

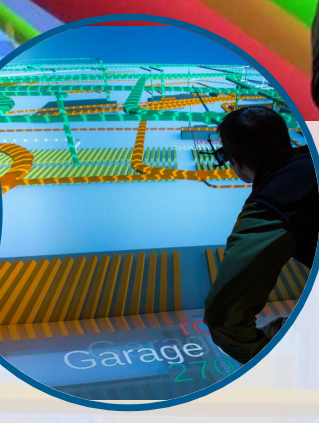


Immersive Digital Twins and Decision Making

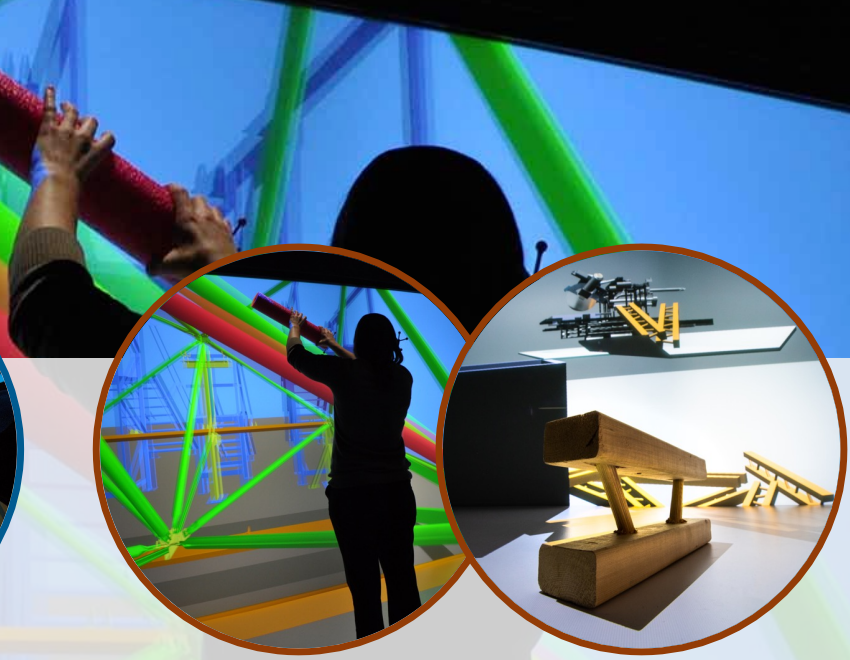
Kenny Gruchalla, Ph.D.
April 26, 2023

NREL/PR-2C00-86113

Immersive Digital Twins



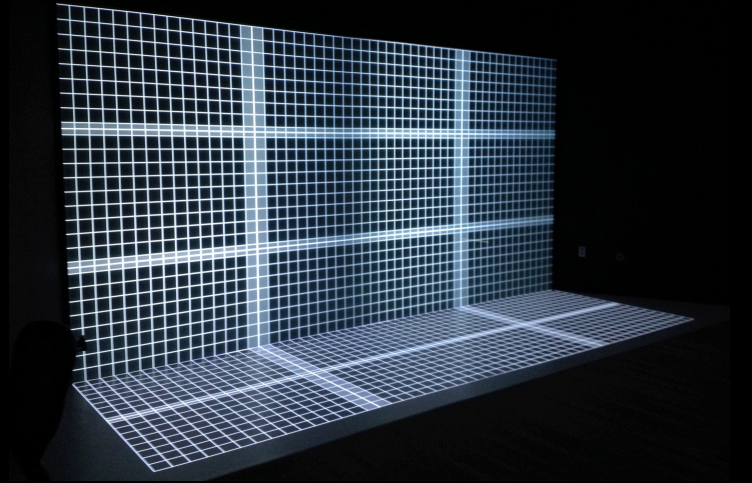
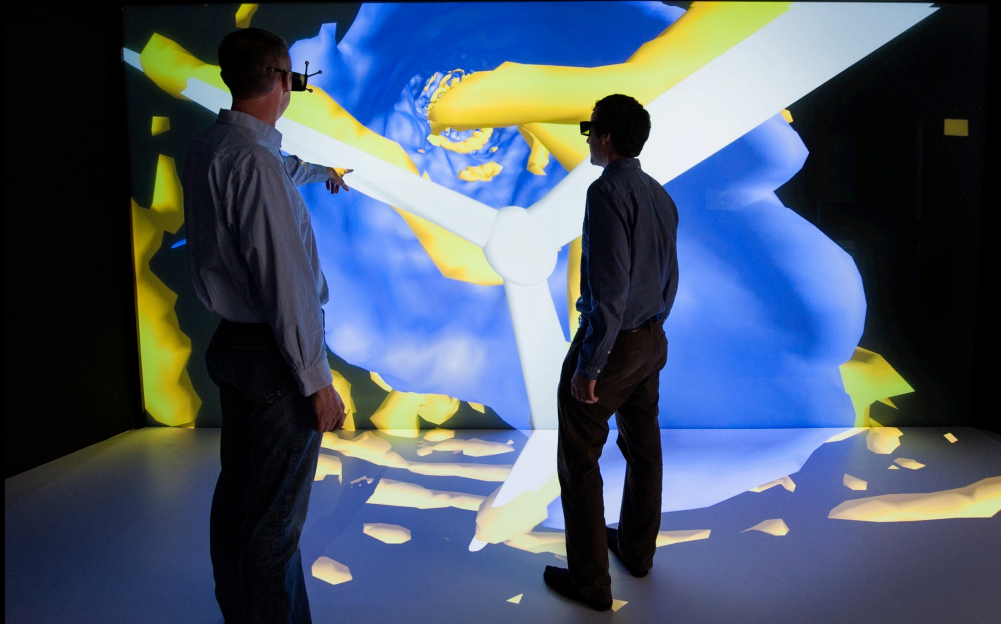
**Energy Planning & Resilience
Studies**



**Time and Motion
Studies**

INSIGHT CENTER – IMMERSIVE VISUALIZATION

Large-scale virtual immersive environment.



6-projector / 2-surfaces

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

IMMERSIVE VISUALIZATION

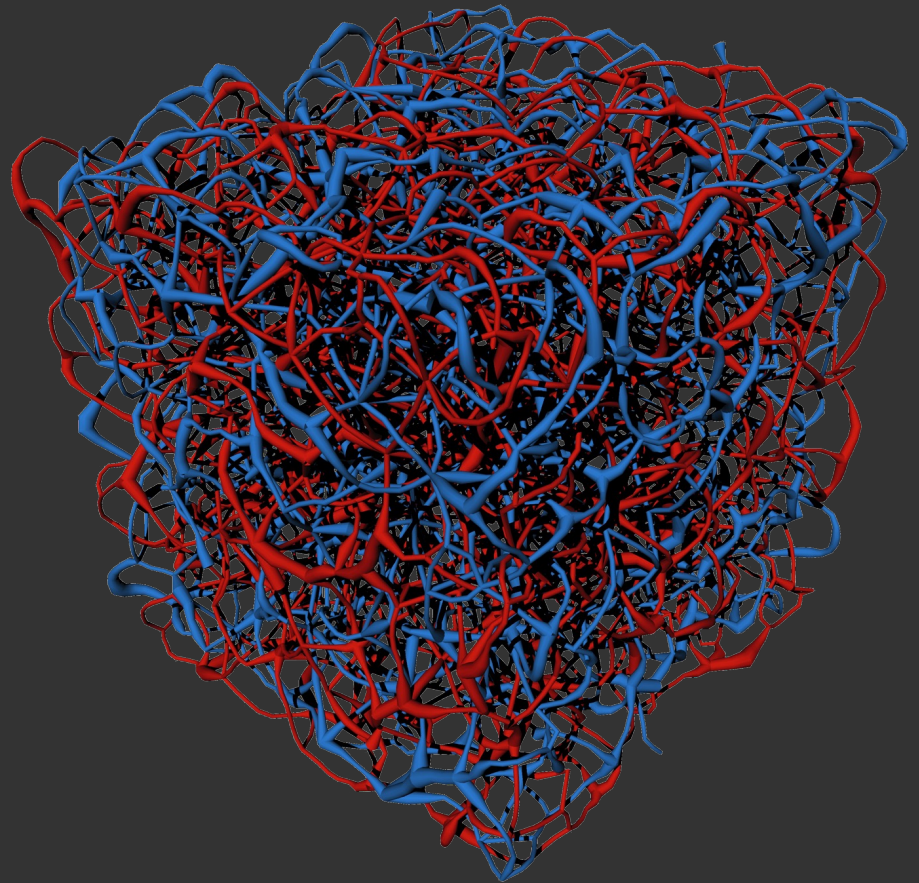
An environment created with a combination of hardware and software that provides the user with a psycho-physical experience of being immersed in a computer-generated scene.

Immersive Factors:

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

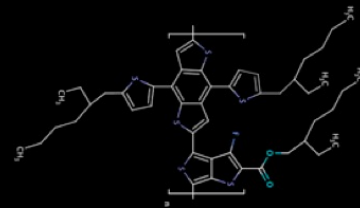
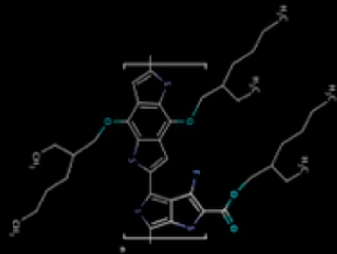
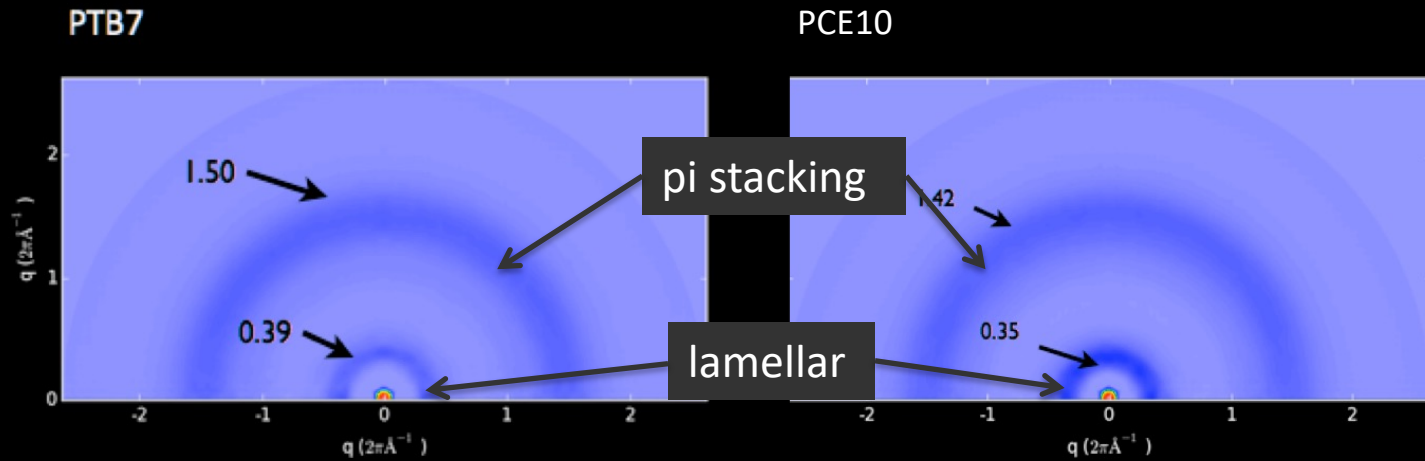


OPV Morphology



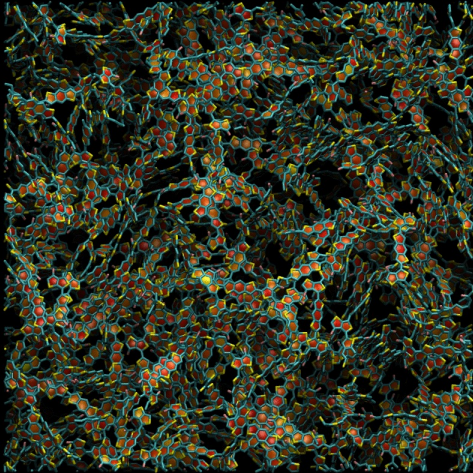
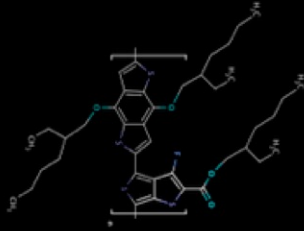


OPV POLYMER STRUCTURE

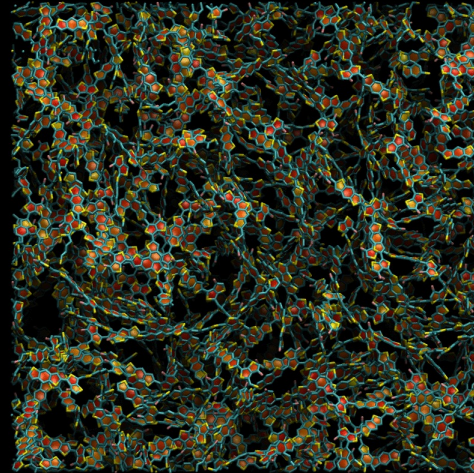
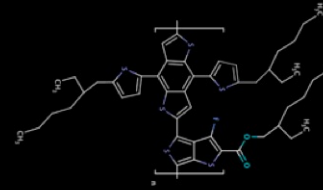


OPV POLYMER STRUCTURE

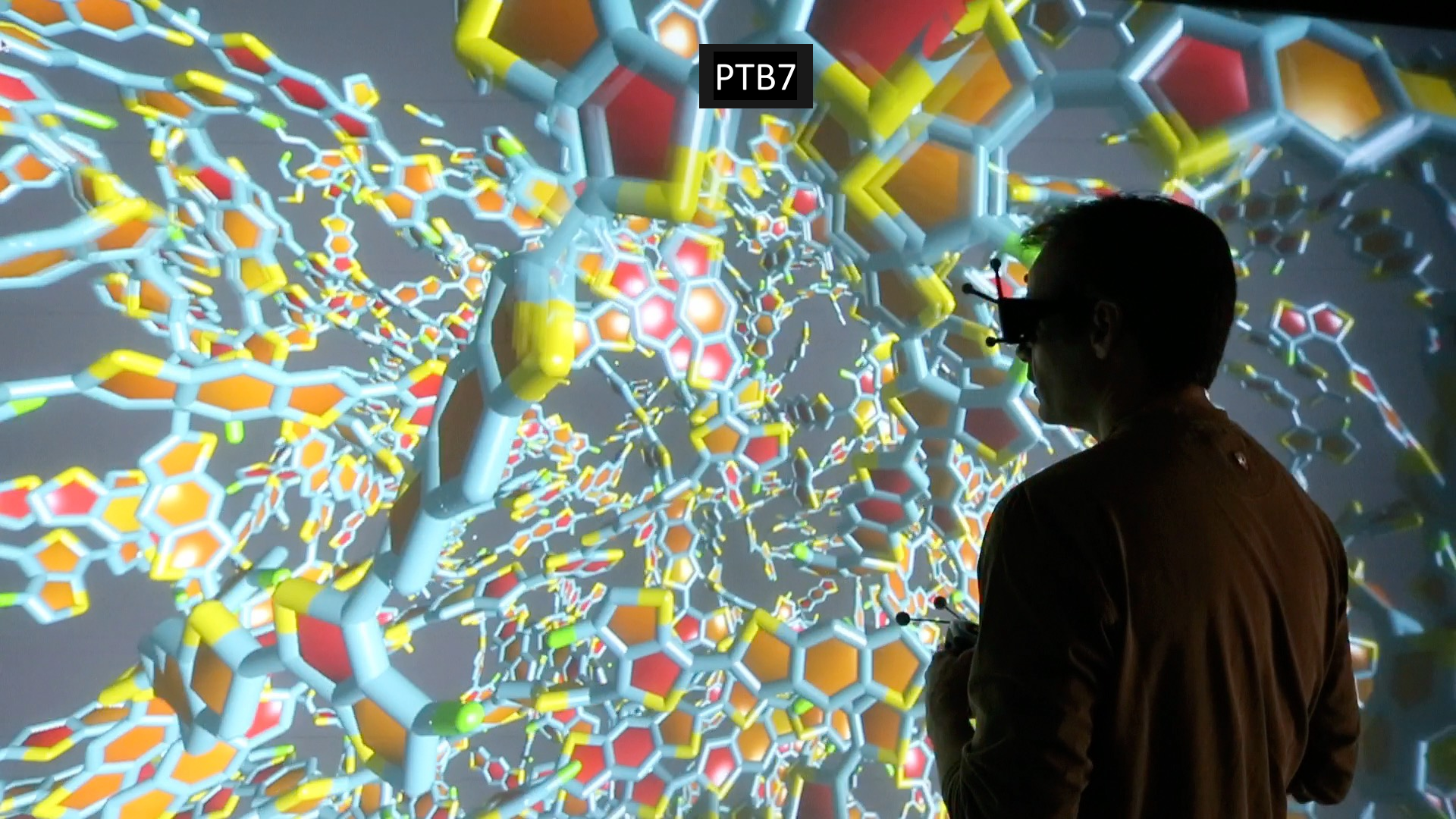
PTB7



PCE10

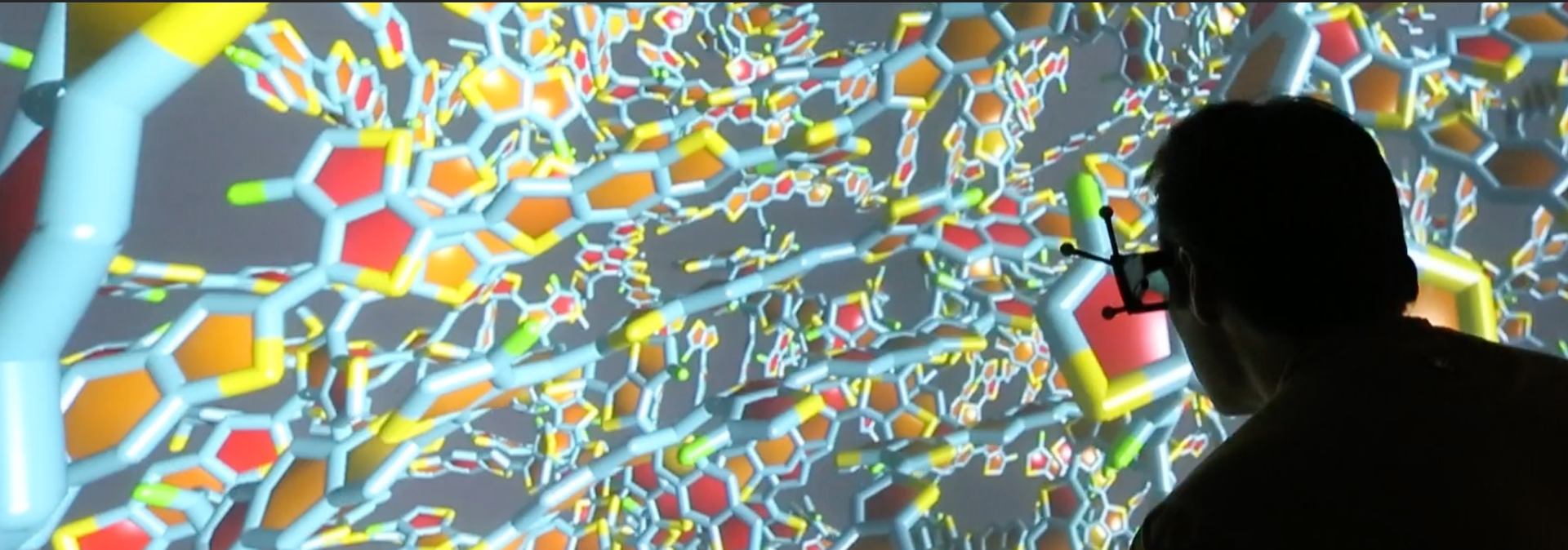


PTB7



EMBODIED COGNITION

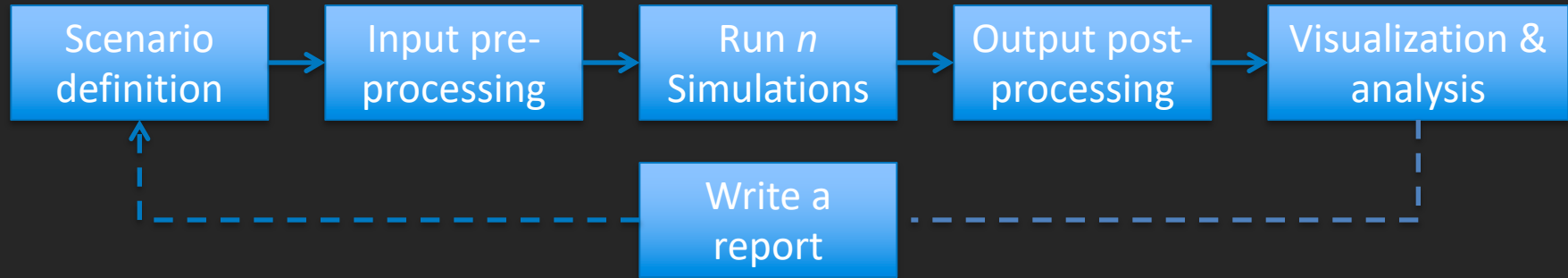
The theory that sensory and motor systems are fundamentally integrated with cognitive processing.



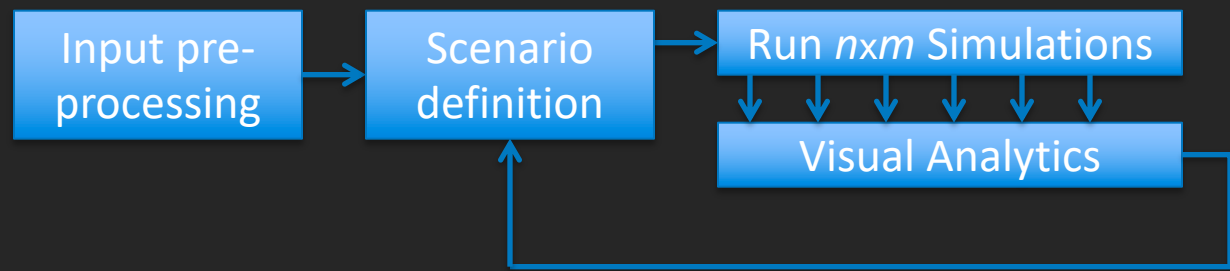
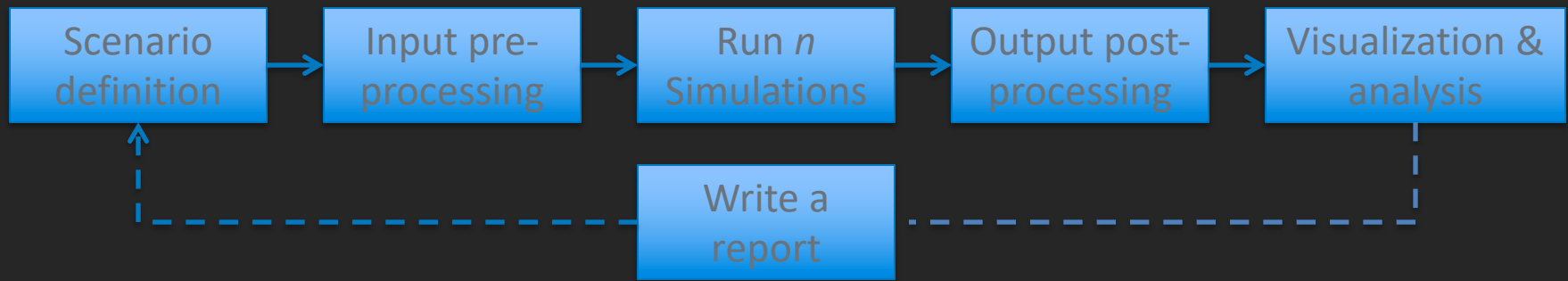
ENERGY PLANNING & RESILIENCE



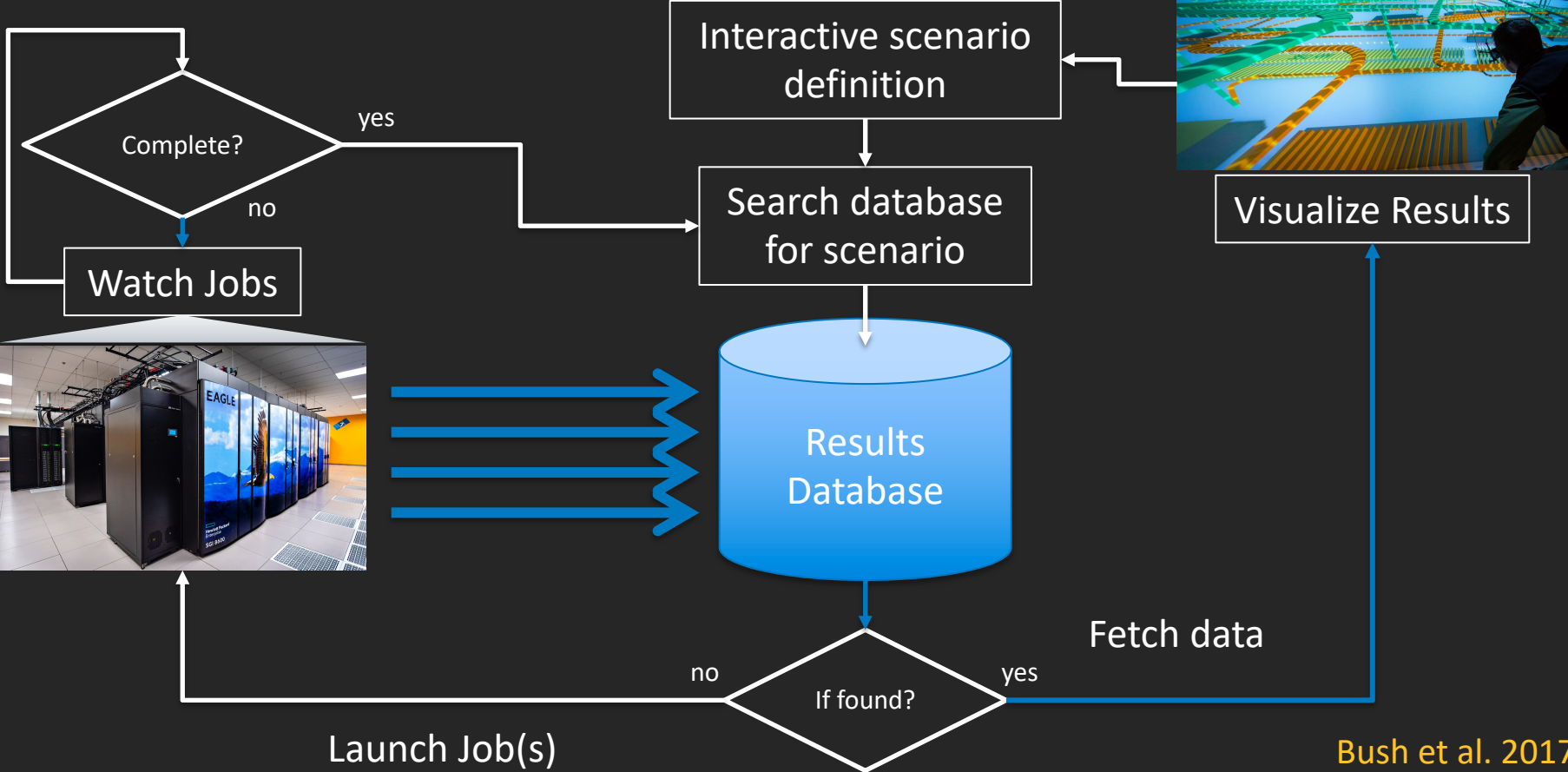
TRADITIONAL ENERGY ANALYSIS WORKFLOWS



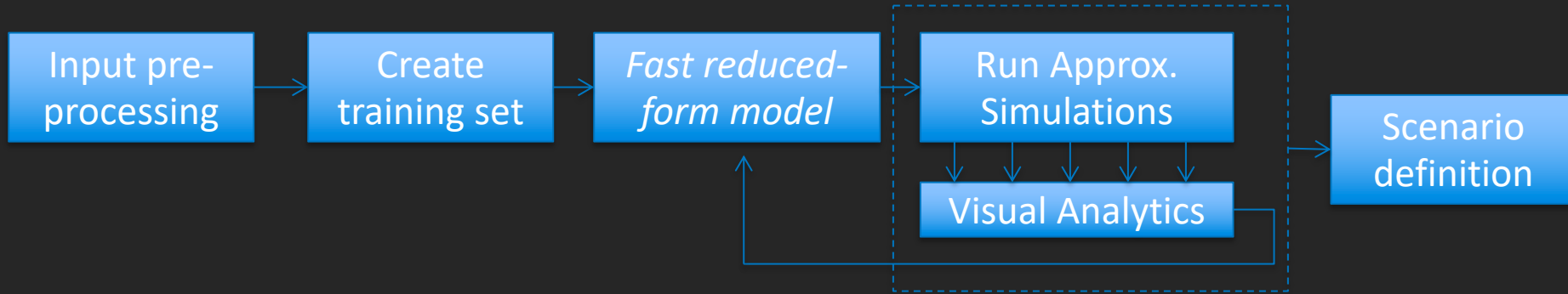
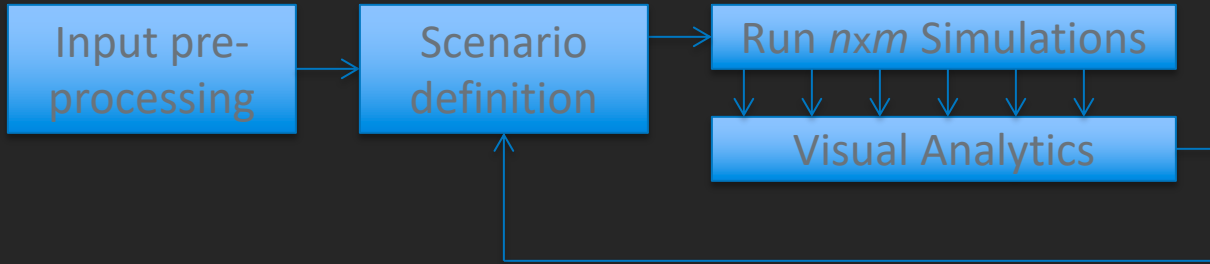
ENERGY ANALYSIS WORKFLOWS



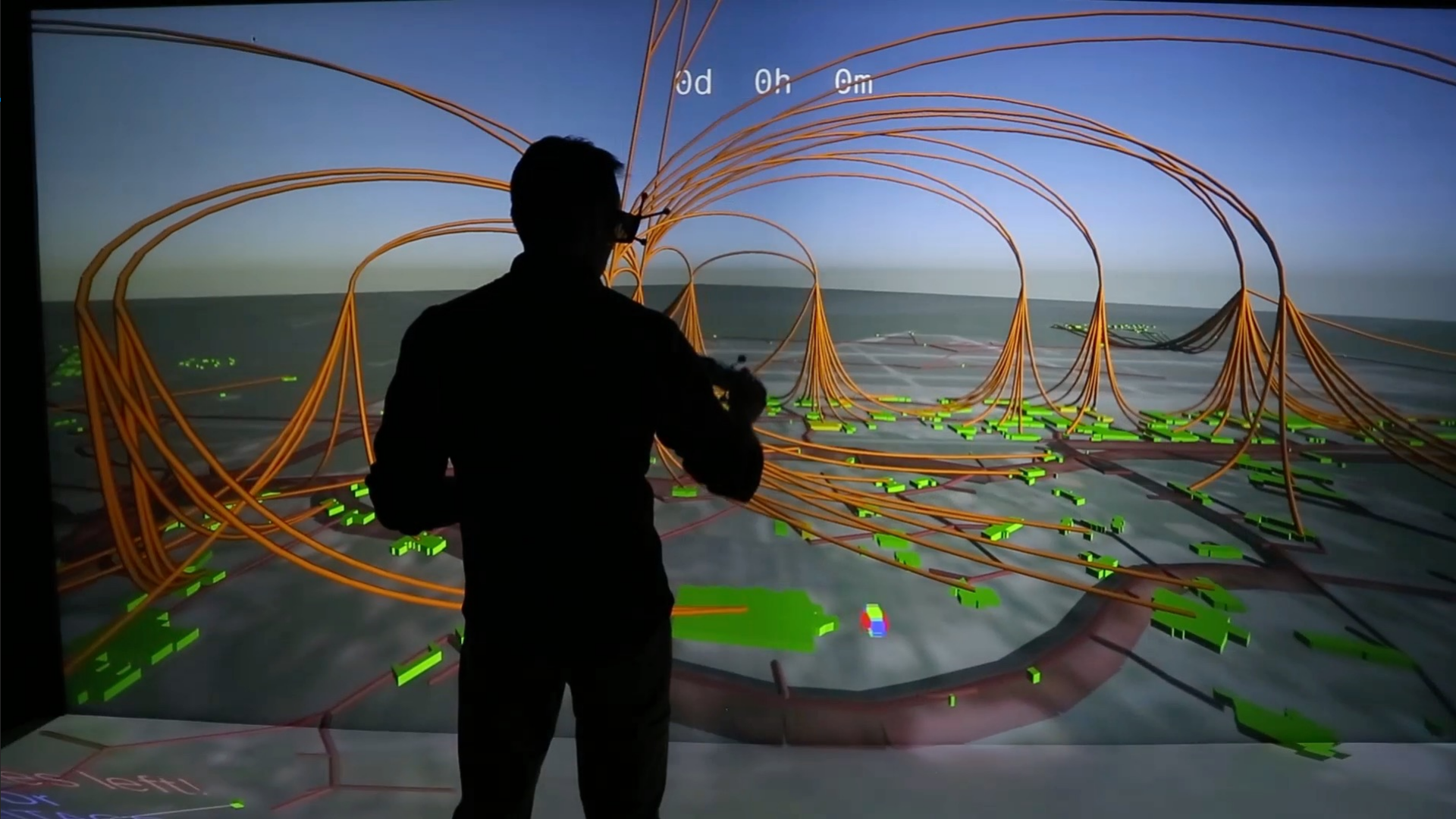
DIGITAL TWIN FLOW CHART



INTERACTIVE ENERGY ANALYSIS WORKFLOWS



0d 0h 0m



TIME AND MOTION

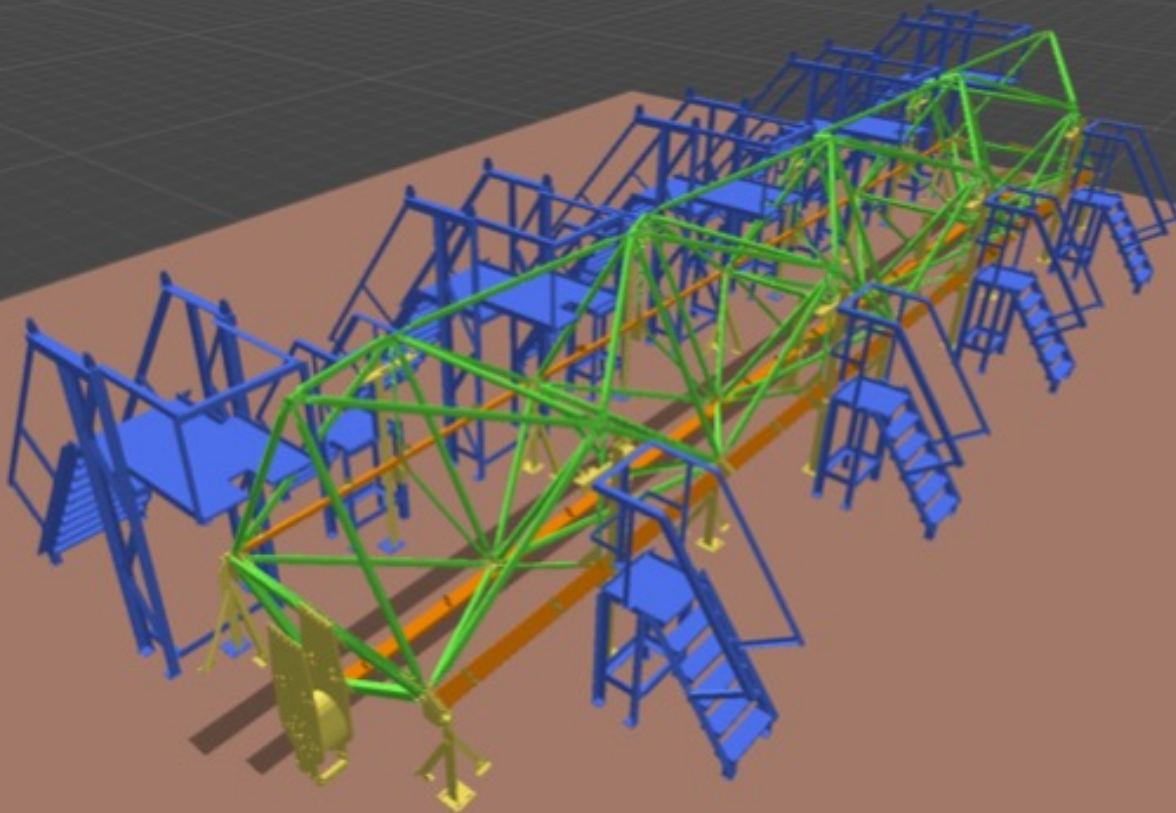
A time and motion study is a method used to analyze and improve the efficiency of work processes by observing workers performing a specific task and recording the time taken for each step, as well as analyzing the individual motions involved in performing the task.



Concentrating Solar Power (CSP)



CSP ASSEMBLY



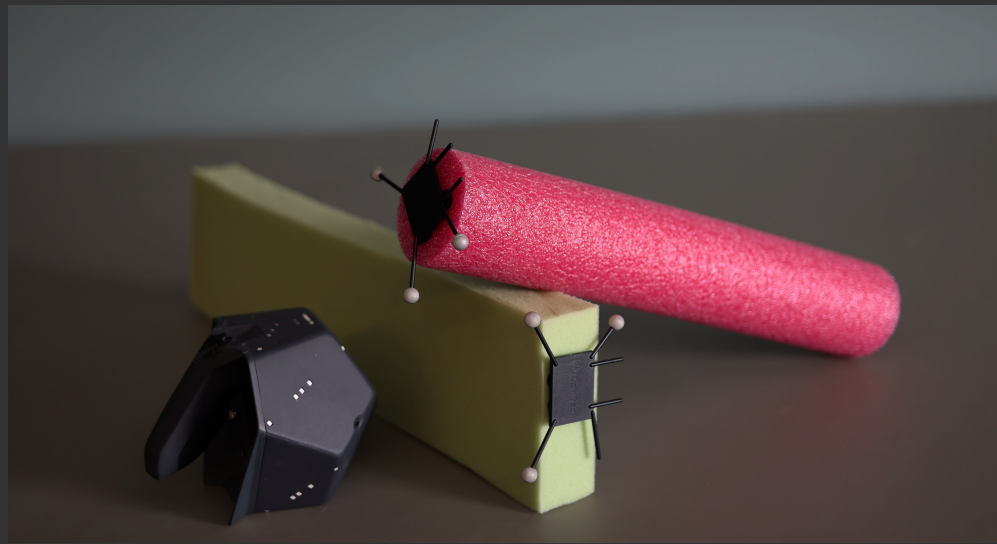
Scaffolding

Struts

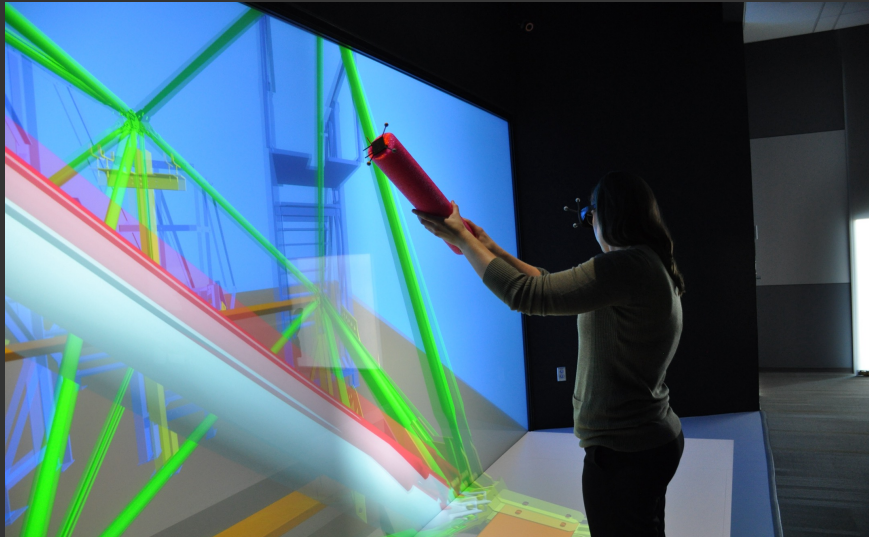
Beams

Jig

3D Interaction



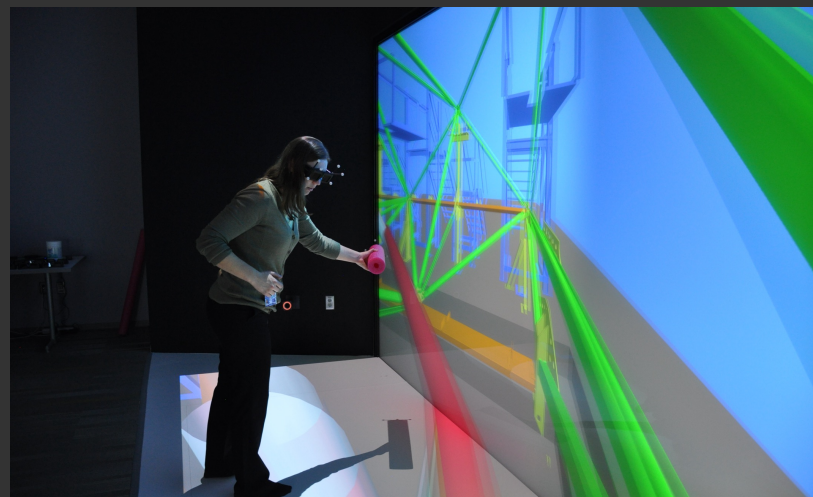
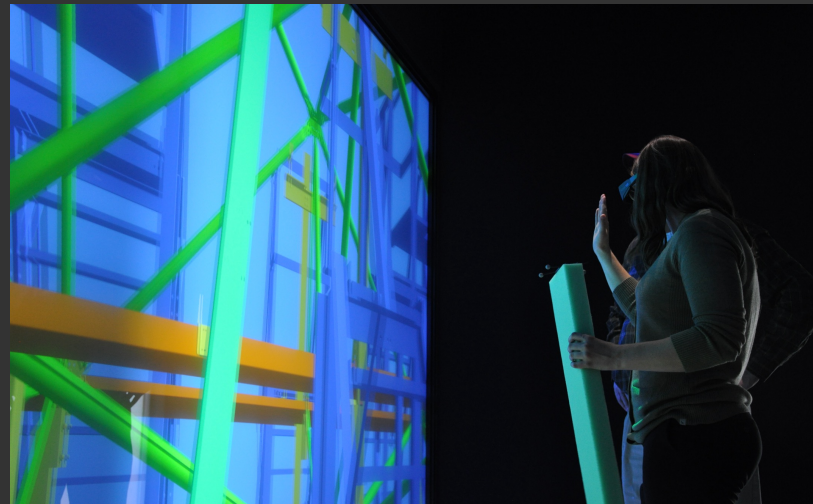
- Strut
- Beam
- Rivet gun



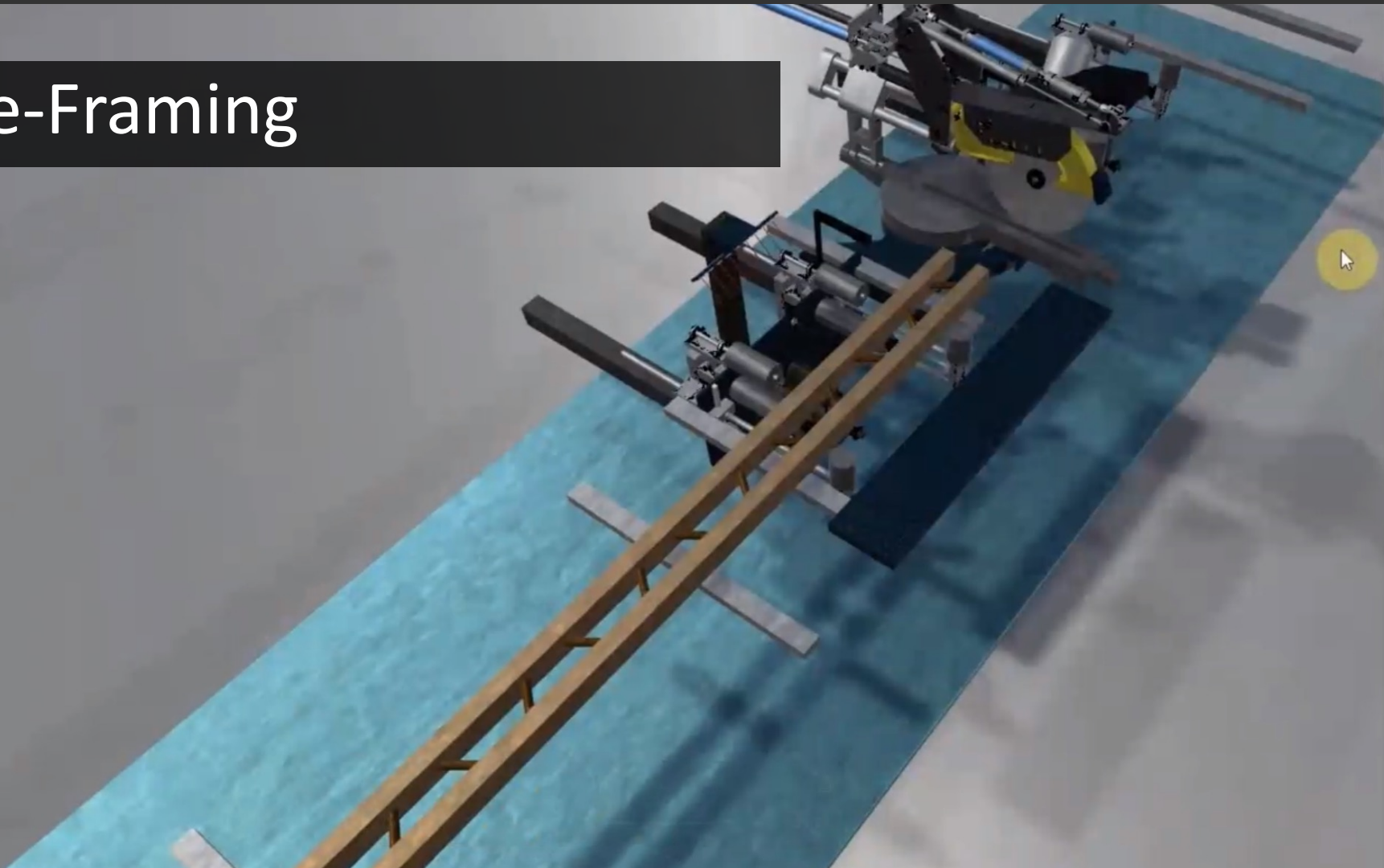
90-minute working session

Discovered:

- Dangerous extensions
- Ergonomics improvements
- Difficult manipulations
 - Beams / structs
 - Rivet guns

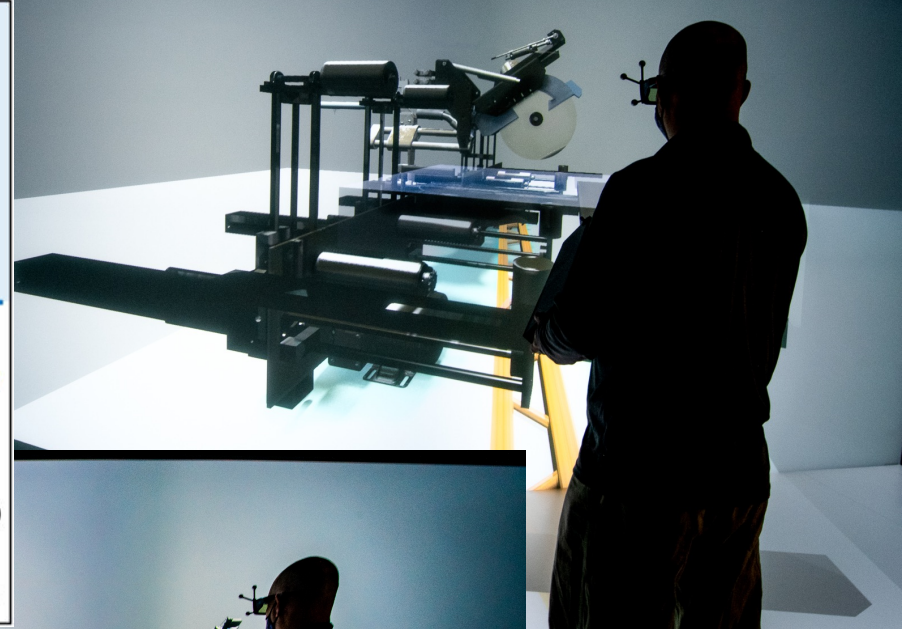
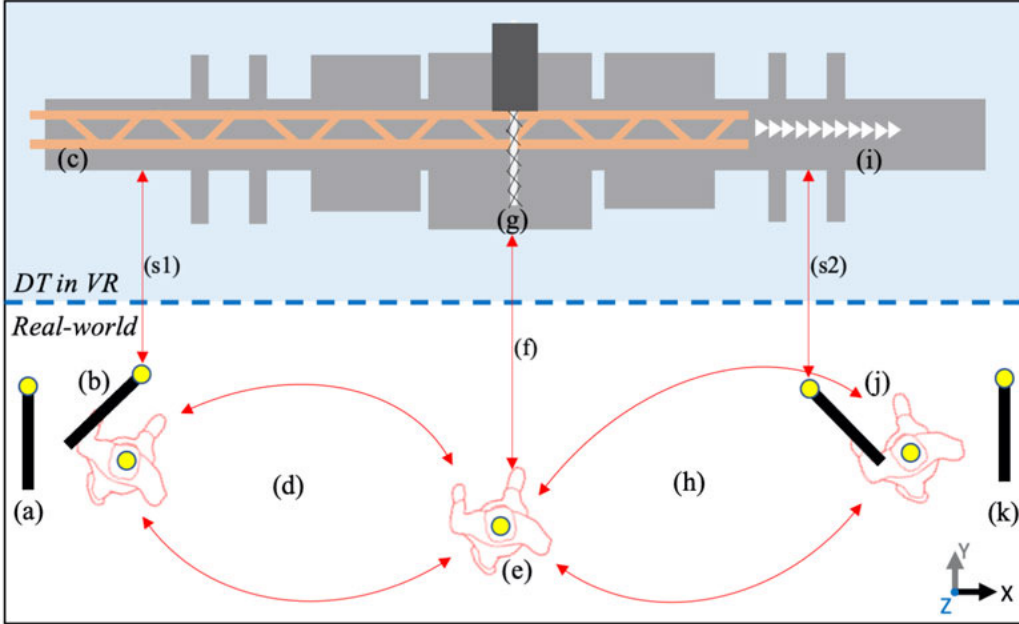


Pre-Framing



Insulated Truss Studs





REFERENCES

- A. Podder, K. Gruchalla, N. Brunhart-Lupo, S. Pless, M. Sica and P. Lacchin. **Immersive Industrialized Construction Environments for Energy Efficiency Construction Workforce.** *Frontiers in Virtual Reality*, March 2022.
- K. Gruchalla & N. Brunhart-Lupo. **The Utility of Virtual Reality for Science and Engineering** In W.R. Sherman (Ed.), *VR Developer Gems*, 2019.
- B. Bugbee, B.W. Bush, K. Gruchalla, K. Potter, N. Brunhart-Lupo, V. Krishnan. **Enabling Immersive Engagement in Energy System Models with Deep Learning.** *Statistical Analysis and Data Mining: The ASA Data Science Journal*, June 2019.
- B. Bush, N. Brunhart-Lupo, B. Bugbee, V. Krishnan, K. Potter, K. Gruchalla. **Coupling Visualization, Simulation, and Deep Learning for Ensemble Steering of Complex Energy Models.** *DSIA: Data Systems for Interactive Analysis*, October 2017.

ACKNOWLEDGMENTS



This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08G028308. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.