



Advanced Visualization for Scientific Data Analysis and Insight

Kenny Gruchalla, Ph.D.
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NREL/PR-2C00-88217

NATIONAL RENEWABLE ENERGY LABORATORY

Energy Efficiency

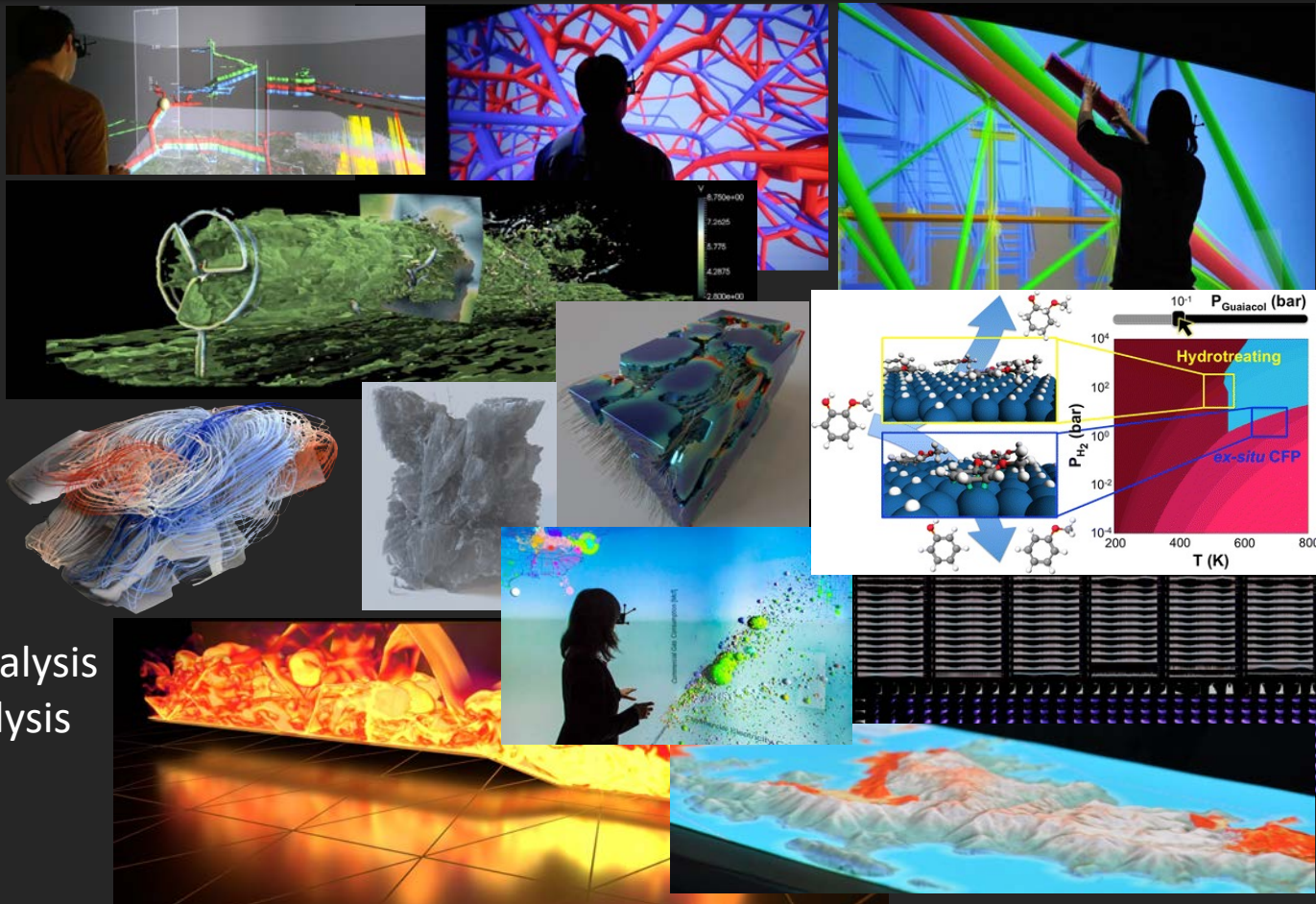
- Vehicle Technologies
- Building Technologies
- Industrial Technologies

Renewable Energy

- Wind
- Solar
- Bio-fuels
- Geothermal
- Energy Storage

Energy Analysis

- Technology Systems Analysis
- Market and Policy Analysis
- Sustainability Analysis
- Resiliency Analysis



INSIGHT CENTER MISSION

Combine state-of-the-art visualization and human-computer interaction techniques and tools to promote knowledge discovery for energy systems, providing cross-cutting qualitative and quantitative analysis for all NREL programs and partners



NREL VISUALIZATION RESOURCES

High Performance Computing



- Eagle** - 8 PetaFLOPs HPC
- Kestrel** – 44 PetaFLOPs HPC
- DAV & GPU Nodes

Prairie Chicken – GPU Cluster
Insight Servers

Immersive visualization installations



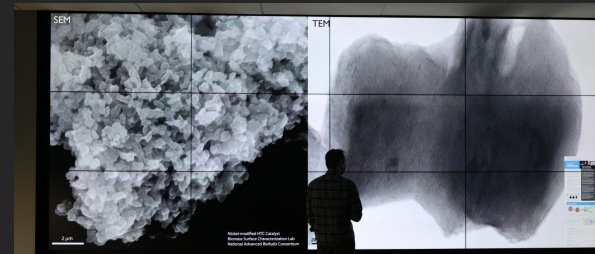
2-surface 6-projector

- Active Stereo (Christie Mirage)
- Optical Tracking (Vicon)
- Blended (Christie Twist)

HMDs

- Vive, MagicLeap, XTAL

High-resolution display walls.



100 MP large-scale display wall



MultiTouch wall & table

IMMERSIVE VISUALIZATION

An environment created with a combination of hardware and software that provides the user with a psycho-physical experience of being immersed in a computer-generated scene.



Improved Spatial Judgments



Direct 3D Interaction



High-Dimensional Data



Collaboration



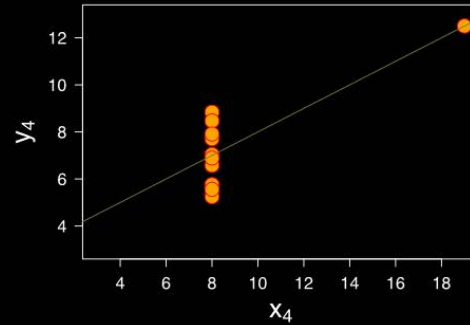
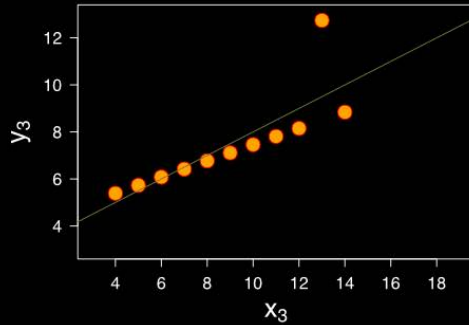
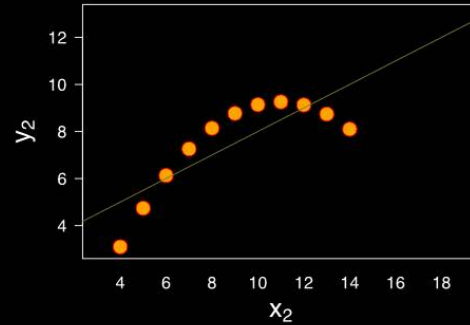
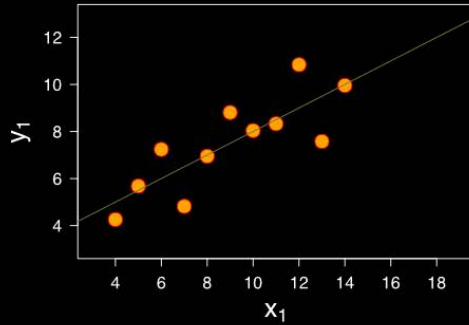
Anscombe's Quartet

1a		2		3		4	
X	Y	X	Y	X	Y	X	Y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Mean	9.00	7.50	9.00	7.50	9.00	7.50	9.00	7.50
Variance	10.0	3.75	10.0	3.75	10.0	3.75	10.0	3.75
Correlation	0.816		0.816		0.816		0.816	
Linear Regression	3.00 + 0.500x		3.00 + 0.500x		3.00 + 0.500x		3.00 + 0.500x	

F. J. Anscombe. 1973. Graphs in Statistical Analysis. *The American Statistician* 27, 1 (Feb. 1973), 17–21. <https://doi.org/10.1080/00031305.1973.10478966>

Anscombe's Quartet



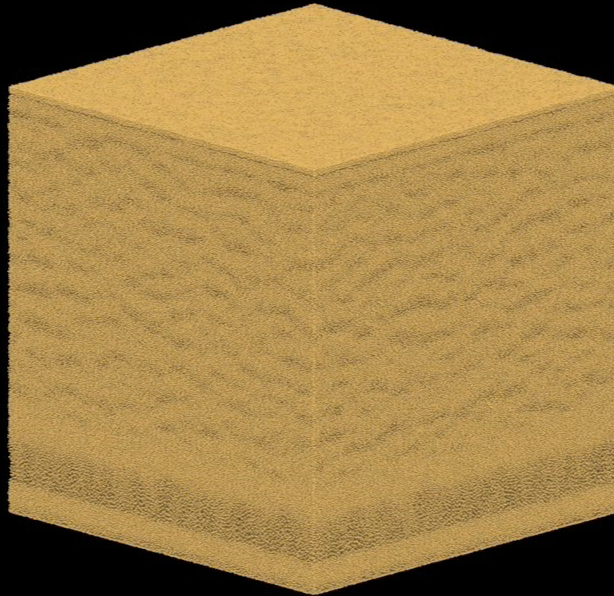
1a		2		3		4	
X	Y	X	Y	X	Y	X	Y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
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11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
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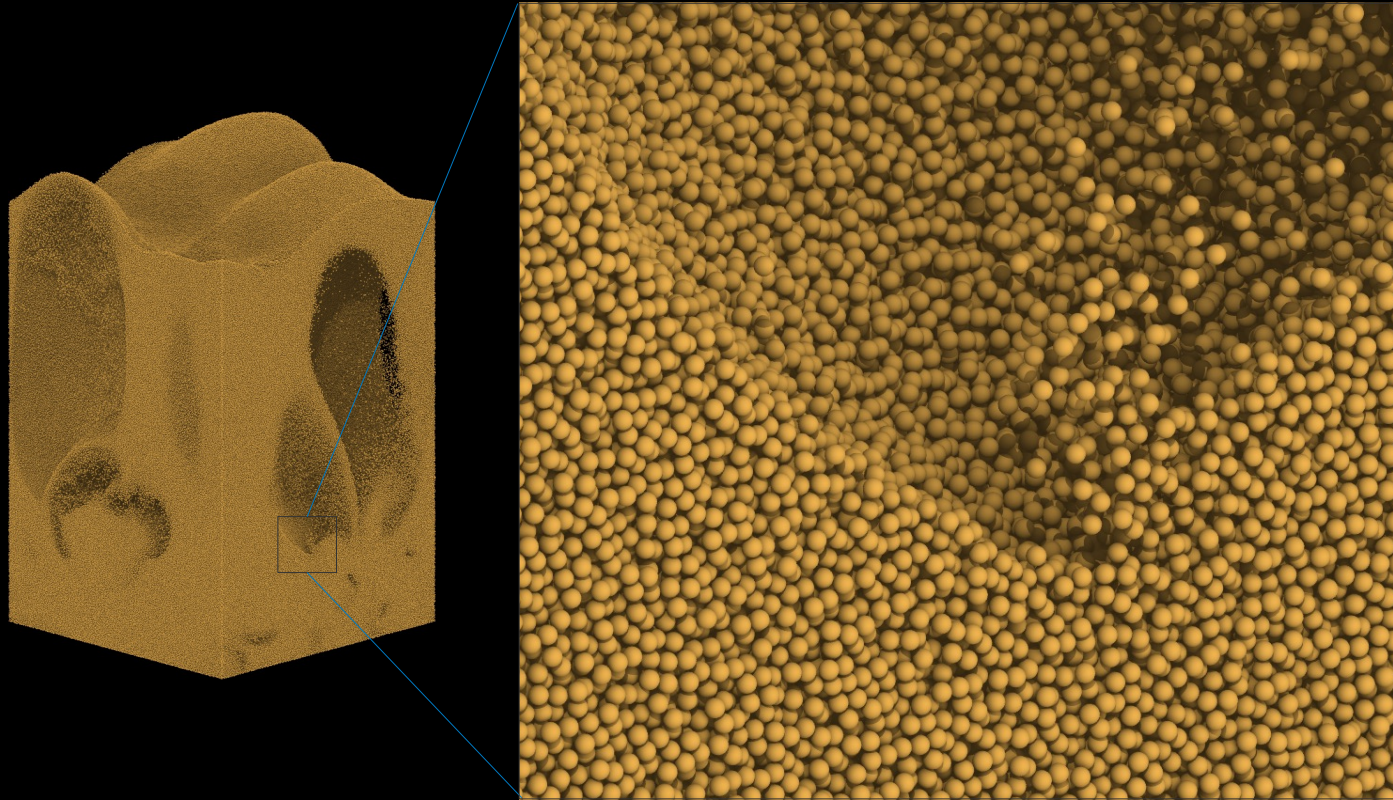
F. J. Anscombe. 1973. Graphs in Statistical Analysis. The American Statistician 27, 1 (Feb. 1973), 17–21. <https://doi.org/10.1080/00031305.1973.10478966>

11,904,336 Particles

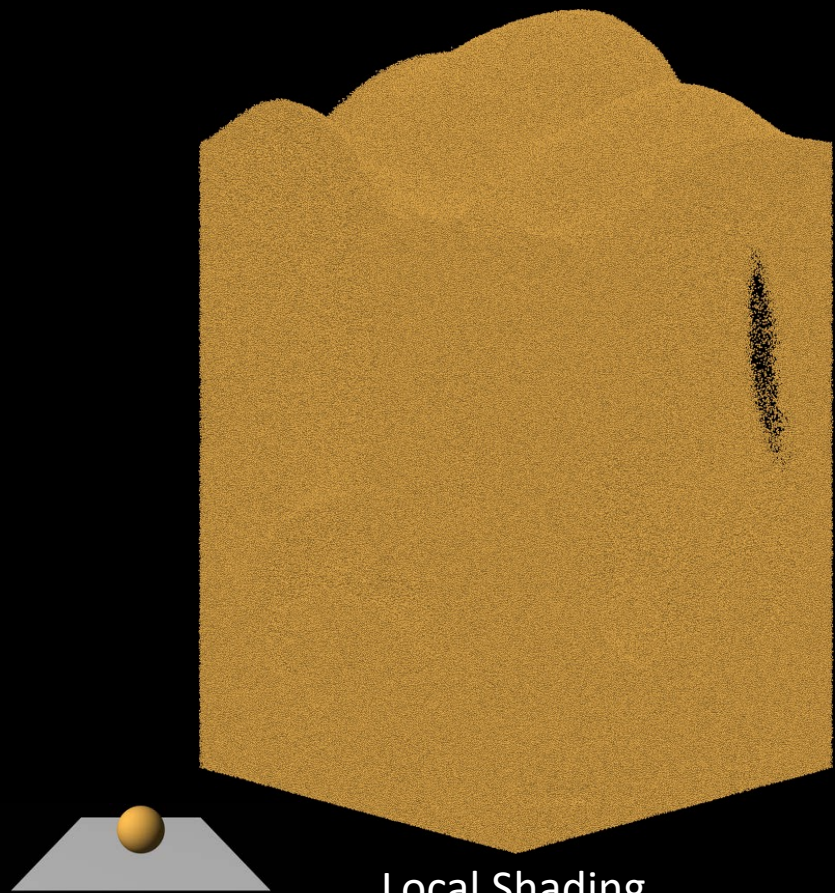
Simulation Time \approx 49,000 compute hours
Post-Processing Time \approx 600 compute hours



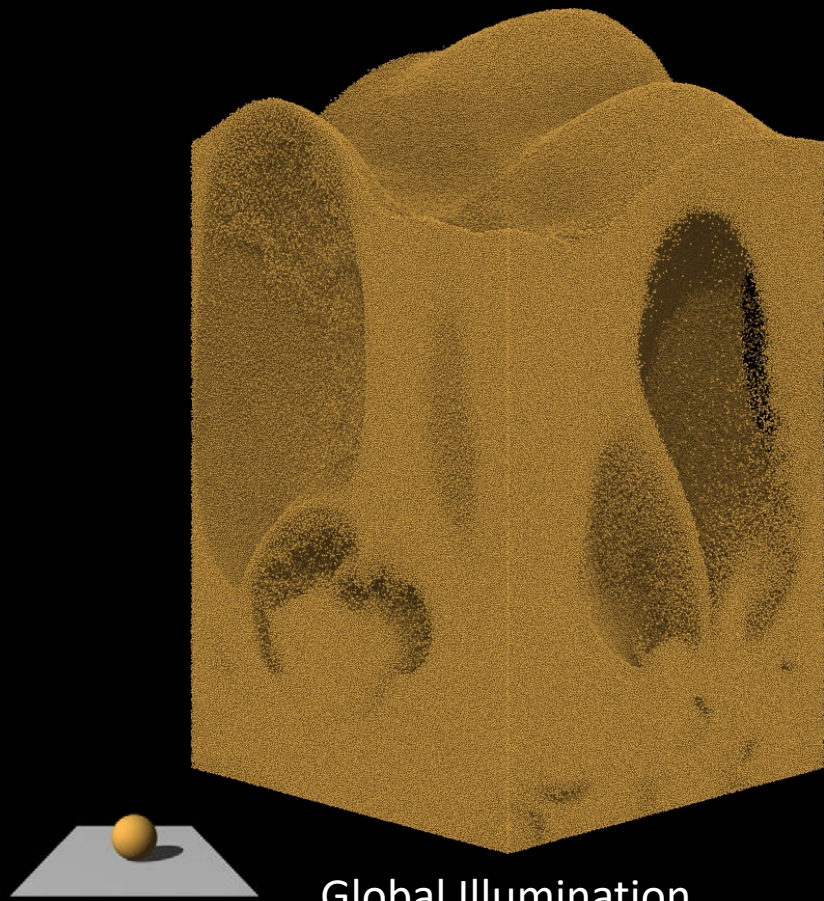
BIOMASS GASIFICATION - PARTICLE RENDERING



TECHNIQUE MATTERS

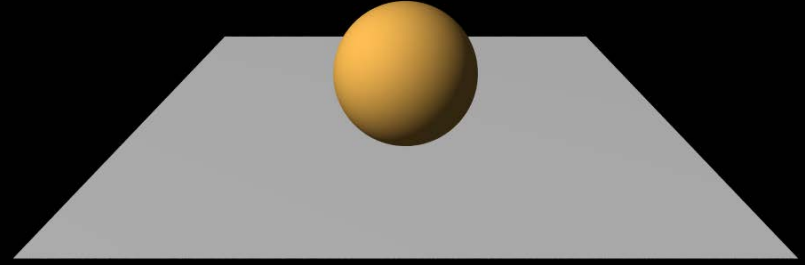


Local Shading

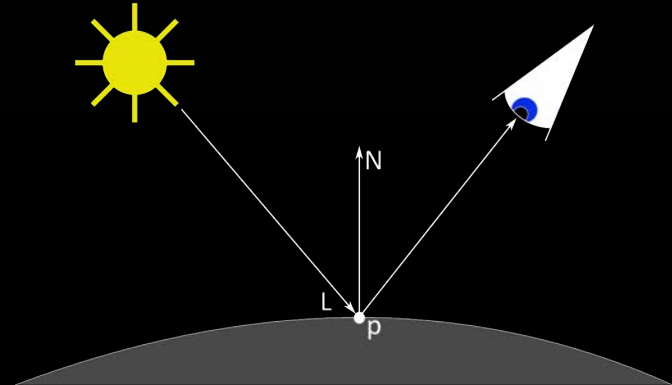


Global Illumination

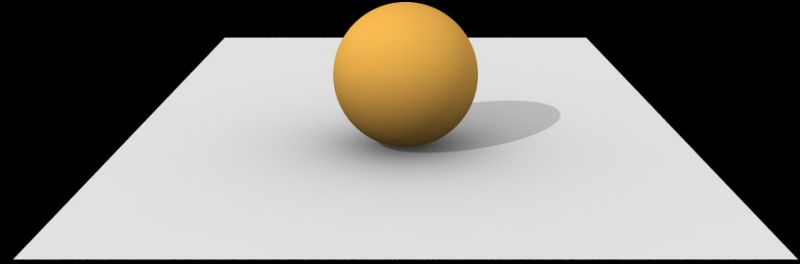
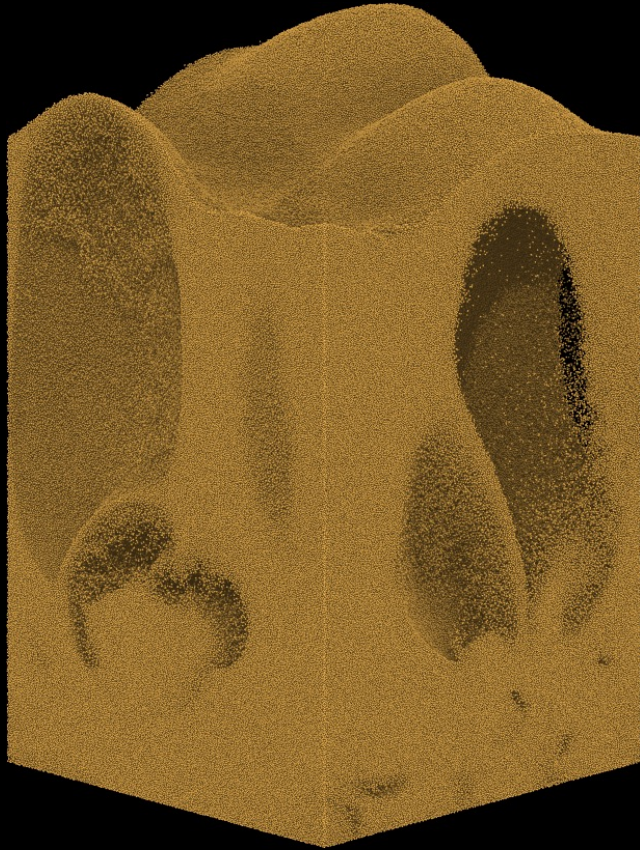
DIFFUSE LIGHTING (LAMBERTIAN REFLECTION)



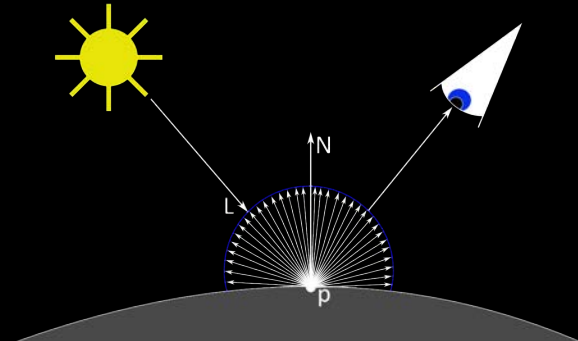
$$I_p = I_a K_a + \sum_i I_i K_d (\overline{N} \cdot \overline{L}_i)$$



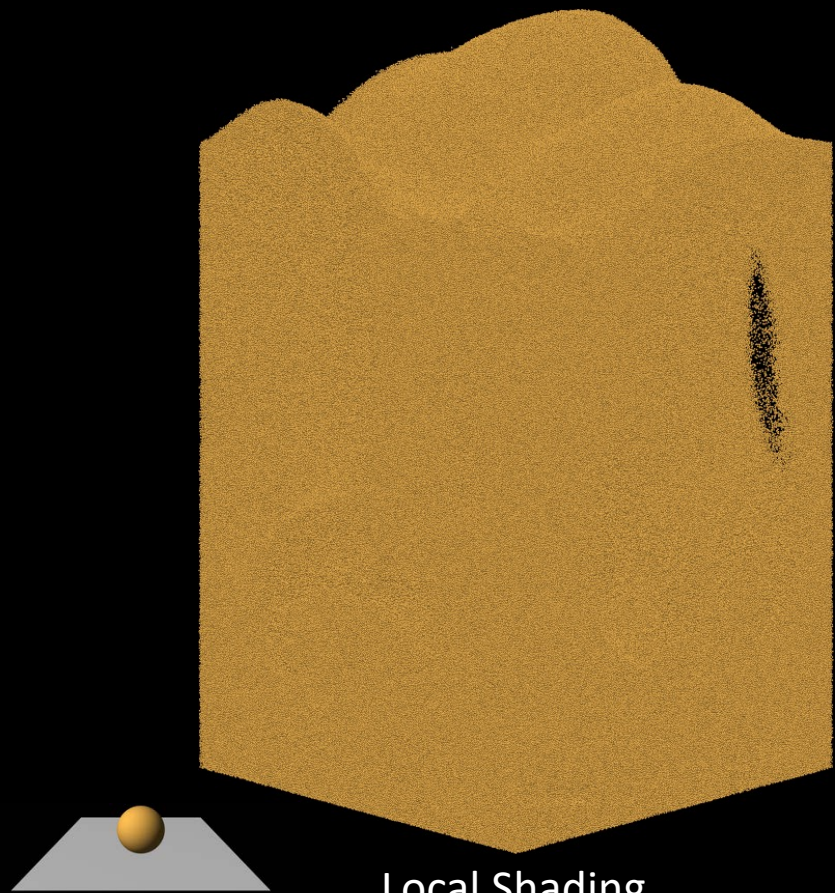
AMBIENT OCCLUSION



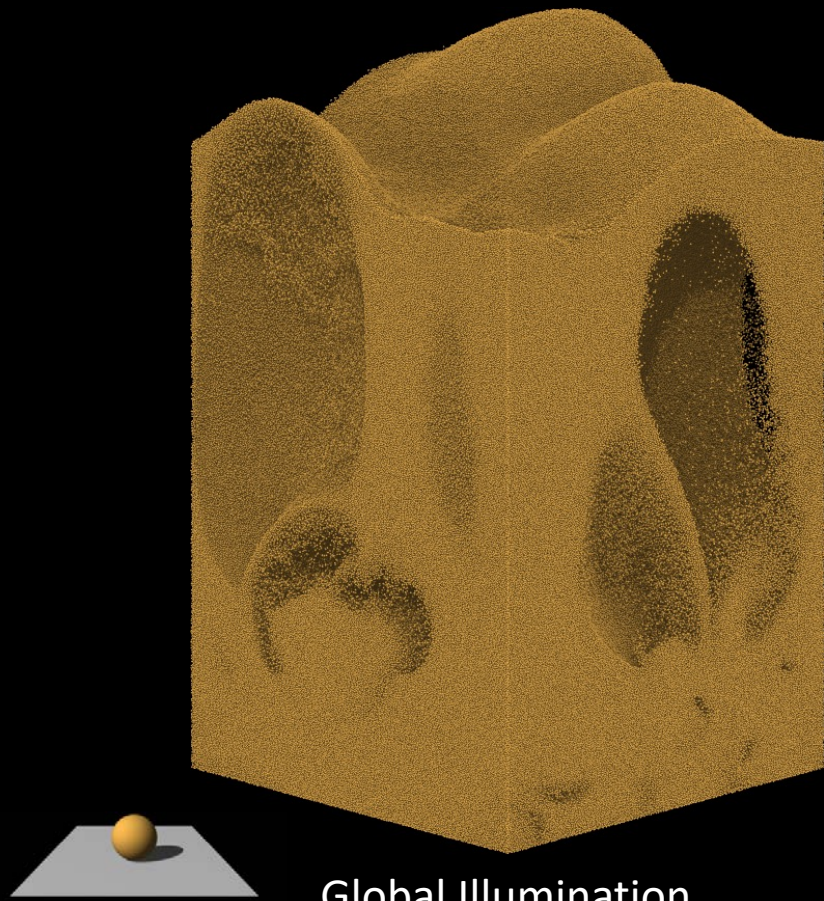
$$I = I_a K_a + \sum_i A_p I_p K_d (\overline{N} \cdot \overline{L}_i)$$
$$A_p = \frac{1}{4\pi} \int V_{p,\omega} (N \cdot \omega) d\omega$$



TECHNIQUE MATTERS



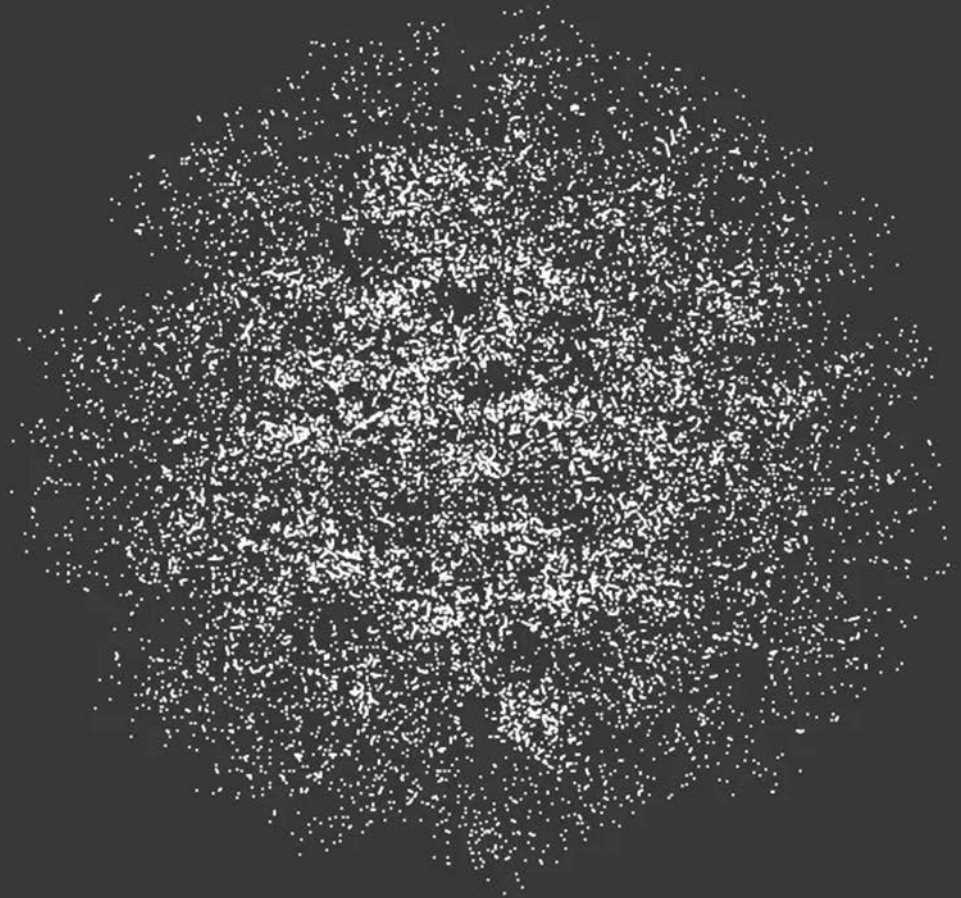
Local Shading



Global Illumination

DEPTH CUES

- structure-from-motion
- lighting and shading
- stereopsis
- convergence
- oculomotor accommodation
- texture gradient
- defocus blur



K. Gruchalla, S. Raghupathi, and N. Brunhart-Lupo. 2021.
Structure Perception in 3D Point Clouds. In *ACM Applied Perception*. Article 9, 1–9.
<https://doi.org/10.1145/3474451.3476237>

IMMERSIVE VISUALIZATION

An environment created with a combination of hardware and software that provides the user with a psycho-physical experience of being immersed in a computer-generated scene.

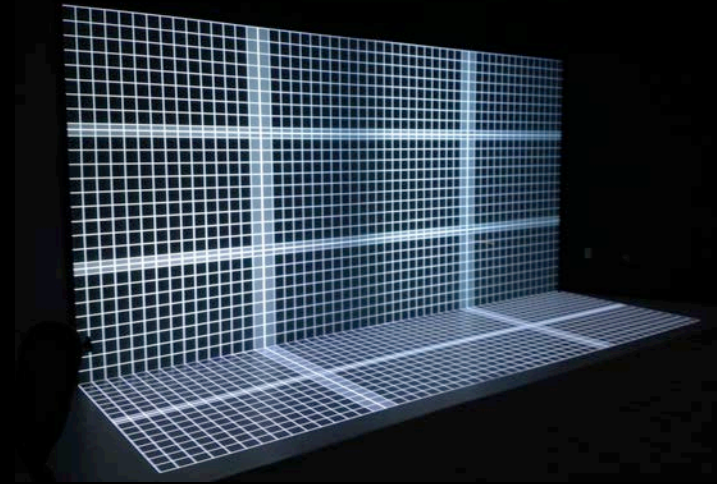
Immersive Factors:

- Egocentric
- Kinesthesia support
- Wide field-of-view
- Resolution
- Stereoscopic
- 3D Interactions



INSIGHT CENTER – IMMERSIVE VISUALIZATION

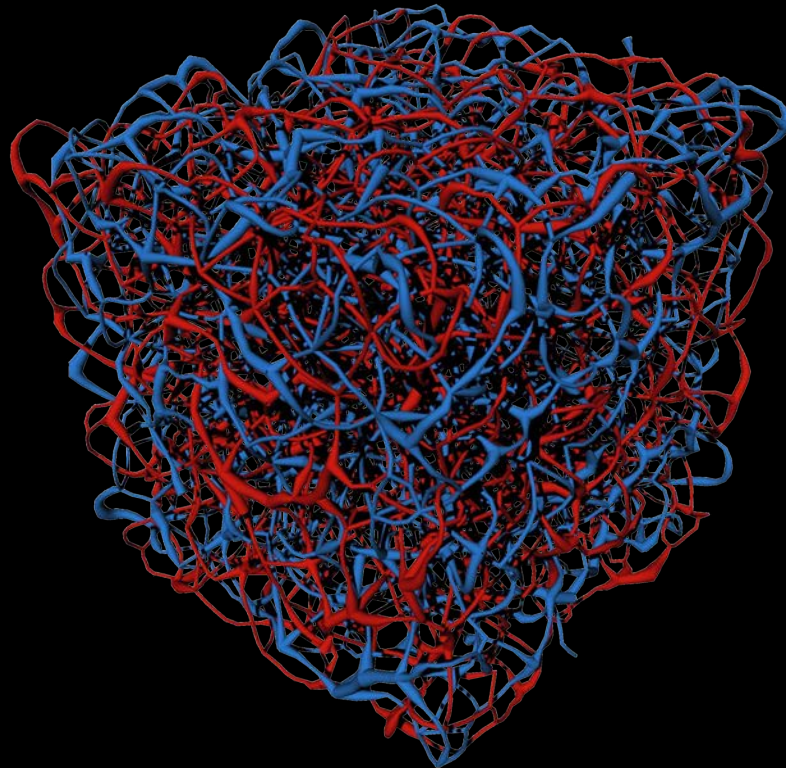
Large-scale virtual immersive environment.



6-projector / 2-surfaces

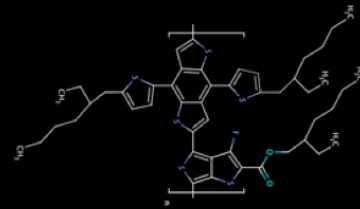
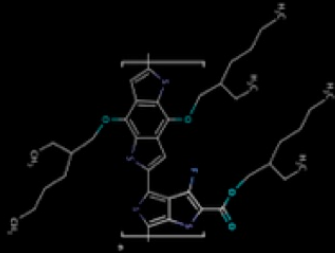
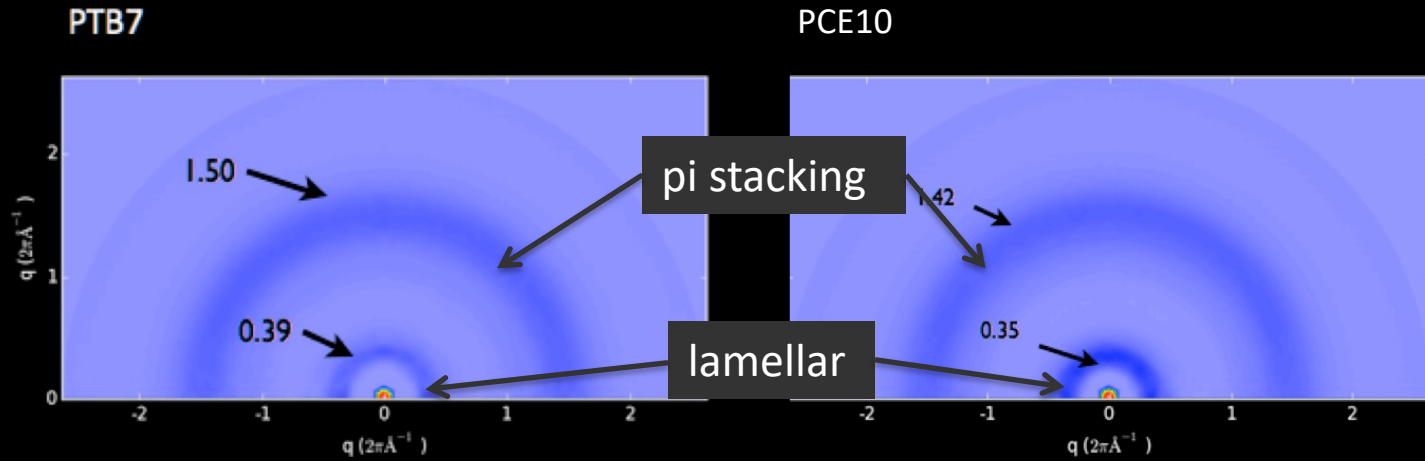
- Active Stereo (Christie Mirage)
- Optical Tracking (Vicon)
- Blended (Christie Twist)

OPV MORPHOLOGY



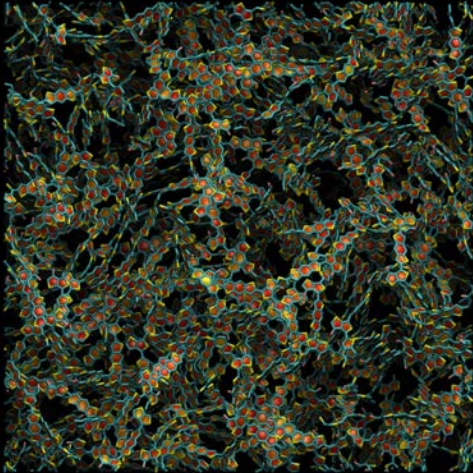
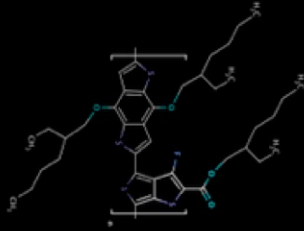


OPV POLYMER STRUCTURE

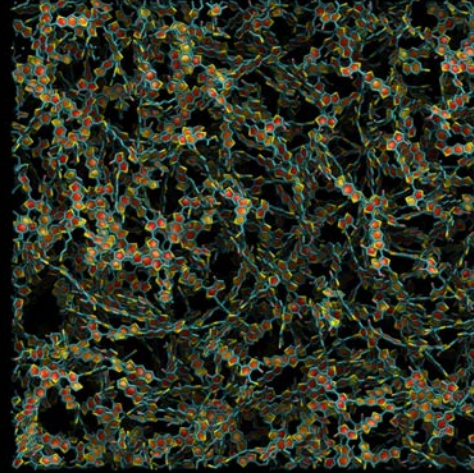
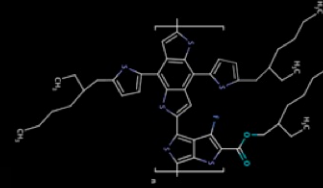


OPV POLYMER STRUCTURE

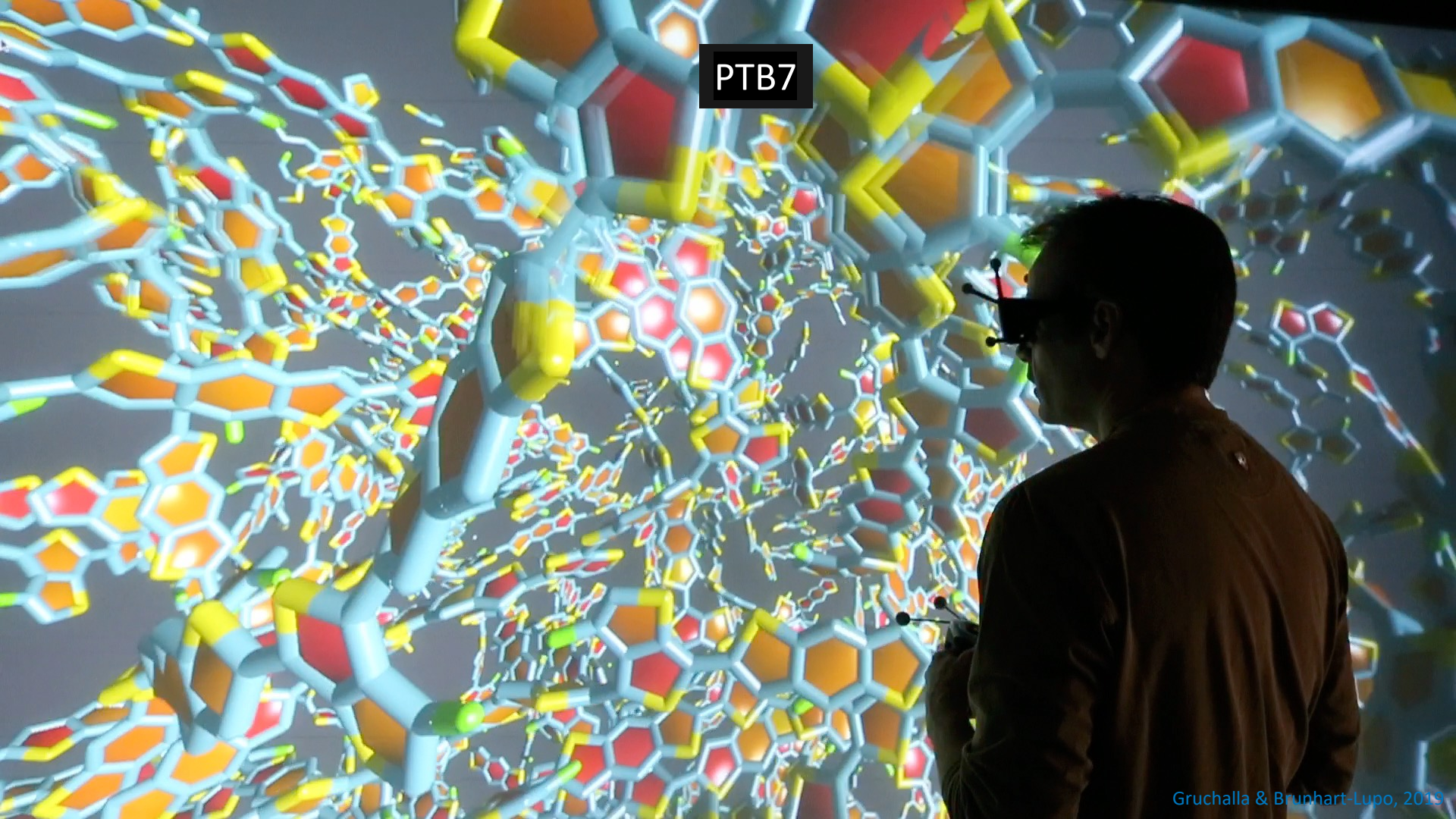
PTB7



PCE10

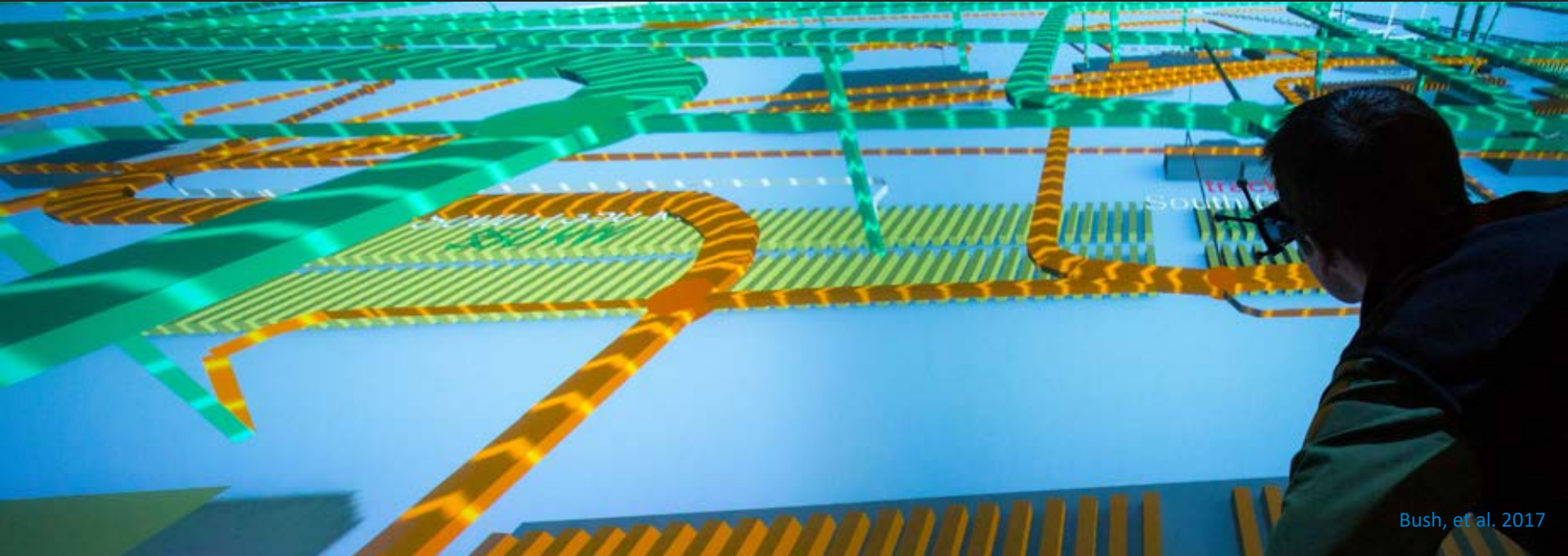


PTB7

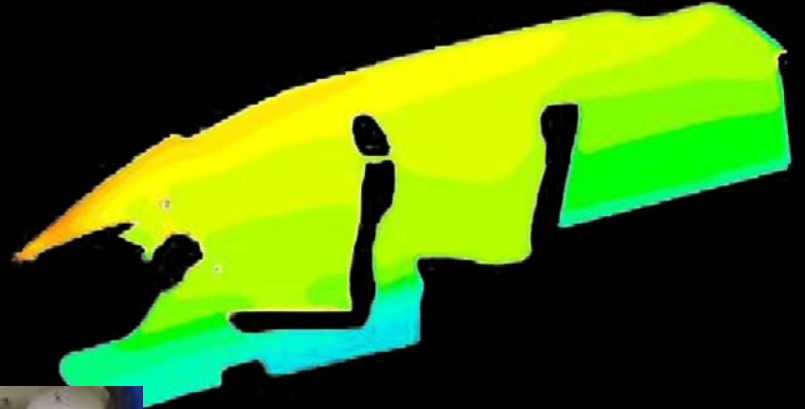
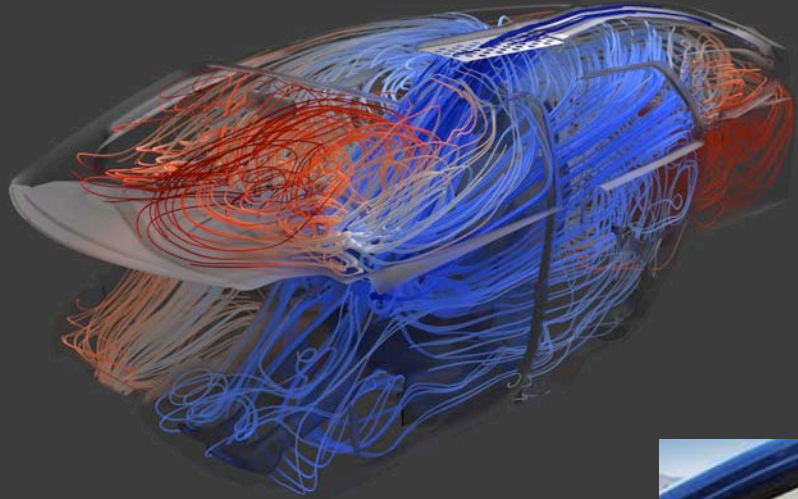


EMBODIED COGNITION

The theory that sensory and motor systems are fundamentally integrated with cognitive processing.

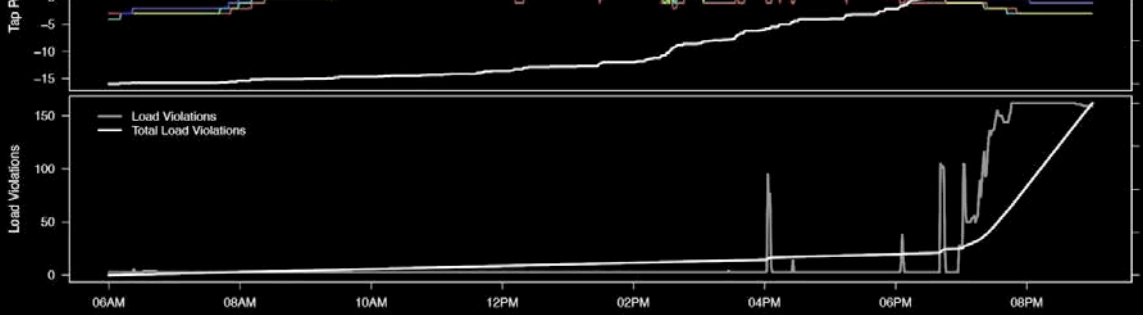
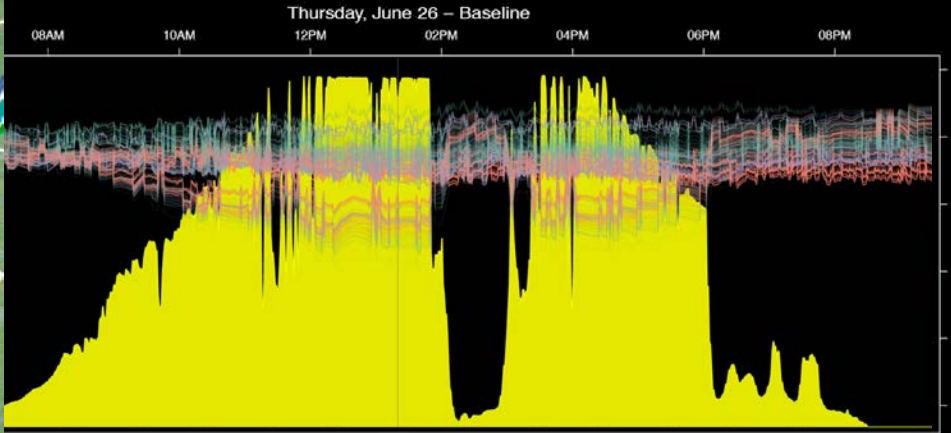
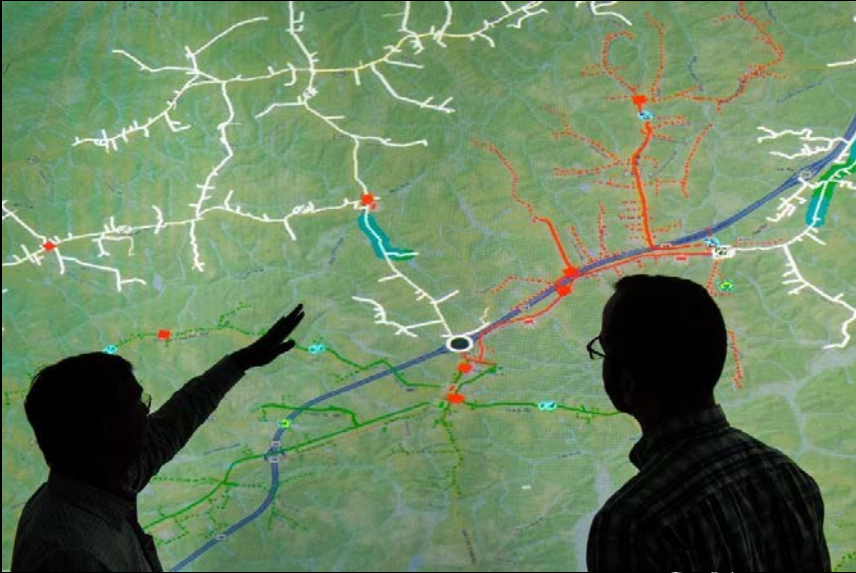


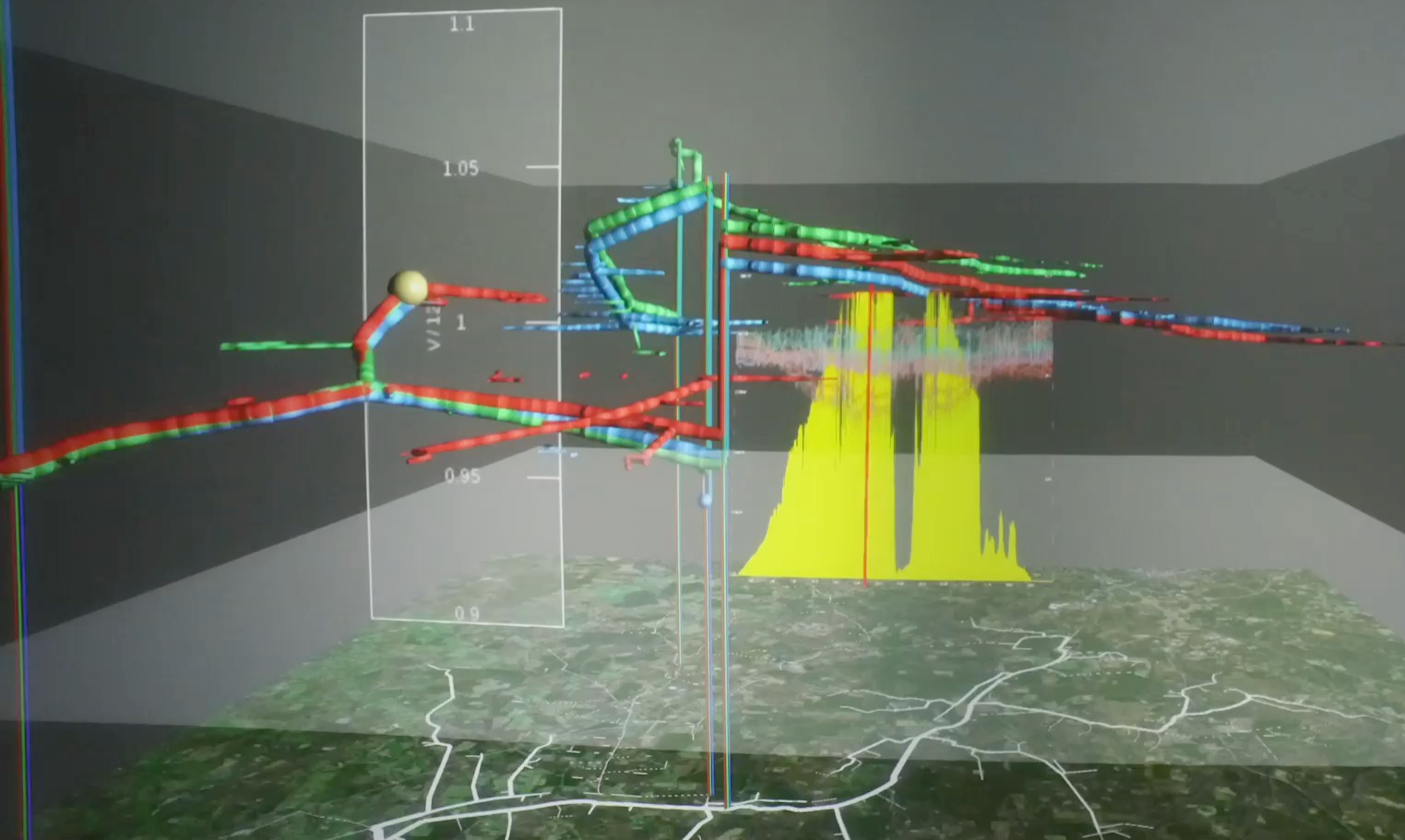
FORD FOCUS HVAC



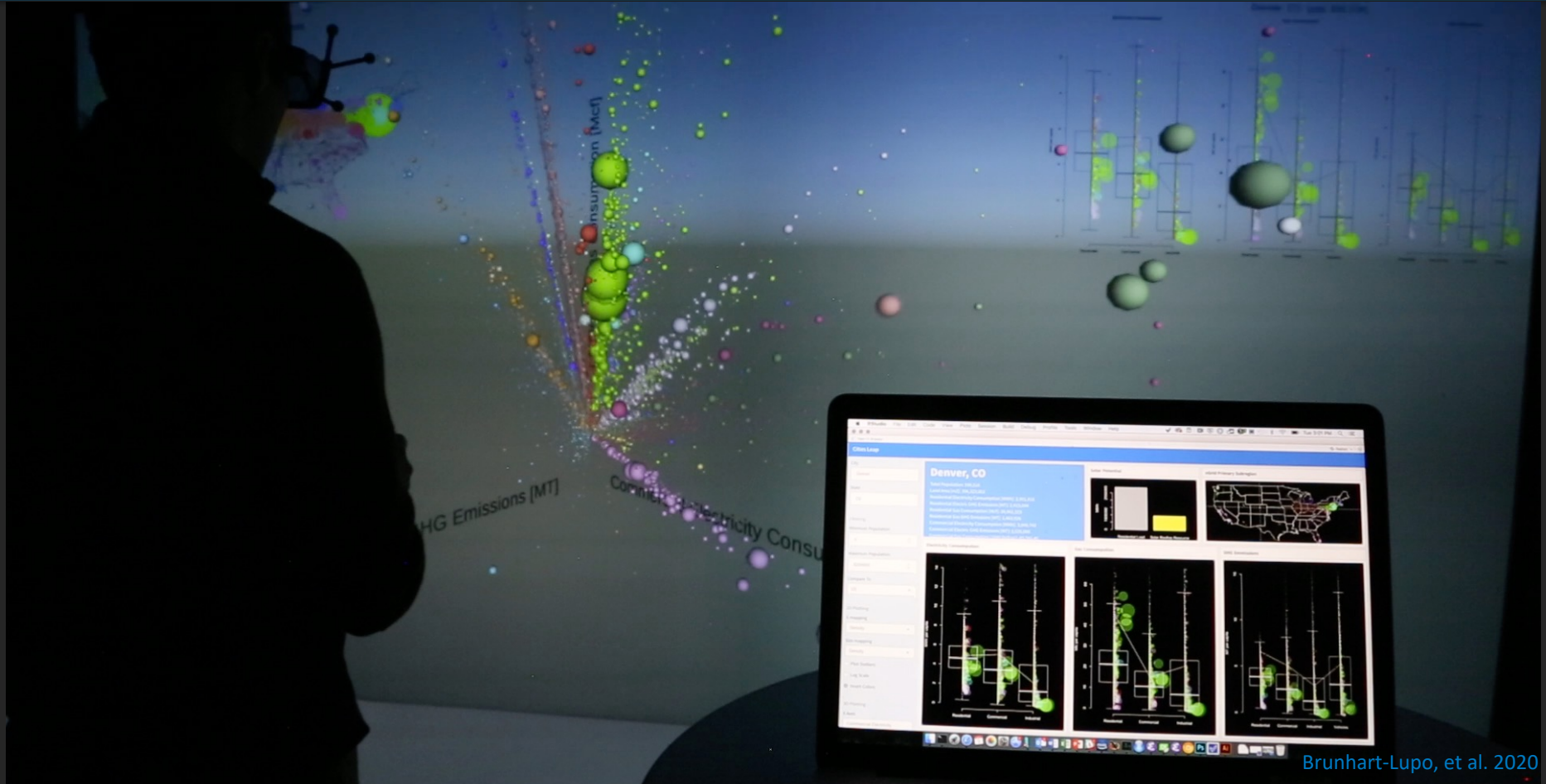


DISTRIBUTION MANAGEMENT SYSTEM





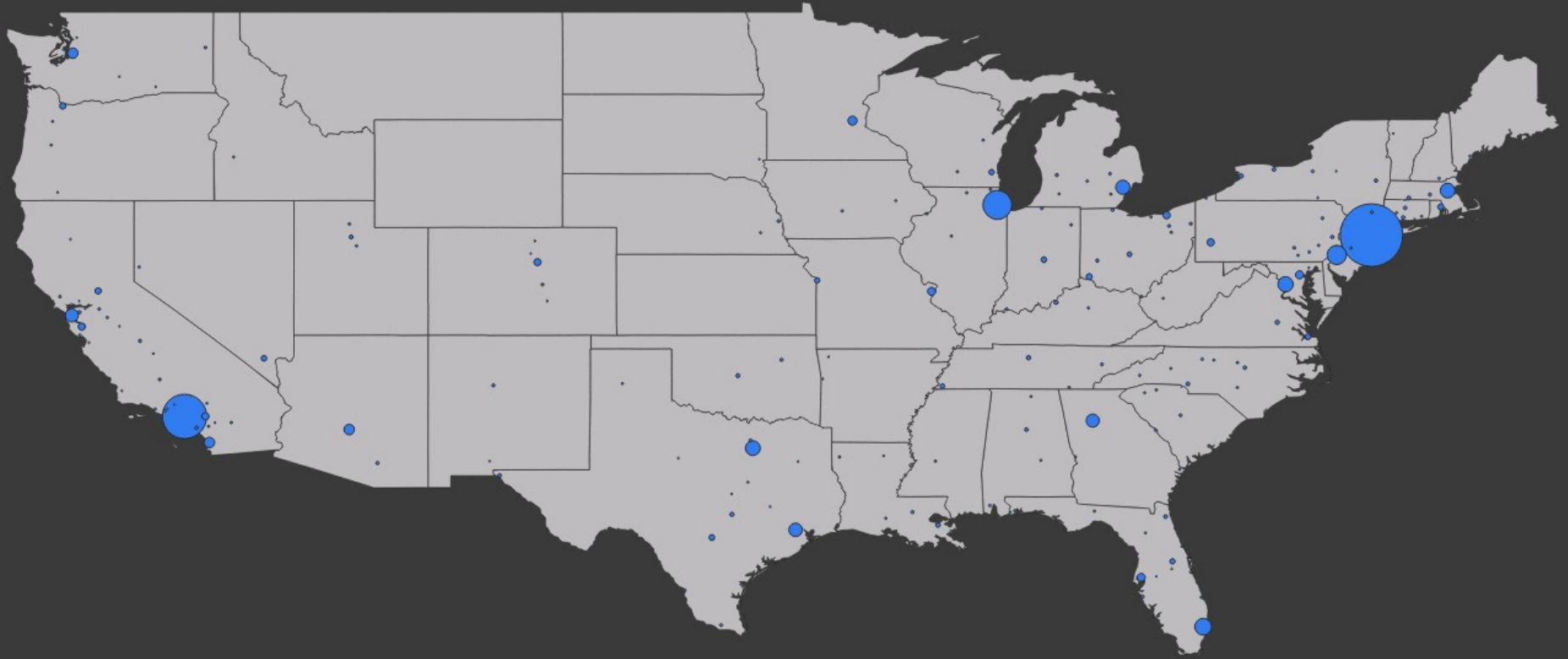
COLLABORATION



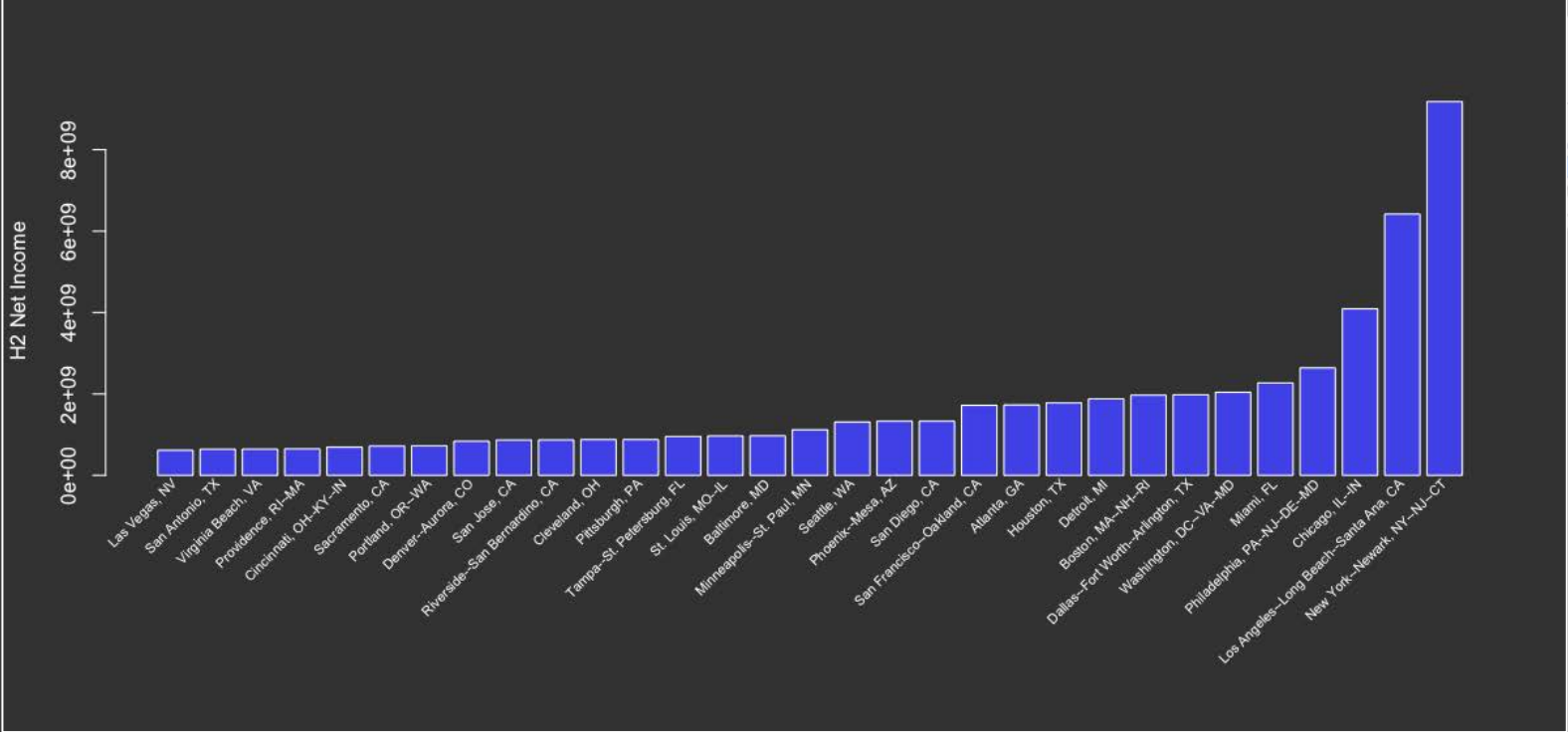
IMMERSION IS NOT ALWAYS BETTER!



IMMERSION IS NOT ALWAYS BETTER!



IMMERSION IS NOT ALWAYS BETTER!



Immersive Visualization Value



Improved Spatial
Judgments



High-Dimensional
Data



Direct 3D Interaction



Collaboration



2D VISUALIZATION LABORATORY

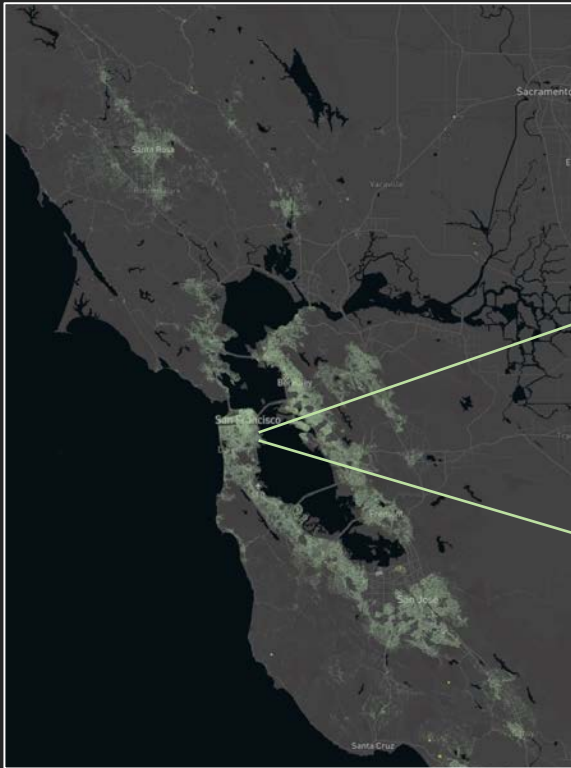


• High-resolution (100 MP)

• Tiled touch wall (10 MP)

• Mobile touch table

HIGH-RESOLUTION VISUALIZATION



Large
Field-of-View



Visual Acuity



Spatial memory

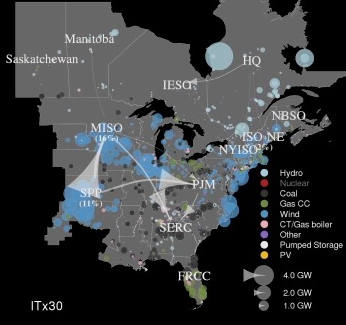
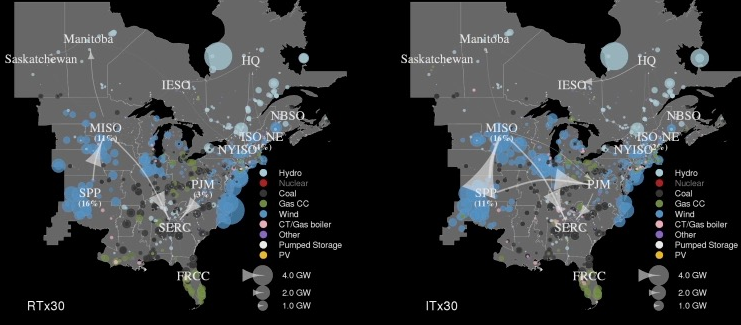
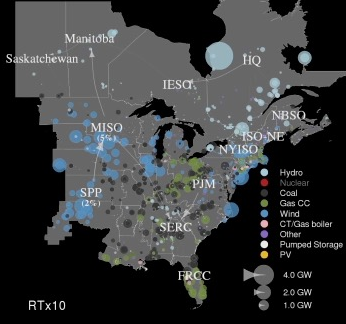
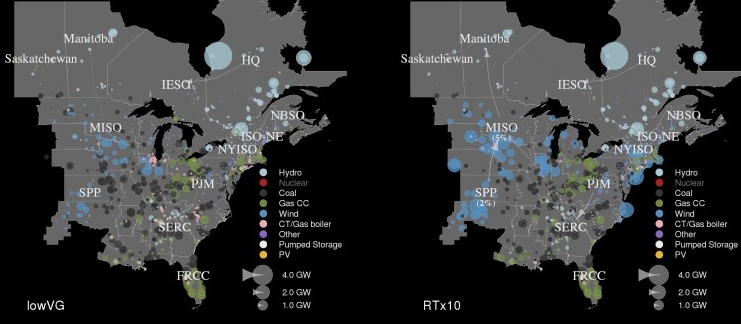


Visual real-estate

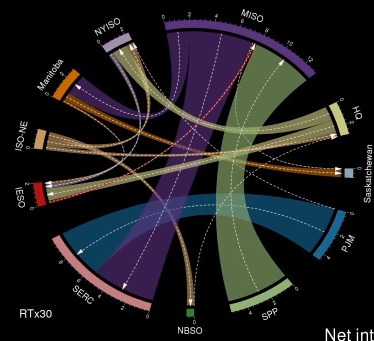
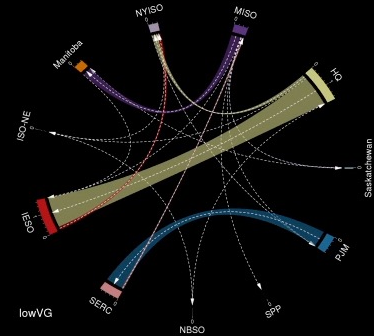


Eastern Renewable Generation Integration Study

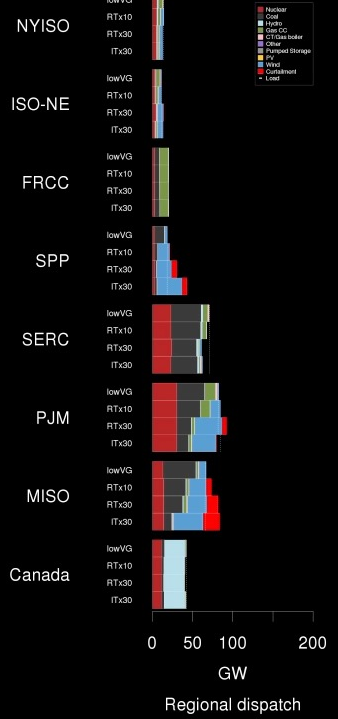
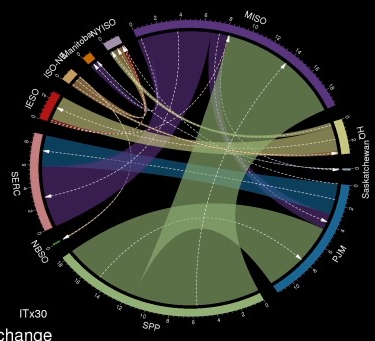
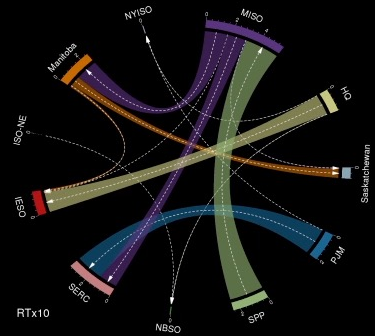
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Generation & Flow



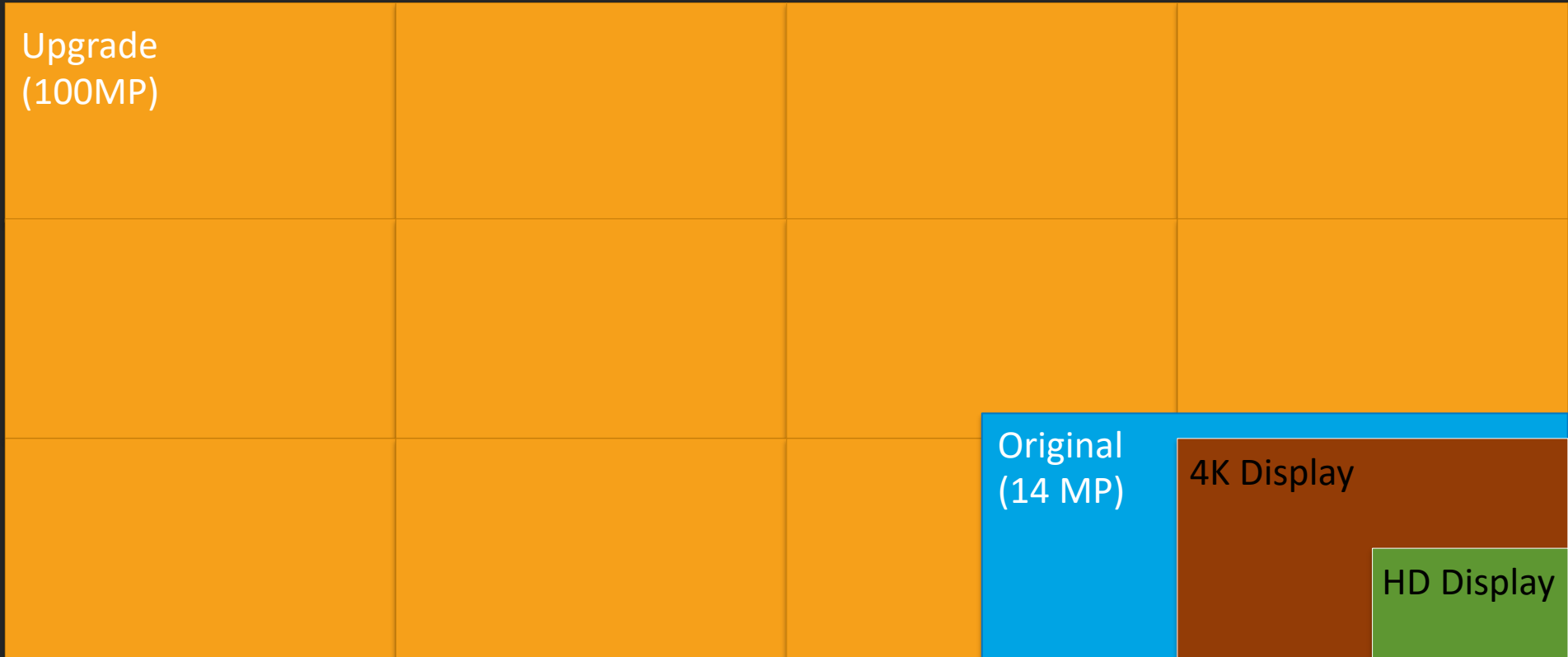
Net interchange



Visual comparison of four 2026 Scenarios

HIGH-RESOLUTION DISPLAY

100 Million Pixels (12 4K Panels)



HIGH-RESOLUTION DISPLAY

100 Million Pixels (12 4K Panels)



Upgrade
(100MP)

This is NOT about making little pictures big
This is about making big pictures (data) visible!

Original
(14 MP)

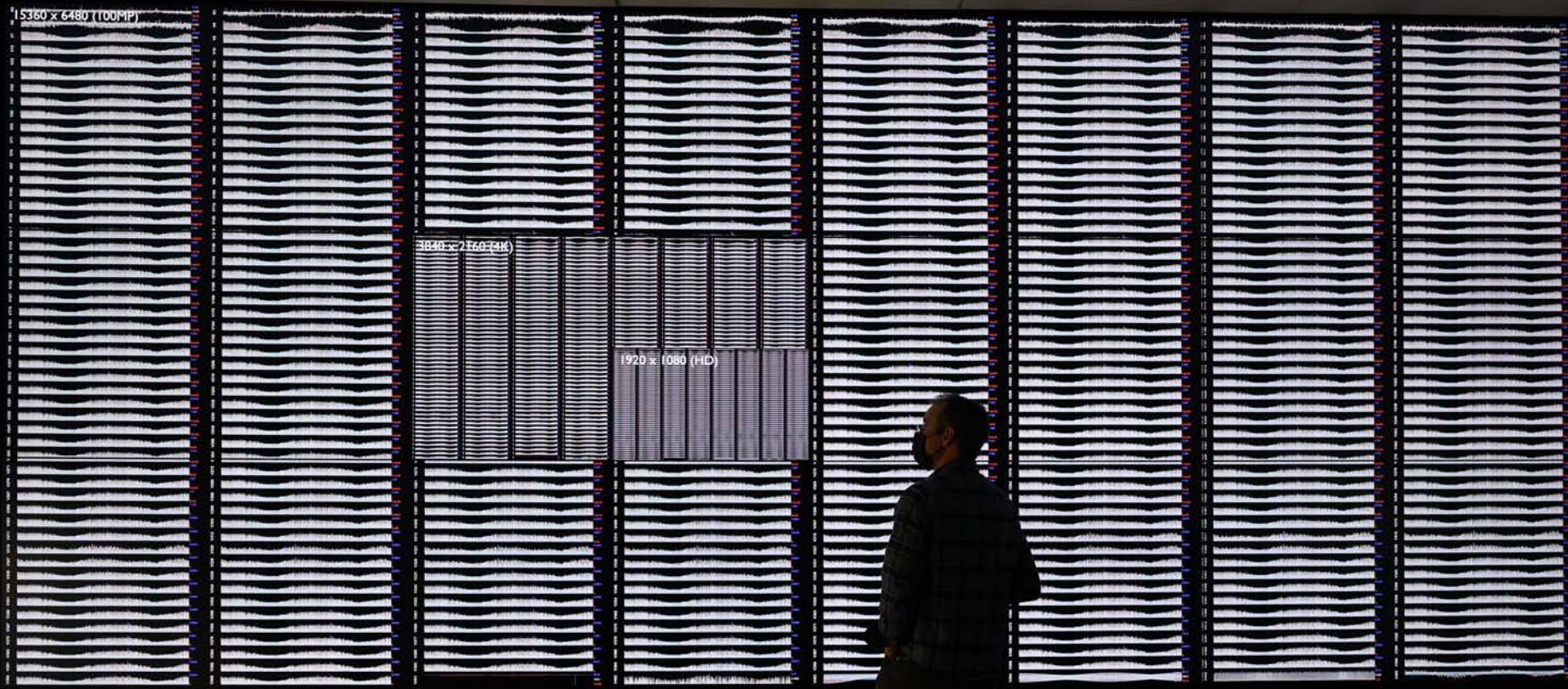
4K Display

HD Display

USE CASE: CITY-SCALE DISTRIBUTION MODELING



USE CASE: SENSOR COLLECTIONS (SMALL MULTIPLES)

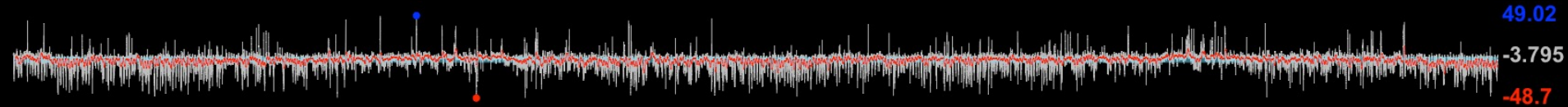


SIDEBAR: HIGH-RESOLUTION FIDELITY

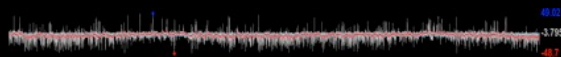


416 separate time series
2Hz for 48 hours
36 million points of data

100 Mpixel Display



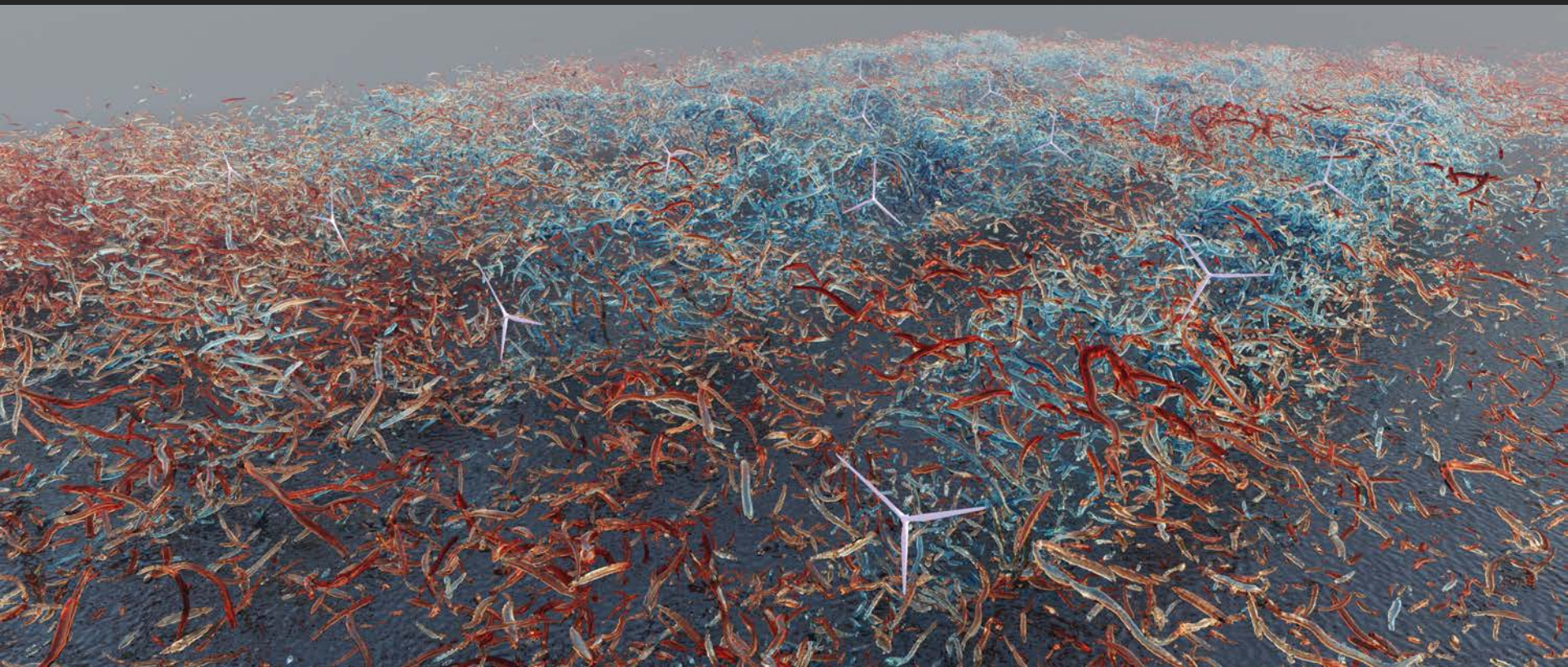
4K Display



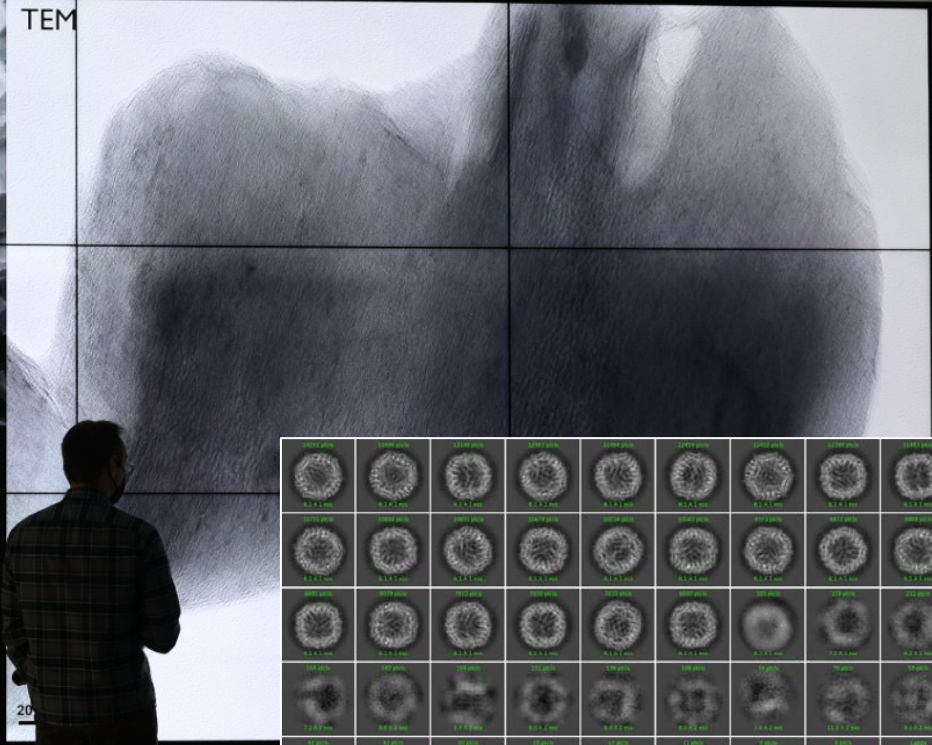
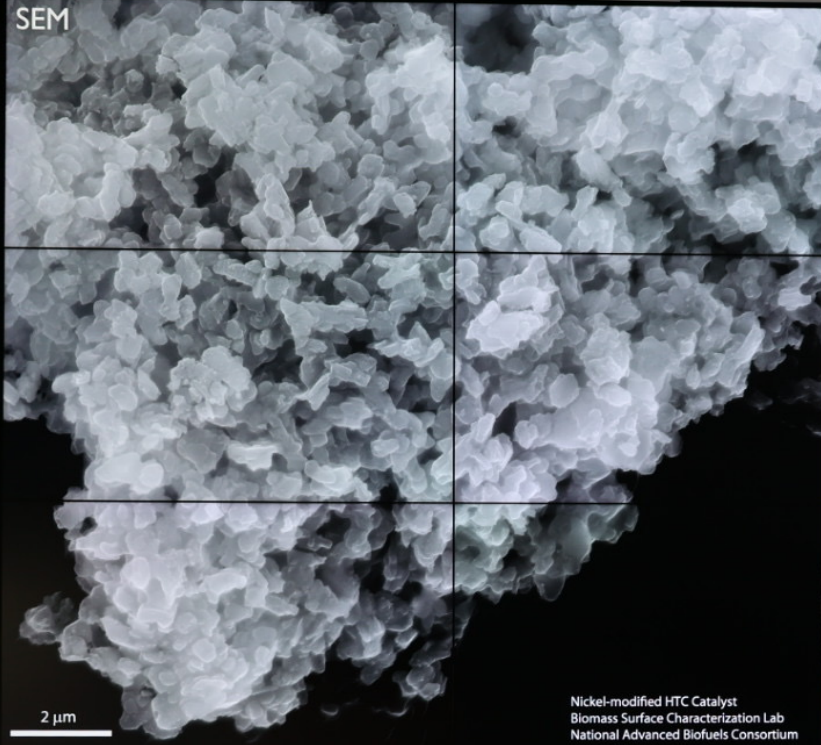
HD Display



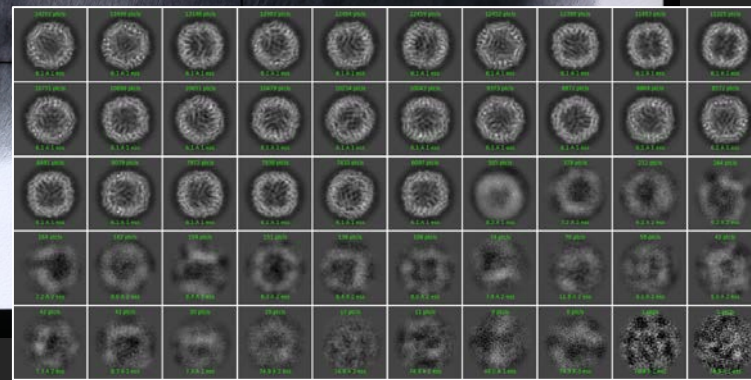
USE CASE: EXTREME-SCALE CFD



USE CASE: MICROSCOPY



Nickel-modified HTC Catalyst
Biomass Surface Characterization Lab
National Advanced Biofuels Consortium



Immersive Visualization Value



Improved Spatial
Judgments



Direct 3D
Interaction



High-Dimensional
Data



Collaboration

Large-Scale Visualization Value



Large
Field-of-View



Visual Acuity



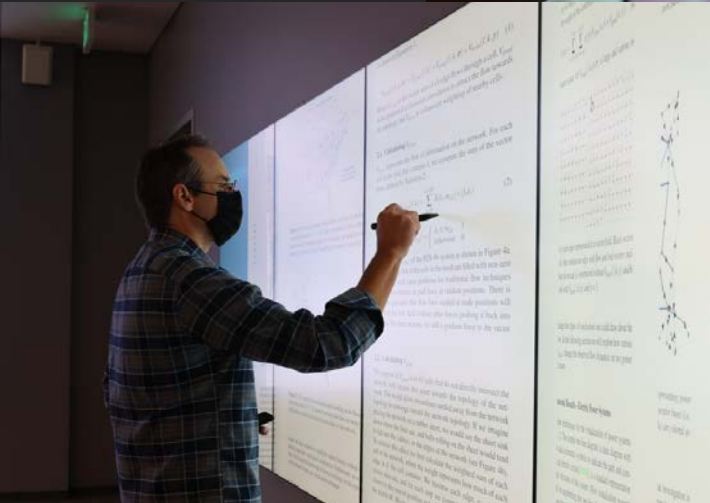
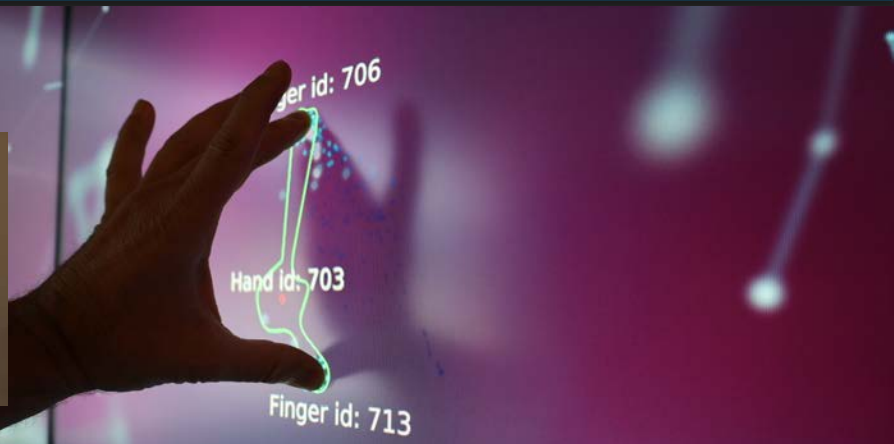
Spatial memory



Visual real-estate

TOUCH SURFACES

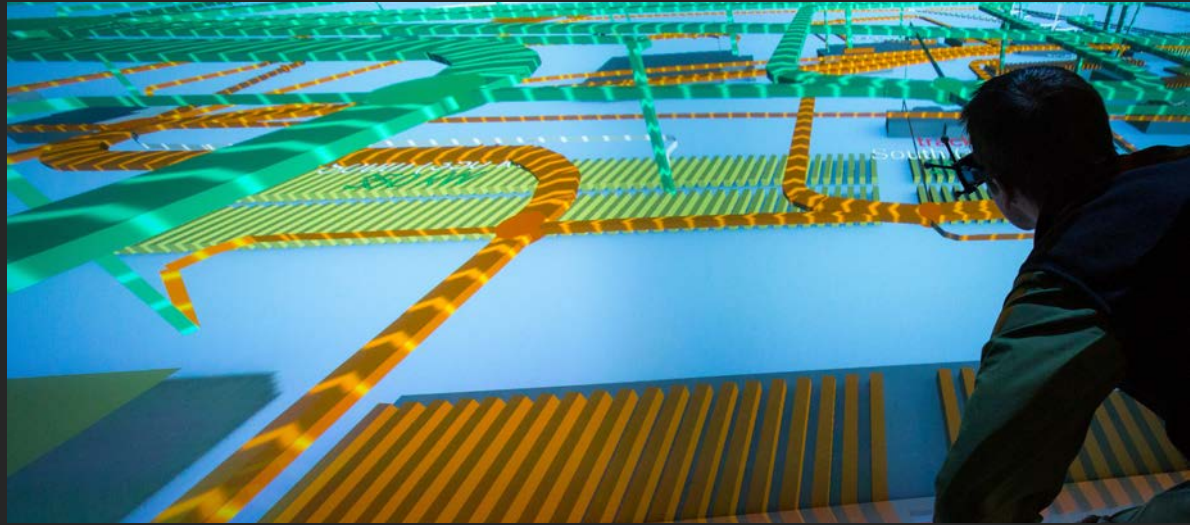
- Tiled touch wall (10 MP)
- Mobile touch table



REFERENCES

- F. J. Anscombe. 1973. Graphs in Statistical Analysis. *The American Statistician* 27, 1 (Feb. 1973), 17–21. doi: 10.1080/00031305.1973.10478966
- N. Brunhart-Lupo, B. W. Bush, K. Gruchalla and S. Smith, "Simulation exploration through immersive parallel planes," *2016 Workshop on Immersive Analytics (IA)*, Greenville, SC, USA, 2016, pp. 19-24, doi: 10.1109/IMMERSIVE.2016.7932377.
- N. Brunhart-Lupo, B. Bush, K. Gruchalla, K. Potter, S. Smith. Collaborative Exploration of Scientific Datasets using Immersive and Statistical Visualization *Proceedings of the 2020 Improving Scientific Software Conference. NCAR Technical Note. NCAR/TN-564+PROC*, August 2020.
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FURTHER READING



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