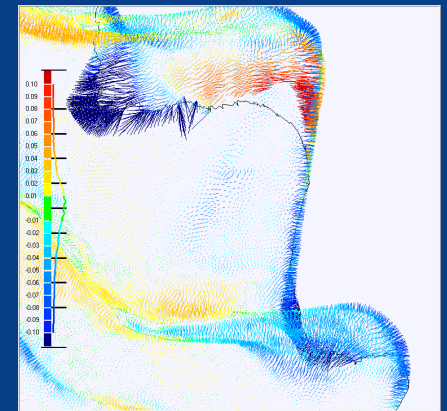
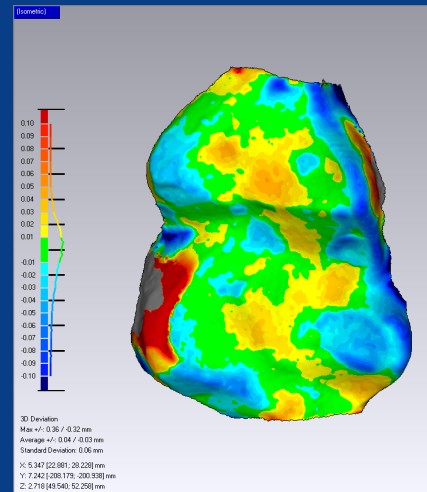
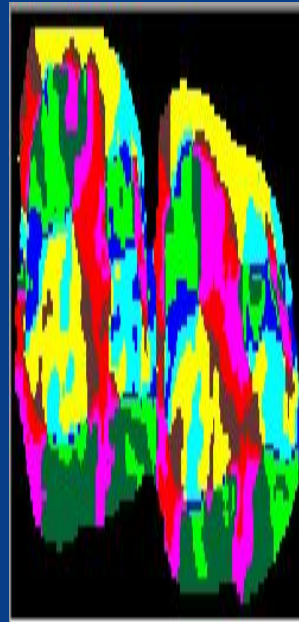
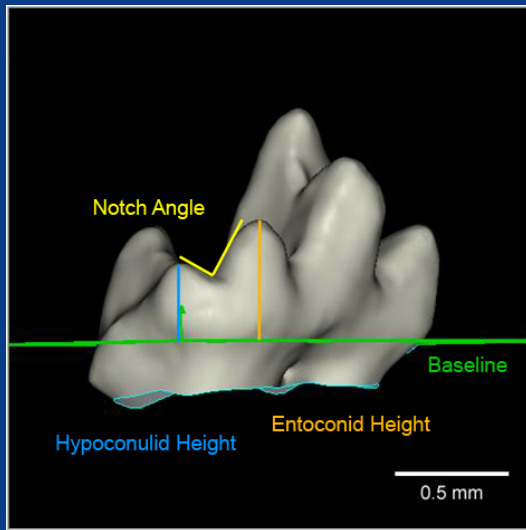


# 3D Laser Scanning: Accuracy and Precision

Suzanne G. Strait  
Biological Sciences  
Marshall University

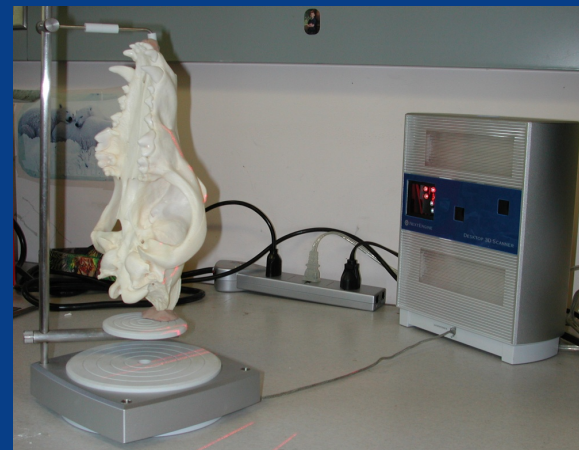
# 3D Data

? wonderful way to effectively visualize and quantify complex morphology



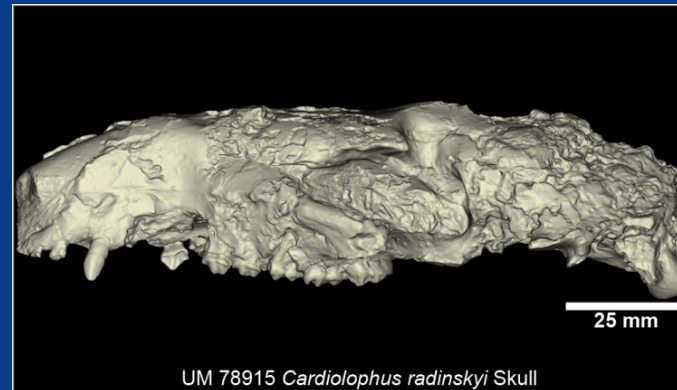
# 3D Scanning vs CT

- ❑ Cost
  - ❑ Initial investment
  - ❑ Service contracts
- ❑ Surface data
- ❑ Less technical expertise necessary
- ❑ More portable

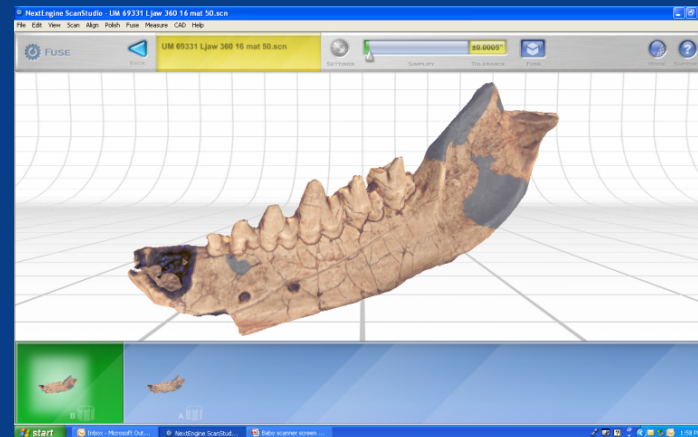
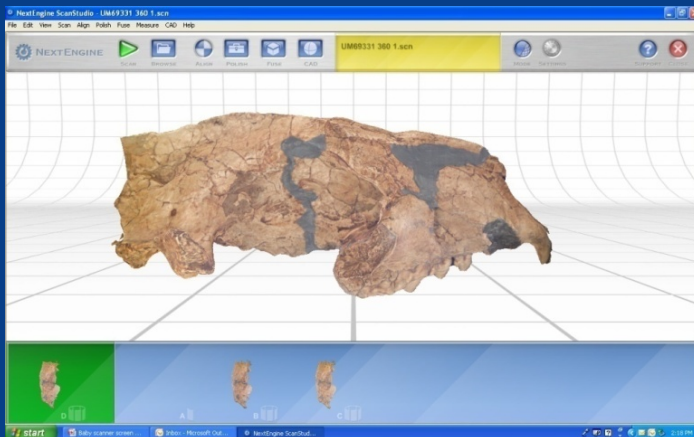


# 3D Scanning Challenges

- ? Blind spots
  - ? Undercuts



- ? Density differences



UM 69331, *Dipsalidictis krausei* (cast), skull length ~15 cm

# 3D Scanning Challenges

## ? Reflectivity

### ? Dark specimens

- ? Absorb light, less signal for sensor

### ? Glossy

- ? Substantial noise increase

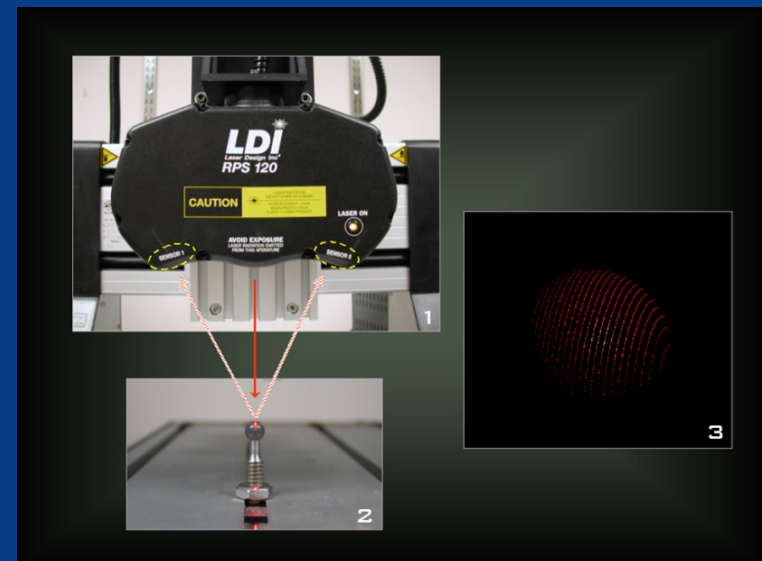
## ? Specimen coating

- ? Paint – white sharpies, spray paint
- ? Powdered sprays
- ? Talcum powder
- ?  $\text{NH}_4\text{Cl}$



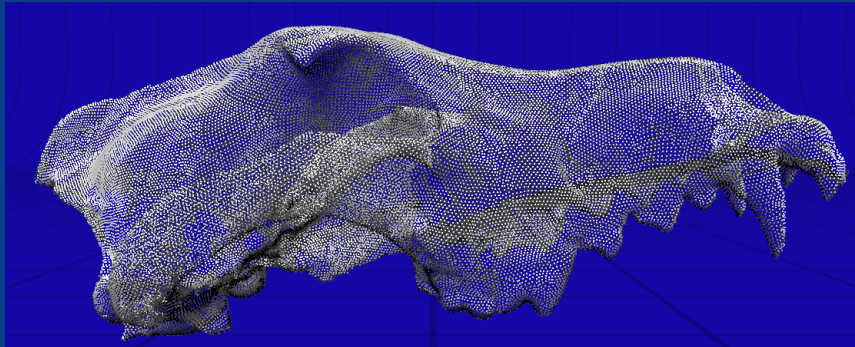
# What is 3D Scanning?

- ? Laser, lights, or x-ray
- ? Anything that can generate a dense point cloud or polygon mesh

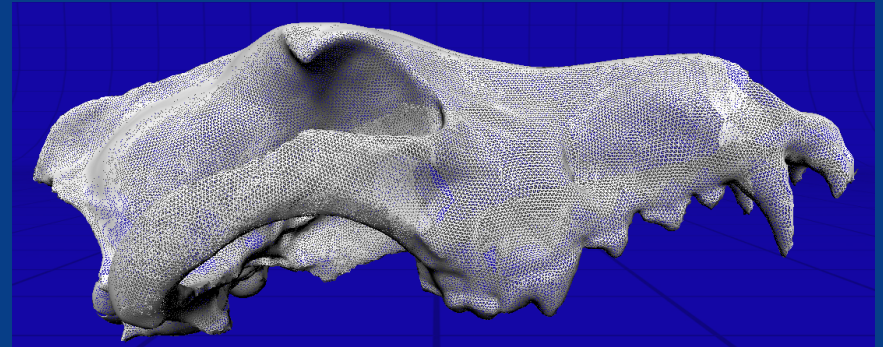


# What is 3D Scanning?

- ❑ Laser, lights, or x-ray
- ❑ Generating a dense point cloud or polygon mesh



Point Cloud

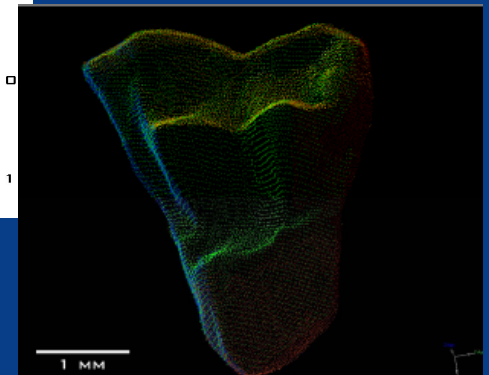
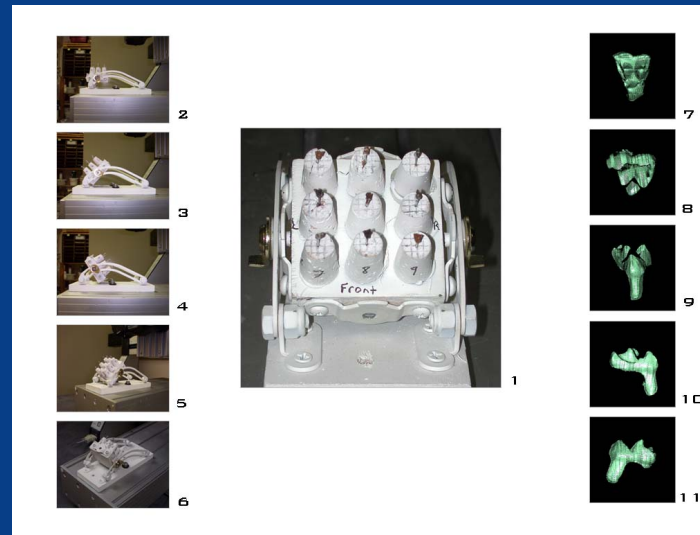
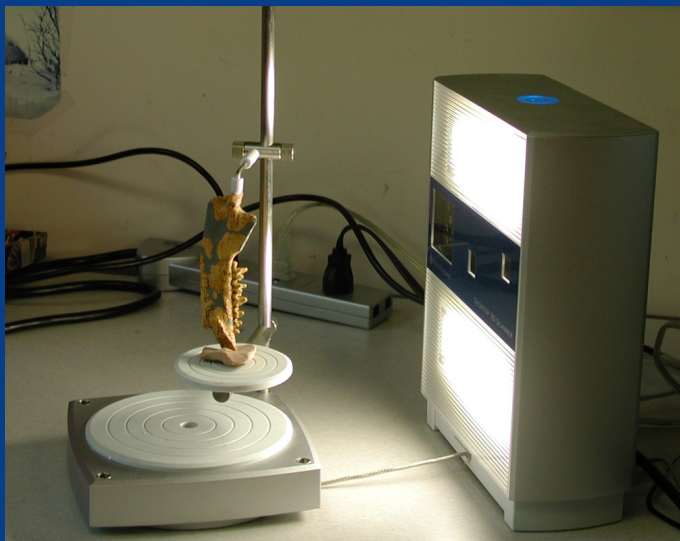


Polygon



# Multiple Scans Required

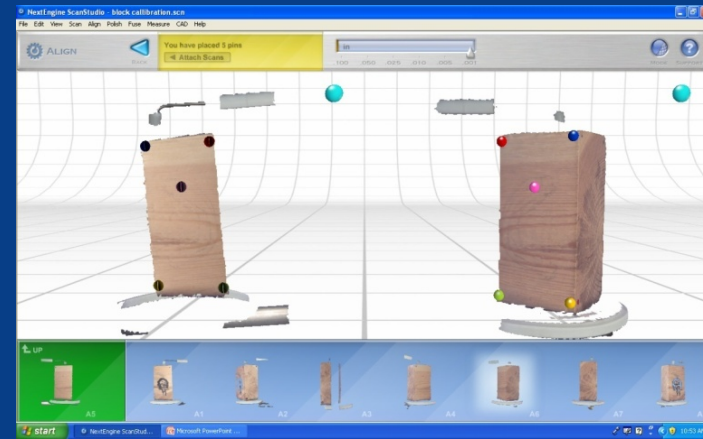
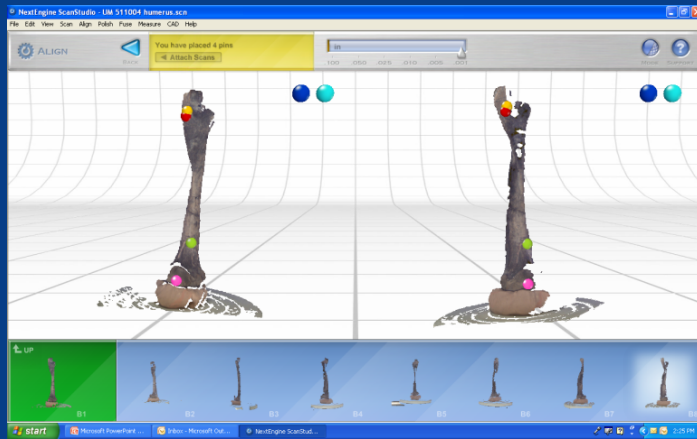
- ❑ Multiple (5, 10, 25, 100+) scans are necessary
  - ❑ Brought into alignment by process of “registration”
  - ❑ Number of scans related to how specimen is mounted (stages and grippers)





# Registration

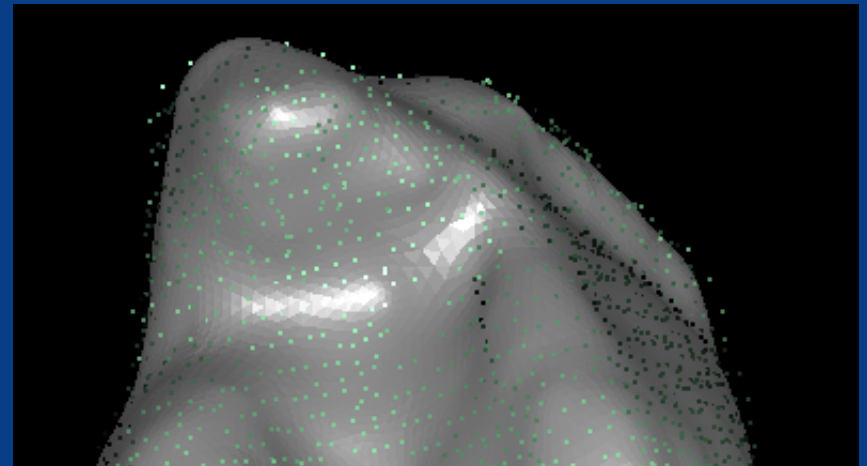
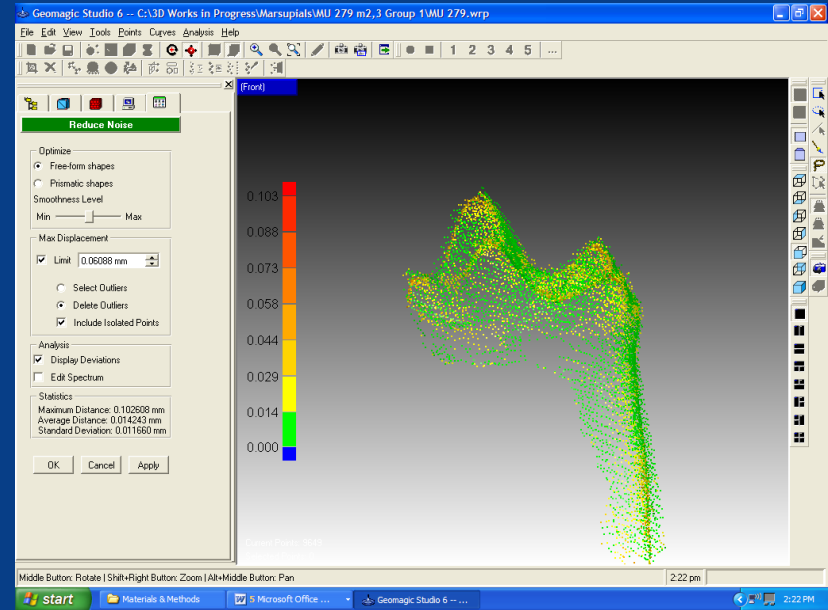
- Multiple (5, 10, 25, 100+) scans are necessary
- Brought into alignment by process of “registration”



Auto-alignment uses previous turntable data for alignment. The first alignment of any turntable position must be user defined. This can be difficult on some specimens - it is much easier to calibrate precisely on an object on which that you can draw landmarks.

# Workflow

- ? Coated
- ? Mounted
- ? Scanned
- ? Registration
- ? Modeling
  - ? Scanner provided
  - ? Third party



geomagic®

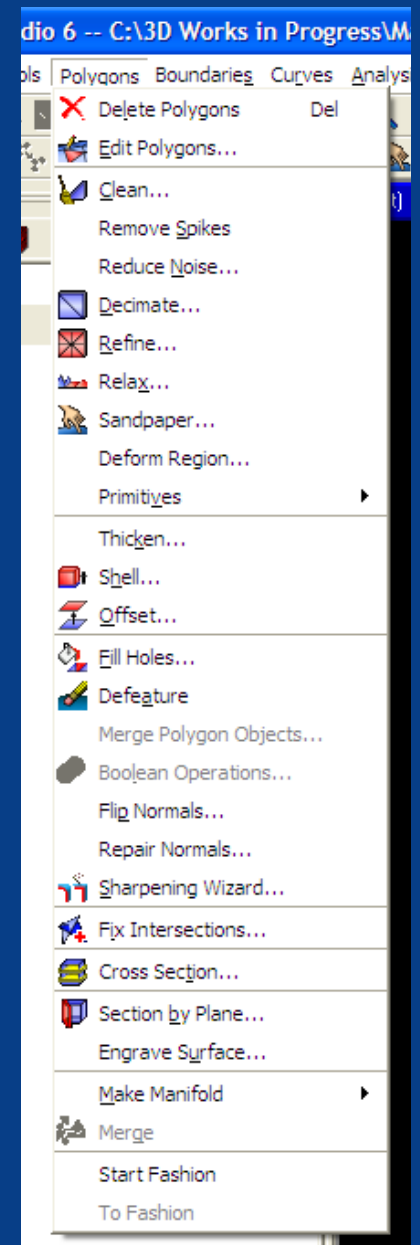
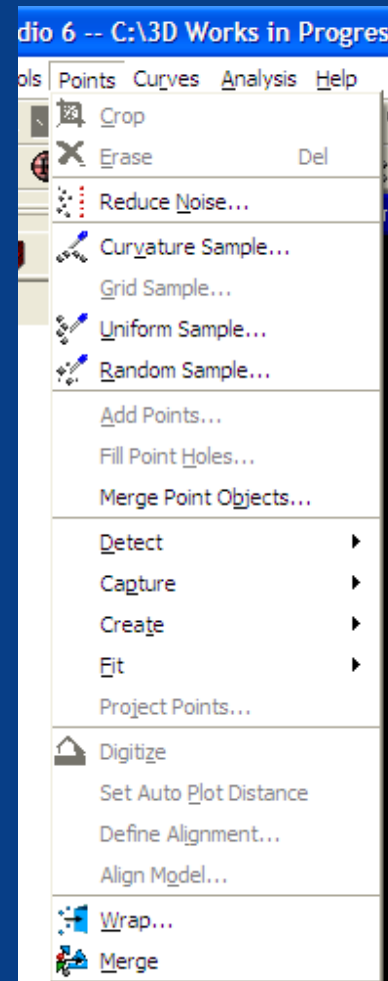
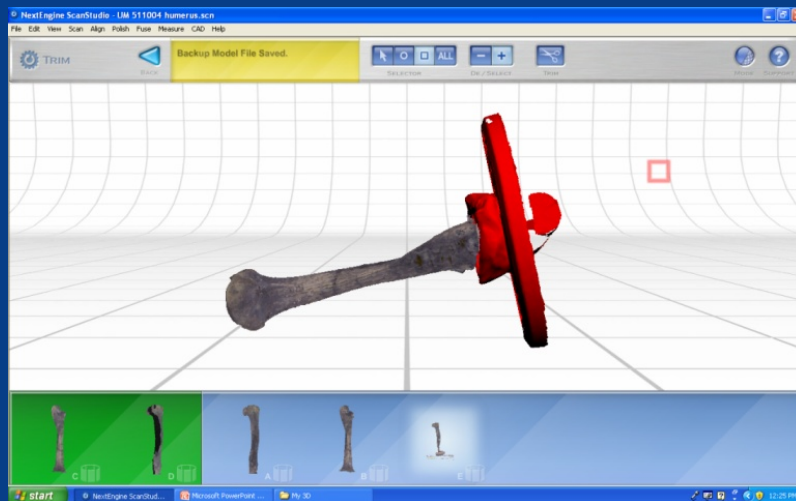
the magic of making it simple™

# Modeling

## ? Edit

? Point cloud/polygons

? Trim

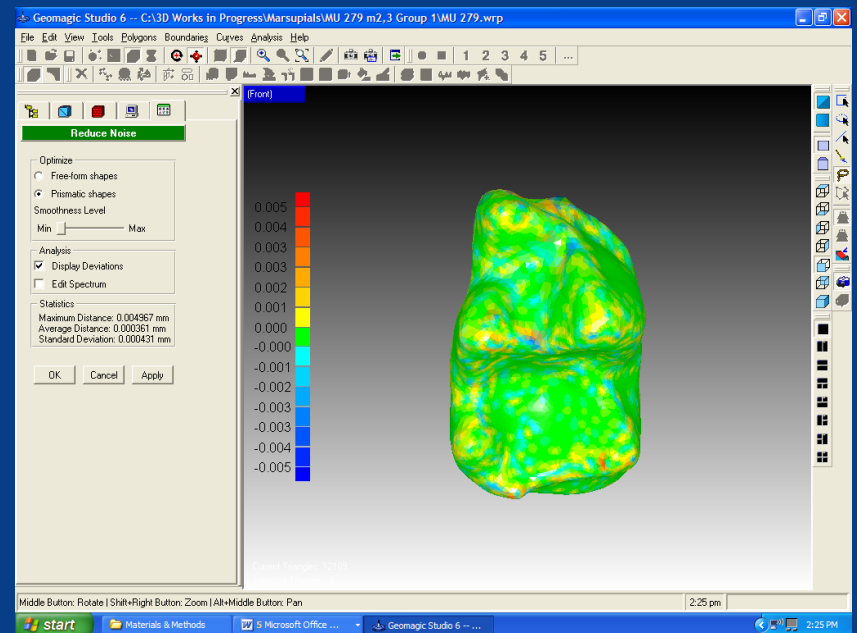
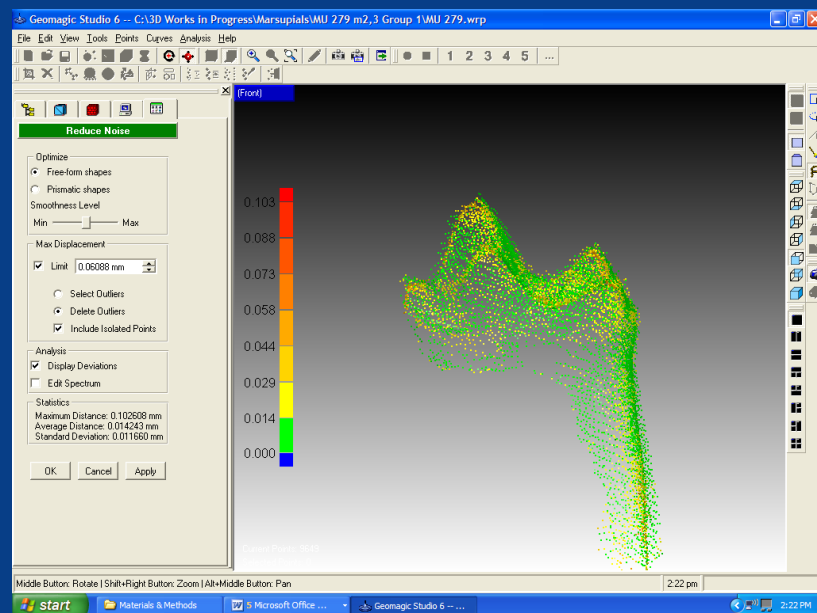


# Modeling

? Noise reduction

? Deviant points or polygons

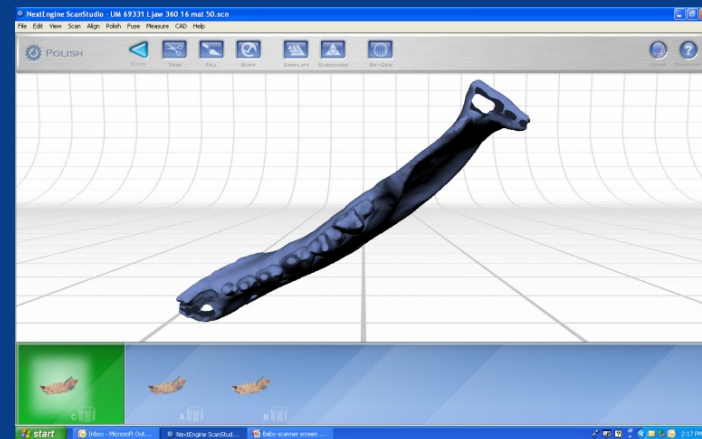
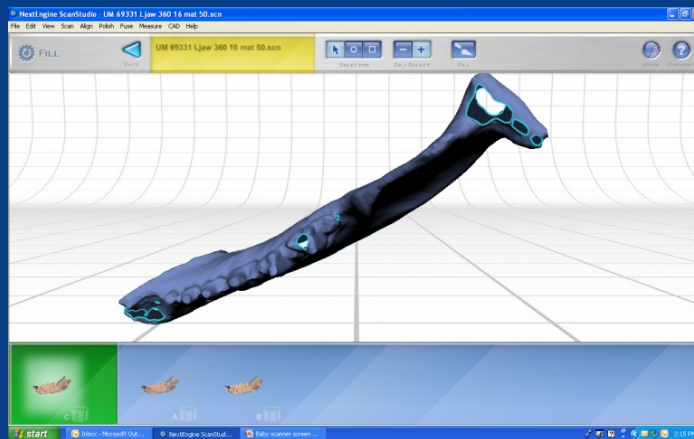
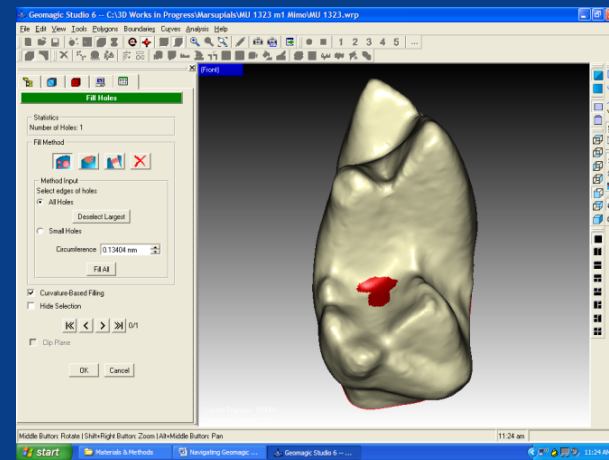
? Spectral model displacement of point (mm) from the projected surface



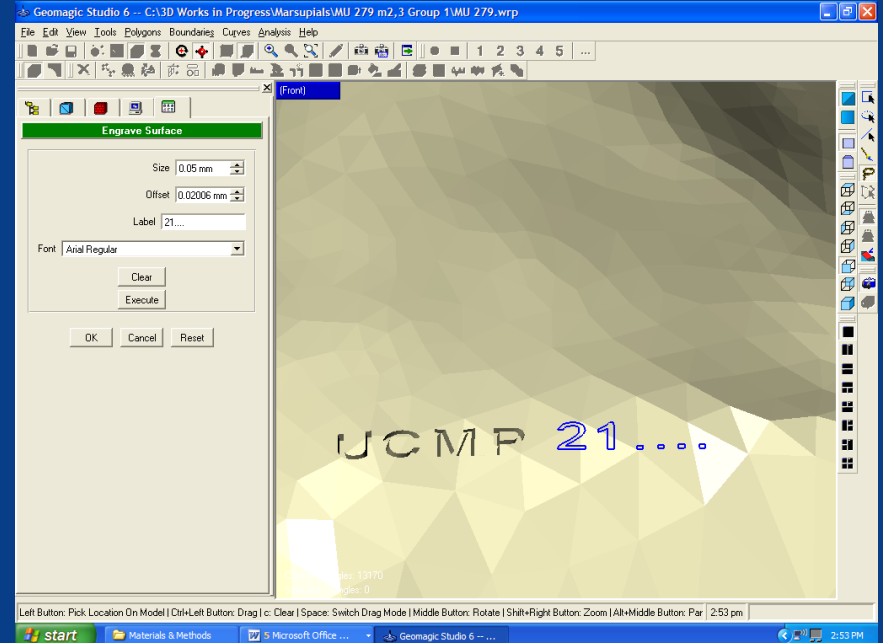
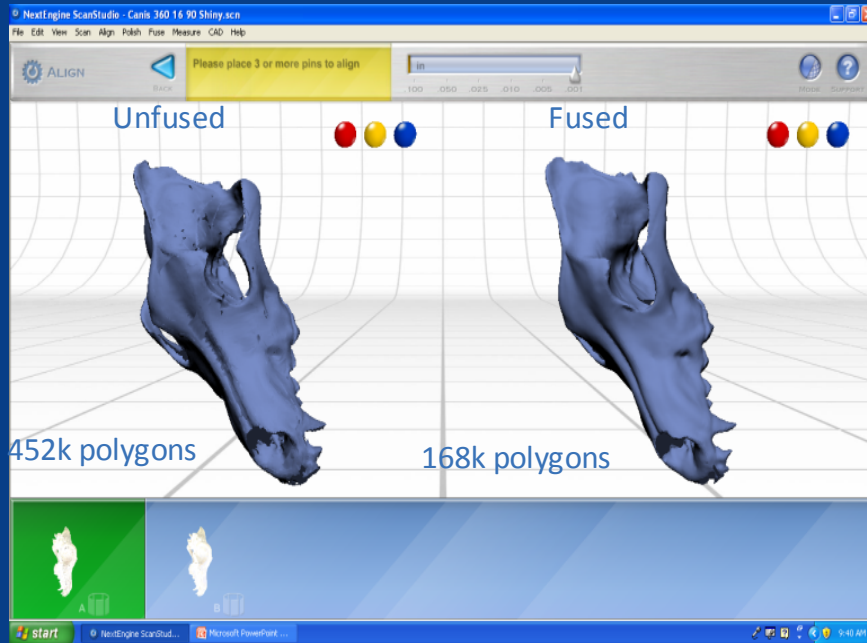
# Modeling

## ? Hole fill

- ? Insufficient data captured
- ? Water-tight model

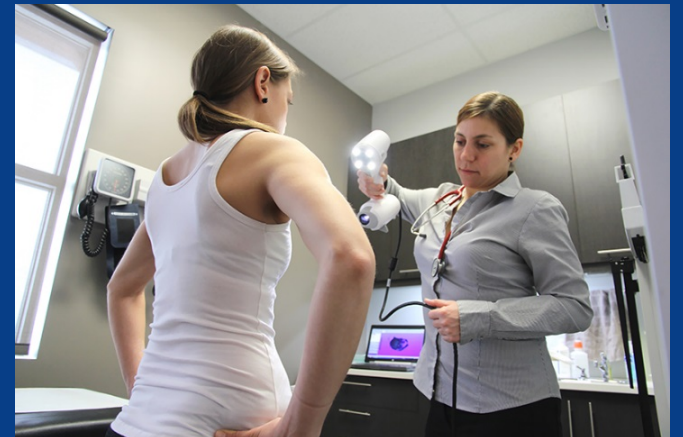


# Modeling



# How to Pick a Scanner??

- ? \$\$\$
- ? Size of your specimens
- ? Detail wanted/needed



# 3D Scanning Prices

## ? Free

- ? Autodesk 123D iOS app

## ? Cheap >5k

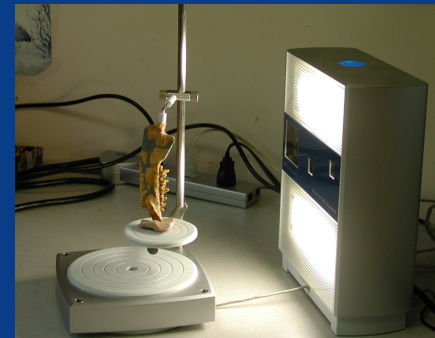
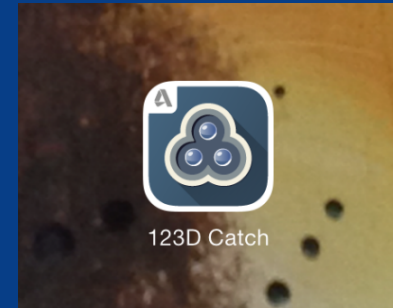
- ? MakerBot ~\$800
- ? Sense ~\$400
- ? NextEngine \$2,995
  - ? (+ 1k for the HD Pro software)

## ? Reasonable 5-20K

- ? Artec 3D scanner ~14k

## ? Expensive 20-100k

- ? Laser Design Surveyor 55k +



You get what you pay for

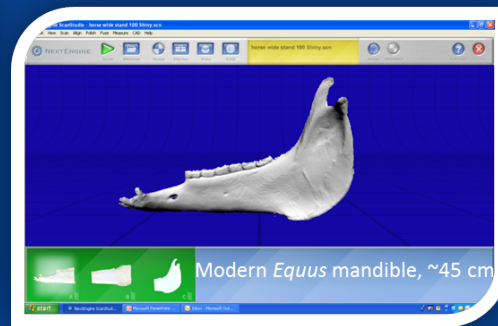
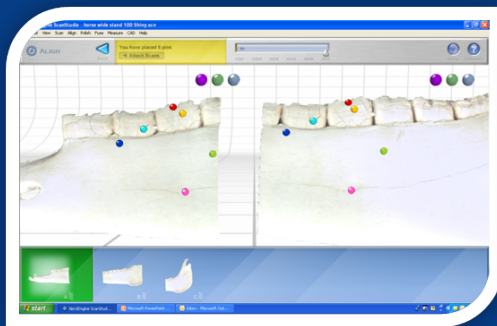


# How Big a Specimen?

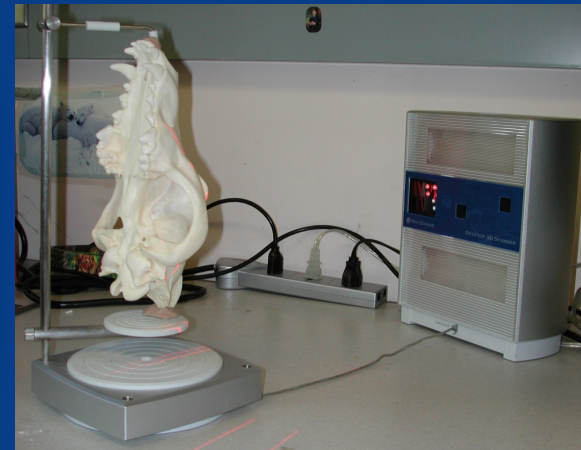
Small



Medium- Big



Place beads and attach scans for composite models.



Any but too big difficult

# How Big a Specimen?

Small



specimens  $< 4$  mm in length:  $10\ \mu\text{m}$  spacing  
specimens 4-8 mm in length:  $20\ \mu\text{m}$  spacing  
specimens 8-12 mm in length:  $30\ \mu\text{m}$  spacing  
specimens  $> 12$  mm in length:  $50\ \mu\text{m}$  spacing

# Detail level

## ? Handyscan 3D

- ? Resolution 0.04 – 0.05 mm

## ? Artec 3D scanner

- ? Resolution (up to 0.2 mm) and accuracy (0.02 mm).

## ? 4Dynamics Mephisto

- ? 0.05 (minimum polygon size)

## ? Next-Engine (0.005 inch accuracy)

- ? 400 points per inch

- ? Resolution 0.1 mm

- ? Error 0.1 mm

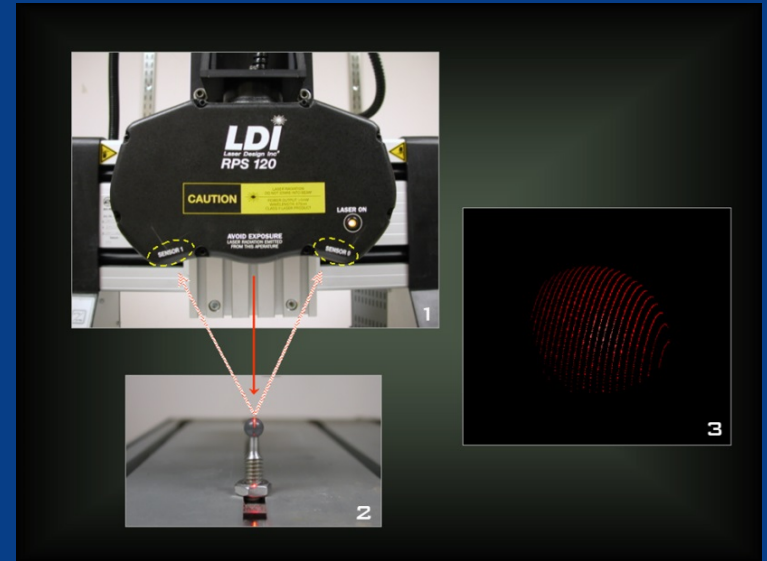
## ? LaserDesign DS2025, LaserDesign Surveyor RPS-120

- ? Resolution 0.01 mm (point spacing)

## ? 123D

# Terms to Know

- ❑ Resolution – image detail
  - ❑ Typically the distance between scan lines
  - ❑ Voxel size (volume + pixel)
- ❑ Precision
  - ❑ Closeness of measured value to its true value
- ❑ Accuracy
  - ❑ Closeness of repeated measurements to the same quantity

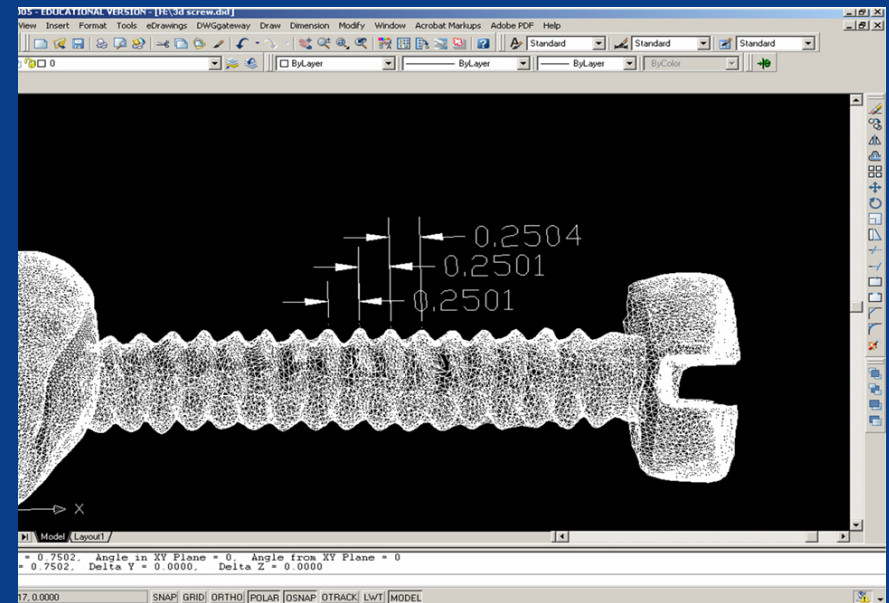


# Morphometric Research

- ❑ If you want to use your 3D models for quantitative data collection you must do your own error study
- ❑ Error study needs to consider all 3 Cartesian axis
- ❑ 1D error - linear study
- ❑ 2D error – area study
- ❑ 3D error – volumetric study
  
- ❑ See Smith and Strait (2008) *Palaeontologia Electronica*
- ❑ Link <http://paleoview3d.marshall.edu/laser2.php>

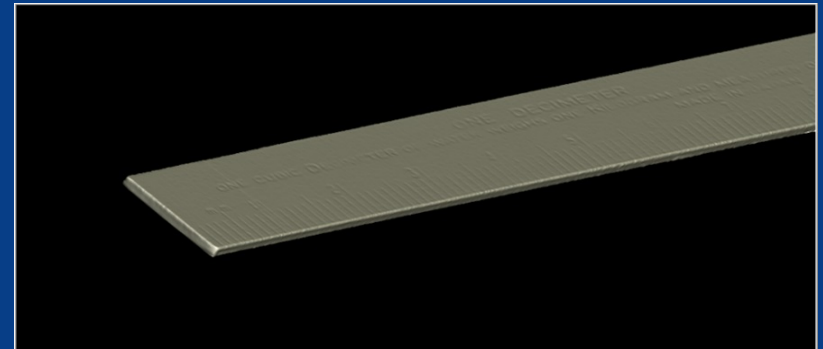
# 1D Error

- ? 5.5 mm machine tooled screw, thread-pitch of 0.250 mm
- ? Scanned a 0.01 mm linear spacing
- ? 5 scans merged
- ? Measured 30X with Autocad
- ? Mean = 0.251, % error 0.4%
- ? Accuracy = +/- 0.001
  - ? Manufacturer claim = +/- 0.00635
- ? Precision = +/- 0.005



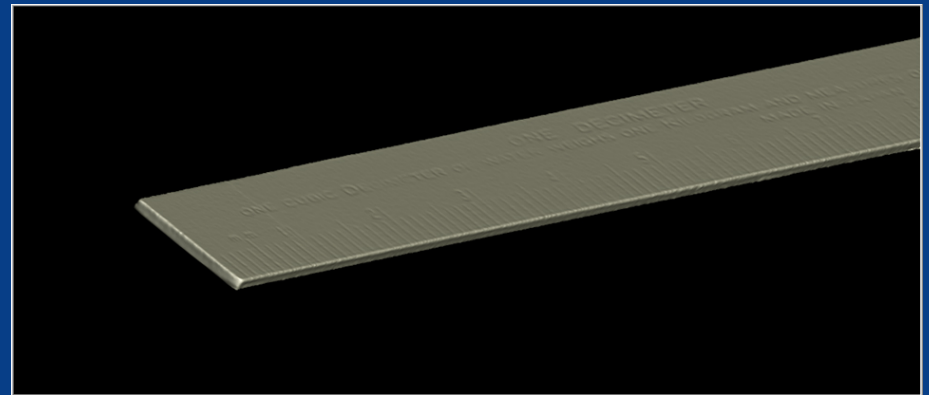
# 2D Error

- ❑ certified scale bar (100 x 10 x 1 mm), know area 1000 mm<sup>2</sup>
- ❑ Scanned a 0.01 mm linear spacing
- ❑ Surface scan and modeled 3X
- ❑ Measured in 3D-Doctor
- ❑ Mean = 999.47 mm<sup>2</sup>, (998.04, 997.71, 1002.67); error 0.05%



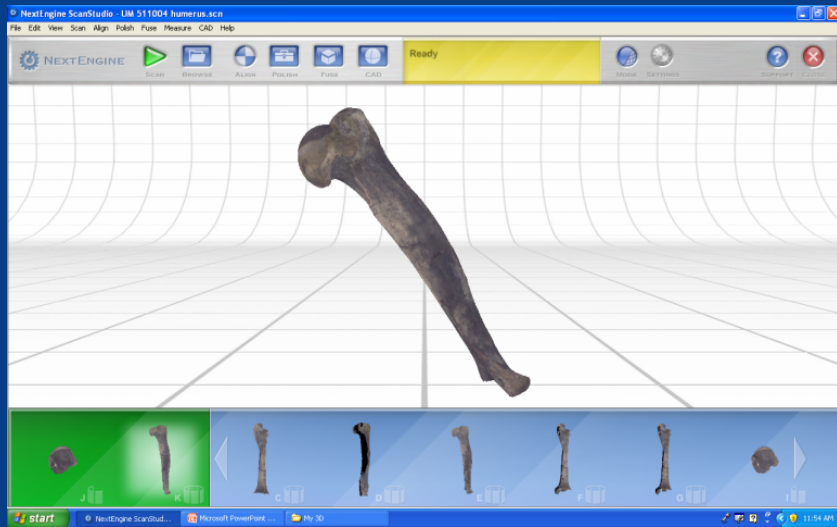
# 3D Error

- ❑ certified scale bar (100 x 10 x 1 mm) 1000 mm<sup>3</sup>
- ❑ Scanned a 0.01 mm linear spacing
- ❑ 6 scans merged and modeled, 3X
- ❑ Measured with Geomagic
- ❑ Mean = 1017.86 mm<sup>3</sup>  
(1007.54, 1026.15, 1019.89),  
error 1.79%

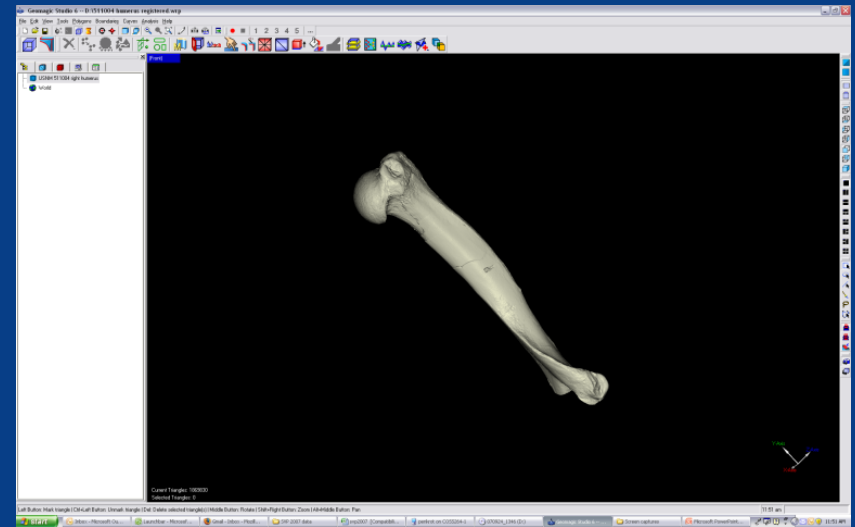




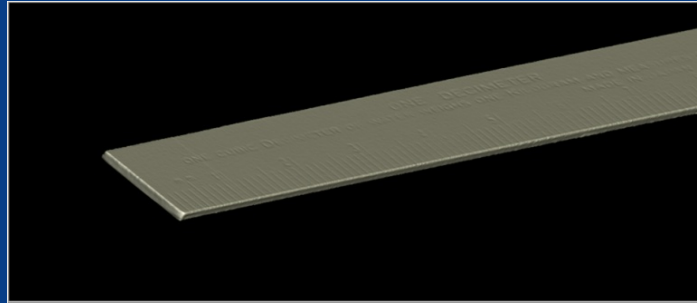
# All Scanners are Not Equal



NextEngine scan of USNM 511004 humerus of *Galecyon* sp. nov. (48,372 polygons, ~5 MB)



Laser Design Inc. Surveyor scan of USNM 511004 humerus of *Galecyon* sp. nov. (1,869,830 polygons, 79 MB)



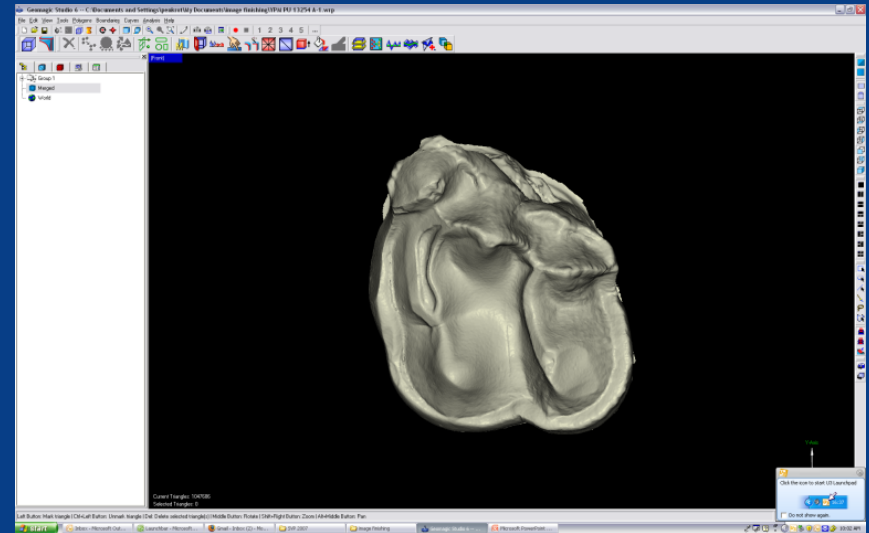
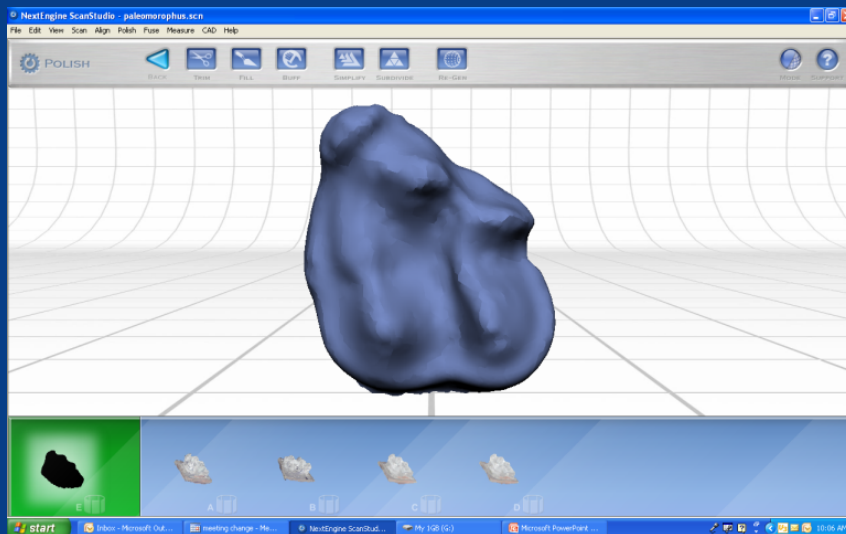
NextEngine Model 2020i Desktop 3D Scanner has a  $\pm 1.00$  mm linear accuracy in “Macro” mode (1% error rate).



Laser Design Inc. Surveyor RPS-120 Scanner (<\$55K system) has a  $\pm 0.001$  mm linear accuracy.

# Conclusions

- All scanners are different and act differently with different specimens
- If you are going to lots with it invest in high end modeling software (i.e., Geomagic)
- Test your scanner error rates in a way that will be most informative to your use of the data



Comparisons of NextEngine and Laser Design Inc. scan of YPM PU 13254, *Paleomoropus jepseni* LM3, Length ~ 1.5 cm (9,961 and 1,047,686 polygons, respectively)

# Acknowledgements

- ❑ Funded by the National Science Foundation Biological Databases & Informatics program
- ❑ Nick Smith for contributing to the images and content
- ❑ iDigBio

