
# Using Unity for Scientific Visualization as a Course-based Undergradaute Research Experience

Idunnuoluwa Adeniji [1,2] Lark Baincaren [1] Cymantha Blackmon [1] Michael Casarona [1] Melissa Menzel [1]

Matthew G. Niepielko [1] Leonard Bielory [1,3,4] Nan Perigo [1] Joseph Insley [2,5] David Joiner [1]

1 Kean University, Union, NJ 2 Argonne National Laboratory, Lemont, IL 3 Rutgers University – Center of Environmental Prediction, New Brunswick, NJ 4 Hackensack Meridian School of Medicine, Nutley, NJ 5 Northern Illinois University, Dekalb, IL

# Course-based Undergraduate Research Experiences (CUREs)

- Activities focused on following the research process and performing inquiry is used in addition to or in place of traditional laboratory activity [1]. Positive benefits of CUREs have been seen in
  - professional identity [2]
  - research skills [3]
  - project ownership [4]
  - higher retention [5]
- Our context for implementation is a computational science and engineering program at Kean University, a regional university in northern New Jersey. The program is part of a 5-year combined BS/MS honors program in the School of Integrative Science and Technology.
  - RFI Program: 6 credits research training semesters 1-3, up to 6 credits independent research, 3 credit capstone, 6 credit MS Thesis
- The projects presented in this paper involve development or enhancement of software in Unity Game Engine
  - Volumetric rendering of hyperstack data
  - Performance testing and implementation of point cloud renderers in Unity using VR hardware.


[1] A. J. Buchanan and G. R. Fisher, "Current Status and Implementation of Science Practices in Course-Based Undergraduate Research Experiences (CUREs): A Systematic Literature Review," *CBE—Life Sci. Educ.*, vol. 21, no. 4, p. ar83, Dec. 2022, doi: 10.1187/cbe.22-04-0069.

[2] S. E. Brownell *et al.*, "How students think about experimental design: novel conceptions revealed by in-class activities," *BioScience*, vol. 64, no. 2, pp. 125–137, 2014.

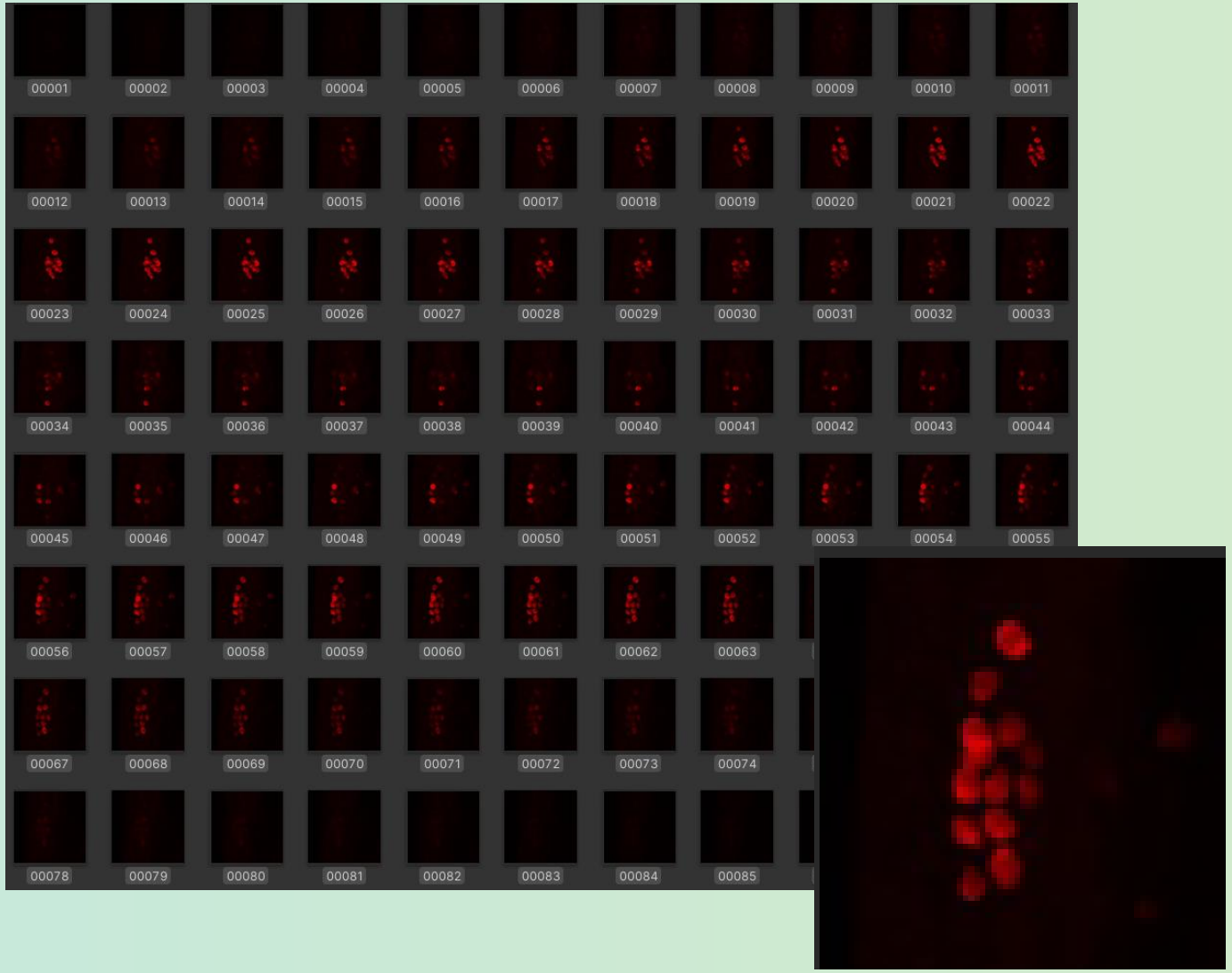
[3] A. Alneyadi, I. Shah, and S. S. Ashraf, "An innovative bioanalytical research project course to train undergraduate students on liquid chromatography–mass spectrometry," *Biochem. Mol. Biol. Educ.*, vol. 47, no. 3, pp. 228–238, 2019.

[4] D. I. Hanauer, J. Frederick, B. Fotinakes, and S. A. Strobel, "Linguistic analysis of project ownership for undergraduate research experiences," *CBE—Life Sci. Educ.*, vol. 11, no. 4, pp. 378–385, 2012.

[5] J. C. Drew and E. W. Triplett, "Whole genome sequencing in the undergraduate classroom: outcomes and lessons from a pilot course," *J. Microbiol. Biol. Educ.*, vol. 9, no. 1, pp. 3–11, 2008.

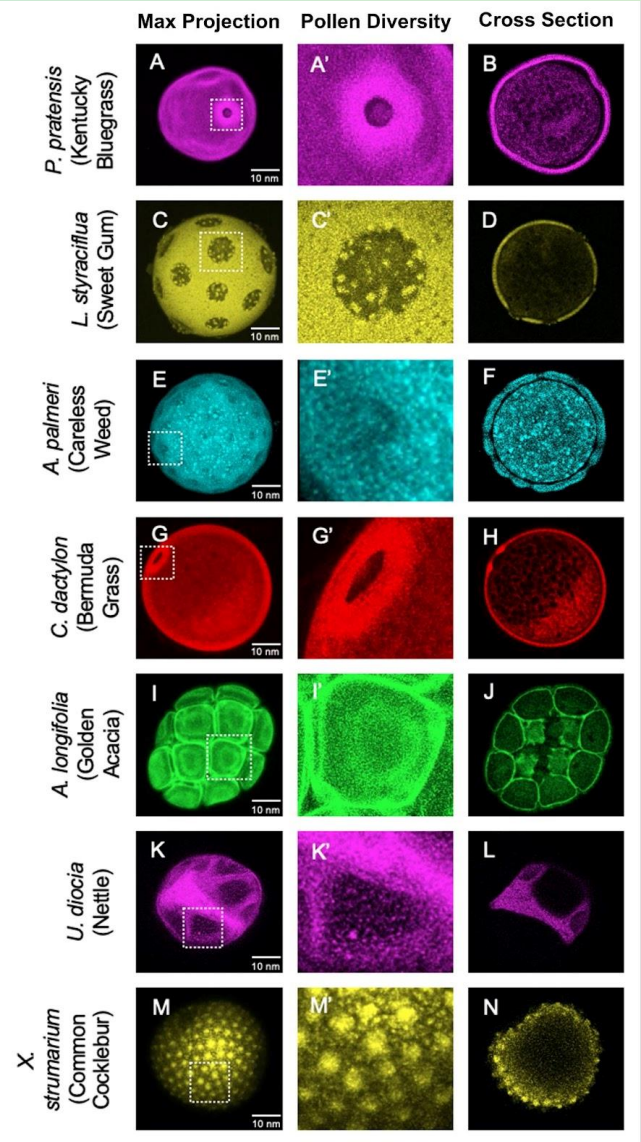
# Project 1: Primordial Germ Cell Viewer

- Partnership with computational biology faculty
- Source of data
  - Leica STELLARIS 5 white light laser system and Leica LIGHTNING
- Goal: Networked scene allowing volumetric rendering and analysis in a shared VR room



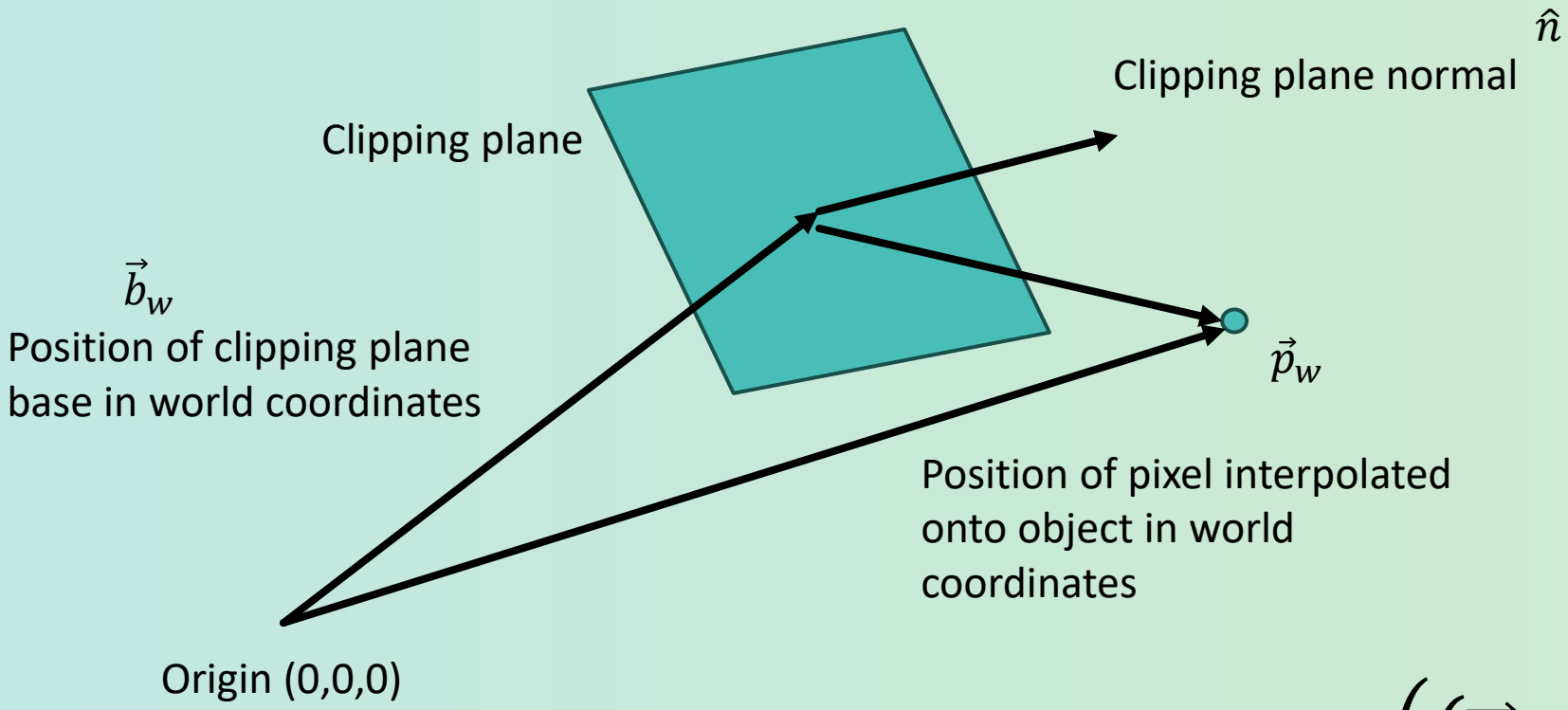
# Project 2: Database of 3D Pollen Grain Images

- Partnership with computational biology faculty
- Source of data
  - Leica STELLARIS 5 white light laser system and Leica LIGHTNING
  - Dry pollen samples were mounted in ProLong Glass (Life Technologies) and imaged using pollen's autofluorescent properties that are produced when exposed to UV.
- Goal: Produce database of volumetric renderings with animation



# Project 3: Clipping shader implementation

- Student experience in Shader creation, UI design
- Applied to volumetric rendering in other projects




$$\mathbf{clip}\left(\left(\vec{\boldsymbol{p}}_{\boldsymbol{w}} - \vec{\boldsymbol{b}}_{\boldsymbol{w}}\right) \cdot \hat{\boldsymbol{n}}\right)$$

# Project 4: HACC Simulation Visualization

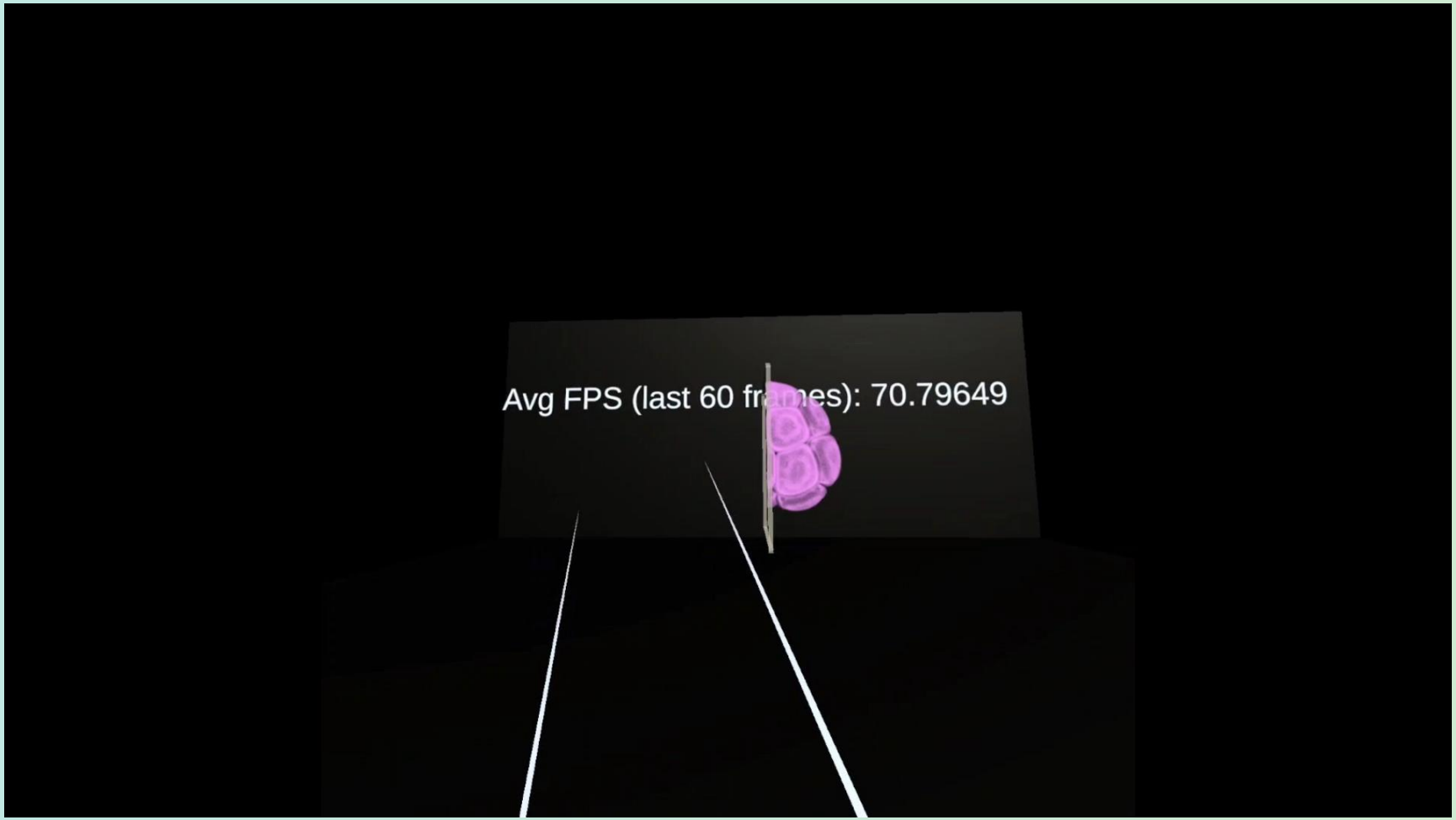
- Student Internship at ANL, after initial work with RFI program
- Project continued through independent research
- Source of data
  - Point cloud data of a grid cell from a larger run
  - 4 million points, evolving over time
- Goal: Produce volumetric rendering in VR using Oculus hardware, coupled with tools for identifying dark matter halos. Explore data pipelines to move from ParaView to Unity.

# Enabling Technology

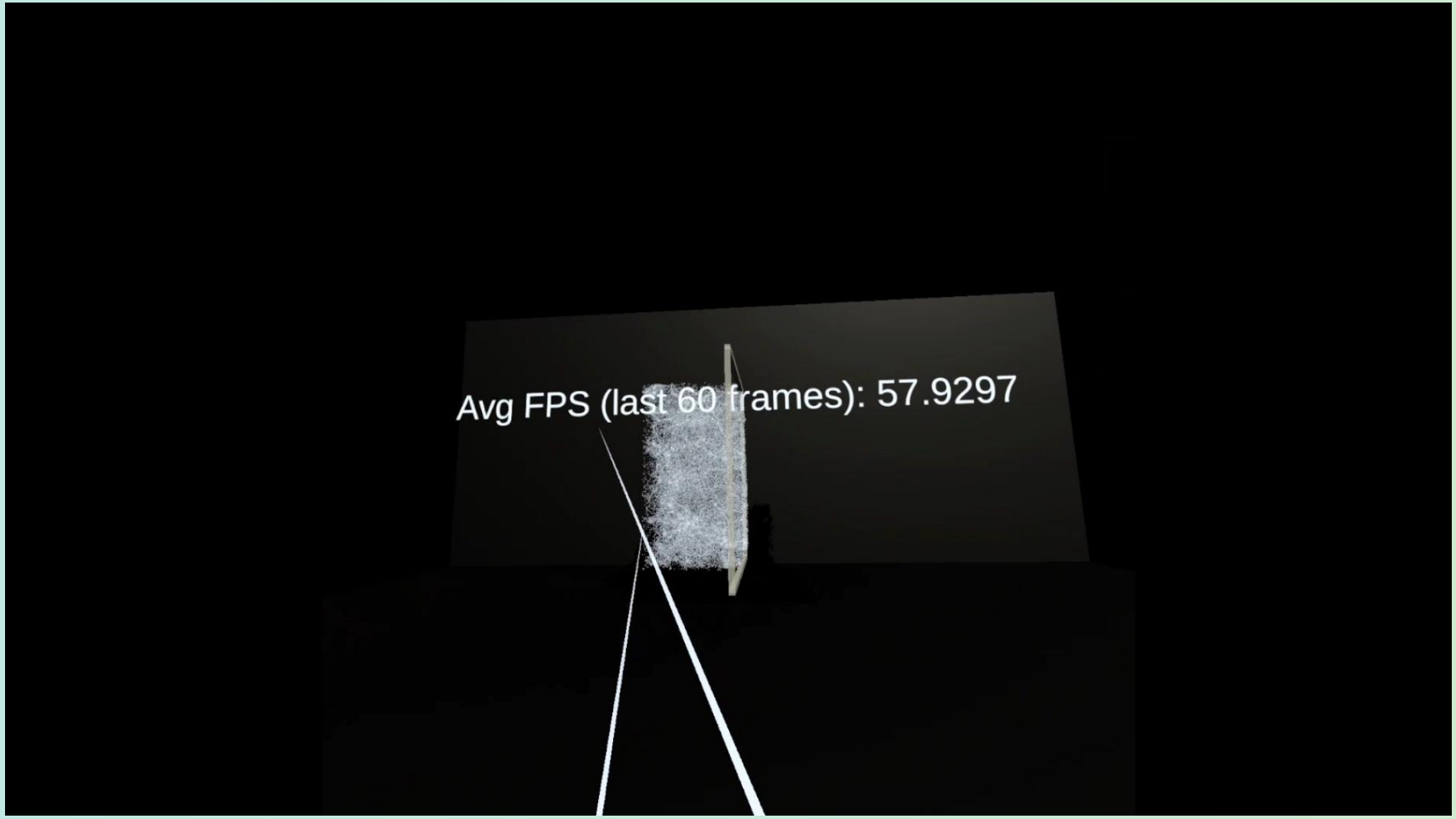
- Each of these projects focused on use of Unity for VR visualization
  - Volumetric Rendering of Hyperstack Images
    - https://github.com/joinerda/HyperstackViewer
    - Images are loaded as sprites, with pixels below a set threshold set to (0,0,0,0)
    - Images are arranged in z-order in Unity scene
    - Double sided unlit transparent shader is applied, with transparency multiplier applied based on intensity of pixel
    - Good frame rates with 1024x1024x100 native Quest app
  - Point Cloud Rendering
    - https://github.com/joinerda/PointCloudRenderer
    - CSV file loader reads data into point topology meshes of 64K vertices each
    - Unlit geometry shader applied to render points as billboard hexagons with or without transparency (Note, newer Macs do not support geometry shaders)
    - Good frame rates with 1M points native Quest app, 10M points link cable + gaming PC

# DEMONSTRATIONS

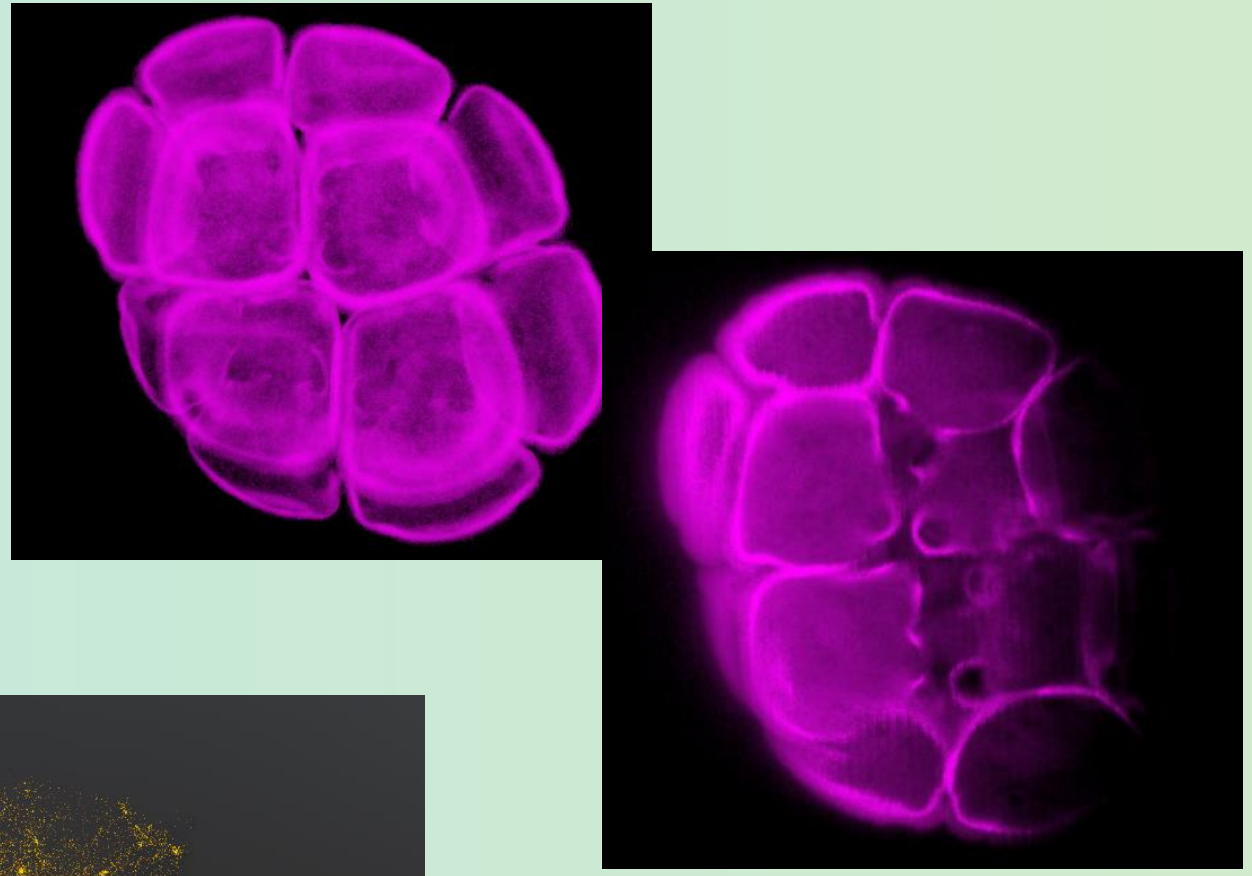
# VIDEO 1: Golden Acacia Pollen Grain as an Image Stack with clipping



# VIDEO 2: Large Scale Structure Simulation Data as Point Cloud with clipping



# Student Results

# Considerations

- VR based visualization can be an accessible starting point for many students just engaging in research
- Unity+Quest can provide a low cost option for project work
  - Compile directly to headset instead of using link cable – fewer restrictions on student hardware
- Unity is well suited to typical student curriculum
  - Lots of beginner-focused self-guided tutorials
  - Students with Java background will find C# very familiar
- Deprecation of OpenGL support for M-series macs does require a work-around for some shaders, but students can still compile and test on Quest from Mac hardware

# Reproducibility

- Unity Version for tests: 2021.3.8f1
- AR Foundation 4.2.8
- Oculus XR Plugin 3.0.2
- OpenXR Plugin 1.4.2
- XR Interaction Toolkit 2.3.2 https://www.youtube.com/watch?v=Qm_o9kcH_HI
- Android Graphics API OpenGLES3.2 w/ Linear color space
- OpenXR Plugin used for PC+Link Cable
- Oculus Plugin used for Android
- Multi-Pass Rendering for both plugins

# Thank You!