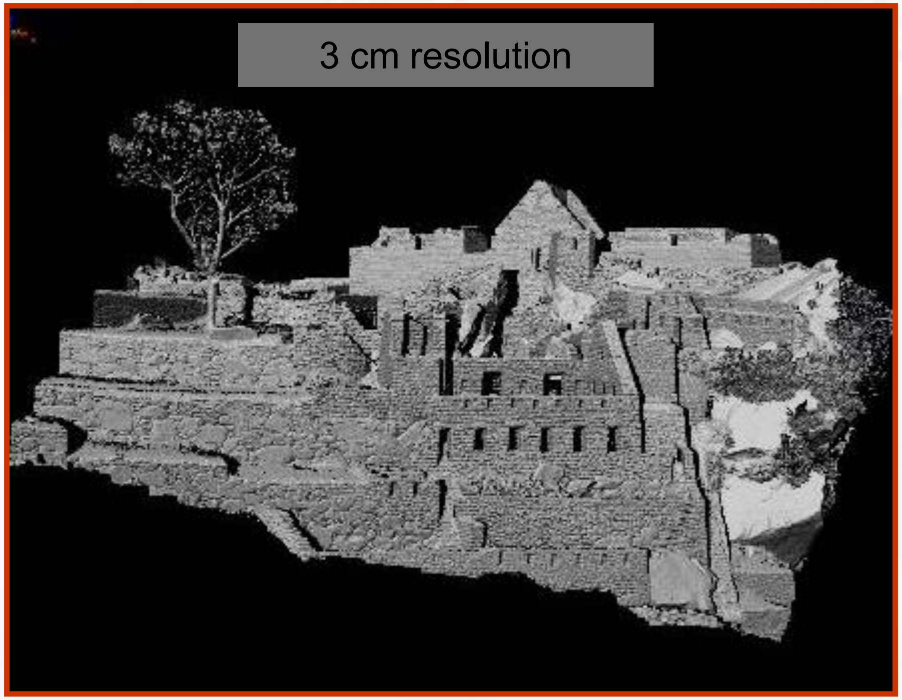
- Access

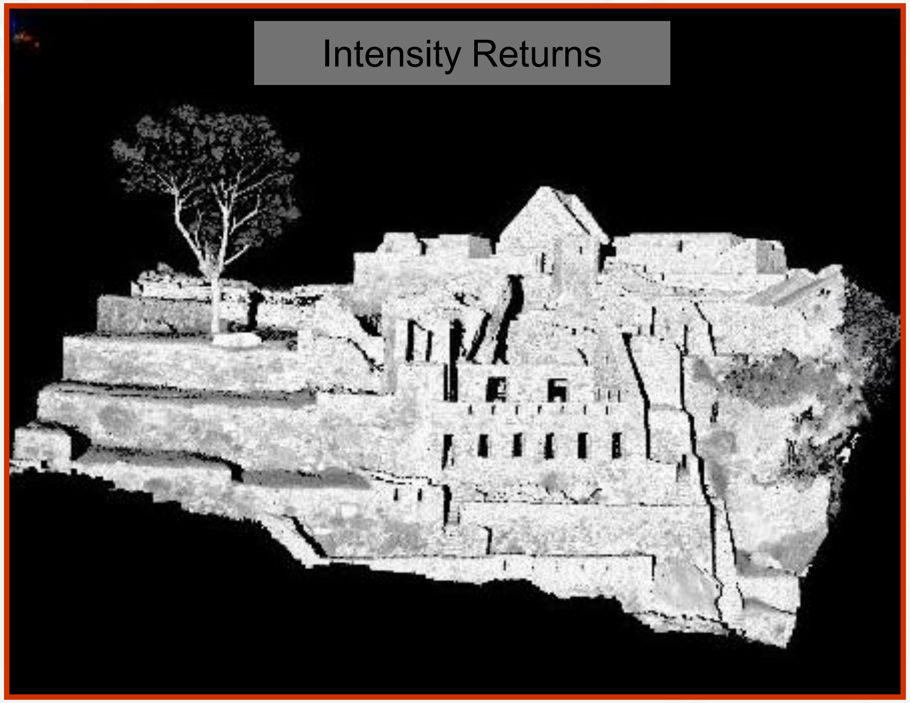


Data Collection

Data Collection

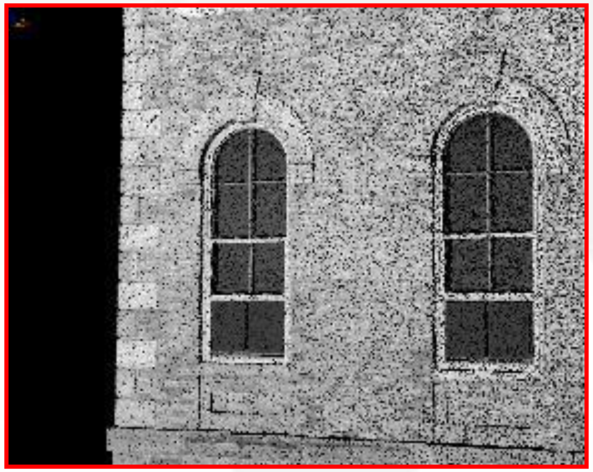
- Return Intensity and surface reflectance



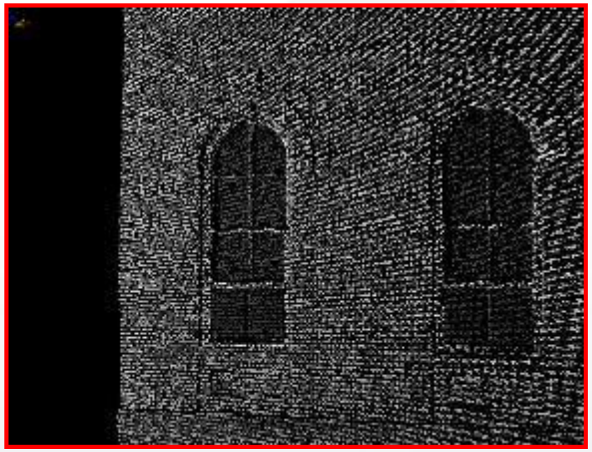


Data Collection

- Resolution

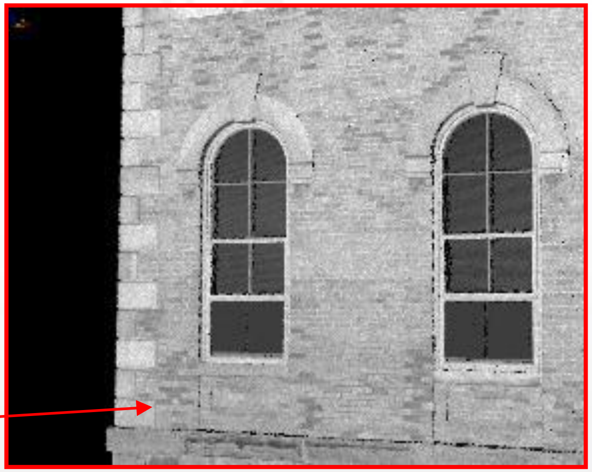


2 cm data
Scan time: 2.5 minutes
File Size: 2mb



1 cm data
Scan time: 9 minutes
File Size: 10mb

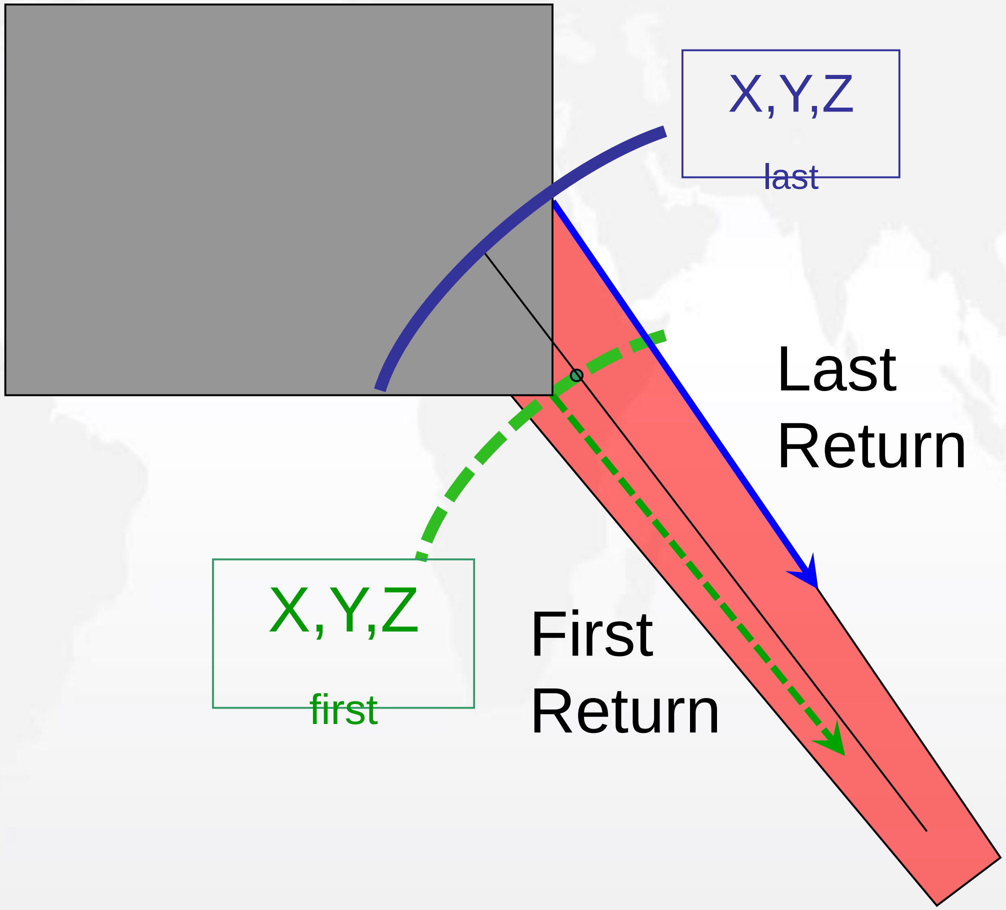
5 mm data
Scan time: 34.5 minutes
File Size: 44mb



Note the detail of individual bricks in the 5mm dataset

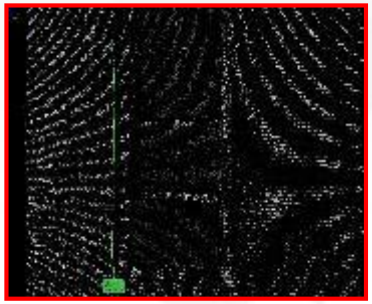
Data Collection

- Resolution and edges

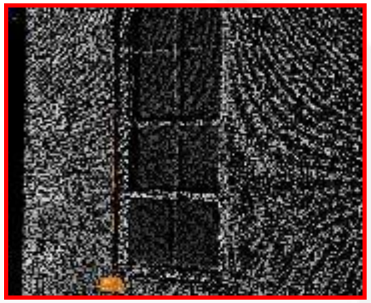


Data Collection

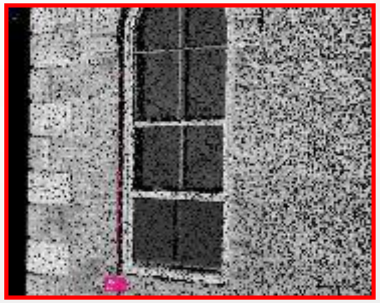
- Resolution



2 cm data



1cm data



5 mm data

Data Collection

- Resolution

Window features extracted from 5mm dataset.

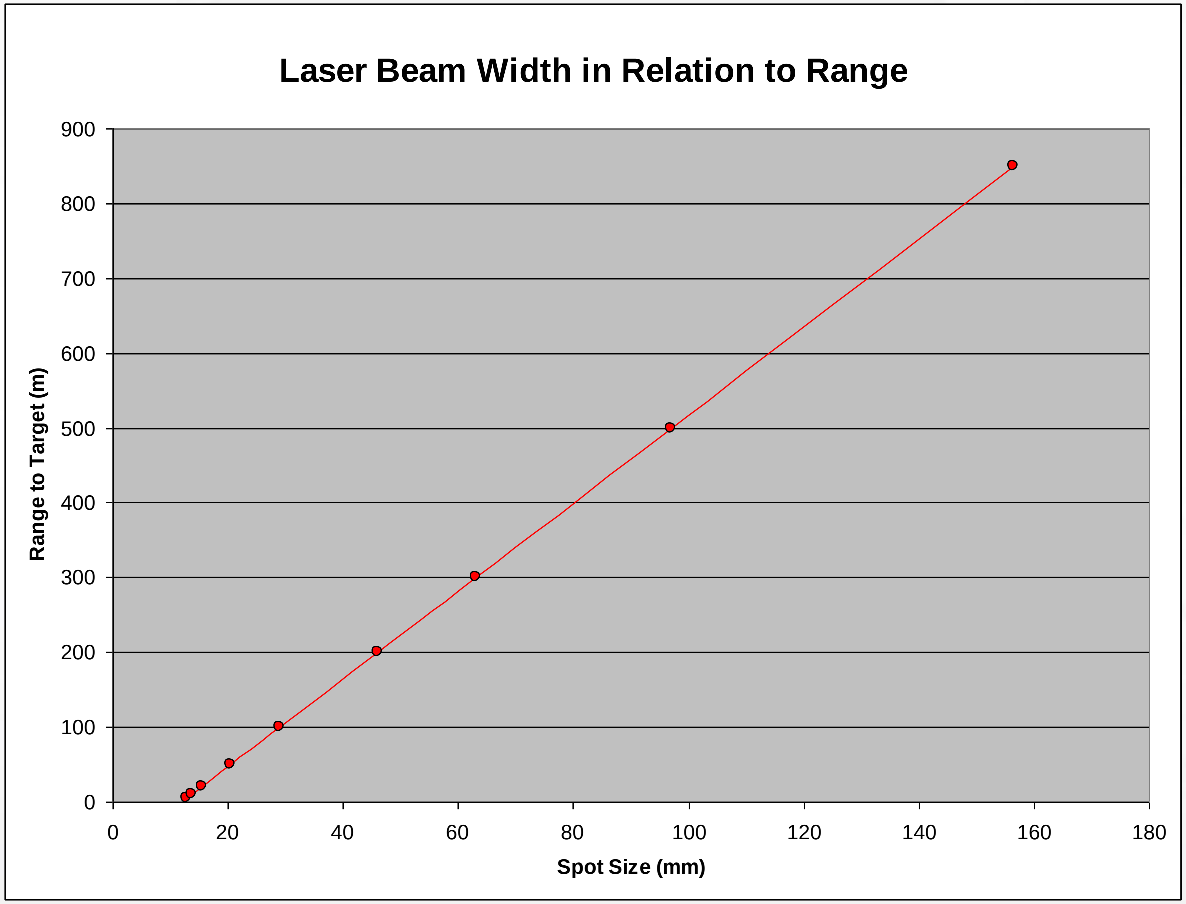
Data Collection

- Beam Divergence

Laser Beam Width
D = 0.17R + 12, where
D = Diameter of Spot (mm)
R = Range to target (m)

Range (m)	Diameter (mm)
5	12.85
10	13.7
20	15.4
50	20.5
100	29
200	46
300	63
500	97
850	156.5

Minimum width: 12mm



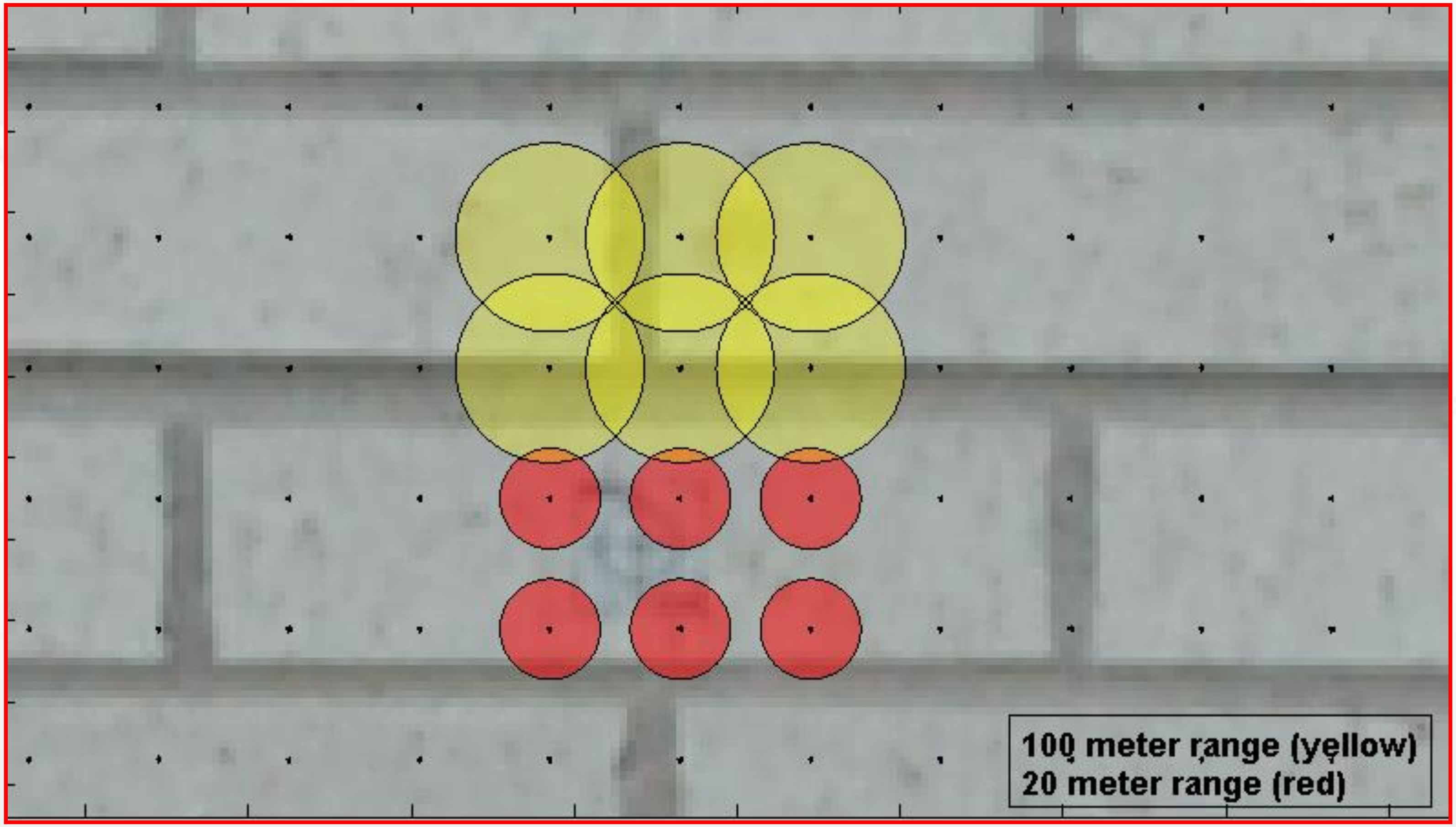
Range (m)	5	10	20	50	100	200	300	400	500
Beam Diameter (mm)	13	14	15	20.5	29	46	63	97	156
Diameter (Inches)	0.5				1.1				6.1

Beam divergence for Optech ILRIS
Diameter in mm = (0.17)* (Range to target in m) + 12 mm.

Note that Optech has one of the better beam divergence numbers

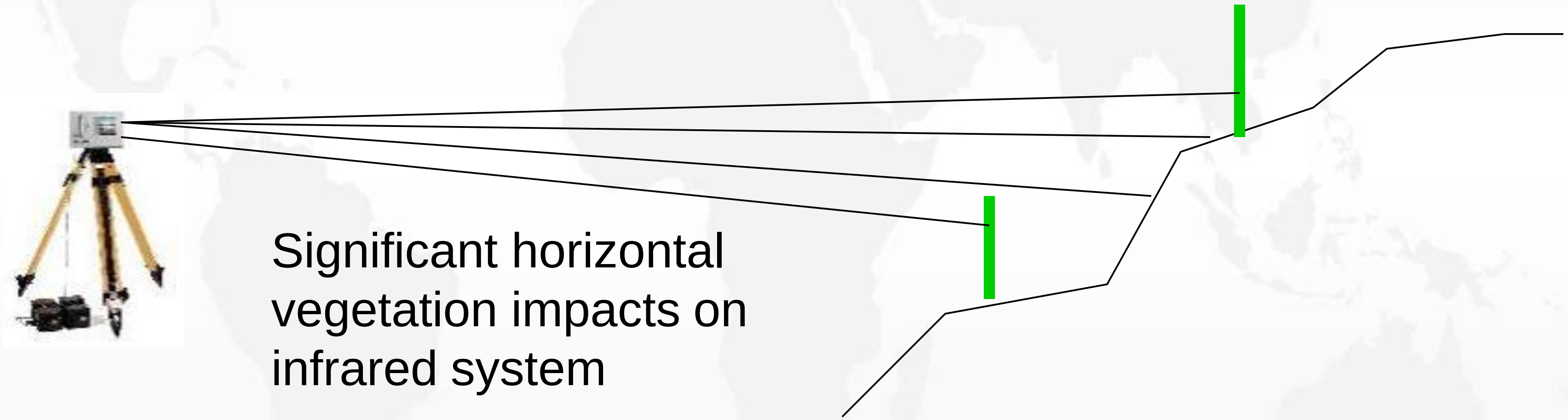
Data Collection

- Beam Divergence



Data Collection

- Obstructions



ASSESSING PERFORMANCE

W. F (Fred) Limp
SPARC Webinar
January 2014

Some potential criteria

- Accuracy
- Resolution
- Noise
- Speed
- Repeatability
- Portability
- Range or maximum object size
- Data formats/interoperability
- Cost!

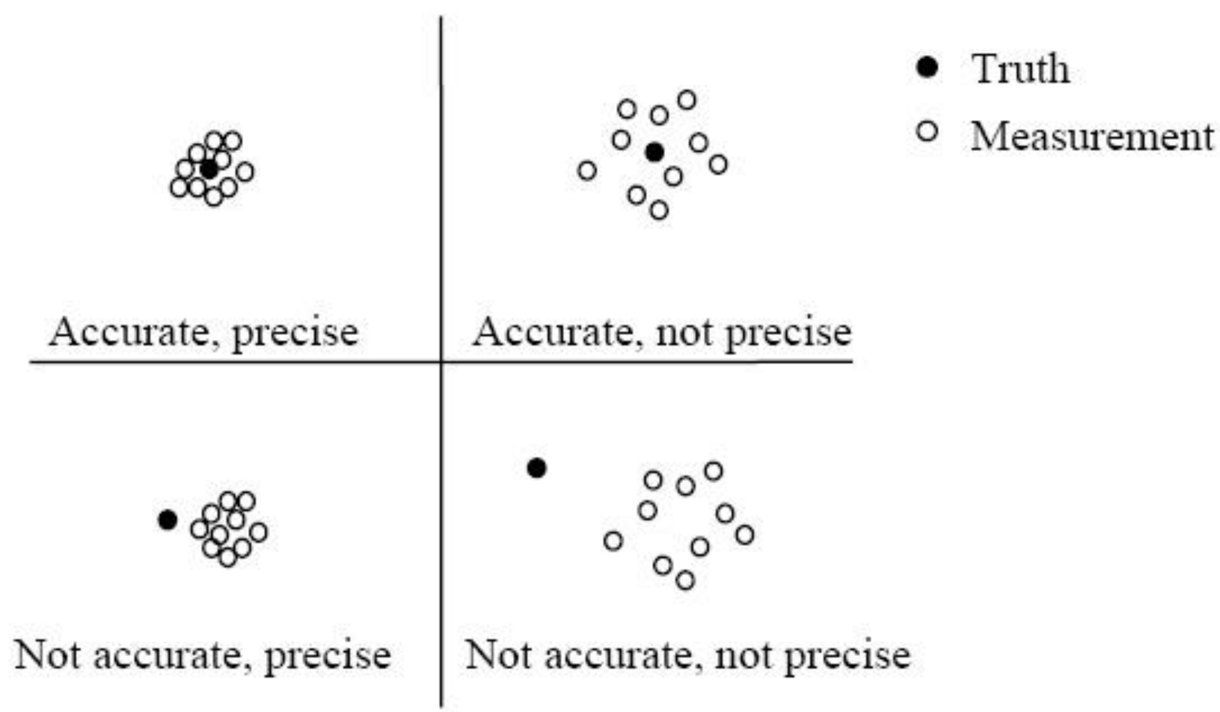


Figure 3.1. Accuracy vs. Precision.

NIST 2005

6 meter range

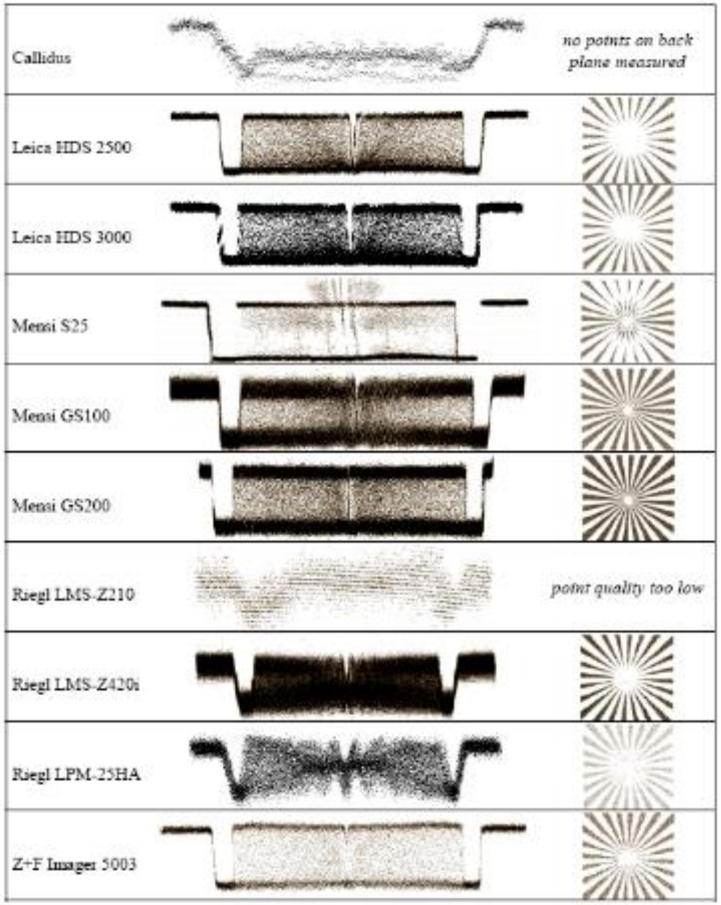


Figure 9a. Results of the resolution test using the target shown in Figure 5. Scanned at **6 m** range. Left: Cross section of point cloud. Right: Points on back plane of target (in smaller scale).

22 meter range

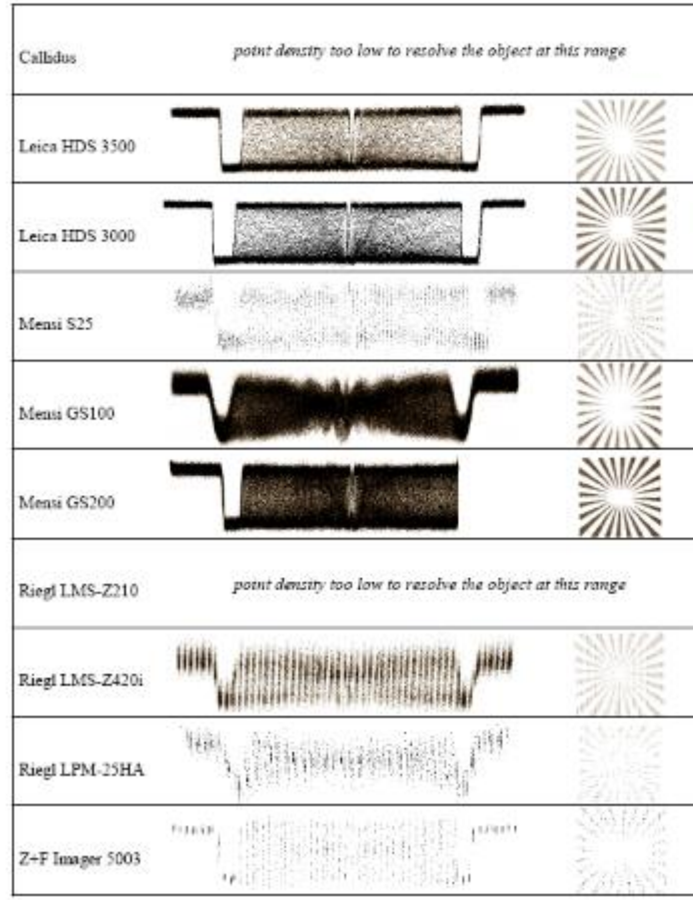
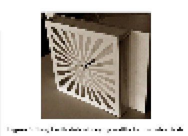


Figure 9b. Results of the resolution test using the target shown in Figure 5. Scanned at **22 m** range. Left: Cross section of point cloud. Right: Points on back plane of target (in smaller scale).



INVESTIGATING LASER SCANNER ACCURACY (2005)
http://www.scanning.fh-mainz.de/scannertest/results300305.pdf

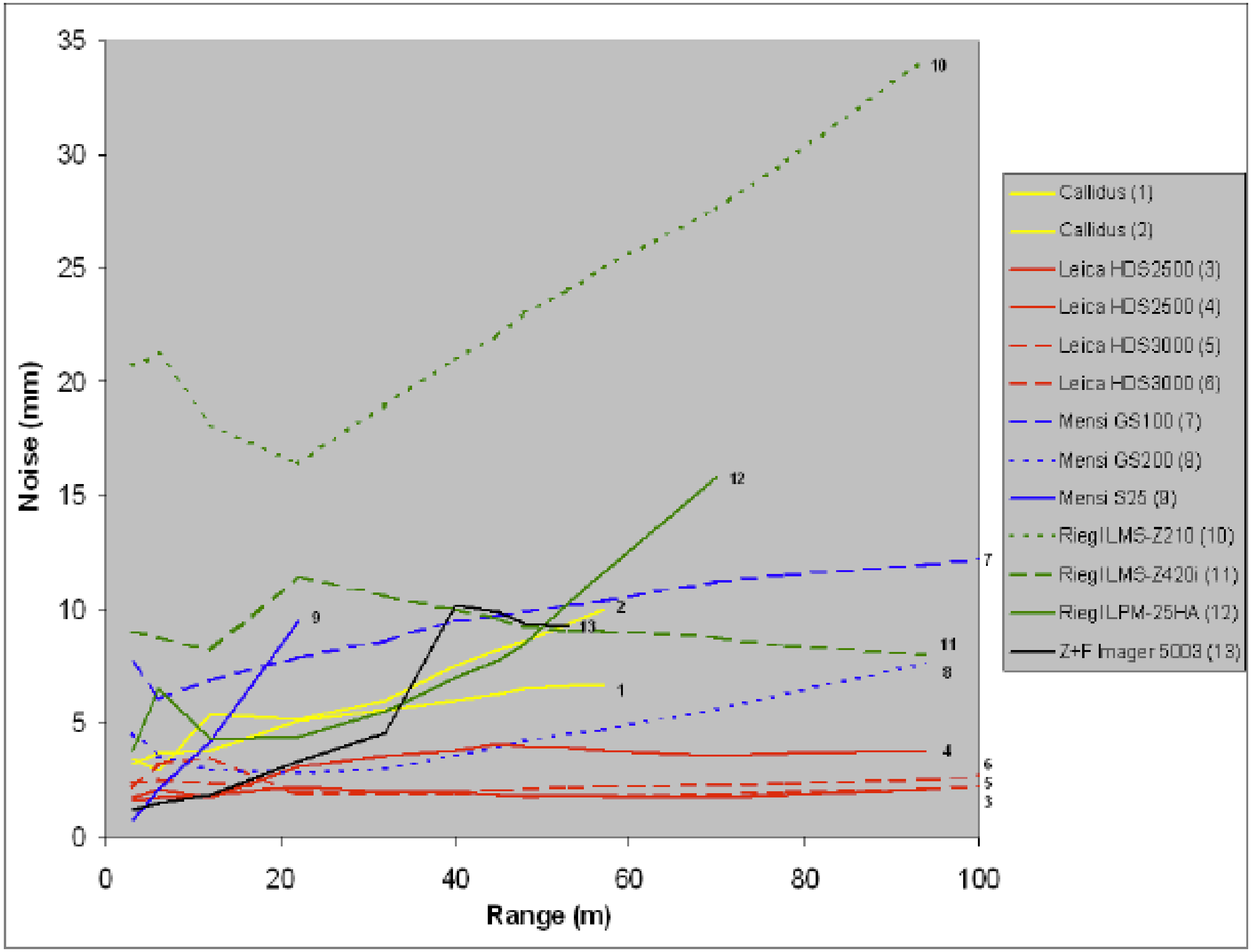


Figure 8. Measuring noise in range direction (standard deviation for a single point) for different scanners on a gray surface (40% reflectivity).

Table 2. Differences between known and scanned distances between two spheres orthogonal to range. Standard deviations (mm) based on 12 independent vertical and 12 independent horizontal spatial distances.

[a] Because of limited angular increment tested for short ranges only.

[b] Influenced by low range accuracy due to triangulation principle at far range; much better for close ranges (e.g. 0.8 mm vert. and 0.2 mm horiz. at 4 m range)

	Vertical distances (std. dev.)	Horizontal distances (std. dev.)	Maximal absolute difference
Callidus Precision Systems (1)	5.6[a]	4.3[a]	12.2[a]
Callidus Precision Systems (2)	9.9[a]	2.5[a]	18.3[a]
Leica HDS2500 (1)	0.8	0.8	1.6
Leica HDS2500 (2)	0.5	0.5	1.1
Leica HDS3000 (1)	1.3	1.1	2.9
Leica HDS3000 (2)	1.1	1.8	2.8
Mensi S25	3.8[b]	3.4[b]	9.2[b]
Mensi GS100	1.9	2.3	3.3
Mensi GS200	4.7	2.2	8.3
Riegl LMS-Z210	10.2[a]	16.8[a]	27.1[a]
Riegl LMS-Z420i	1.7	2.1	4.1
Riegl LPM-25HA	2.5	3.9	6.5
Zoller+Froehlich Imager 5003	2.9	7.5	11.1

- 3DMD Qlonerato
- FR1 projection +1 camera
- FR2 projection +3 cameras
- KM 910
- Polhemus FastTrack

Scanner	Mean Global Accuracy	Mean Repeat Accuracy	Number of Points	Number of Polygons
3DMD	0.106504	0.067726	11000	22000
FR1	0.35859	0.243976	3000	5500
FR2	0.924995	0.606283	50000	100000
Minolta	0.07977	0.014917	92000	185000
Polhemus	0.152945		46000	90000
Ground Truth			70000	140000

Scanner	RMS Global Accuracy	RMS Repeat Accuracy	Number of Points	Number of Polygons
3DMD	0.242287	0.515699	11000	22000
FR1	1.783649	1.564316	3000	5500
FR2	1.21512	1.14467	50000	100000
Minolta	0.181542	0.20415	92000	185000
Polhemus	0.281818		46000	90000
Ground Truth			70000	140000

Accuracy numbers shown are in millimeters

Table 2: Accuracy Summary

Boehnen and Flynn 2005 Accuracy of 3D scanning technologies in a face scanning scenario
Proceedings of the Fifth International Conference on 3-D Digital Imaging and Modeling (3DIM'05)

Forensic Science International article

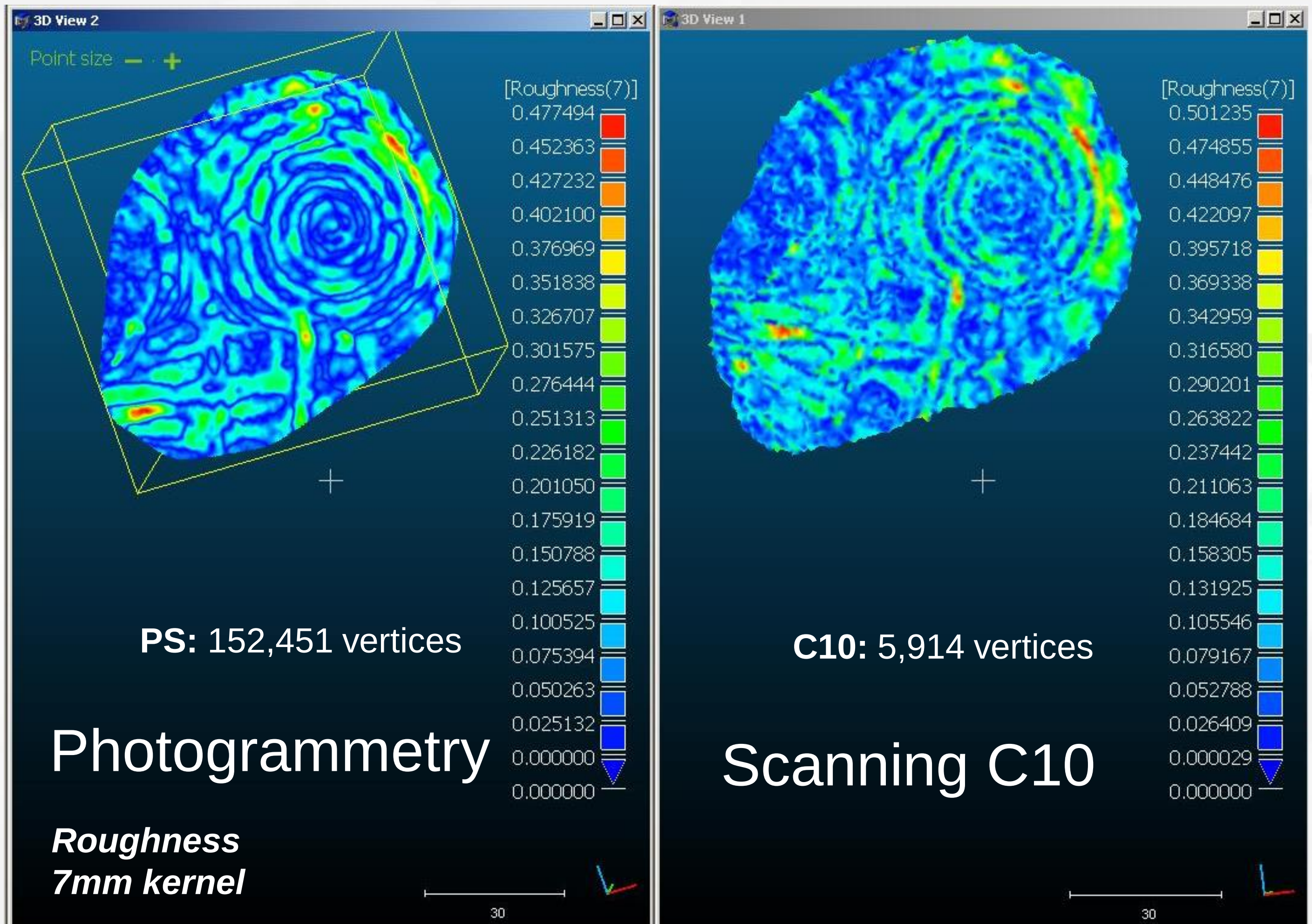
The results of the present study validate the use of the Di3D stereo-photogrammetry system for indirect anthropometric measurements. Linear measurements on 3D soft tissue surface model made with the Minolta Vivid 900 laser scanner, KaVo 3D exam CBCT scanner and Di3D stereo-photogrammetry system are accurate when compared with direct calliper measurements. **Therefore, the measurements recorded by all three 3D systems appear to be extremely accurate and very reliable for research and clinical use**. There were also no clinical differences between the 3D techniques suggesting that data obtained from these systems maybe combined for future research. By analyzing human remains via 3D models, forensic anthropologists can construct biological profiles using precise and accurate metrical data to determine key aspects of identity.

Evaluation of anthropometric accuracy and reliability using different three-dimensional scanning systems 2011 Z Fourie, J Damstra , P. Gerrits, Y Ren

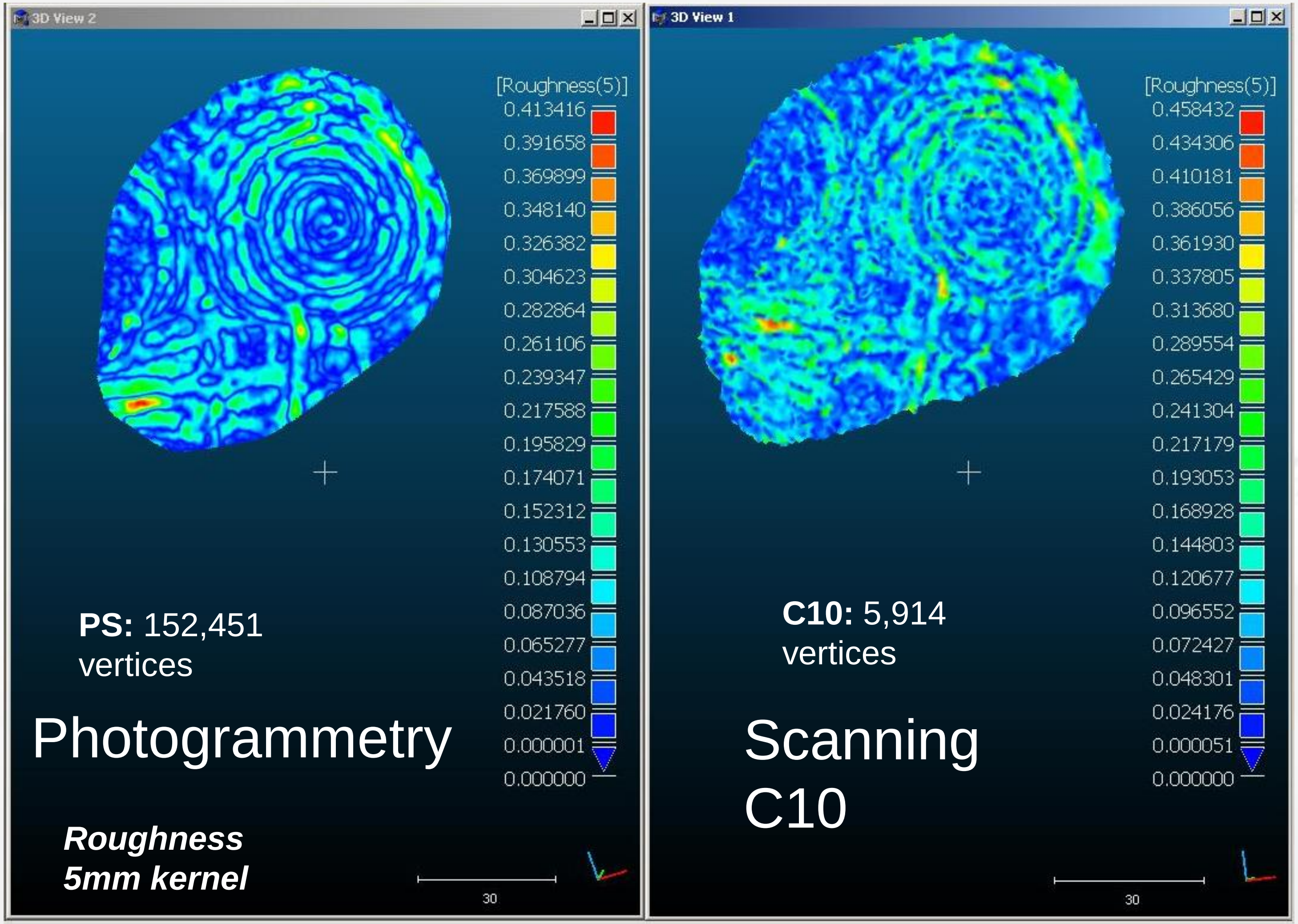
Table 1
Mean and standard deviations (SD) of the four anthropometric measuring techniques (all measurements in mm).

Soft tissue measurements	Measuring techniques							
	Reference (calliper)		Cone beam CT		laser surface scan		3D stereo-photogrammetry	
	Mean	SD (±)	Mean	SD (±)	Mean	SD (±)	Mean	SD (±)
1. (n-gn)	114.99	6.10	115.48	6.04	115.06	6.04	115.01	6.06
2. (n-sto)	77.68	3.92	78.16	3.69	78.24	4.05	77.83	3.60
3.(sn-gn)	60.27	5.89	60.20	5.72	60.54	5.80	59.54	5.82
4. (g-sn)	70.02	5.96	70.16	5.90	70.72	5.51	70.31	5.48
5. (t-n) – right	125.72	6.61	125.53	7.39	126.65	6.74	126.55	5.68
6. (t-n) – left	126.14	6.30	125.77	6.61	126.15	6.40	126.49	6.86
7. (t-sn) – right	130.89	8.76	128.93	7.37	130.59	8.99	130.45	8.10
8. (t-sn) – left	131.14	2.24	131.59	2.78	128.31	6.68	129.50	6.63
9. (t-gn) – right	149.79	12.07	149.27	11.76	147.83	13.56	146.17	11.93
10. (t-gn) – left	148.24	9.05	149.63	7.61	146.72	11.02	147.98	9.36
11. (en-en)	33.62	4.03	33.92	3.66	34.04	4.02	33.48	3.71
12. (ex-ex)	89.81	6.22	88.86	5.95	89.75	5.46	89.43	6.28
13. (al-al)	37.70	4.66	36.99	3.84	37.30	4.81	36.99	4.92
14. (n-sn)	56.44	3.39	55.33	3.20	56.69	3.88	56.46	3.88
15. (n-prn)	53.52	3.20	50.09	5.26	51.46	4.44	51.87	4.75
16. (al-prn) – right	33.28	5.23	33.46	4.82	34.94	5.01	36.31	2.35
17. (al-prn) – left	33.03	3.52	32.02	4.60	34.29	4.02	31.49	4.30
18. (ch-ch)	55.04	10.10	57.77	8.79	58.03	9.30	56.87	8.67
19. (sn-sto)	23.90	3.66	22.92	3.50	21.68	2.60	21.72	3.11
20. (sn-ch) – right	43.76	3.97	43.24	3.89	41.38	5.04	43.27	4.30
21. (sn-ch) – left	43.20	1.97	43.10	2.21	41.98	3.44	42.95	2.39

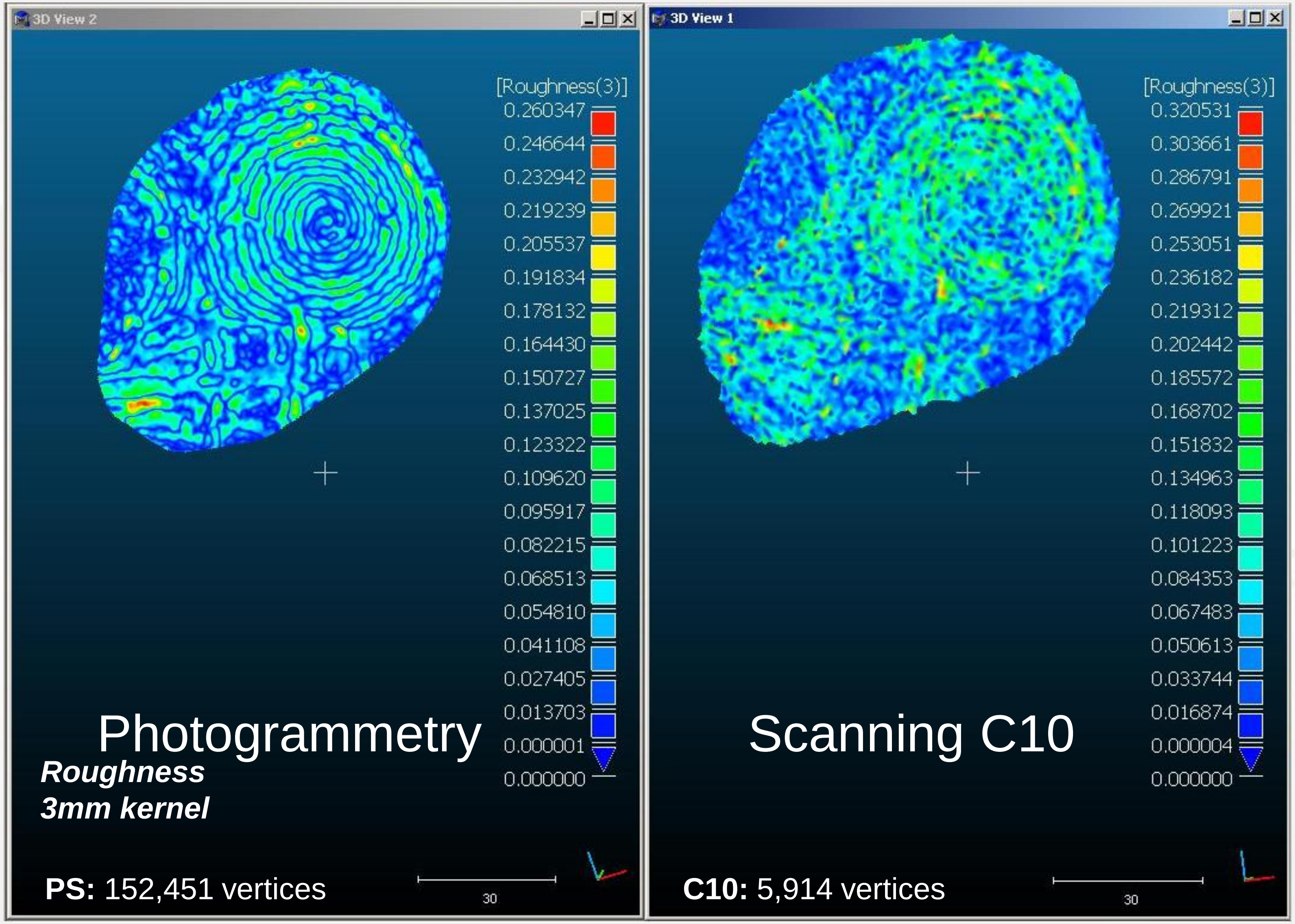
Resolution on mesh saliency metrics – 7 mm kernel



Mesh
saliency metrics – 5 mm kernel

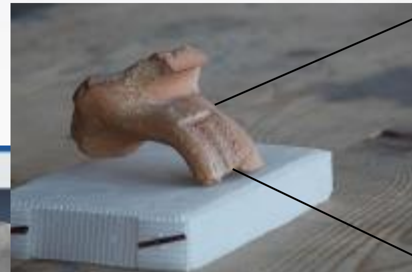


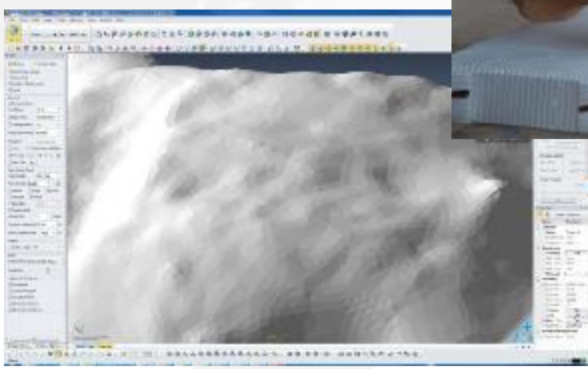
Mesh saliency metrics – 3 mm kernel



Comparing Photogrammetric Products:

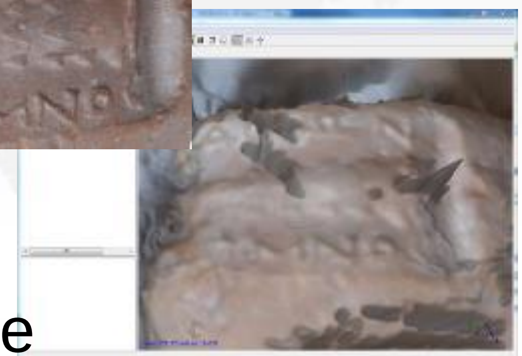
Both the algorithms and how individual software implements the algorithms affect processing results.





123D Catch

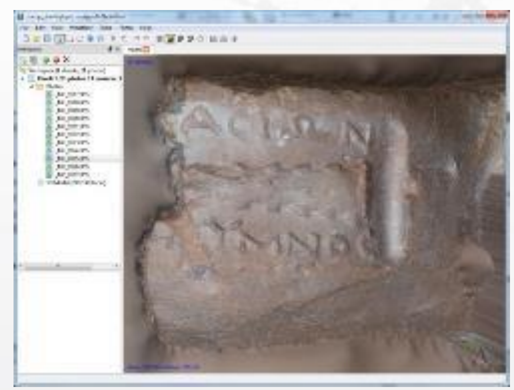
Without texture just the 3D "data"



Photoscan Med. Resolution

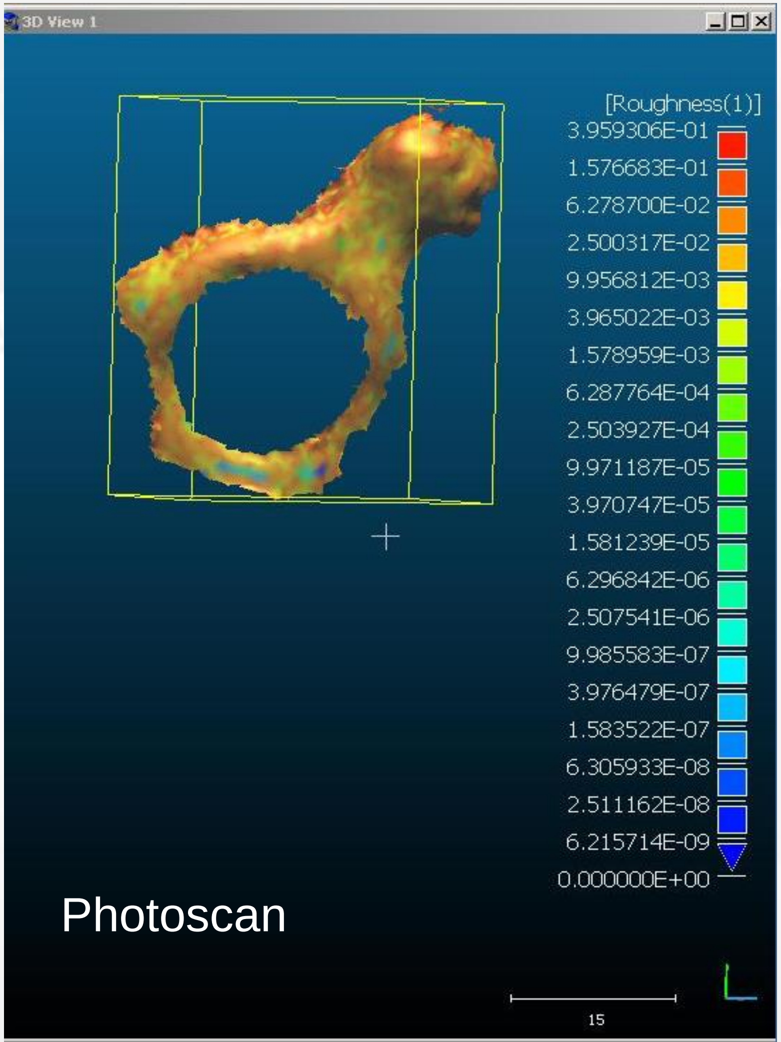
123D Catch

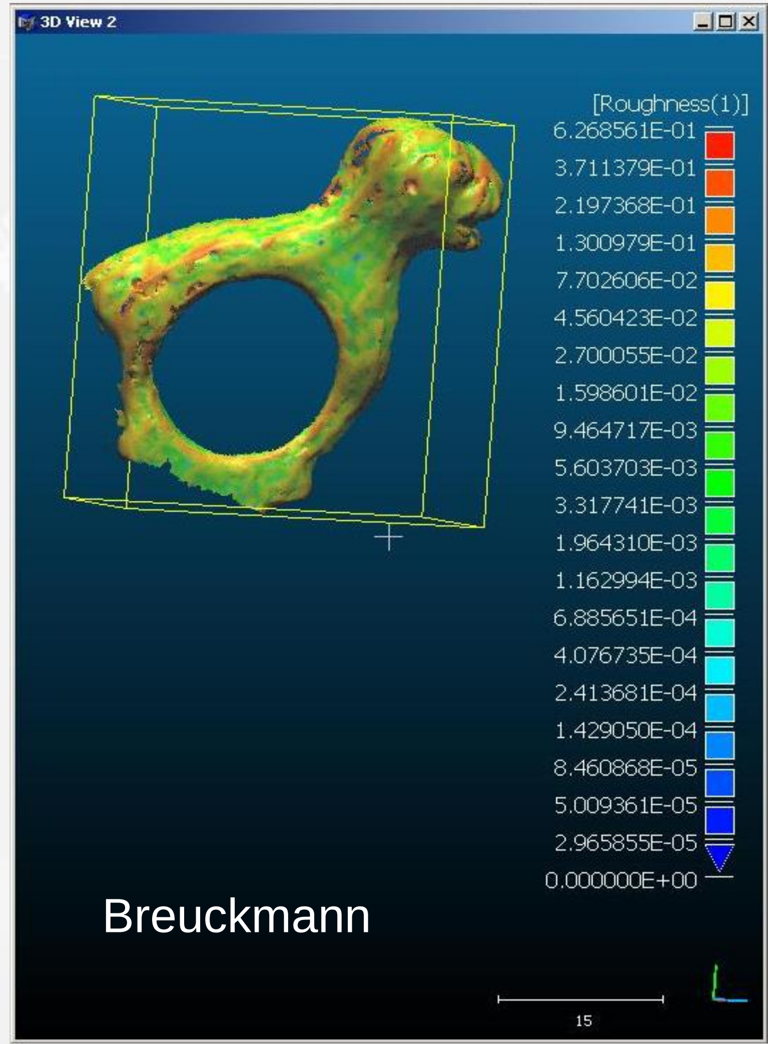
With texture

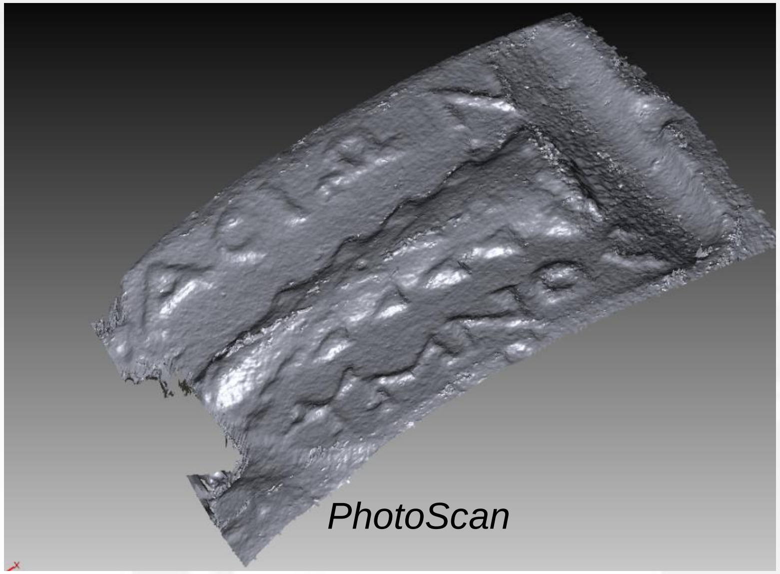


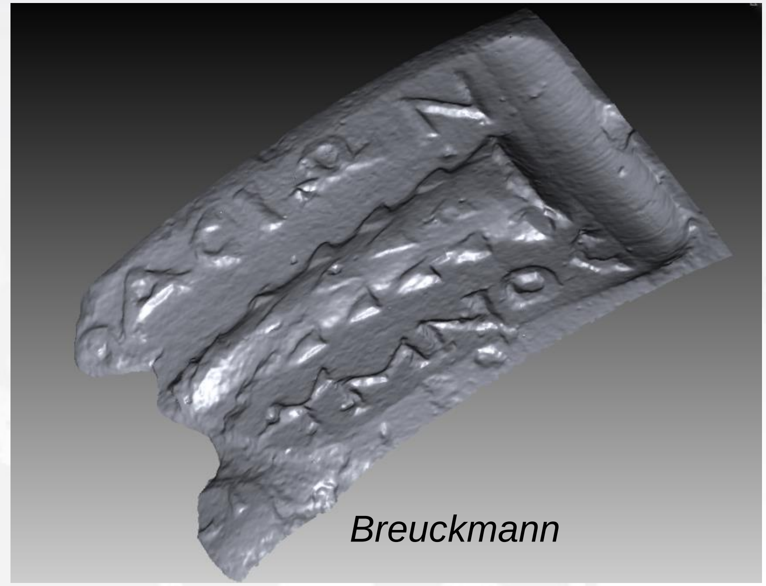
Photoscan Ultra High Resolution

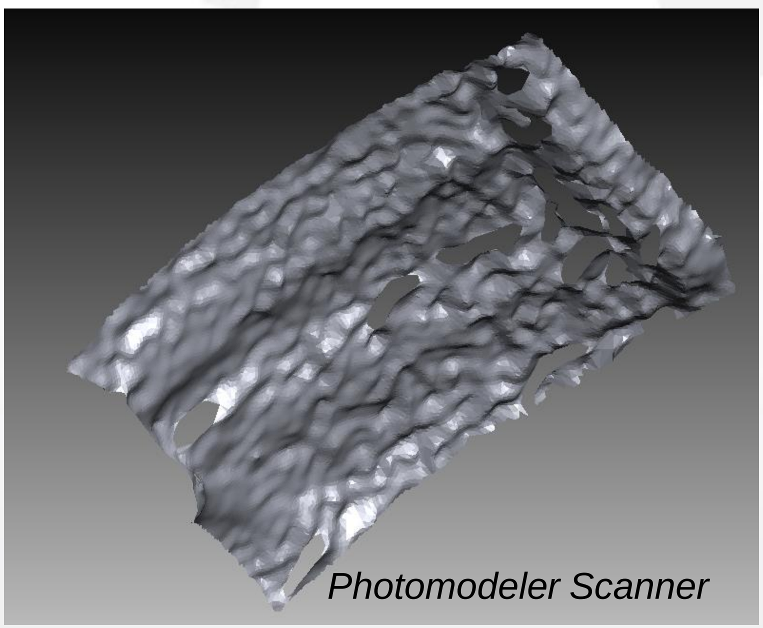
Monochromes, uniform textures, and other obstacles

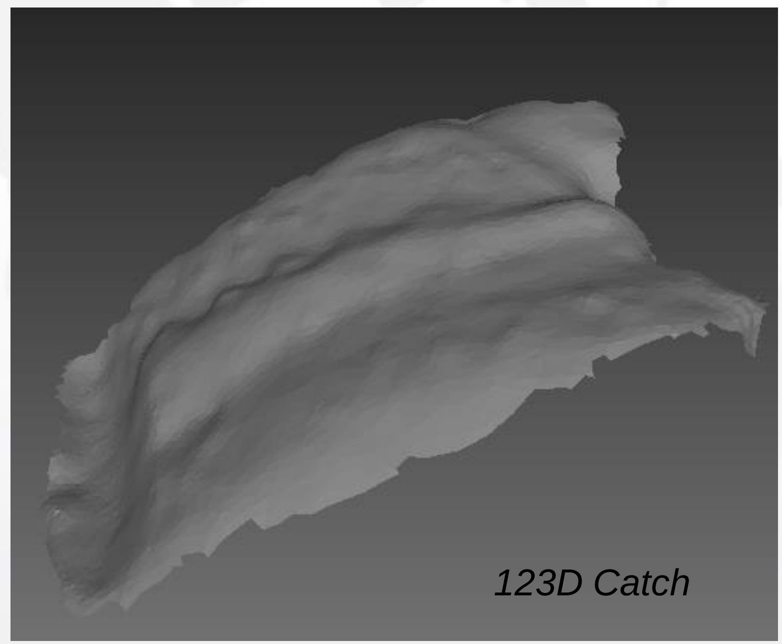





PhotoScan


Breuckmann


Photomodeler Scanner

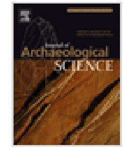

123D Catch

Close-Range Photogrammetry: Software

	Pros	Cons
123D Catch (Autodesk)	• Good point matching algorithm • No *a priori* camera calibration • Focus can be adjusted • Allows multiple focal lengths • Processing on remote server • Extreme smoothing/very clean results • Resulting models are a manageable size	• Extreme (over) smoothing • Black box processing • Minimal parameter control
PhotoScan (Agisoft)	• Good point matching algorithm • No *a priori* camera calibration • Focus can be adjusted • Allows multiple focal lengths • Extremely detailed models • Local processing (more control) • Good parameter control relative to 123D Catch • Detailed reporting/logs	• Processing intensive • Memory intensive 12+ gb • Less parameter control relative to *PhotoModeler Scanner*
PhotoModeler Scanner	• Detailed reporting and logs • Best parameter control • Customizable processing • Local Processing	• Fixed focus required • A priori camera calibration required • Matching algorithm is dated • Time consuming with more manual intervention

Journal of Archaeological Science

Volume 40, Issue 12, December 2013, Pages 4450–4456



Performance evaluation of a multi-image 3D reconstruction software on a low-feature artefact

Anestis Koutsoudis[a], Blaž Vidmar[b], Fotis Arnaoutoglou[a, 1]

[a] Institute for Language and Speech Processing, Multimedia Department, Research Centre 'Athena', PO Box 159, Xanthi 67100, Greece

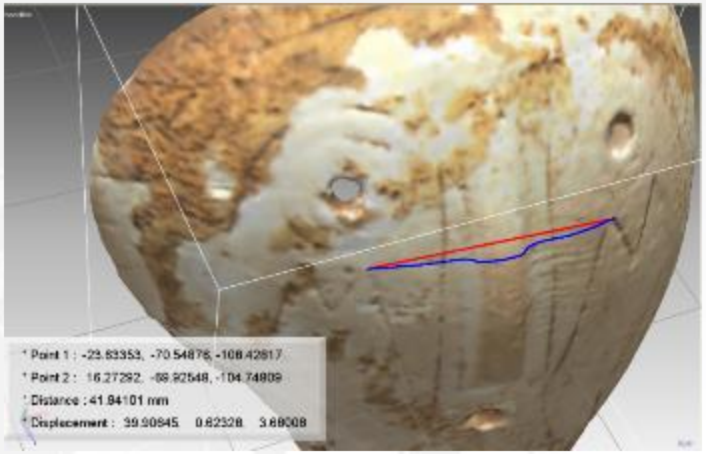
[b] University of Ljubljana, Faculty of Civil and Geodetic Engineering, Ljubljana 1000, Slovenia

"The **model produced by the 3D laser scanner is of higher quality than the image-based 3D reconstructions** and this can be easily understood even with subjective methods (e.g. visual comparison of the two models in terms of geometrical details and lack of noise). It should be mentioned that the current case study was based on a challenging, for image-based methods, artefact. This is due to its surface properties (e.g. lack of strong features, low frequency of colour changes, almost white surface)." page 4454

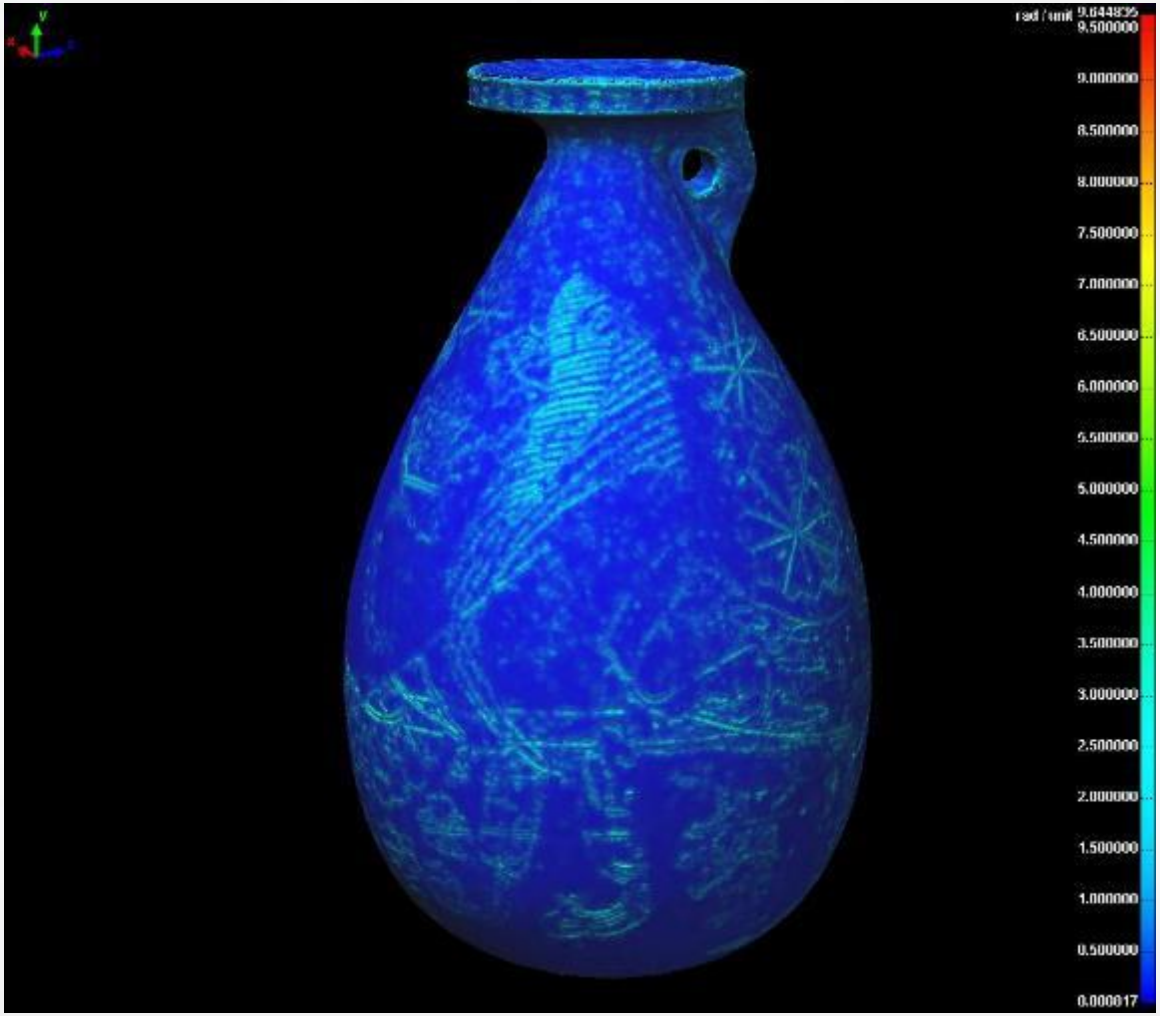
EXPANDING THE ANALYTICAL FRONTIERS WITH DIGITAL REPRESENTATIONS

Beyond Traditional Measurements

- Volume
- Radius
- Surface Area
- Perimeter Length
- Point to point
  - Can be constrained to an axis in 2d
  - Across a 3D surface
- Vertices and plane angle measurements (including dihedral)
- Ease of investigation around the entire object
  - sustained views at difficult angles

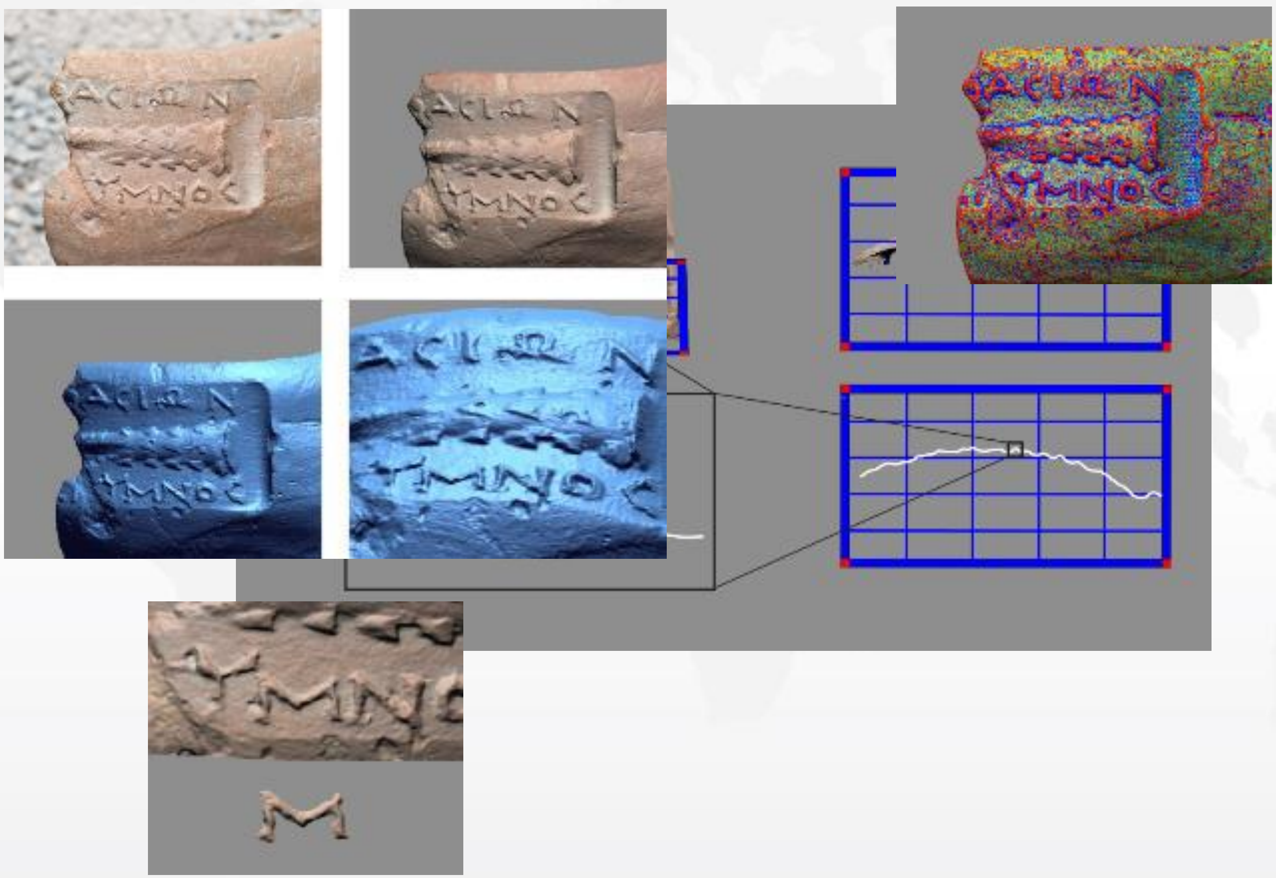


Curvature Mapping

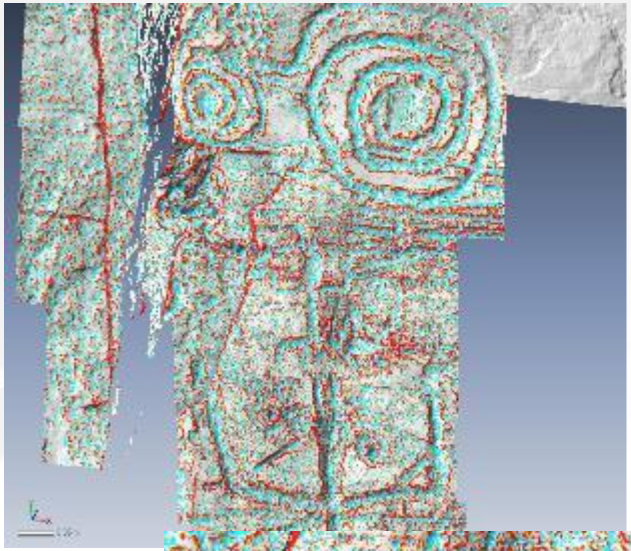


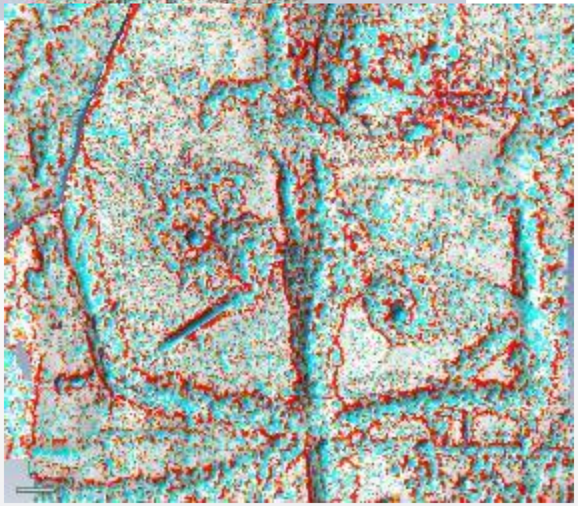
Shows manufacturing details

Wear analysis on Greek amphora stamps



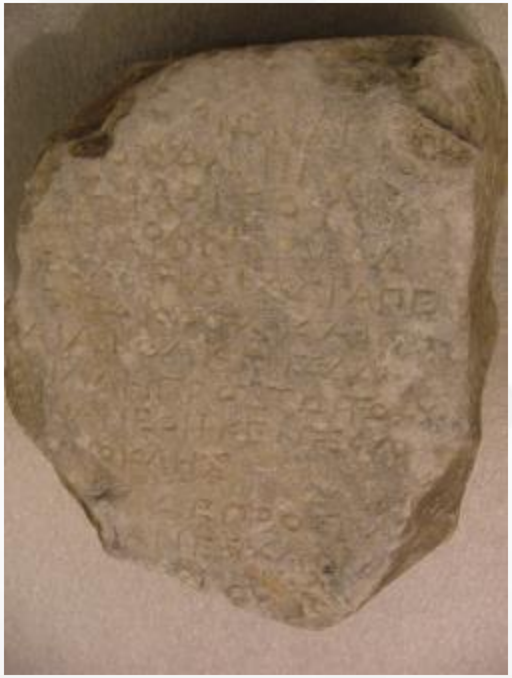
Automatic extraction of semantically relevant elements

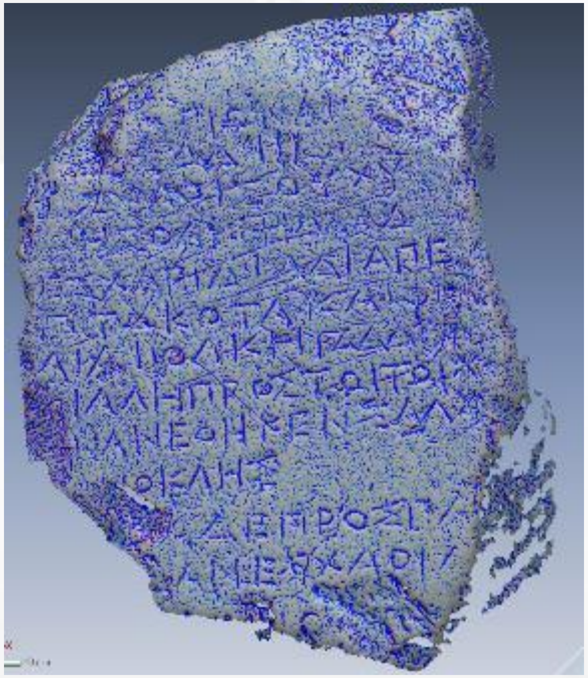




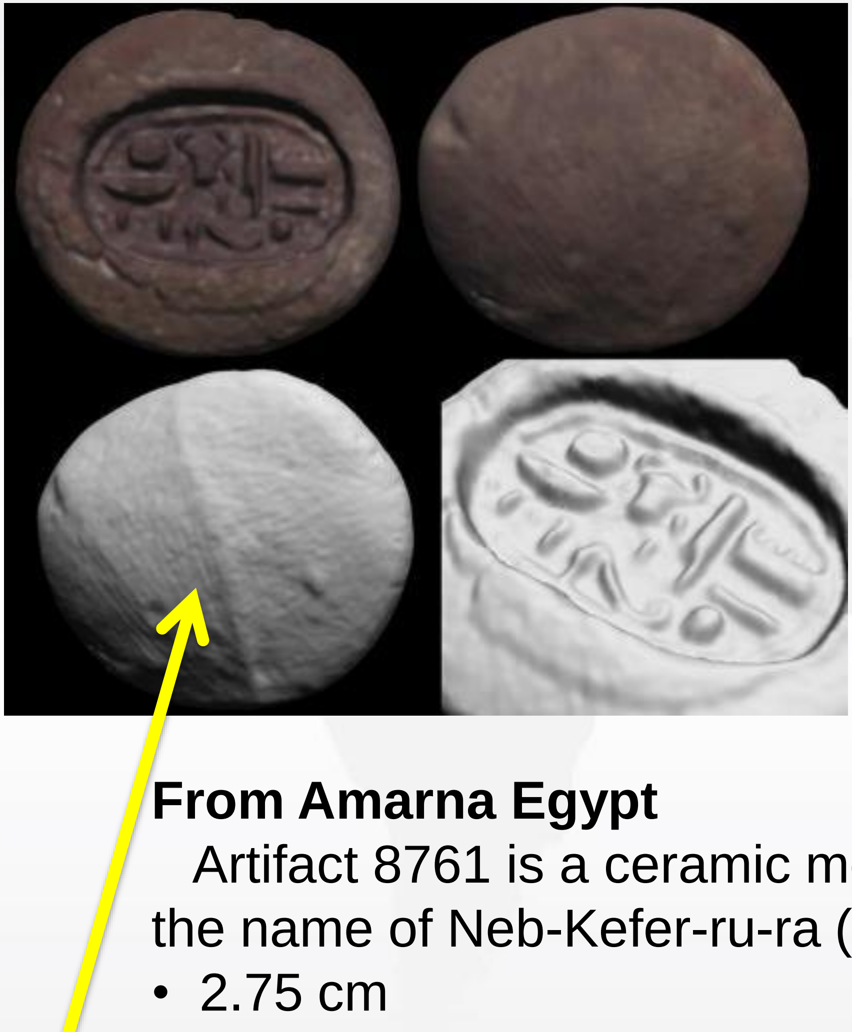
- Images to elements
  - Computer vision tools
  - Object recognition and isolation
- Selected "GIS" analytical operations

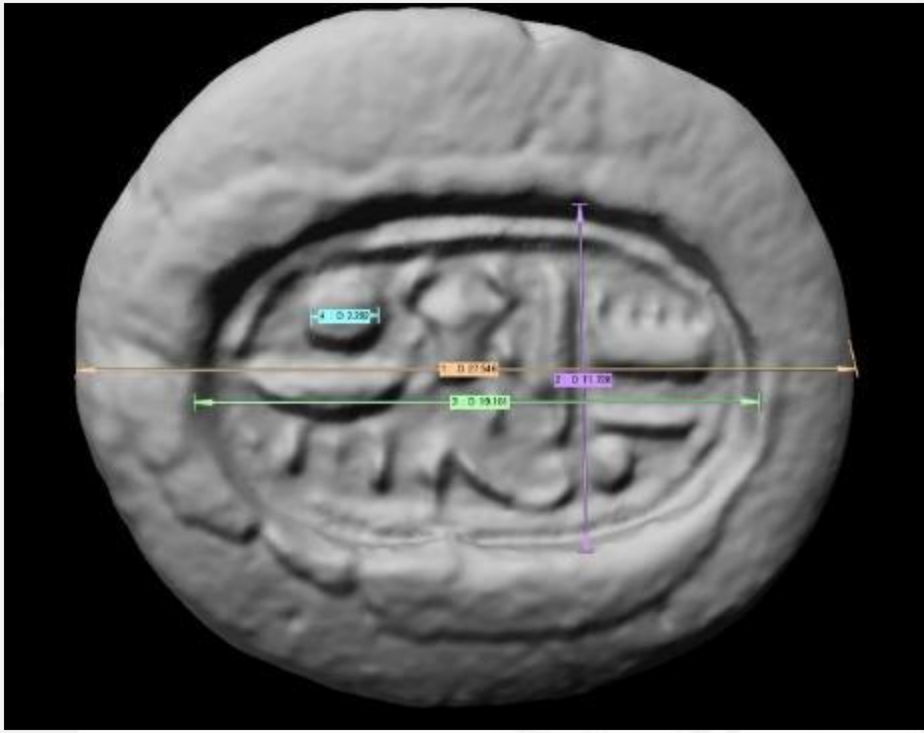
Identifying “hidden” characters on stele





- photo
- color stripped
- curvature mapping



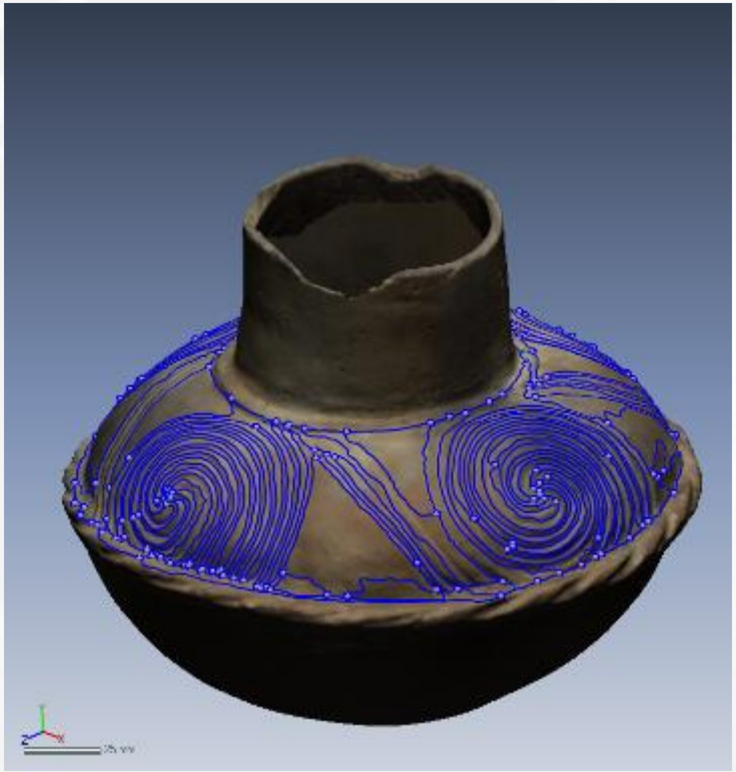


From Amarna Egypt

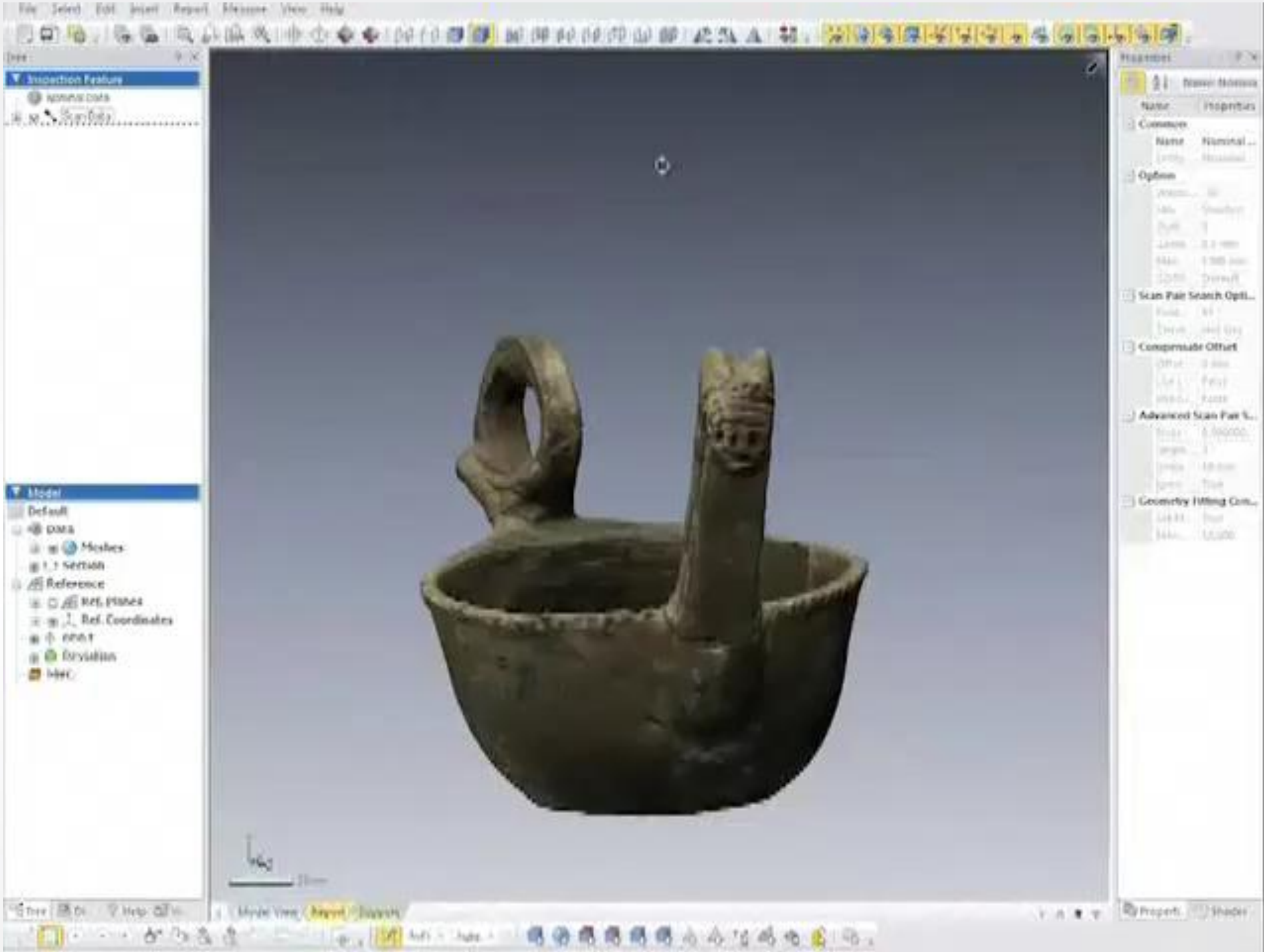
Artifact 8761 is a ceramic mould for a faience ring bezel that bears the name of Neb-Kefer-ru-ra (later Tutankhamen)

- 2.75 cm
- Note fingerprint and fabric imprints

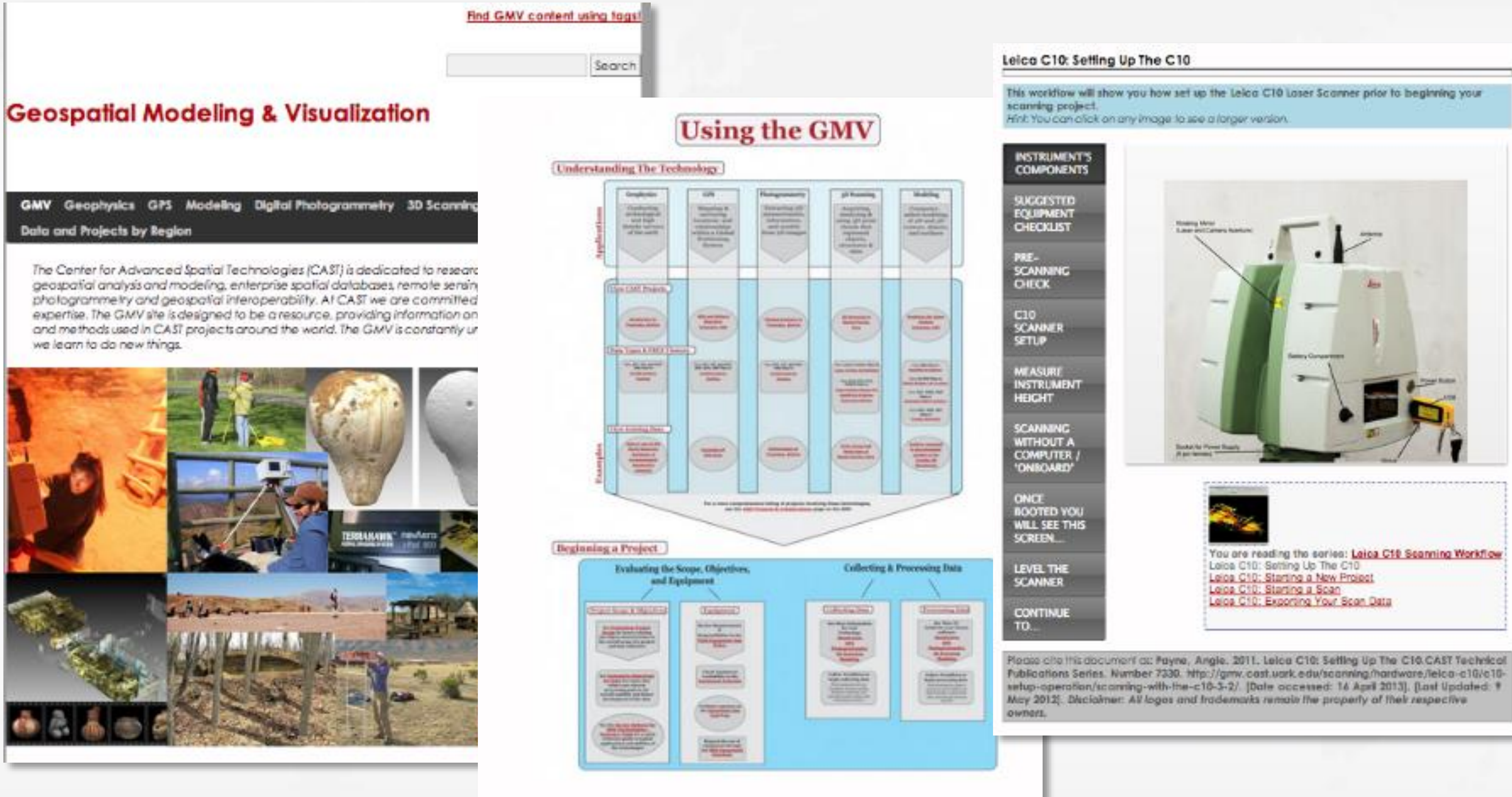
Automated style analysis
- uses three dimension not just two



W. F (Fred) Limp
SPARC Webinar
January 2014


Inspection Feature
Model
Default
Meshes
Reference
Ref. Coordinates
Deviation
Common
Options
Scan Pair Search Opti...
Compensate Offset
Advanced Scan Pair S...
Geometry Fitting Con...

For more on methods -- NSF funded project



http://gmv.cast.uark.edu

NSF funded workflow and resources

Geospatial Modeling & Visualization

A Method Store for Advanced Survey and Modeling Technologies

GMV | Geophysics | GPS | Modeling | Digital Photogrammetry | 3D Scanning | Equipment | Data and Projects by Region

Evaluating the Project Scope

This document will introduce you to some of the initial issues involved in evaluating the overall scope of a project as it relates to data collection.
Hint: You can click on any image to see a larger version.

- INTENDED AUDIENCE OF THIS GUIDE
- OBJECTIVE
- DISTANCE, SIZE, DATA RESOLUTION
- RANGE OF DISTANCE
- SIZE OF FEATURES
- DATA RESOLUTION
- SITE/OBJECT CHARACTERISTICS
- DARK, REFLECTIVE, TRANSLUCENT SURFACES
- DEPTH & ANGLES OF THE SURFACE
- SCATTERED OR SUBSURFACE FEATURES, VEGETATION
- PHYSICAL & TEMPORAL ACCESS

Goal of this Guide

It is critical to note that the processes described here focus ONLY on the collection of data and the limited processing of that data necessary to make it ready for an archive and intelligible to others. **The primary objective of this document is to provide a source of guidance on the various different methods and technologies that are possible and where and when such techniques are usually most effective.** It aims to aid users in evaluating which technologies are appropriate by considering :

I. **Distance, Scale and Resolution of Data**

II. **Which technologies are appropriate for which characteristics of the site or feature(s) of interest**

III. **The physical and temporal access that is available to the site/object**

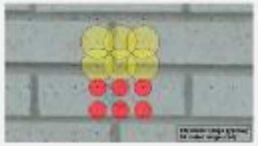
Disclaimer: Some factors, such as the physical size of the site(s) and/or object(s) that you are documenting, immediately suggest which technologies and methods might be used and which would generally be avoided. However, all projects are different – experiences, unique needs and specific situations often decide which technologies are appropriate.

Please cite this document as: **Stevens, Caitlin. 2013. Evaluating the Project Scope.CAST Technical Publications Series. Number 12651. http://gmv.cast.uark.edu/uncategorized/evaluating-the-project-scope/. [Date accessed: 24 January 2014]. [Last Updated: 12 March 2013]. *Disclaimer: All logos and trademarks remain the property of their respective owners.***

---

overlap between mid and long-range scanning depending on the equipment being considered. The Optech ILRIS has a minimum distance of 3 meters, for example, but a mid-range scanner would typically be used at this range (depending on the specific situation). Similarly, the Leica C10's specifications list an effective scanning range up to 200 meters depending on the desired resolution, atmospheric conditions and the reflectivity of the surface being captured and deciding between the C10 and the Optech at this distance would, again, depend on the situation. (See the slide in this guide regarding Qualities of Features for more information on surface reflectivity).

NOTE: When considering long-range 3D scanning, beam divergence must also be considered. At greater distances, the diameter of the laser beam itself affects the density of points that may be captured across a surface. Consult specifications for individual scanners for more details on how range and beam divergence relates to data resolution.



Which technologies are appropriate for which characteristics?

While all sites and situations are different, there are some qualities that, if present, make certain survey methods more preferable than others. Deciding which technologies to use is largely based on characteristics of the site and/or object(s) and what type of information is needed. See the Survey Options for GMV Technologies table for a summary of the typical uses and abilities for the technologies at specific ranges given certain characteristics.

Common questions about the site and/or object(s) you wish to survey include:

I. **Are there darkly colored, highly reflective (mirror-like), and/or translucent surfaces within the site that you want to capture?**

II. **What is the amount of relief and/or depth in the layer(s) of the surface being captured and what are the angles between these surface(s) and the equipment you are using?**

III. **Are there features or artifacts scattered across the site?**

IV. **Will subsurface features be included in your survey?**

HDSM Scanning Options

	General Usage/ Resolution	Primary Strength(s)	Primary Weakness(es)	Typical Data Collection Time	Typical Basic Processing Time (e.g. preliminary cleaning & alignment)	Capture Standing Structures / Ruins	Capture Interior Spaces/Rooms	Capture Fine Scale Features (e.g. shallow inscriptions, tool markings)	Capture Planimetric Features	Capture Topography	Scattered Features / Artifacts
3D Scanning Long-Range (50-500 meters) *ex: Optech ILRIS 3D*	Long distance (>200m) 3D documentation of exterior, standing architectural structures/remains & surrounding topography CENTIMETER RESOLUTION	- Long distance scans up to 800m are possible but depend on target reflectivity - With good vantage point, can capture large areas - Can scan at night with the same results at daylight scans	Specific to Optech: - Small, fixed, 40° field of view - No color collected - More noise than Leica C10 - Very slow (2,500 pts/sec) - Terrible in interior spaces - Requires external power source (i.e. power outlet or batteries)	Typically 20 minutes per scan but dense scans over very long distances can take more than 1 hour 5-10 minutes of setup time per scan	Double the data collection time	✓			✓	✓ (if high vantage point is accessible)	
3D Scanning Mid-Range (1-200 meters) *ex: Leica C10* (300 m. max) *ex: Z+F 5006i* (80 m. max)	3D documentation of interior & exterior standing architectural structures/remains & surrounding topography MILLIMETER to CENTIMETER RESOLUTION	- Relatively fast - Include options to collect color - 360°x270° full dome field of view - Works well in exteriors & interiors	- Cannot capture 60° area below scanner resulting in circular 'hole' in data in this area - Darkly colored surfaces and/or highly reflective/ specular surfaces are problematic to scan	For 1x1 cm resolution at 20 m distance: Time-of-flight (C10) is typically 20 minutes per scan* Phase-based (Z+F): 6 mins per scan* 5-10 minutes of setup time per scan * Collecting color & acquiring targets requires additional field time	Double the data collection time * Unless targets were acquired in field, which significantly reduces processing time	✓	✓		✓	✓ (high vantage point helps significantly)	
3D Scanning Short-Range (1-5 meters) *ex: Breukmann HE*	3D documentation of small objects, artifacts, engravings, inscriptions SUB-MILLIMETER RESOLUTION	- Extremely precise & accurate data for resolutions up to 60 microns - Excellent RGB control w/ HDR capabilities - Can be used w/ turntable for efficient object scanning - Quick processing time when data capture is good	- Requires external power - Relatively time consuming collection time when subject is in fixed position (i.e. scanner moved for each scan) - Darkly colored and/or reflective surfaces are problematic - Systems are designed for use in interior / lab conditions. Use in field is challenging but possible.	For fairly flat surfaces approx. 7 hours to collect: 60 micron resolution of 1x1m area OR 30 micron resolution of 1x2 meter area For exterior of simple, ceramic vessel with a non-reflective surface (size of a soccer ball): 1 hour (depends greatly on computer, power source, use of a turntable & familiarity with the software) 30 minutes of setup time per scan + 1 hour of calibration time after travel or lens change	1/8 - 1/4 data collection time (when noise is minimal or non-existent) Varies greatly if noise is present			✓ (best option for 3D)			

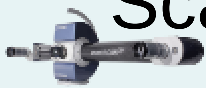
http://gmv.cast.uark.edu/uncategorized/survey-options-for-gmv-technologies-summary-table/

HDSM Photographic Options

	General Usage/ Resolution	Primary Strength(s)	Primary Weakness(es)	Typical Data Collection Time	Typical Basic Processing Time (e.g. preliminary cleaning & alignment)	Capture Standing Structures / Ruins	Capture Interior Spaces/Rooms	Capture Fine Scale Features (e.g. shallow inscriptions, tool markings)	Capture Planimetric Features	Capture Topography	Scattered Features / Artifacts
Reflection Transformation Imaging (RTI)	2D documentation (w/ simulated 3D effect) of small objects, artifacts, engravings, inscriptions SUB-MILLIMETER RESOLUTION	- Very high resolution/ accuracy of surface normal information - Ability to analyze very finely scaled features - Fast data collection & processing - Very easy to view & share	- Final product is a fixed view of object/surface (i.e. cannot rotate or orbit) - Limited to ca. 1.5 x 1.5 meter area - Multiple RTI views cannot be 'stitched' together/ registered but can be viewed simultaneously - Surfaces in direct sunlight are challenging	Typically 20-40 minutes to collect image set 15 minutes of setup time	1 - 1.5 hours per RTI image set			✓ (best option for speed but limited to 2D results)			
Terrestrial / Close-Range Photogrammetry (using a tripod)	3D documentation of large & small structures / objects MILLIMETER to CENTIMETER RESOLUTION	- Fast data collection - Flexible camera mounting options (i.e. tall tripods to reach elevated features) - Very flexible in terms of shape/size/relief of object being surveyed - Highly automated processing	- Requires object/surface to be well-lit - Processing large projects can be difficult & time-consuming, requires high-powered computer - Requires scaling w/ known points or features for meaningful measurements	Varies greatly depending on the structure/object & conditions (ex: 20 **minutes** to collect 10 images of an inscribed tablet vs. 2-3 **days** to collect 50+ images of the exterior of a large structure such as the Colosseum in Rome)	Varies greatly depending on the structure/object & conditions (ex: 2 **hours** to process 10 images of an inscribed tablet vs. 2-3 **days** to process 50+ images of the exterior of a large structure such as the Colosseum in Rome)	✓	✓ (mid-range scanning is typically a much better option)	✓		✓ (if high vantage point is accessible)	✓ (depending on density and characteristics of artifacts)
Low-Altitude Aerial Photogrammetry (UAV / Kite / Pole)	2D or 3D documentation of expansive sites 5 CENTIMETER + RESOLUTION	- Can document very large areas in a short amount of time - Highly automated processing	- Must obtain permission to fly - If using an UAV, the pilot must be FAA qualified in the USA - Cameras have relatively short battery life	Varies greatly depending on the survey area and the flying height	Varies greatly depending on the number of images (ex: 2 **hours** to process 10 images vs. 2-3 **days** to process 50+ images)	✓			✓	✓ (best option)	✓ (depending on density and characteristics of artifacts)

http://gmv.cast.uark.edu/uncategorized/survey-options-for-gmv-technologies-summary-table/

So how do you choose?



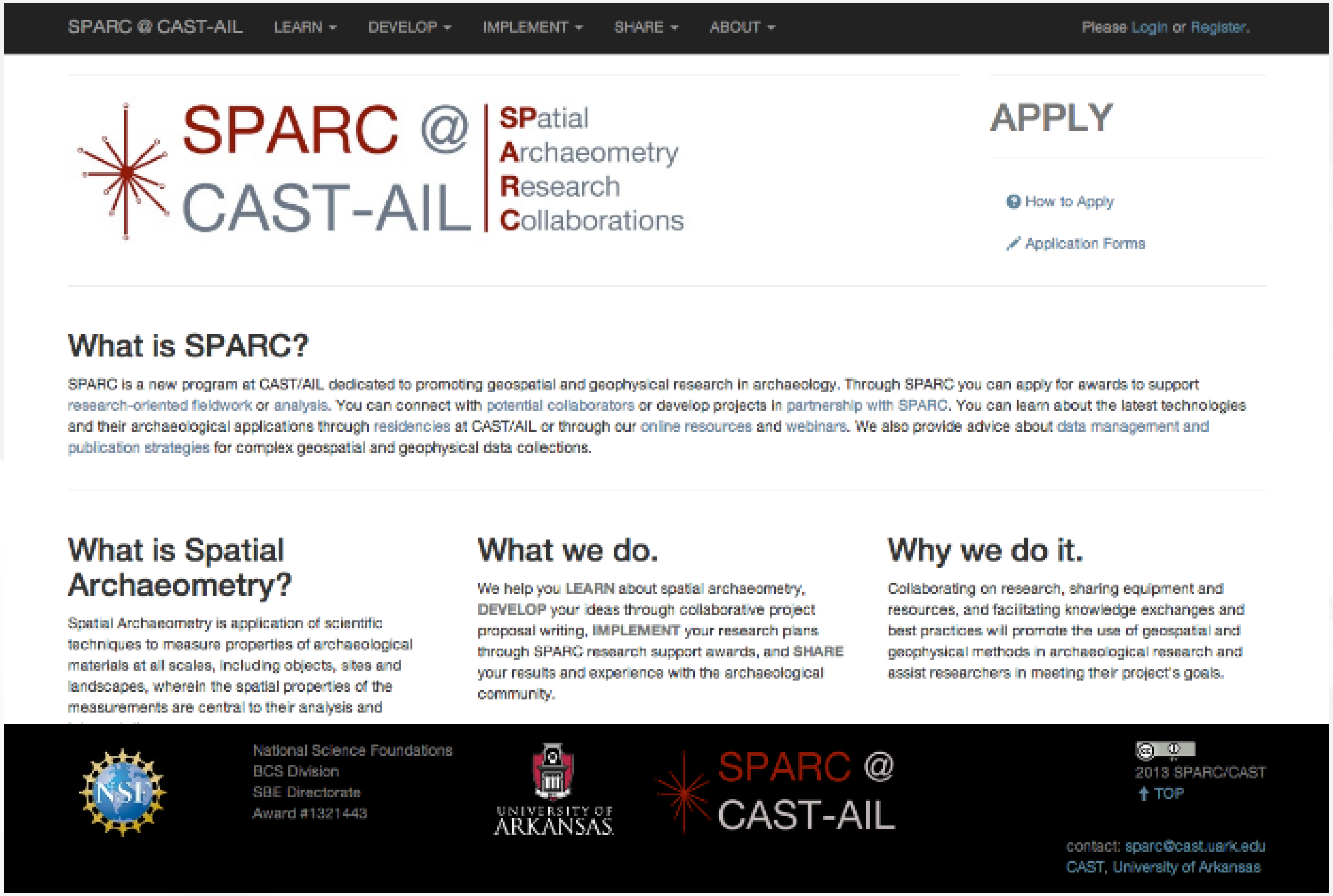
Data Capture

	Scanning	Photogrammetry
$ Equipment	$60,000+ Purchase $1000+ Rental/week	$100s - $1000s Purchase
Dist. to Target	0.5 m to 2 km (plus scanner dimensions)	Limited by focal length and depth of field
Capture Depth	Close-range = centimeters Mid to long = range	Limited by depth of field/ aperture
Lighting	Close-range: low light to dark req'd Mid to long: Lighting only affects texture	Light required Diffuse light or minimal shadows ideal
Time	More complex geometry requires more scans/photos and more processing time Higher resolution requires more time for data collection (i.e. longer scans, more photos)	
Project Goals	Goal #1: Metric precision Goal #2: Visualization	Goal #1: Visualization Goal #2: Metric precision

Further reading – a start

- *Aerial and close range photogrammetric technology* 2008 N. Mathews. BLM TN 48
- *Theory and practice on terrestrial laser scanning* 2008 B. Van Genechte
- *Airborne and Terrestrial Laser Scanning* 2010 G Vosselman H-G Maas (eds)
- *Interpreting archaeological topography: lasers, 3D data, observations, visualization and applications* 2013 R Optiz and D Cowley
- *Close Range Photogrammetry: Principles, Techniques and Applications* 2011. T Luhman, S Robson, S Kyle, I Harley
- *3D laser scanning for heritage* 2nd ed. 2011 English Heritage
- CIPA Symposia publications cipa.icomos.org/index.php?id=28
- 3D-COFORM EU Project www.3d-coform.eu
- Geospatial modeling and visualization gmv.cast.uark.edu

SPARC Project



SPARC @ CAST-AIL LEARN DEVELOP IMPLEMENT SHARE ABOUT Please Login or Register.

SPARC @ CAST-AIL

SPatial **A**rchaeometry **R**esearch **C**ollaborations

APPLY

How to Apply

Application Forms

What is SPARC?

SPARC is a new program at CAST/AIL dedicated to promoting geospatial and geophysical research in archaeology. Through SPARC you can apply for awards to support research-oriented fieldwork or analysis. You can connect with potential collaborators or develop projects in partnership with SPARC. You can learn about the latest technologies and their archaeological applications through residencies at CAST/AIL or through our online resources and webinars. We also provide advice about data management and publication strategies for complex geospatial and geophysical data collections.

What is Spatial Archaeometry?

Spatial Archaeometry is application of scientific techniques to measure properties of archaeological materials at all scales, including objects, sites and landscapes, wherein the spatial properties of the measurements are central to their analysis and

What we do.

We help you LEARN about spatial archaeometry, DEVELOP your ideas through collaborative project proposal writing, IMPLEMENT your research plans through SPARC research support awards, and SHARE your results and experience with the archaeological community.

Why we do it.

Collaborating on research, sharing equipment and resources, and facilitating knowledge exchanges and best practices will promote the use of geospatial and geophysical methods in archaeological research and assist researchers in meeting their project's goals.

National Science Foundations
BCS Division
SBE Directorate
Award #1321443

UNIVERSITY OF ARKANSAS

SPARC @ CAST-AIL

2013 SPARC/CAST
TOP

contact: sparc@cast.uark.edu
CAST, University of Arkansas

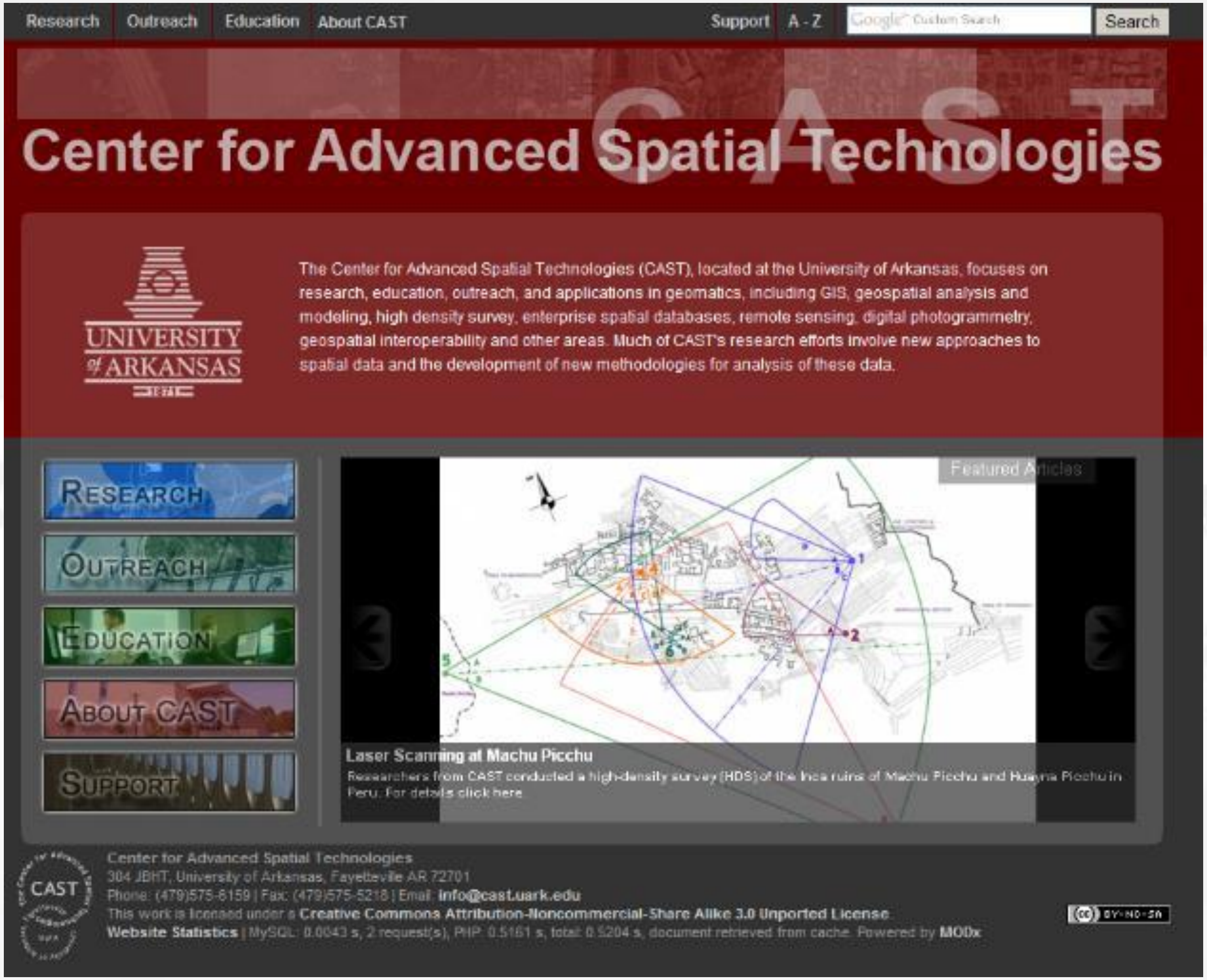
http://sparc.cast.uark.edu

NSF Archaeometry funded project
To provide capabilities to community

QUESTIONS?

Acknowledgements

- Chaco Canyon NHP, Dabney Ford and NPS park staff, Rex Weeks PI
- Rex Weeks, Katie Simon, Fred Limp, Angie Payne, Diane McLaughlin, & Michael Teichmann – Chaco data
- Angie Payne – Machu Picchu data, Old Main images
- Jason Herrmann – Egyptian images
- Katie Simon – Amphorae data, measurement images
- Rachel Opitz – measurement processes, resolution, technique images
- Keenan Cole – Greek ceramics images
- Snow Winters – Hampson images
- Stephanie Sullivan – Stele data
- Jesse Casana – UAV and thermal images
- NSF equipment: NSF BCS 0321286 and CII 0918970 and Leica Geosystems Chair Endowment
- RiskManagement – scanner technology images



www.cast.uark.edu

fred@cast.uark.edu