OAK RIDGE National Laboratory

ORNL Visual Analytics Research & the ORNL VISTA Center

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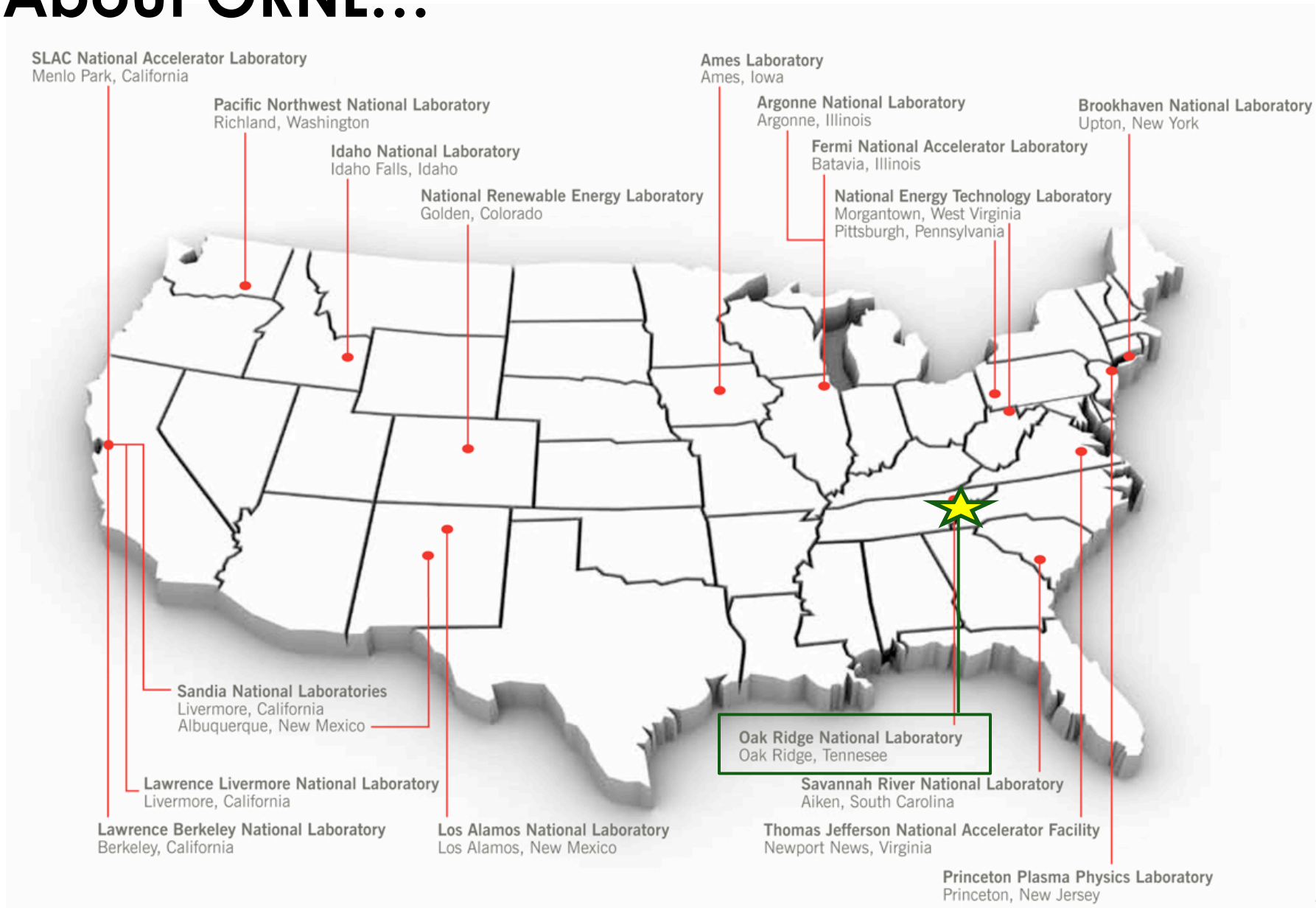
U.S. DEPARTMENT OF ENERGY

Talk Overview

- ORNL Overview
- ORNL Visual Analytics R&D Overview
- Deep Dive on Additive Manufacturing Visual Analytics Project
- Highlights of other Visual Analytics Projects
- The ORNL VISTA Center
- Career Opportunities at ORNL
- Conclusion

A Little About ORNL…



DOE National Laboratories

As stated in the DOE Strategic Plan*, National Laboratories . . .

- Solve important problems in fundamental science, energy, and national security.
- Steward vital scientific and engineering capabilities including technology transfer that are essential to our nation's continued science and technology primacy in a rapidly changing world.
- Design, build, and operate unique scientific instrumentation and facilities that serve tens of thousands of scientists and engineers from academia, government, and industry collaborating on solutions to pressing and complex problems.
- Promote innovation that advances U.S. economic competitiveness and contributes to our future prosperity.

*http://energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf

ORNL's mission

Deliver scientific discoveries and technical breakthroughs
that will accelerate the development and deployment of solutions
in clean energy and global security, and in doing so
create economic opportunity for the nation

Signature strengths

- Computational science and engineering
- Materials science and engineering
- Neutron science and technology
- Nuclear science and technology

CCSD vision

Sustain leadership and scientific impact in computing and computational sciences

- Provide world's most powerful open resources for scalable computing and simulation, data and analytics, and infrastructure for science
- Follow a well-defined path for maintaining world leadership in these critical areas
- Attract the brightest talent and partnerships from all over the world
- Deliver leading-edge science relevant to missions of DOE and key federal and state agencies
- Invest in cross-cutting partnerships with industry
- Provide unique opportunity for innovation based on multiagency collaboration
- Invest in education and training

DATA

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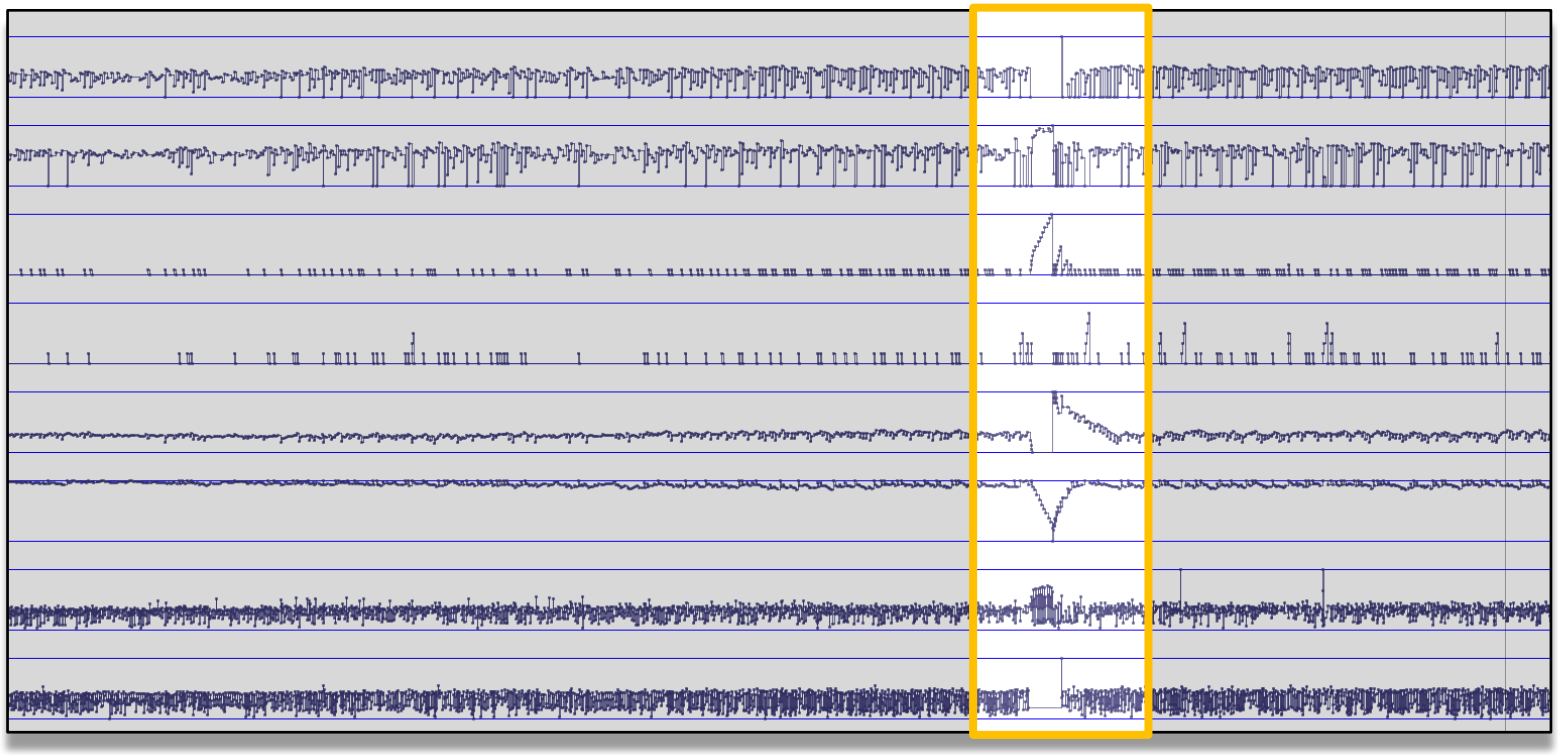
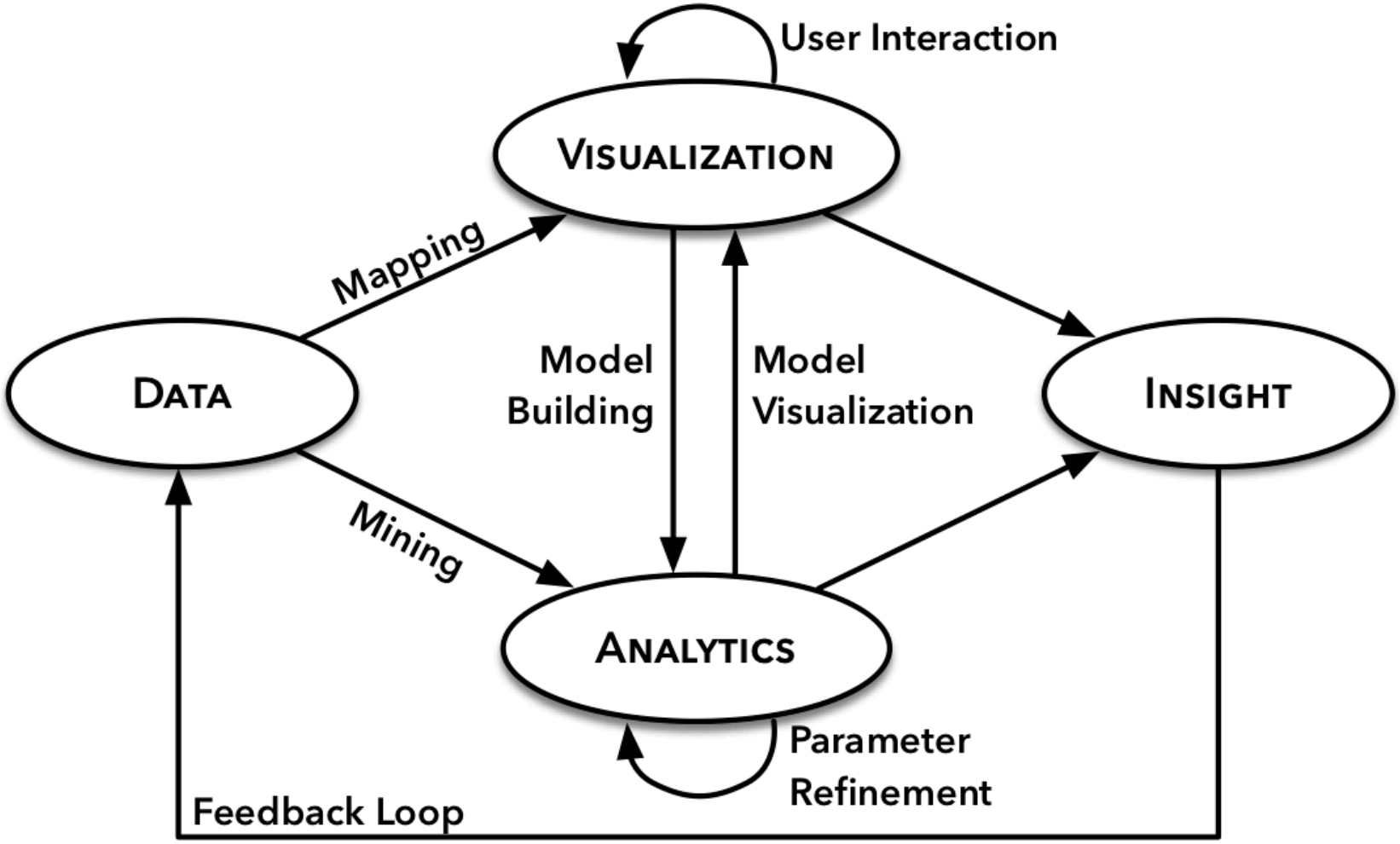
Insight



Visual Analytics: Uniting Humans and Computational Strengths

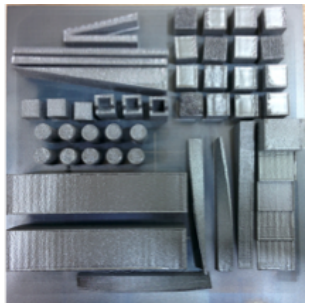


A Typical ORNL Data Visualization Project

Domain Experts
Dr. Ryan Dehoff
Additive Manufacturing

Scientific Domains
Large-scale 3D Printing

Real-world Data
Large, Complex, Unique



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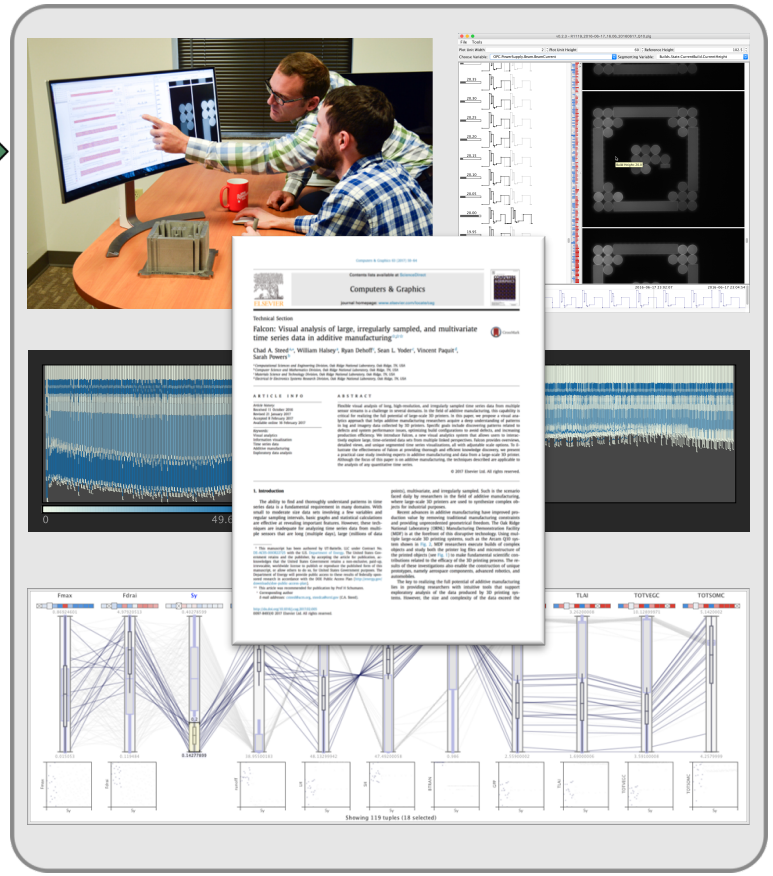
Results / Artifacts
Tools, Techniques, Publications, Patents, Open Source Software



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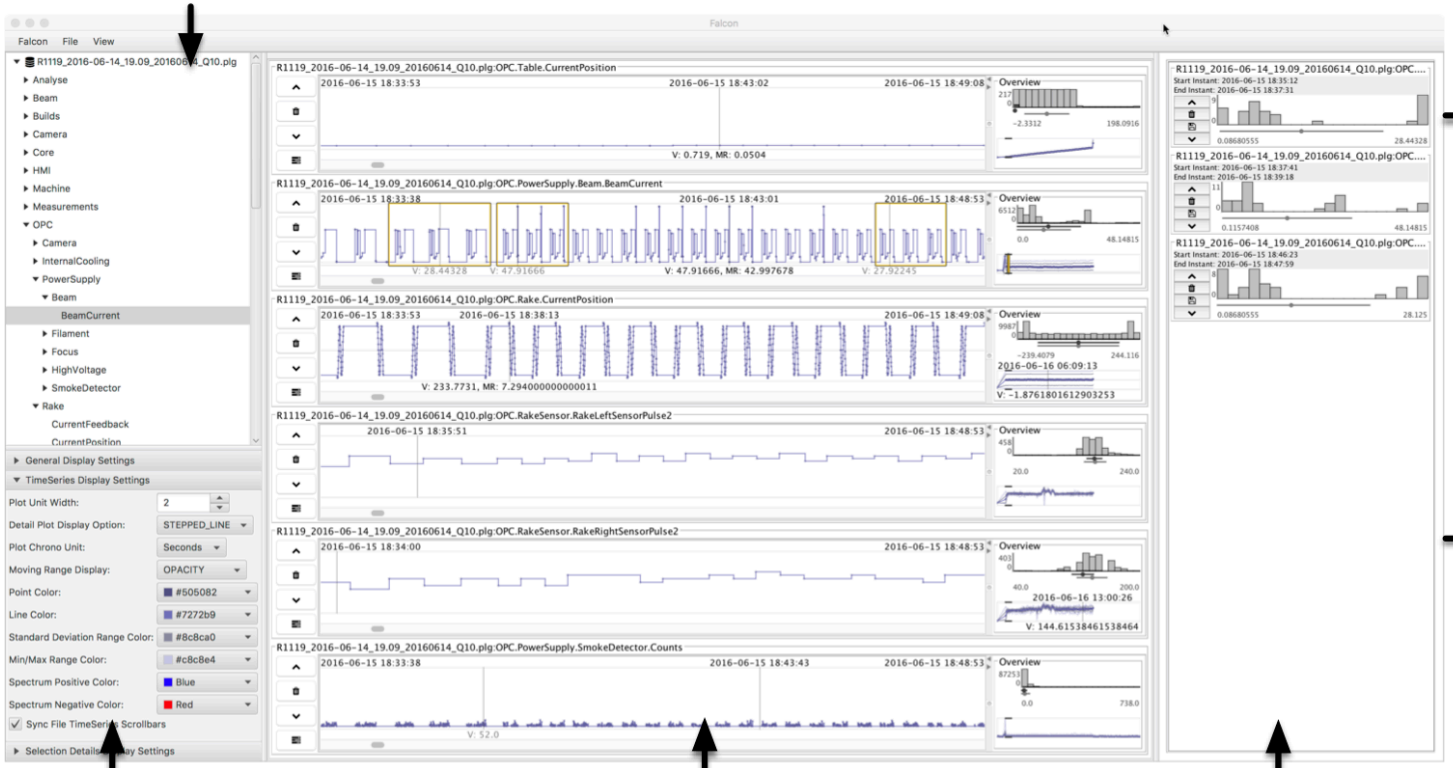
Introducing Falcon

Main Analysis Window

File / Variables Tree View

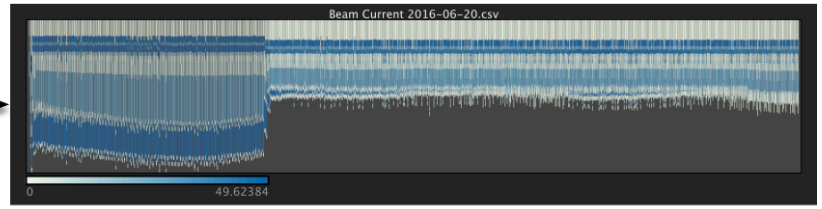


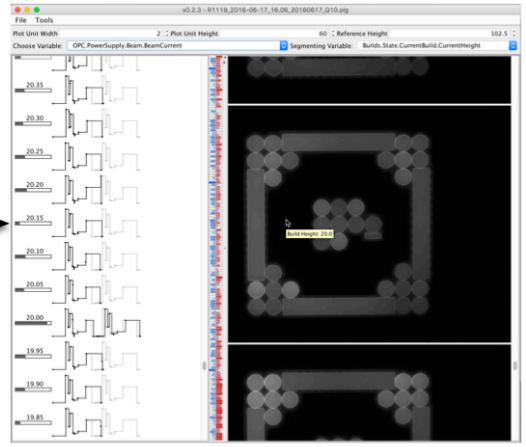
Settings Panel

Variable Visualization Panel
(Left: detailed time series, Right: overview)

Selection Details Panel

Waterfall Visualization





Segmented Time Series Visualization

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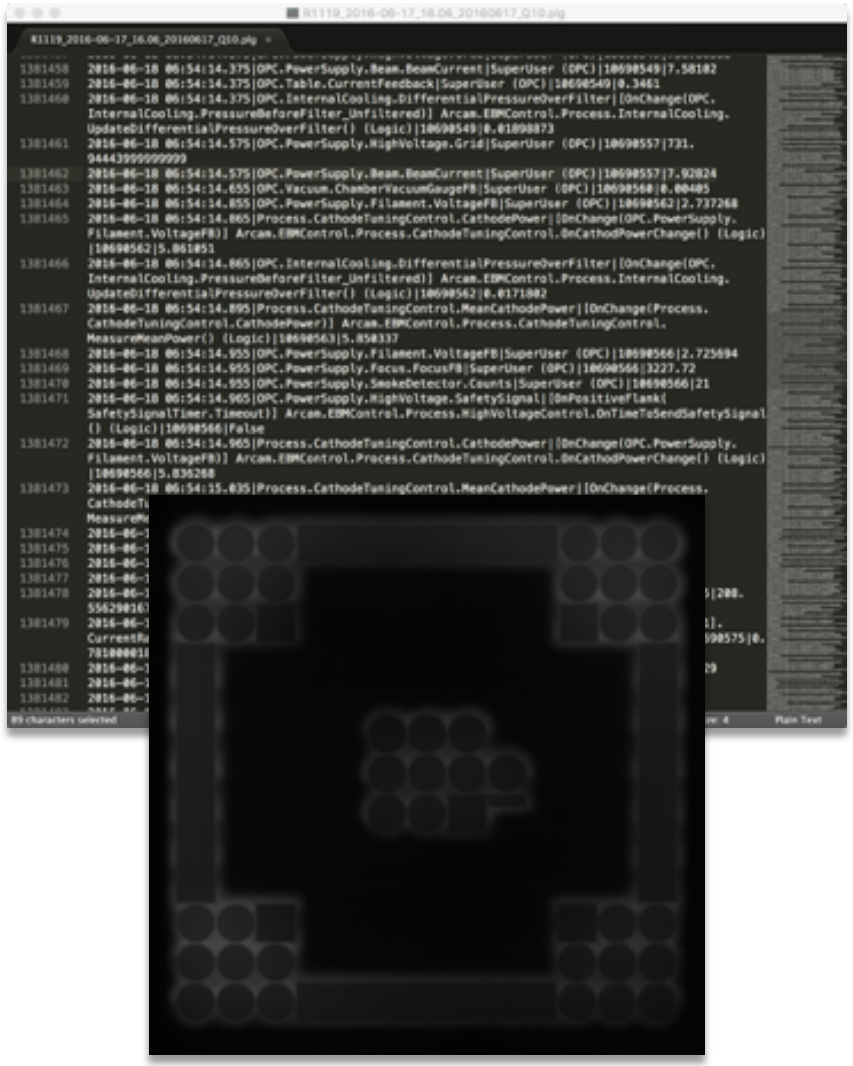
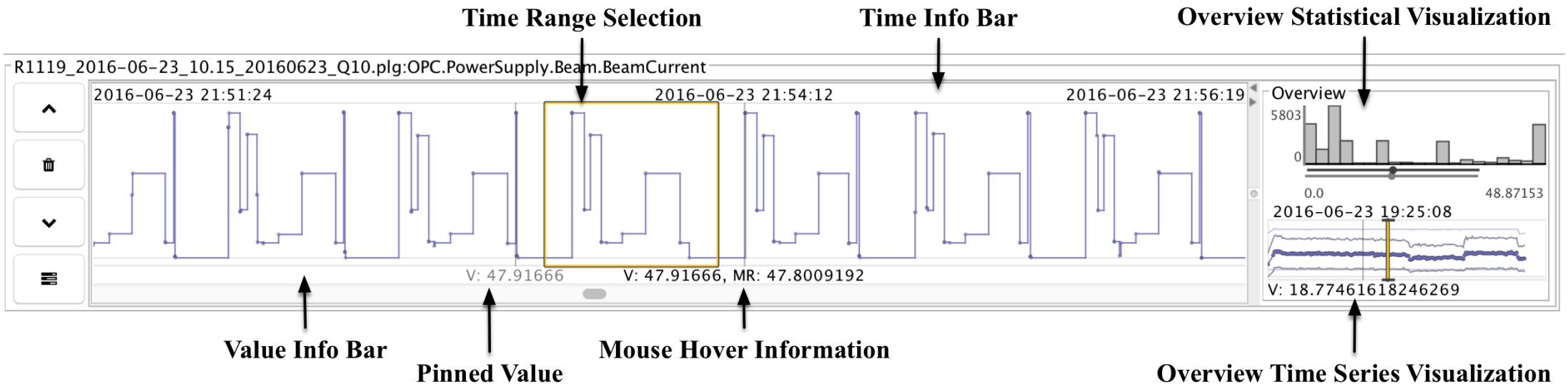
Data Transformation and Modeling

- Log files are read into time-based bins at variable levels of detail
  - Support drill down / roll up between overviews and detailed visualizations
- Statistical summaries derived from raw data
- Only read variable data into memory if requested
- CSV import or custom reader available

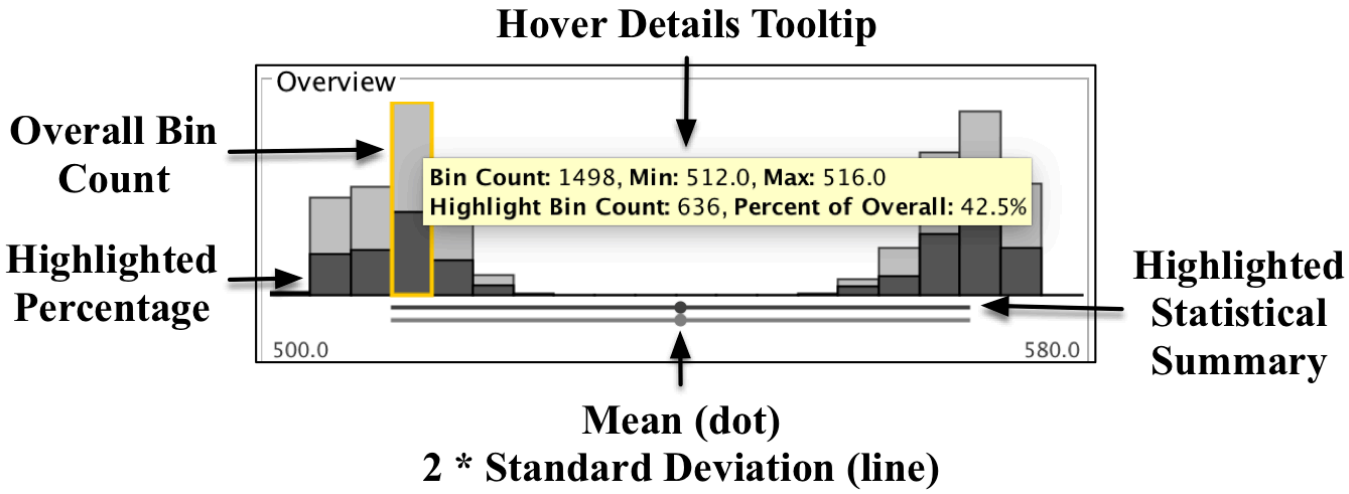


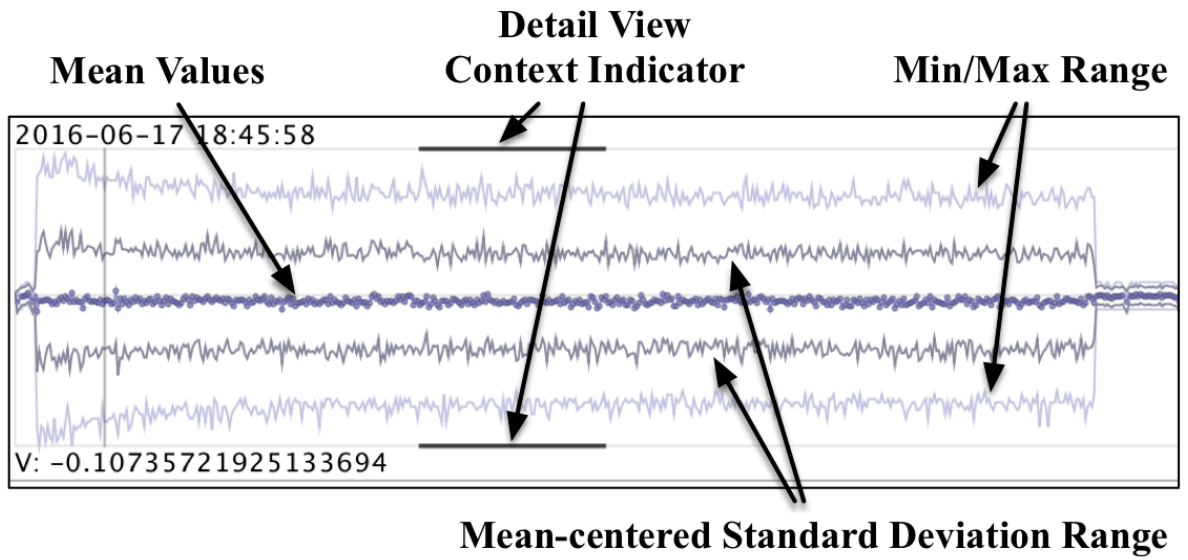
Variable Visualization Panel

- Consists of 1 detail visualizations and 2 overviews for a particular variable of interest (stacked for multiple variables)
- Interactions within each view are linked
- Details-on-demand capabilities

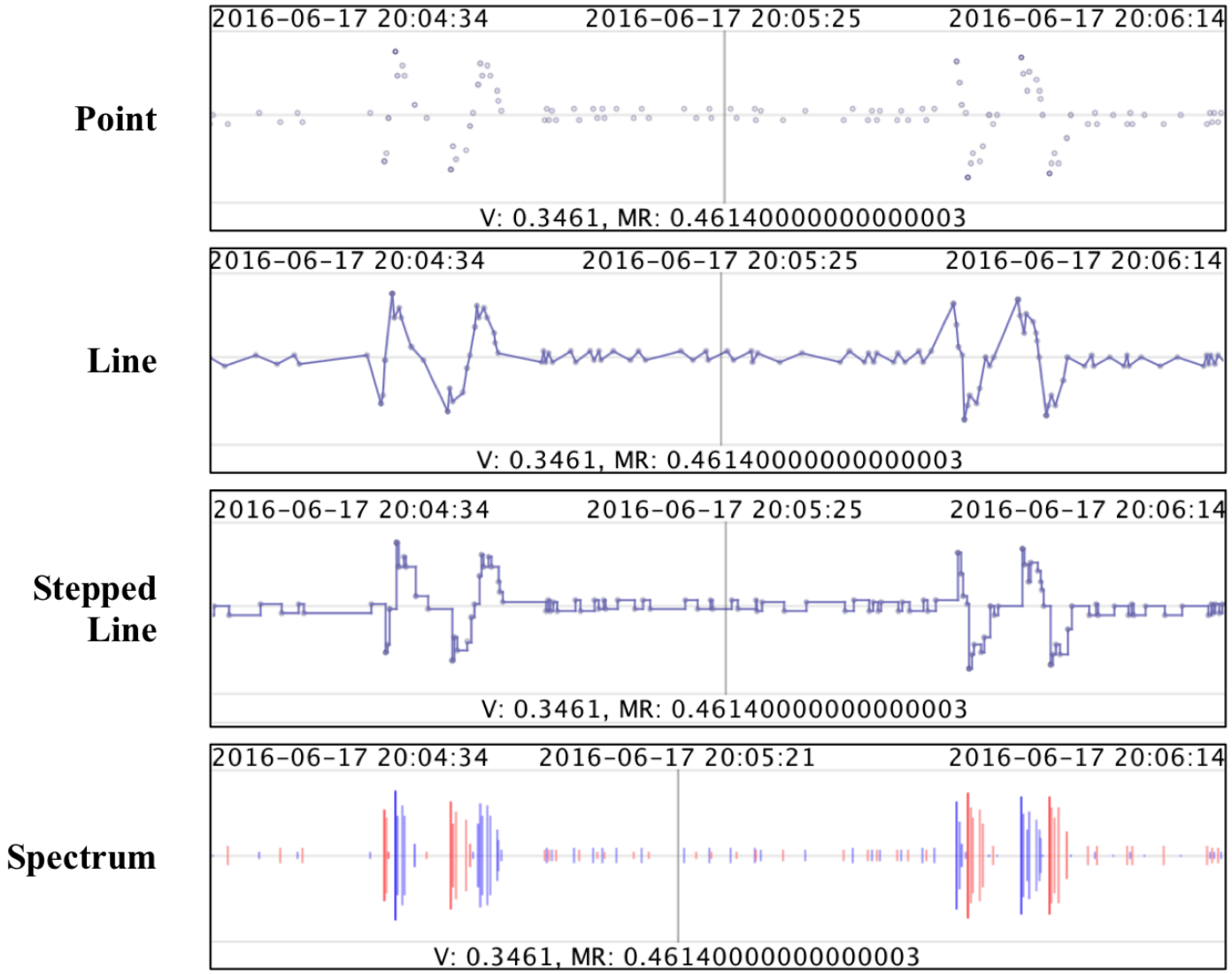


Overview Variable Visualizations

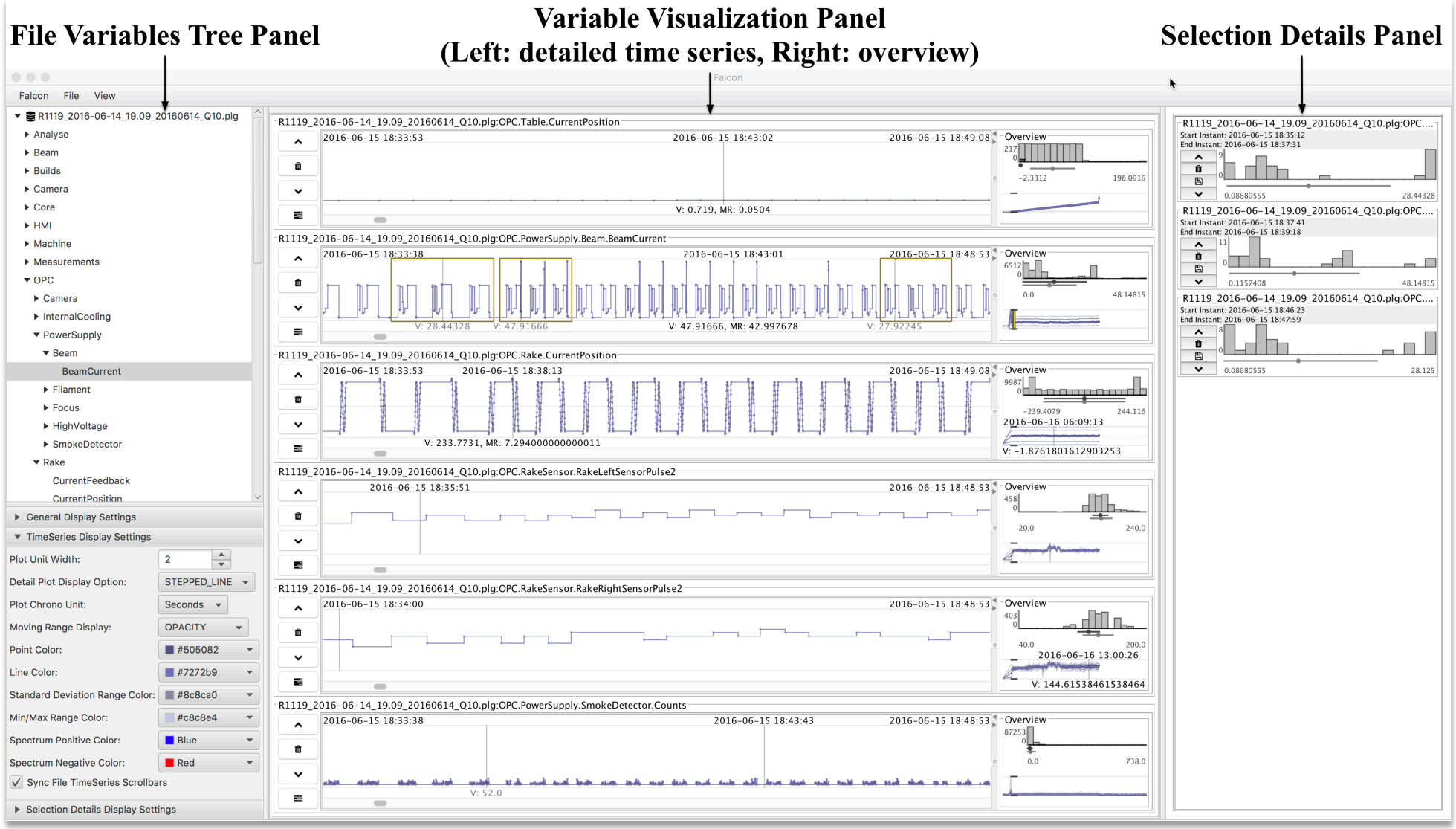




Detailed Time Series Visualization Modes



Selection Details Visualization Panel



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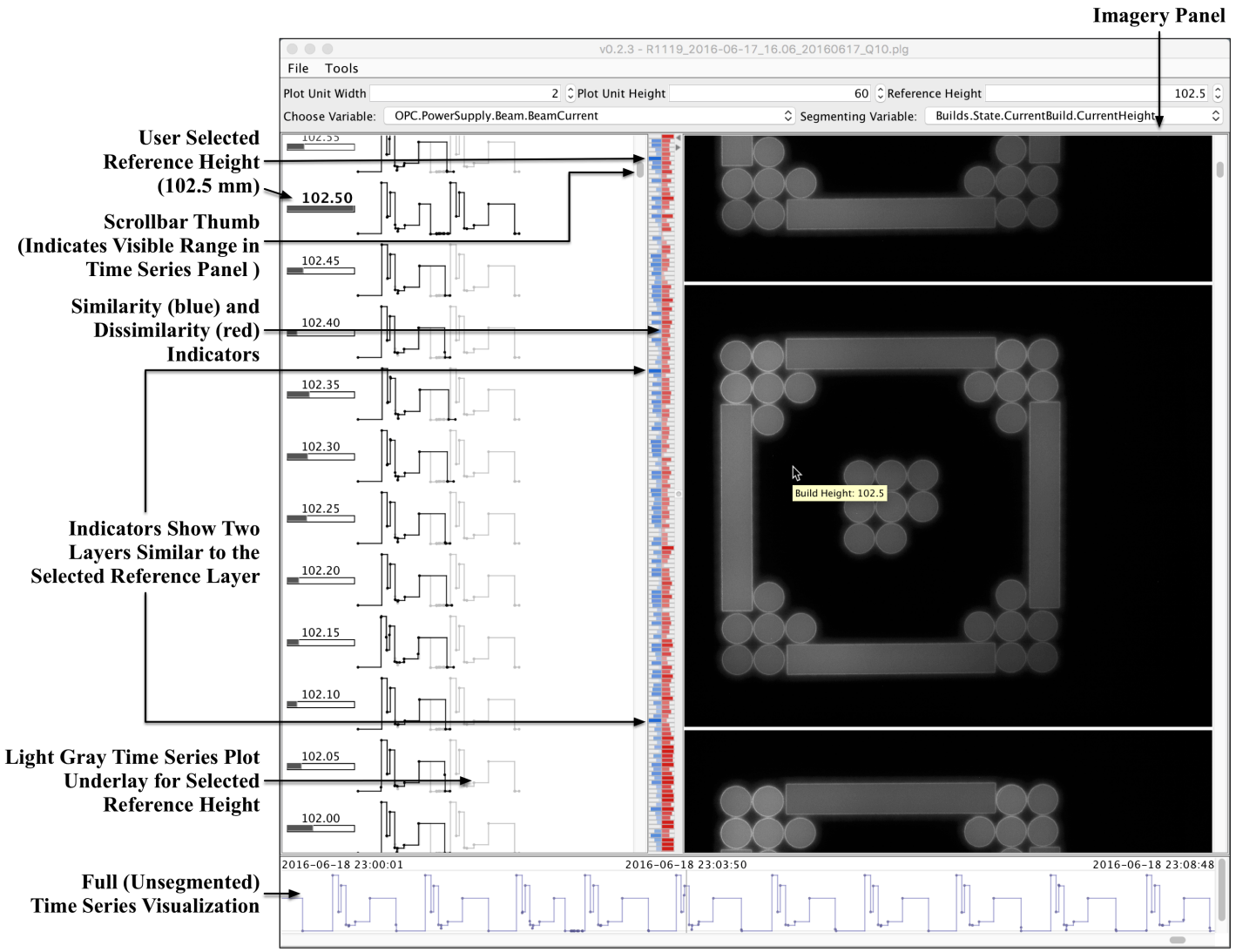
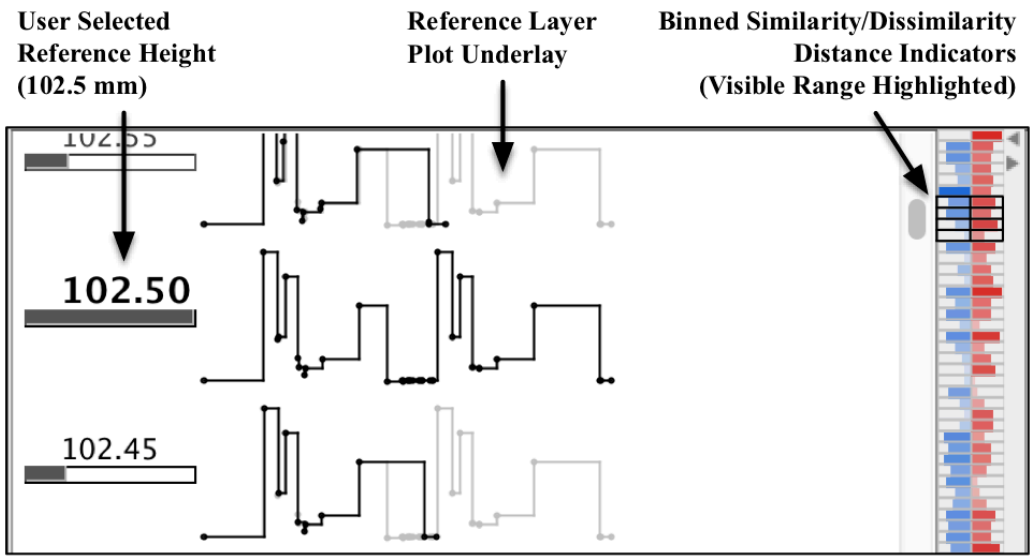
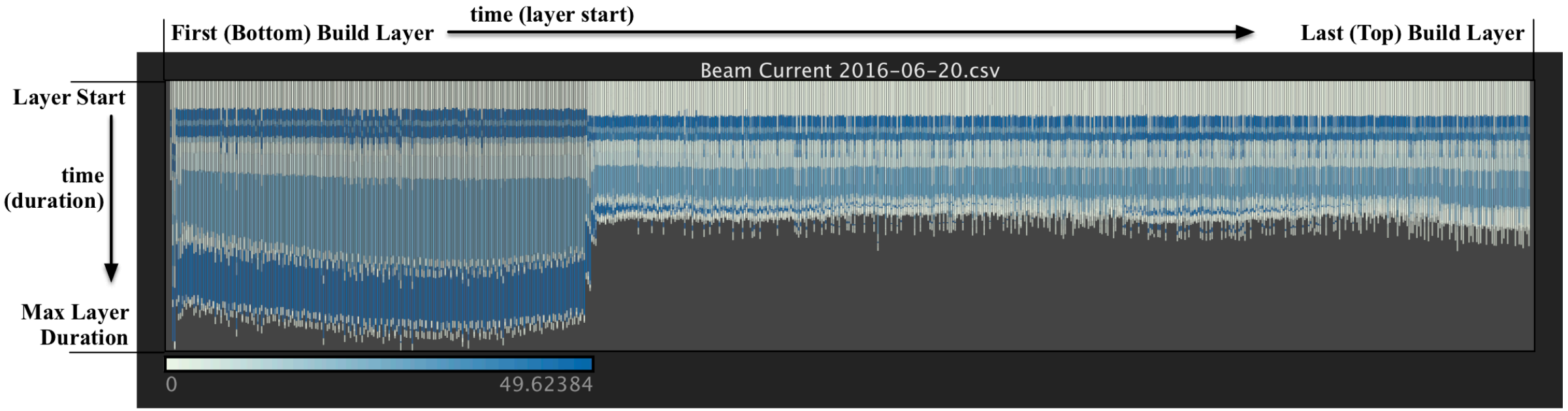
Segmented Time Series Visualization (Layers + Imagery)

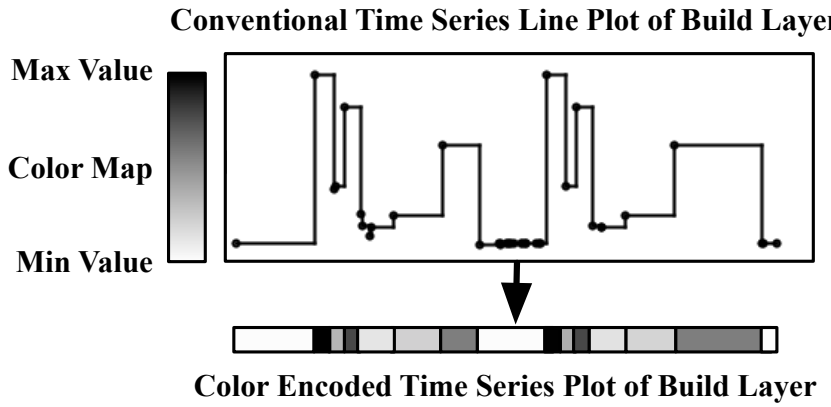


Closeup of Similarity Metrics



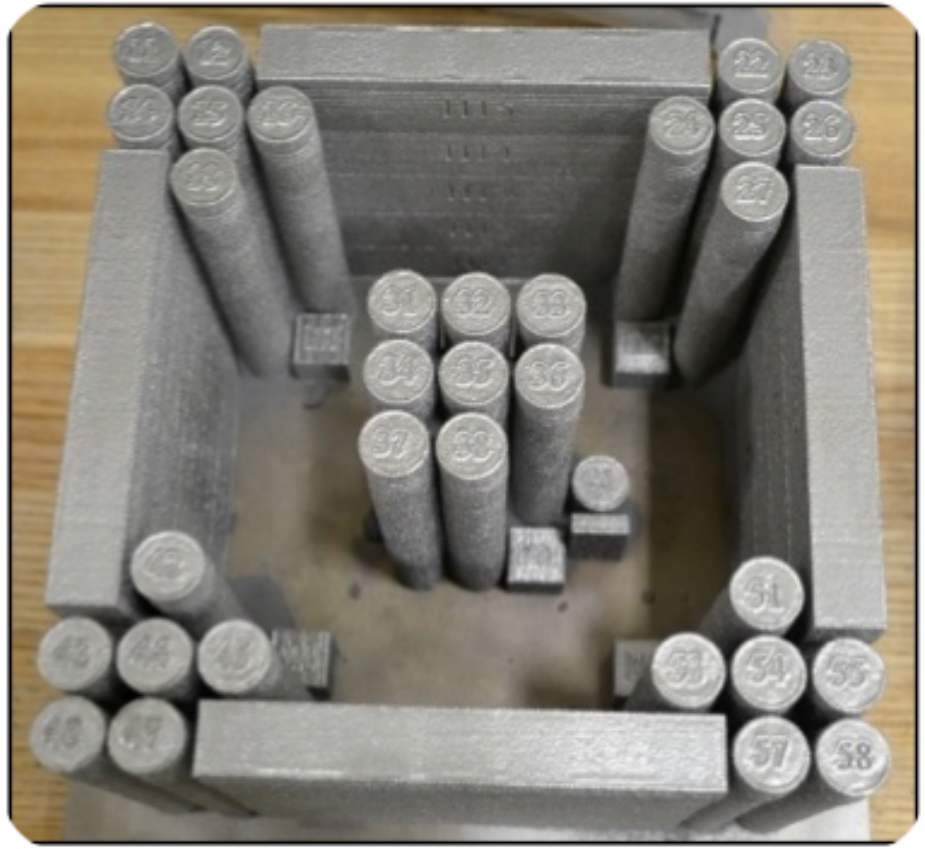
Concise Segmented Visualization (DNA Plot of a 3D Print)





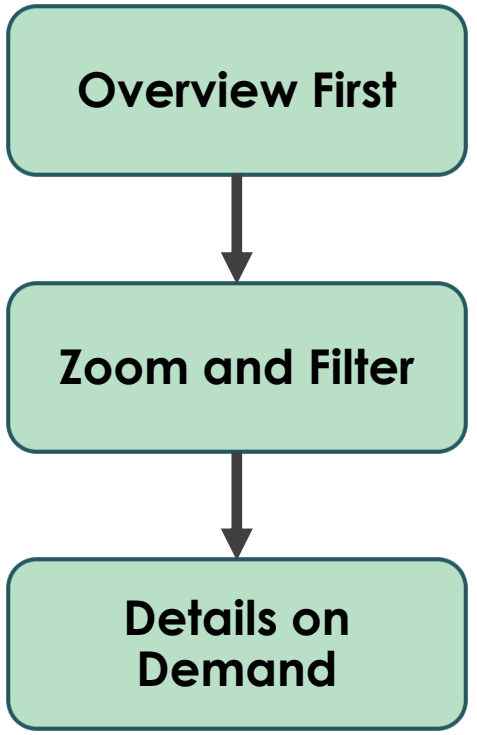
Case Study: Analysis of 3D Printer Build

- Arcam Q10 3D Printer System
  - Uses electron beam melting to synthesize metallic objects
- Data from the build of a special test configuration used to ensure the Q10 system is functioning properly
- Four distinct geometrical layouts and 5 specific features
- Created entirely from the build platform without support structures



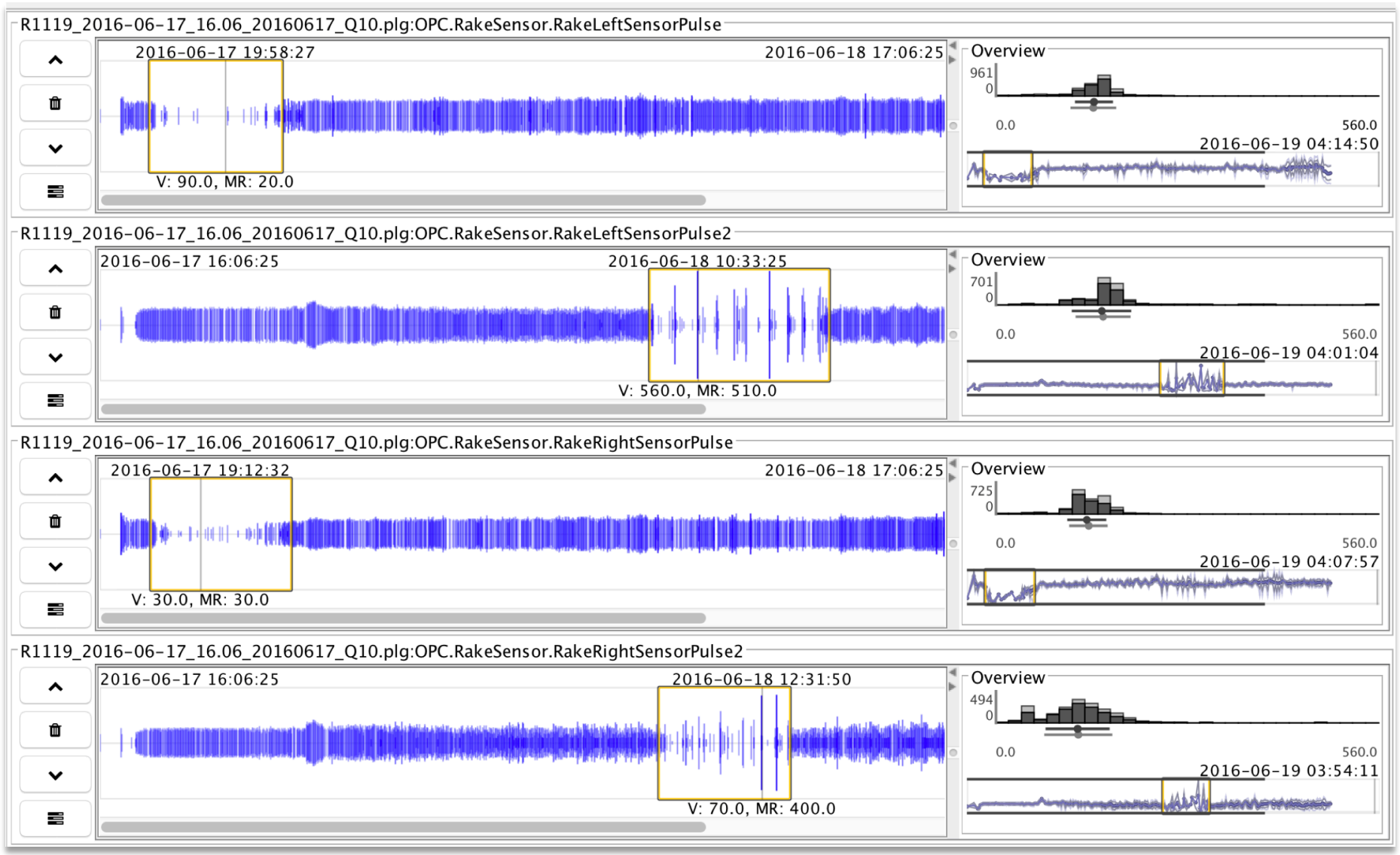
General Analysis Strategy Using Falcon

- Researchers naturally gravitated toward a workflow that parallels Shneiderman's visual information seeking strategy*
- Being with overview of key variables
- Drill down to explore patterns
- Note interesting patterns and trends along the way
- Combine log and imagery data for big picture
- Follow-up with physical investigations to validate findings (e.g., scanning microscopy)



* B. Shneiderman. "The eyes have it: A task by data type taxonomy for information visualizations." In Proceedings of the IEEE Symposium on Visual Languages, pp. 336–343, 1996.

Overview First



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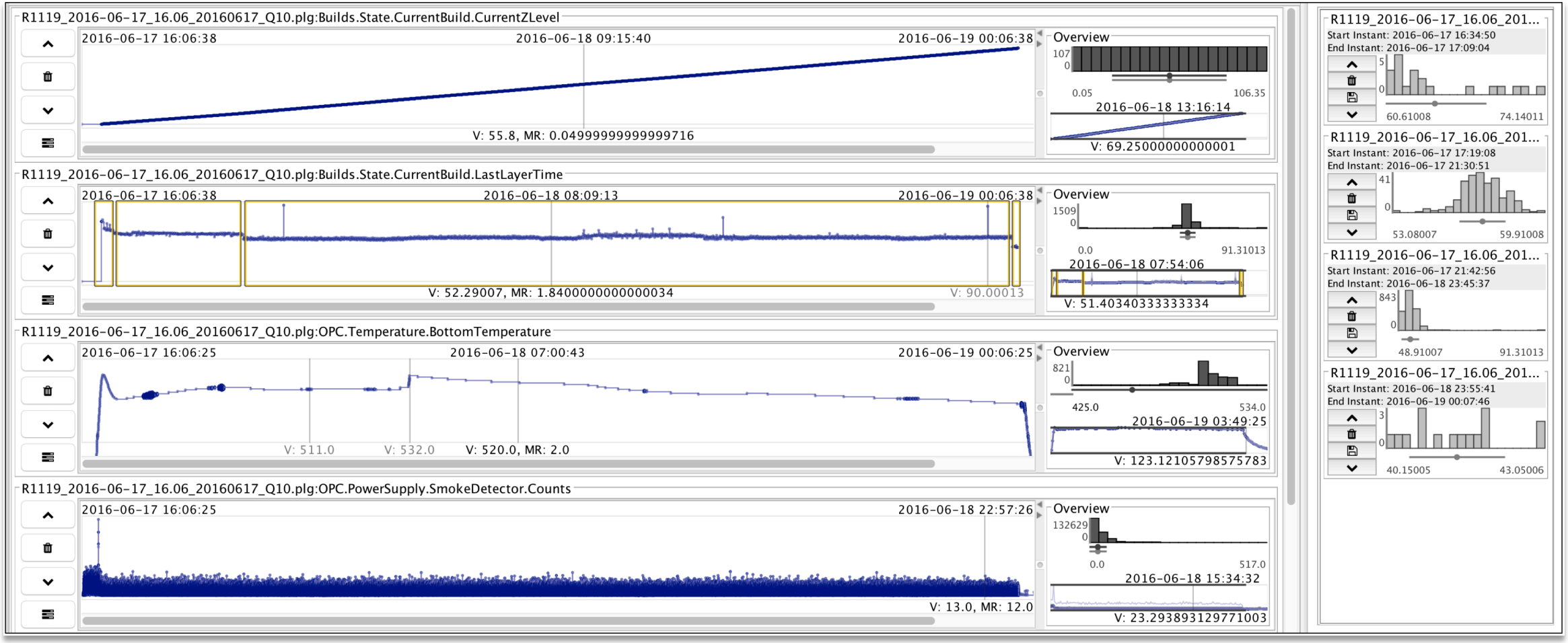
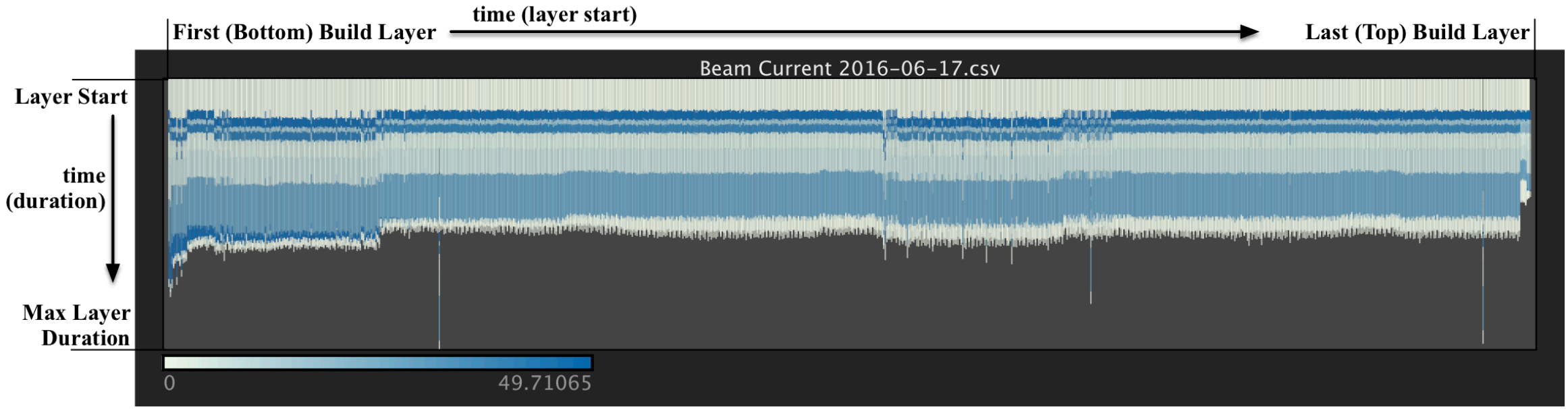
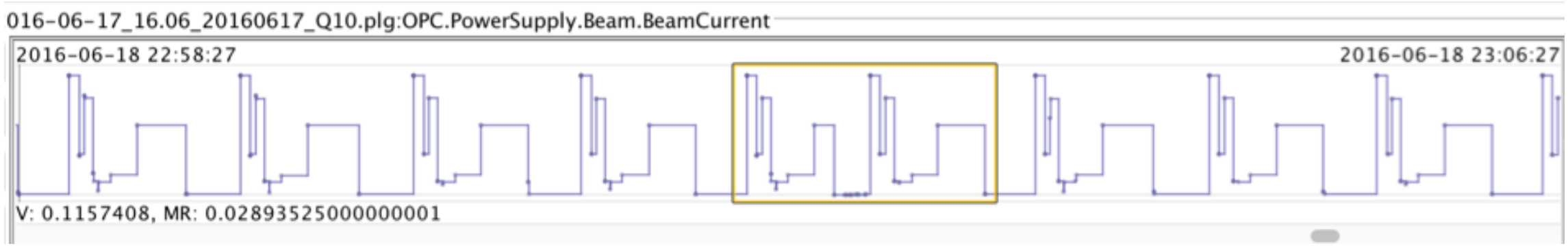
Overview First

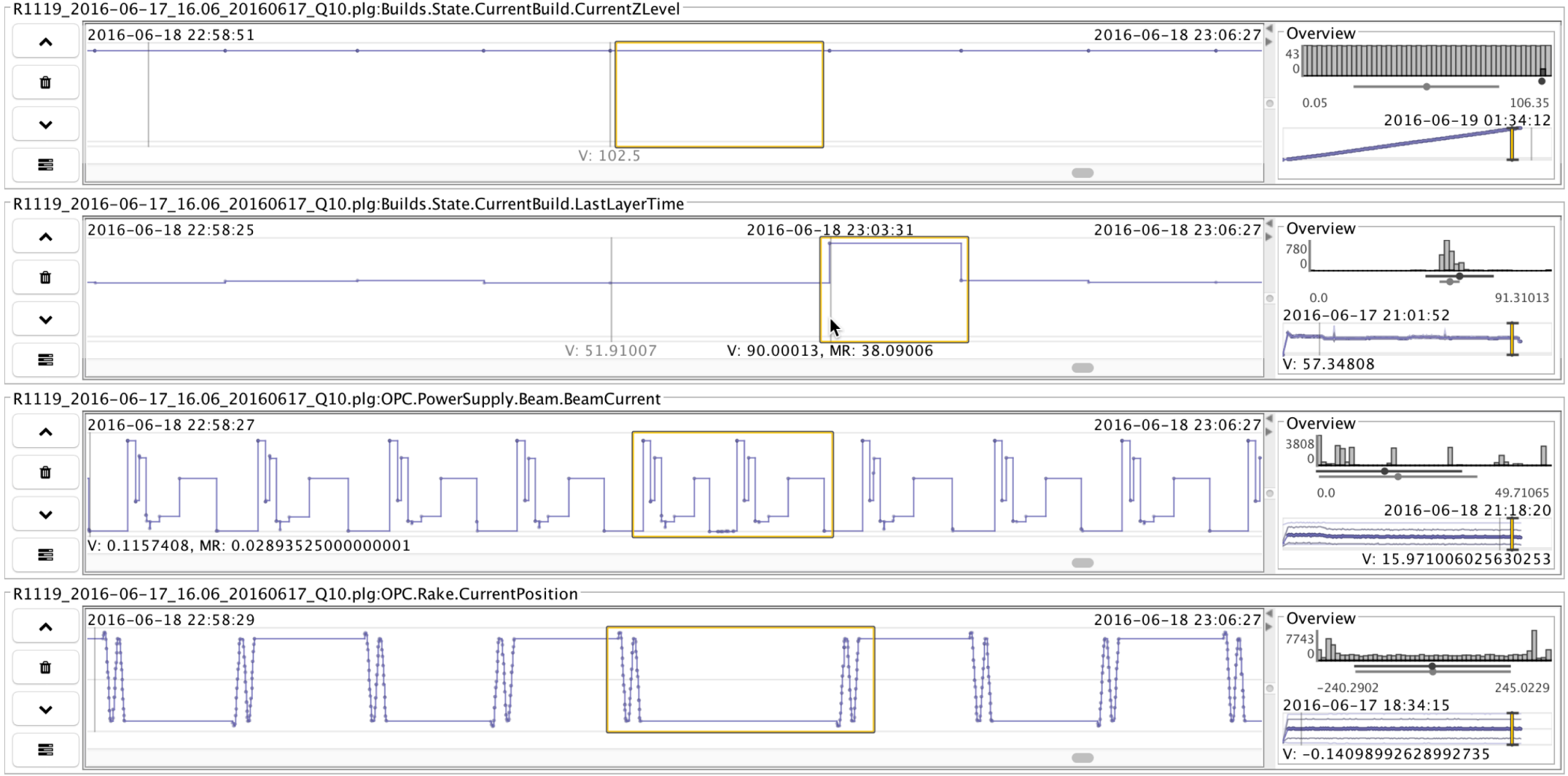


Overview for Particular Variable (Electron Beam Current)

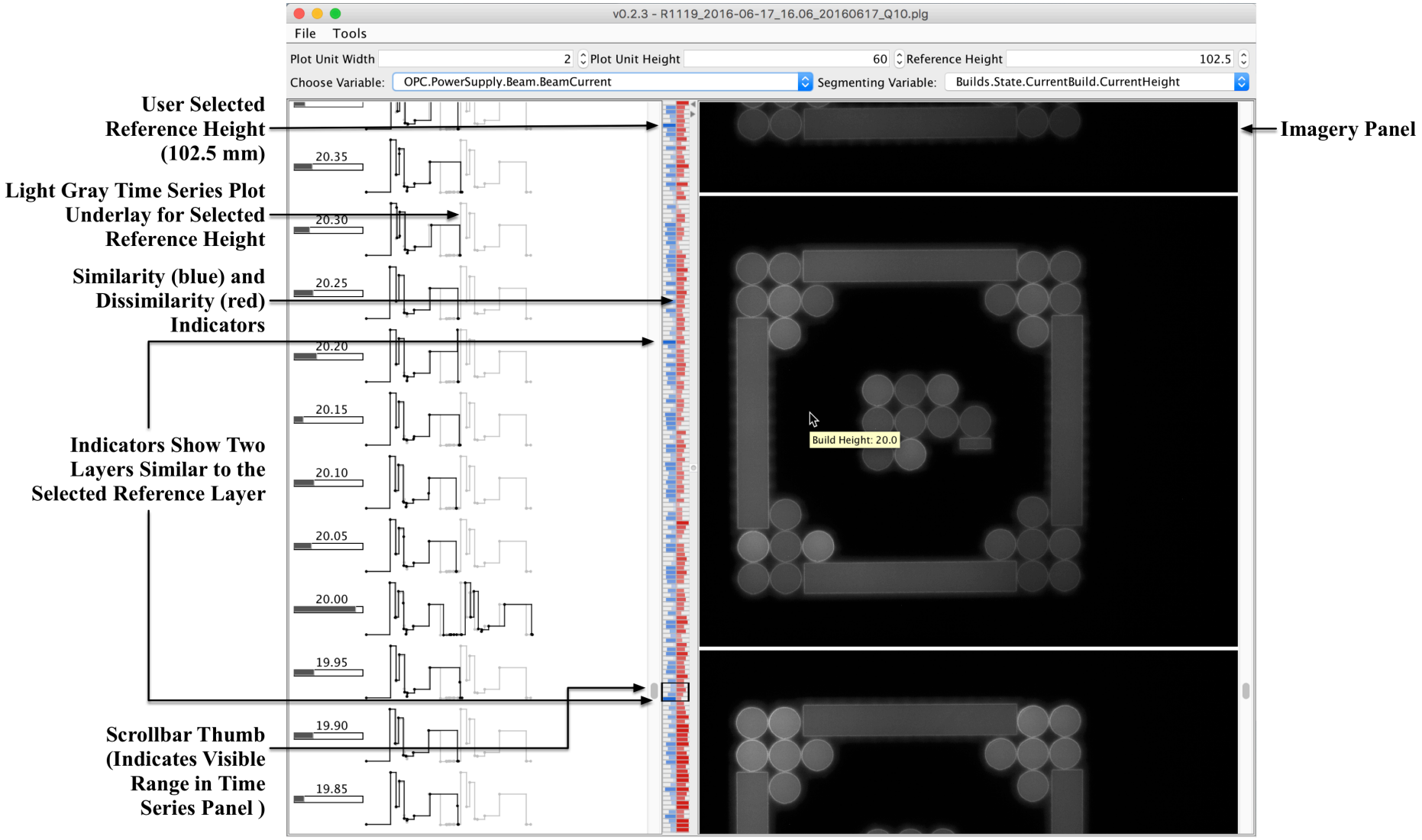




Zoom and Filter



More Detail, on Demand



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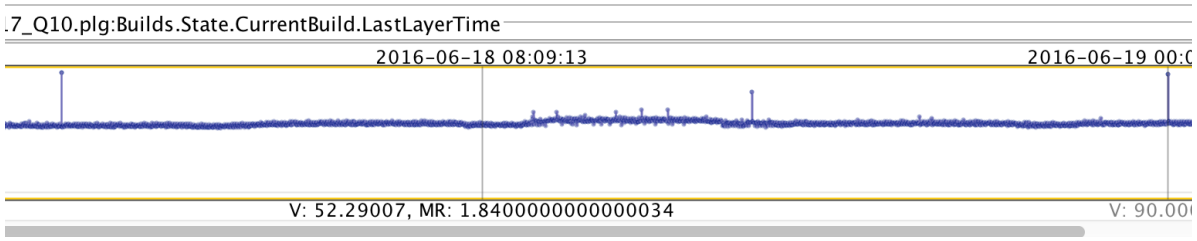
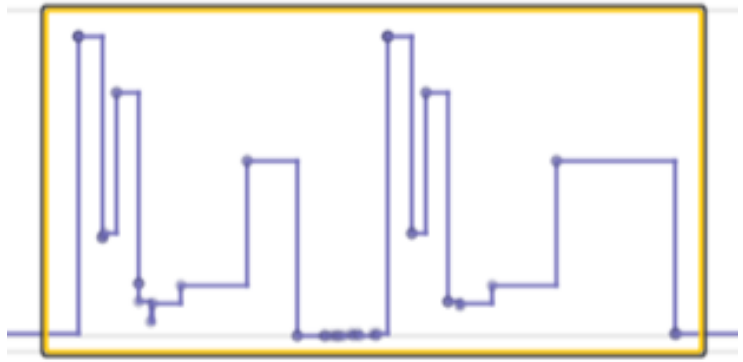
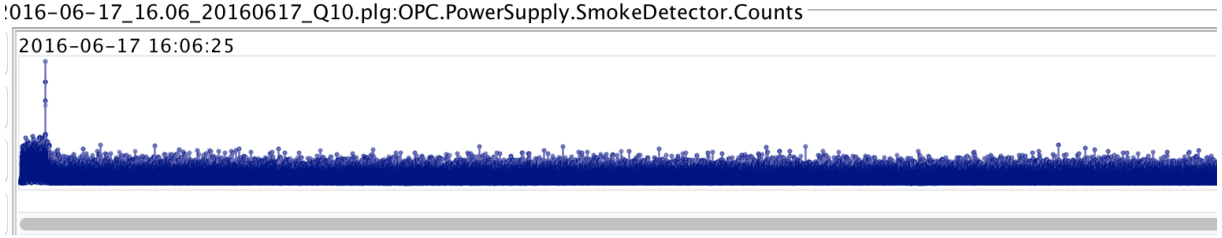
Identifying the Cause of the Outliers

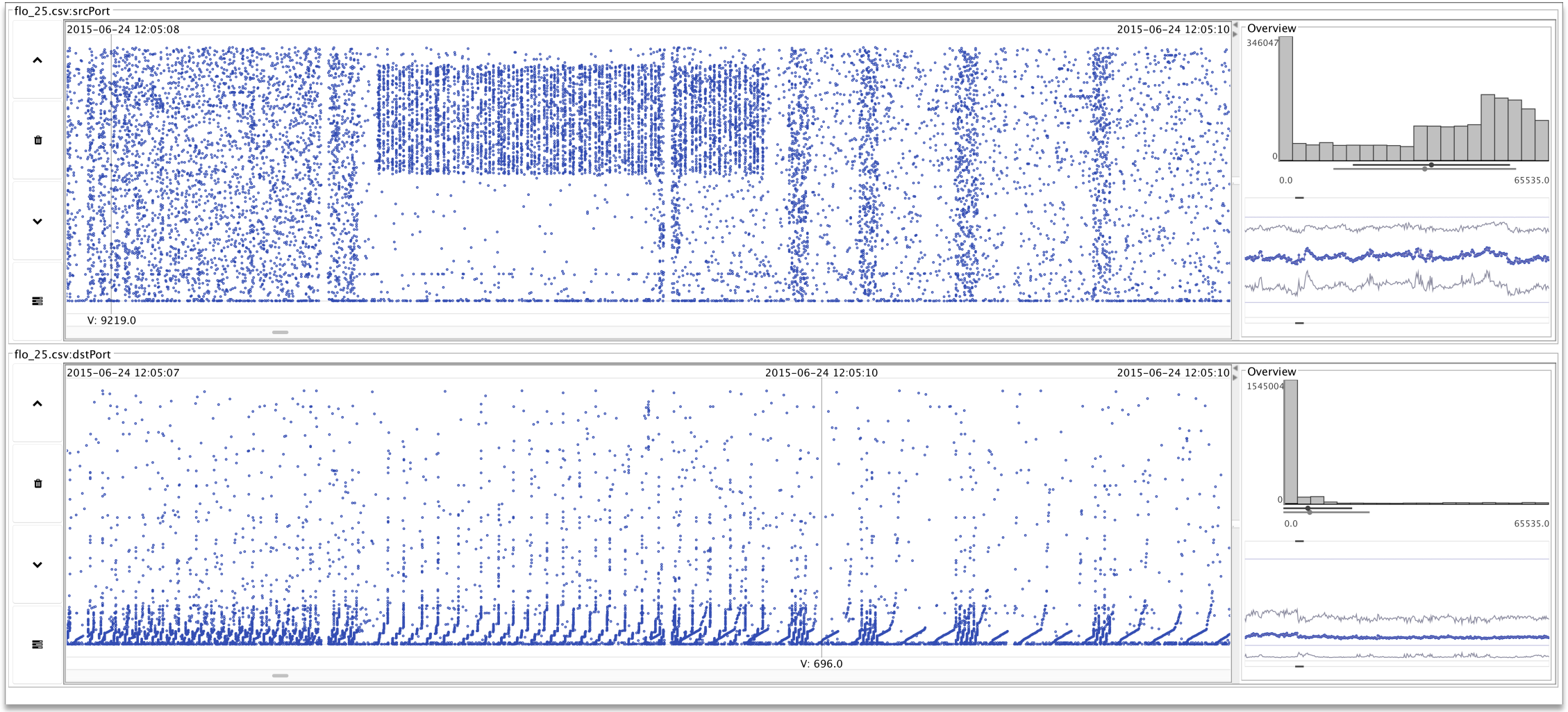
- Two possibilities:
  - Smoke Detector Reset
  - Arc Trip
- Both cause signal repeats
- Here, arc trip is the cause
- This insight led to additional study to see how arc trips affect the microstructure of a build.







Falcon Applied to Network Flow Analysis



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CrossVis: Guided Exploratory Data Analysis

Scientific Achievement

CrossVis enables flexible exploration and comprehensive understanding of large, heterogeneous, and multivariate data by integrating interactive visualizations and statistical analytics.

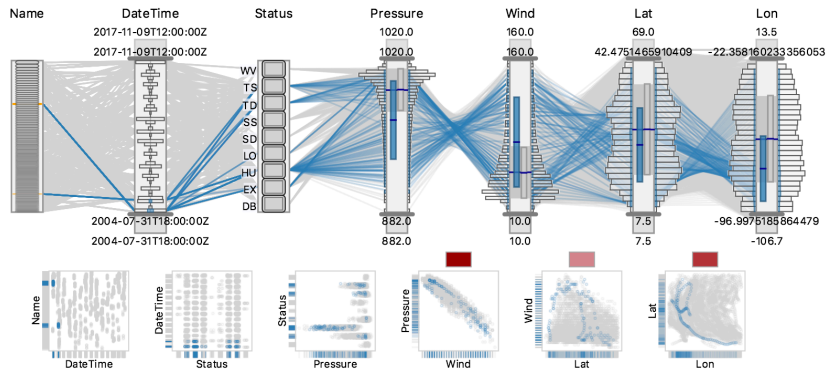
Significance and Impact

CrossVis helped materials scientists at ORNL CNMS understand and improve a neural network classification process for microscopic imagery with genetic engineering applications.

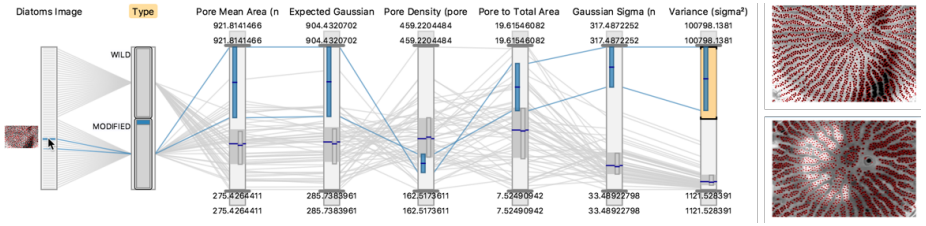
CrossVis allowed ORNL BER climate scientists to consider more variables from large scale, land model parameter sensitivity analyses and ultimately improve DOE model accuracy.

Research Details

- CrossVis implements theoretical information foraging concepts, whereby information dynamically derived from statistical analytics are used to augment interactive data visualizations making key patterns visually salient.
- CrossVis provides an advanced multivariate visual analytics framework supporting heterogenous data types (e.g., images, temporal, categorical), progressive high-performance rendering, and a scalable data model.
- Design requirements stem from over a decade of experience collaborating with scientists from a variety of domains.



Exploration of Historical Hurricane Observations

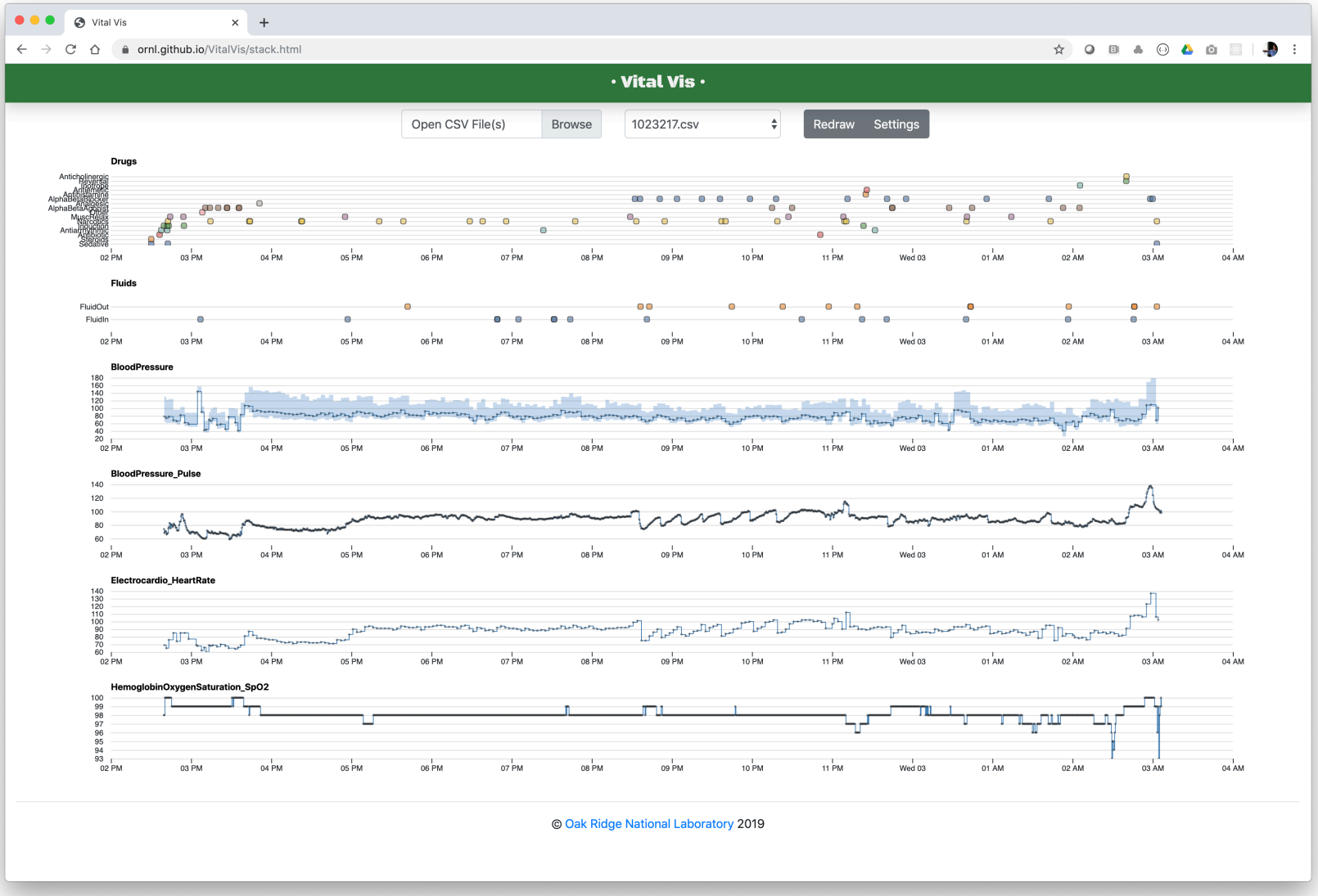


Analyze Neural Networks for Microscopic Imagery

CrossVis is a visual analytics tool that integrates statistical analytics and an extended version of parallel coordinates to allow flexible exploratory of large and heterogenous multivariate data. In addition to climate and materials science, CrossVis has been applied to cyber security, manufacturing, power grid, and system performance projects.

Citation: A. Trofimov, … **C. Steed.** "Deep Data Analytics for Genetic Engineering of Diatoms Linking Genotype to Phenotype via Machine Learning", *npj Computational Materials*, 2019.

VitalVis: Visual Exploration of Anesthesiology Data



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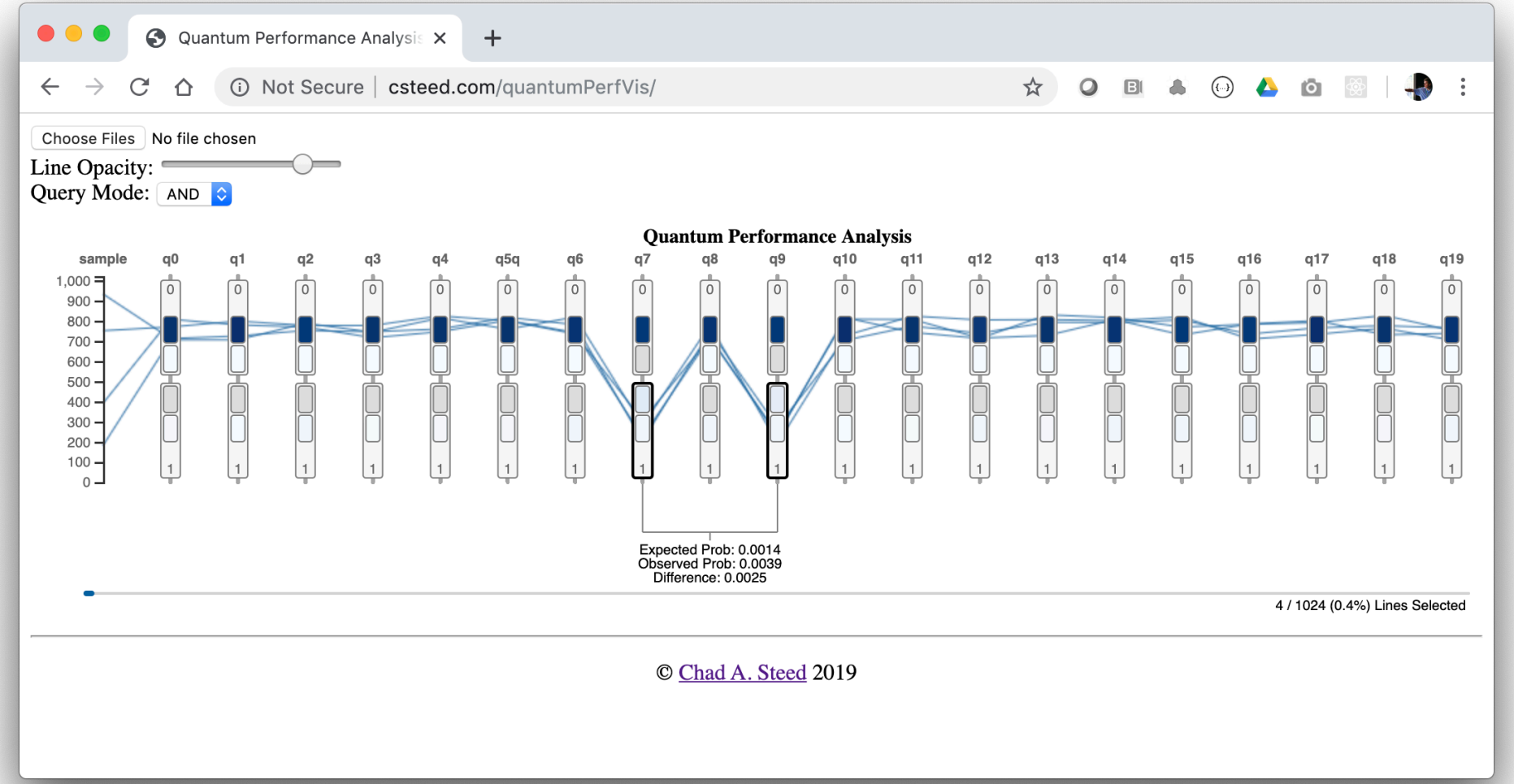
Visual Analysis of Quantum Computing Experiments



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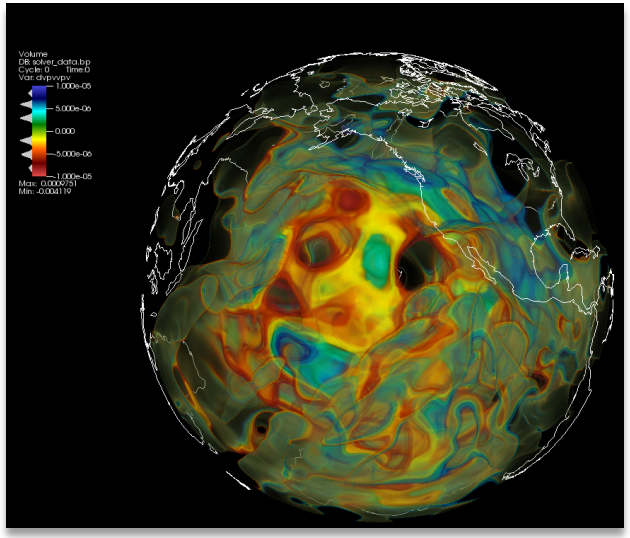
Current State of Data Visualization at ORNL

- Data visualization plays an **important role** in most projects
  - Teams either recruit visualization help or develop in-house solutions
  - Success of projects often hinges on delivering effective visualizations
  - Sometimes data visualization design is delayed until near the end

- Significant expertise / resources that are **mostly disconnected**
  - Experts across all the data visualization sub-disciplines
  - Visualization community is missing
  - Visualization labs are usually not connected

- Data visualization capabilities and highlights have **low visibility**
  - Tools and techniques developed at ORNL are hard to find
  - Domain experts have trouble finding data visualization expertise



PROPOSED SOLUTION:

Establish a Hub for Data Visualization at ORNL

ORNL VISTA Lab Mission

Improve domain experts' ability to explore large and complex data through interactive data visualization and analysis research and development

Build a data visualization community that spans directorates and highlight its work

Form a bridge connecting data visualization expertise to domain-specific data analysis challenges of national significance

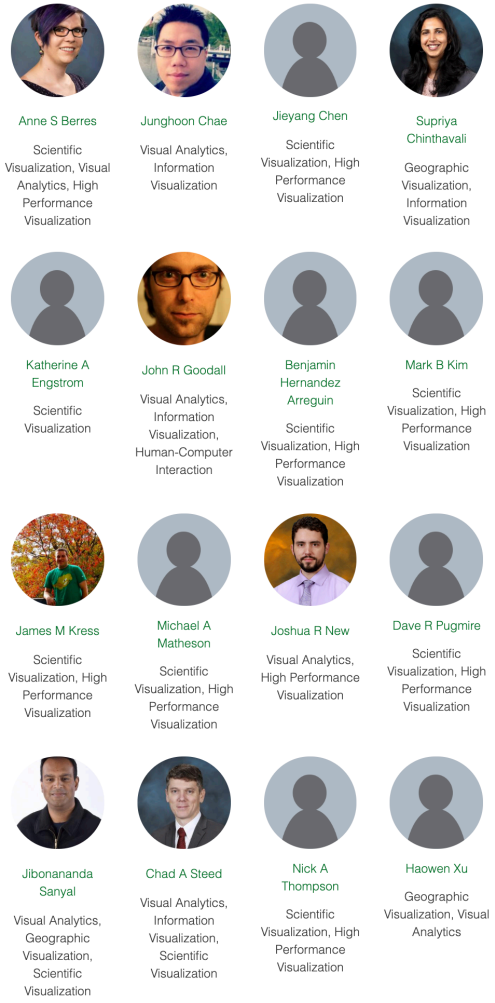
Establish an innovative laboratory with interactive displays and software for collaboratively exploring data

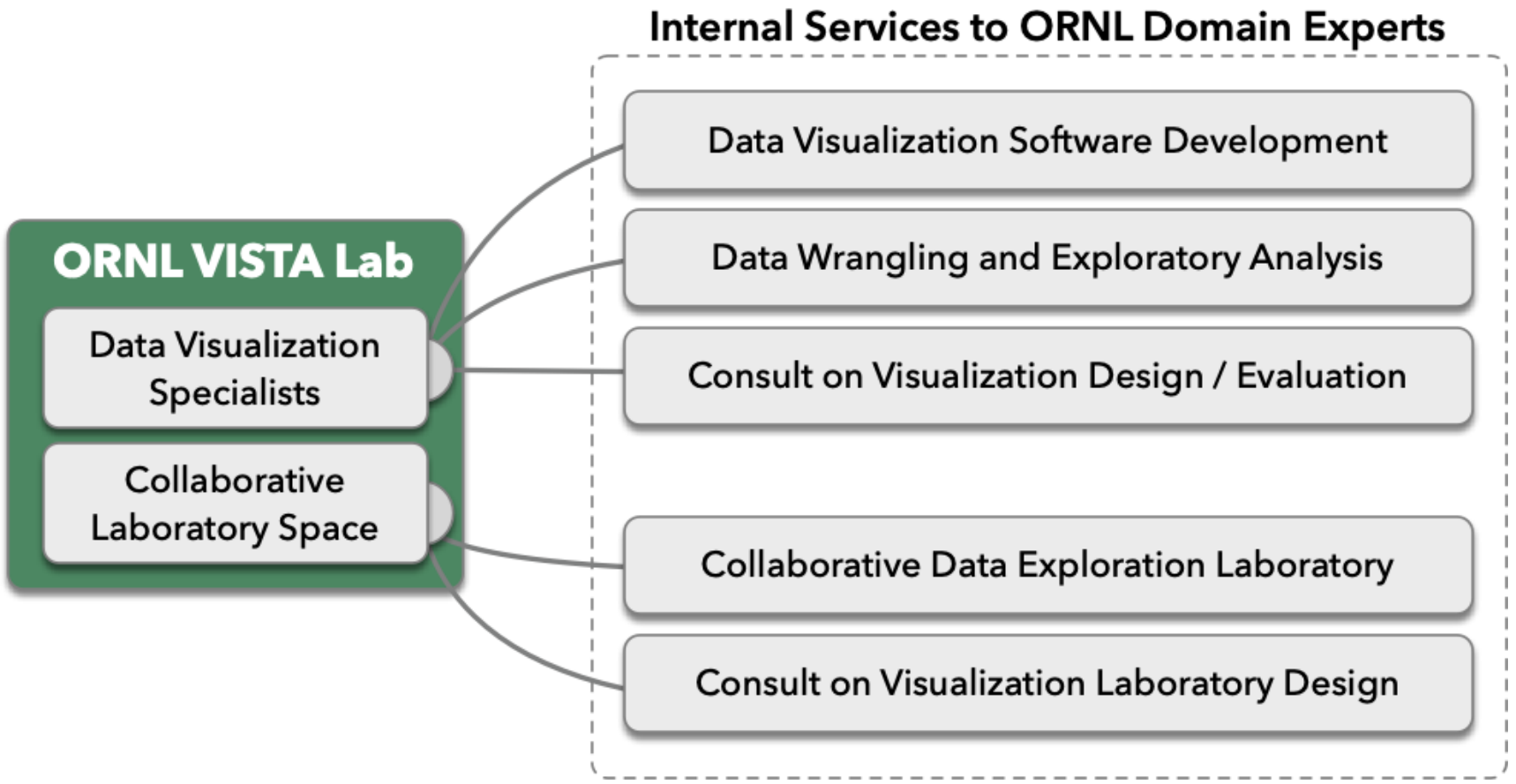
Forming a Bridge Between Visualization and Science

Fulfill the central promise of data visualization by bringing it to bear in data-rich domains where it's needed the most.

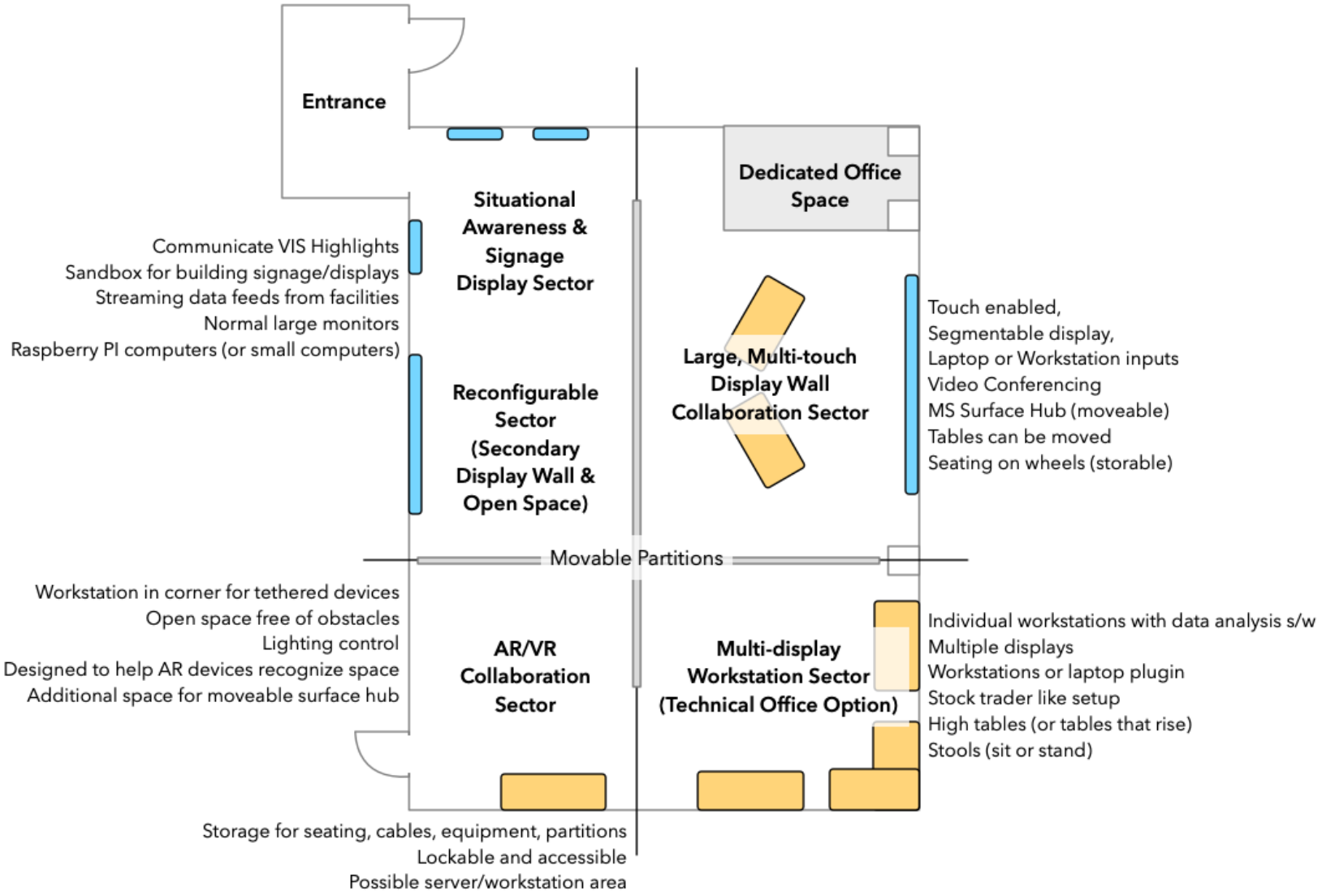
If successful, this bridge will yield new projects, partnerships, and opportunities.

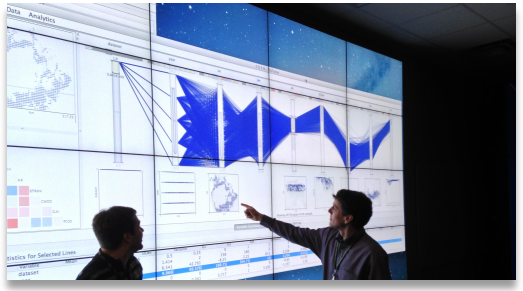
Data Visualization Services for ORNL

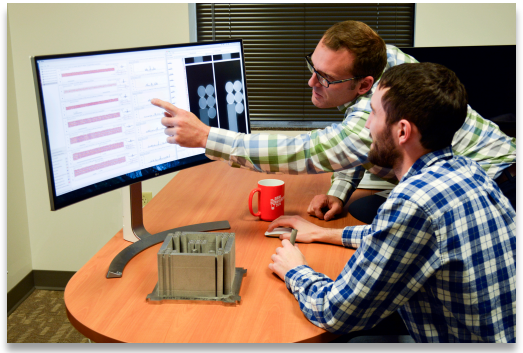




Creating a Collaborative Data Exploration Lab







Other VISTA Lab Activities

- **Research and Development**
  - Apply existing tools and develop new tools for data exploration
  - Publications with domain experts

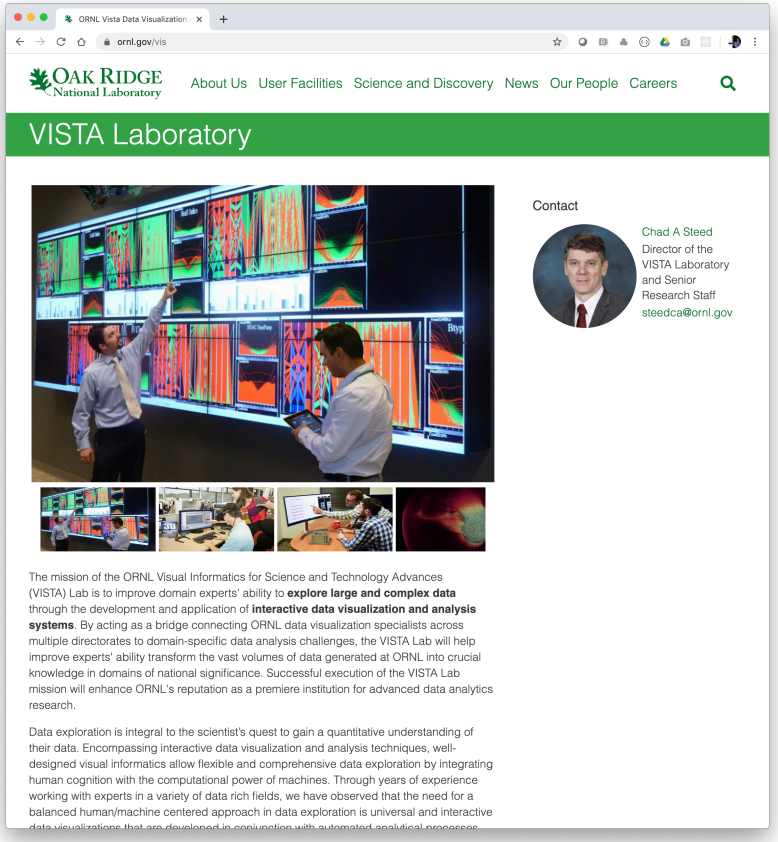
- **Connect and Expand ORNL Data Visualization Community**
  - Share knowledge and build connections via working groups, hack-a-thons, and data challenges
  - Organize workshops together; Collaborate on projects; Publications

- **Promote ORNL Visualization People and Capabilities**
  - Host visitors, recruit, support proposals, and spread the word about specific capabilities

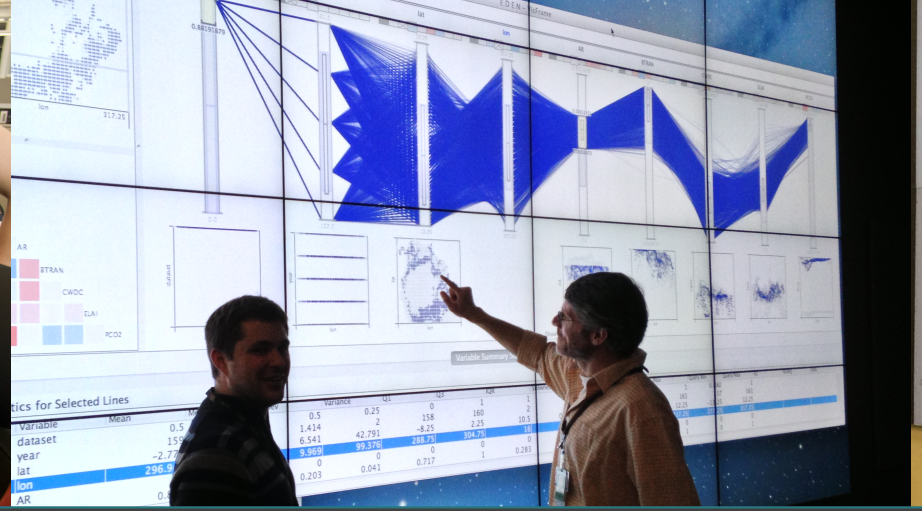
- **Establish External Partnerships**
  - Academic (faculty and students), industry, and other national laboratories.

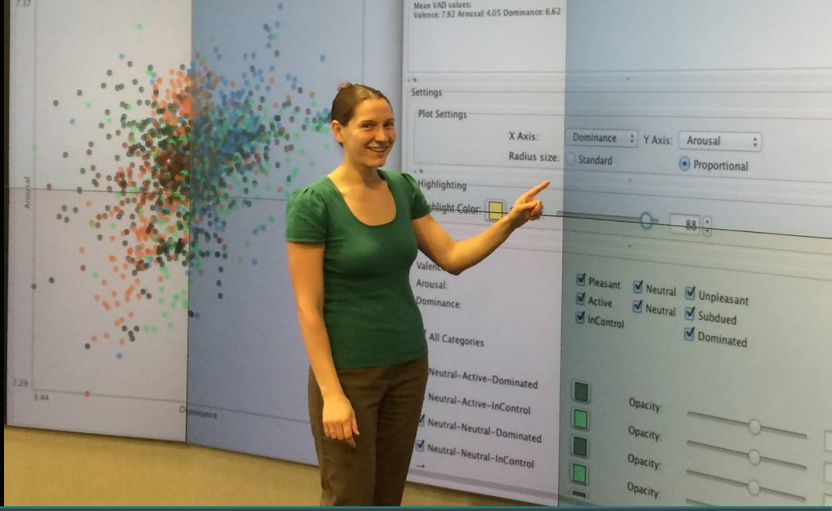
Conclusions

- Data Visualization and Visual Analytics expertise is broad and vital to understanding the vast volumes of data at ORNL.
  - Most domain experts say:
    - They don't look at enough of their data
    - They good at finding what they already know
  - ORNL is a one-stop-shop for data, use cases, and domain experts
- Developing visual analytics tools in close collaboration with domain experts is a rewarding approach
  - Helps fulfill the central promise of data visualization
- VISTA will be the hub for data visualization at ORNL
  - https://vis.ornl.gov
- **We are hiring and open to collaborations**
  - https://www.ornl.gov/division/csmd
  - https://orise.orau.gov/ornl/




Oculus
3D
Data Visualization
Station

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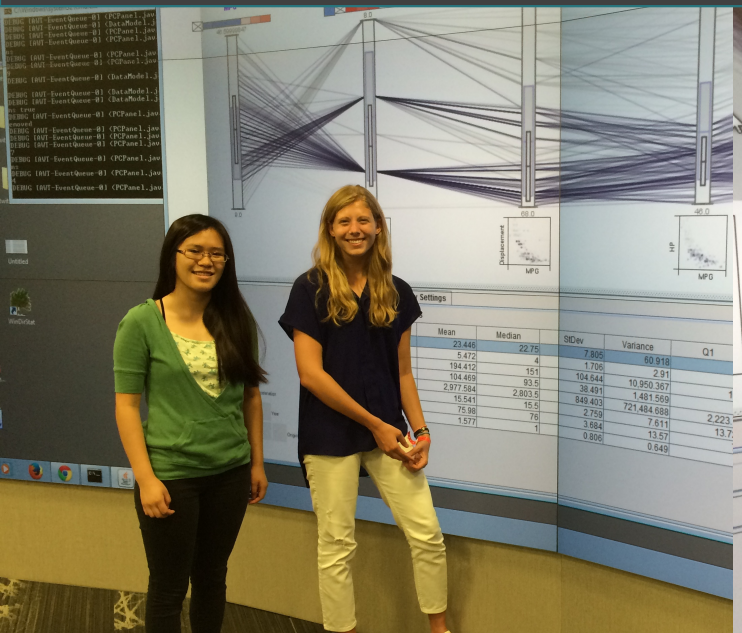
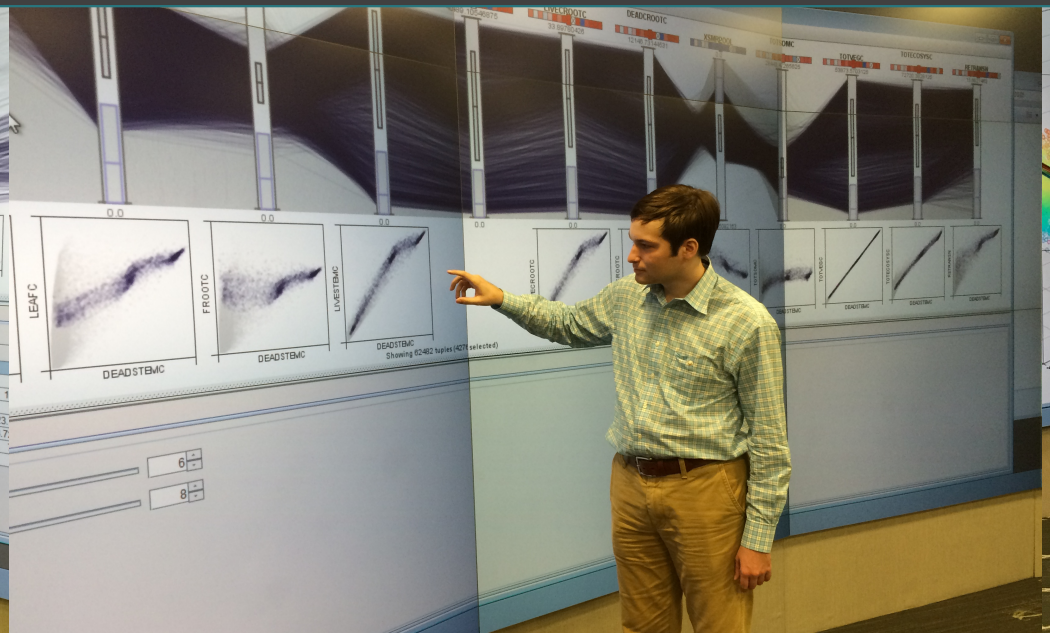
Thank You!

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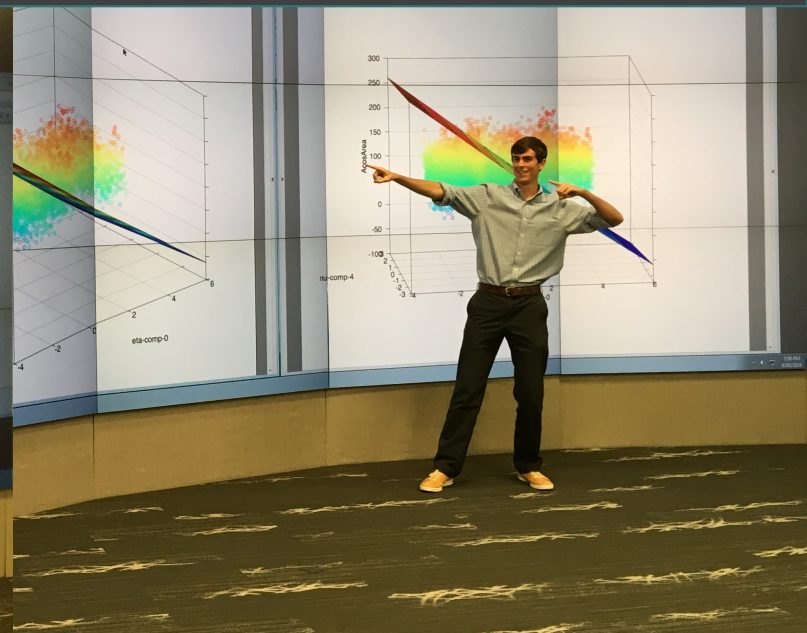
LIVESTEMC
DEADSTEMC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