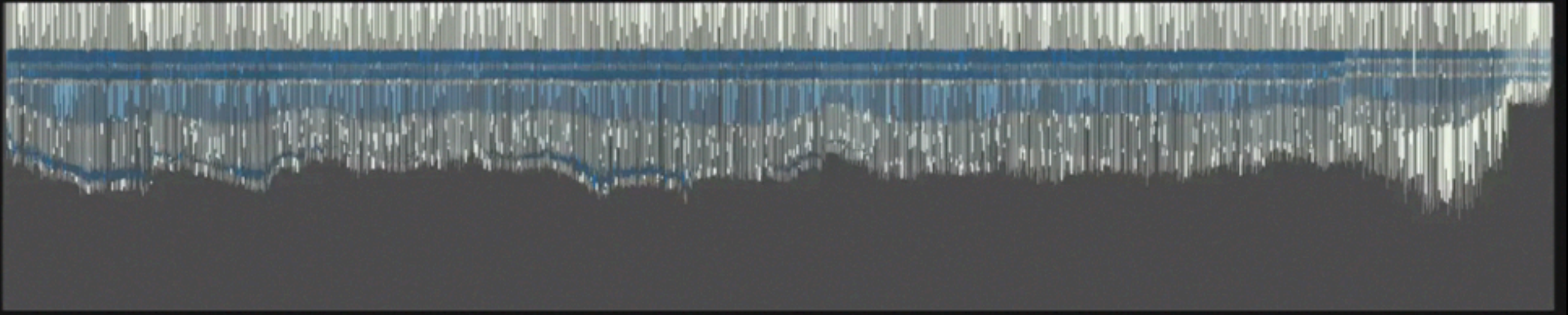CSTEED@ACM.ORG | HTTP://CSTEED.COM

CHAD A. STEED

OAK RIDGE NATIONAL LAB (ORNL)

ADVANCING ADDITIVE MANUFACTURING THROUGH VISUAL DATA SCIENCE

ADDITIVE MANUFACTURING

▸ Collaborations with domain experts from ORNL's Manufacturing Demonstration Facility (MDF)

▸ 3D printing is transforming the manufacturing process

    ▸ Greater geometrical freedom

    ▸ Less material waste

▸ Predict and improve quality of 3D printed objects to unlock the full potential

    ▸ Requires a deep understanding of the log and imagery data from 3D printer builds
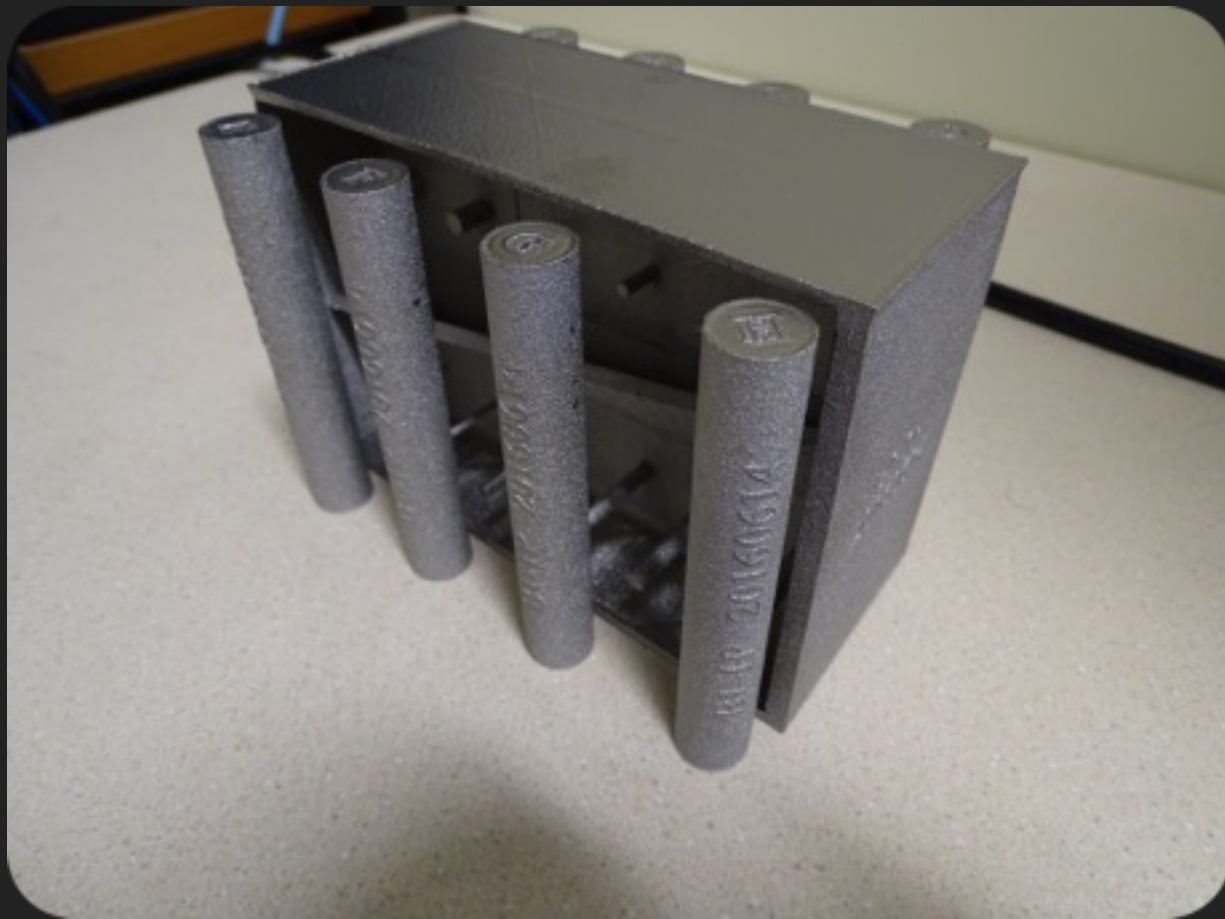
    ▸ Visual data science tools are needed
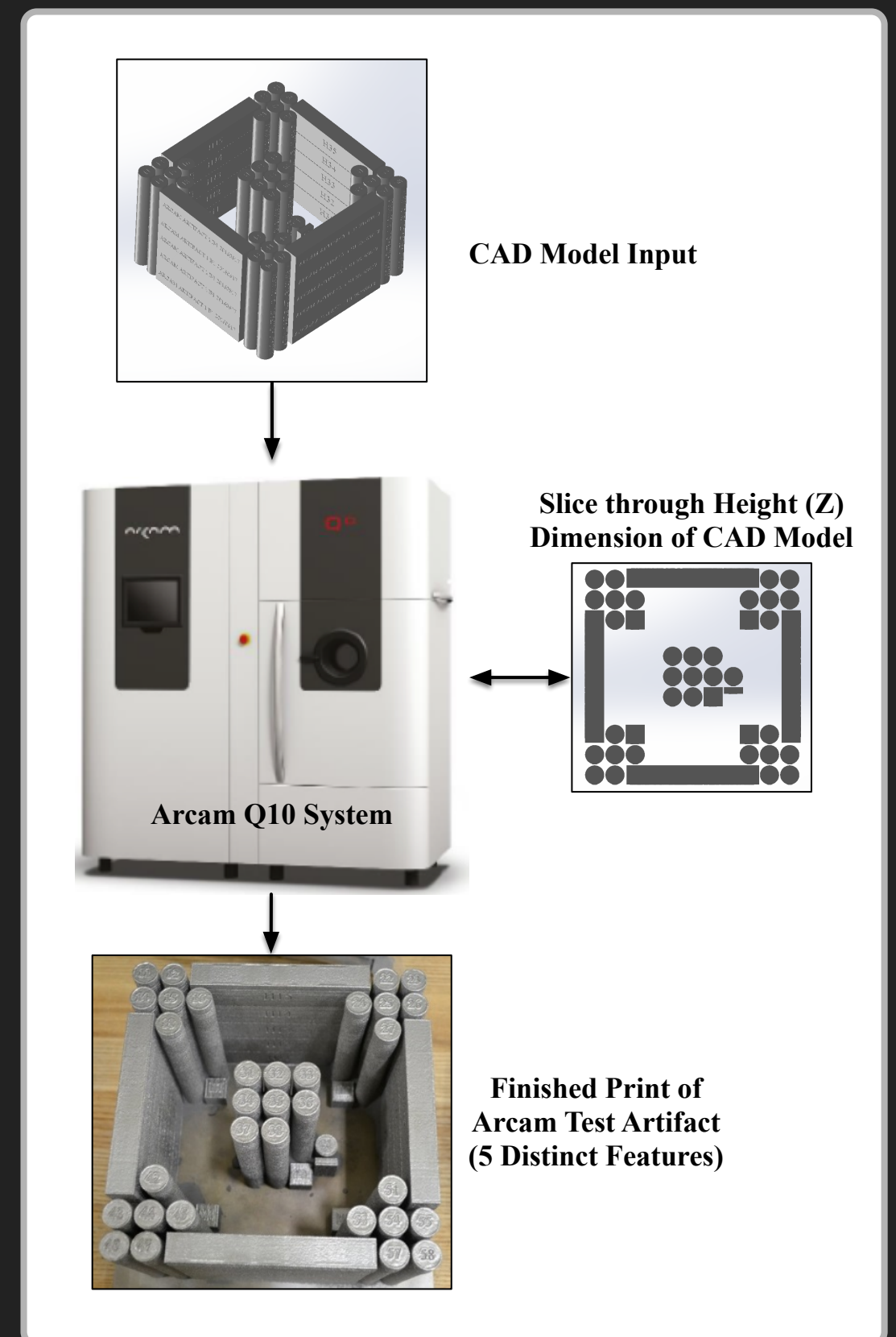
CAD Model Input

Slice through Height (Z) Dimension of CAD Model

Arcam Q10 System

Finished Print of Arcam Test Artifact (5 Distinct Features)

ORNL MANUFACTURING DEMONSTRATION FACILITY
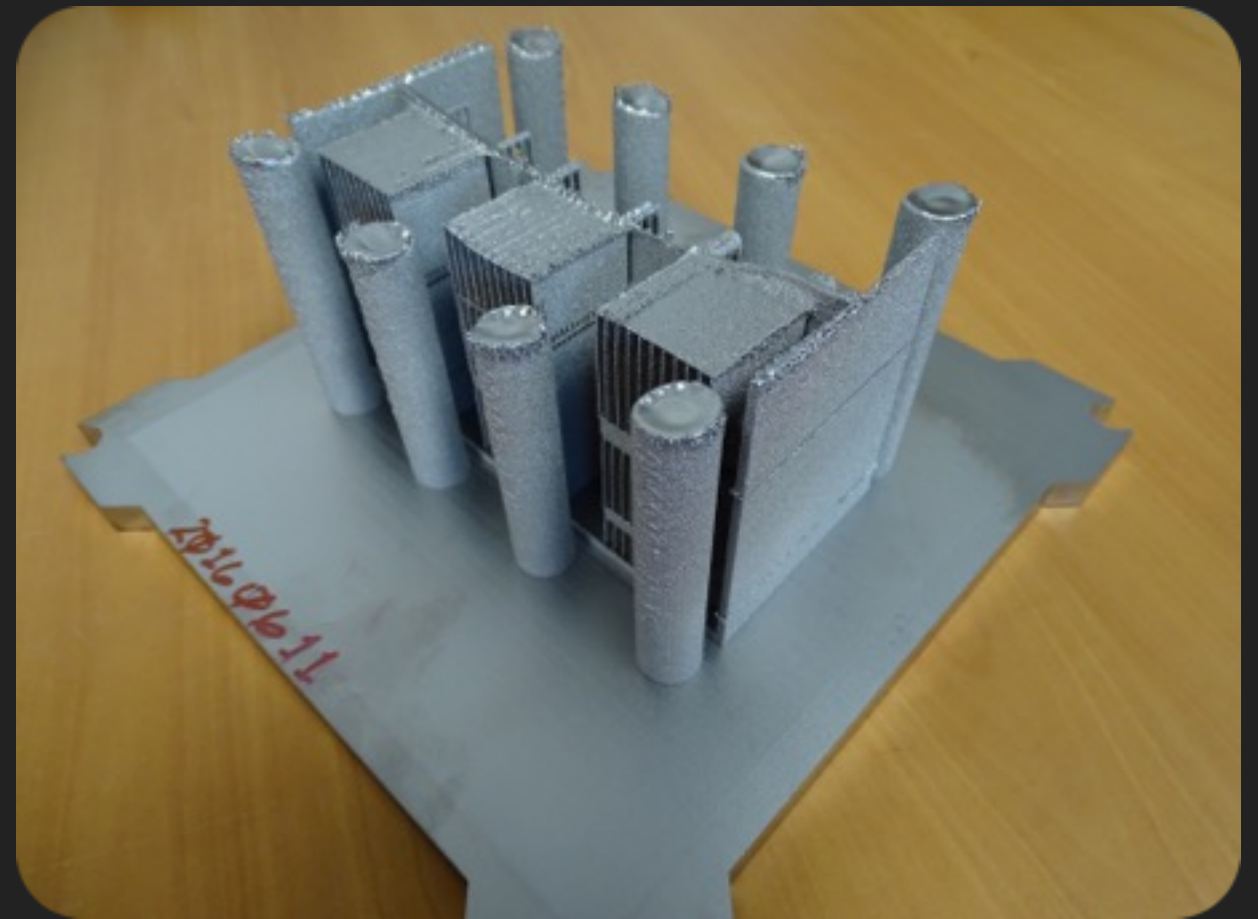
EXAMPLES 3D PRINTER BUILDS (GOOD AND BAD)

Good

Bad

3D PRINTER LOG AND IMAGERY DATA

▸ Log files are critical but challenging:

  ▸ long (multiple days)

  ▸ large (millions of data points, GB to TB)

  ▸ multivariate (thousands of variables)

  ▸ irregularly sampled

  ▸ unstructured text file format

▸ Near infrared (IR) imagery for each build layer

▸ **Traditional data analytics tools are inadequate**

INTRODUCING FALCON

VARIABLE VISUALIZATION PANEL

▸ Consists of 2 overviews + 1 detail visualization for a single variable of interest (stackable for multiple variables)

▸ Interactions in each separate view are linked

▸ Details-on-demand capabilities
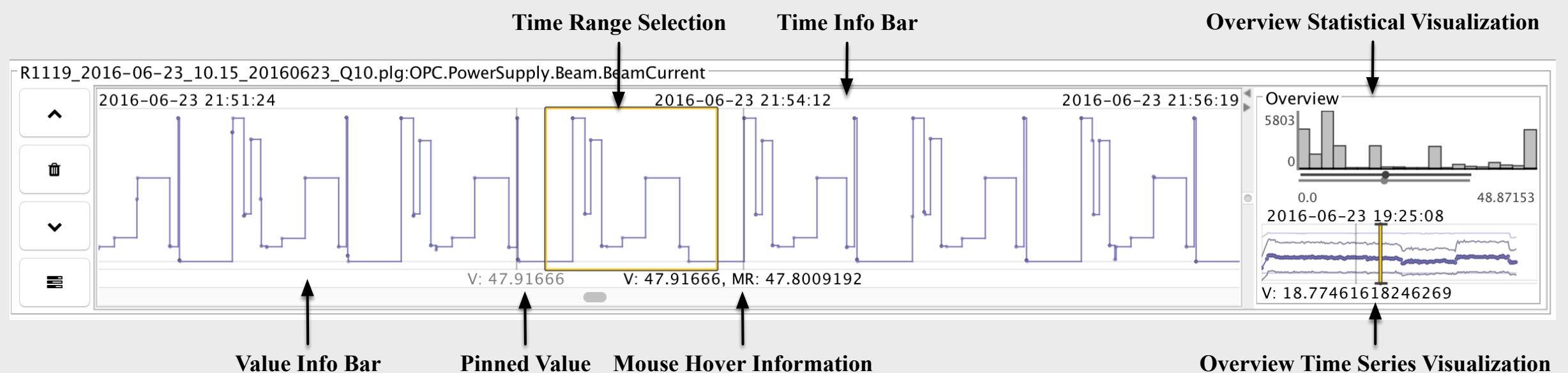
OVERVIEW VISUALIZATIONS
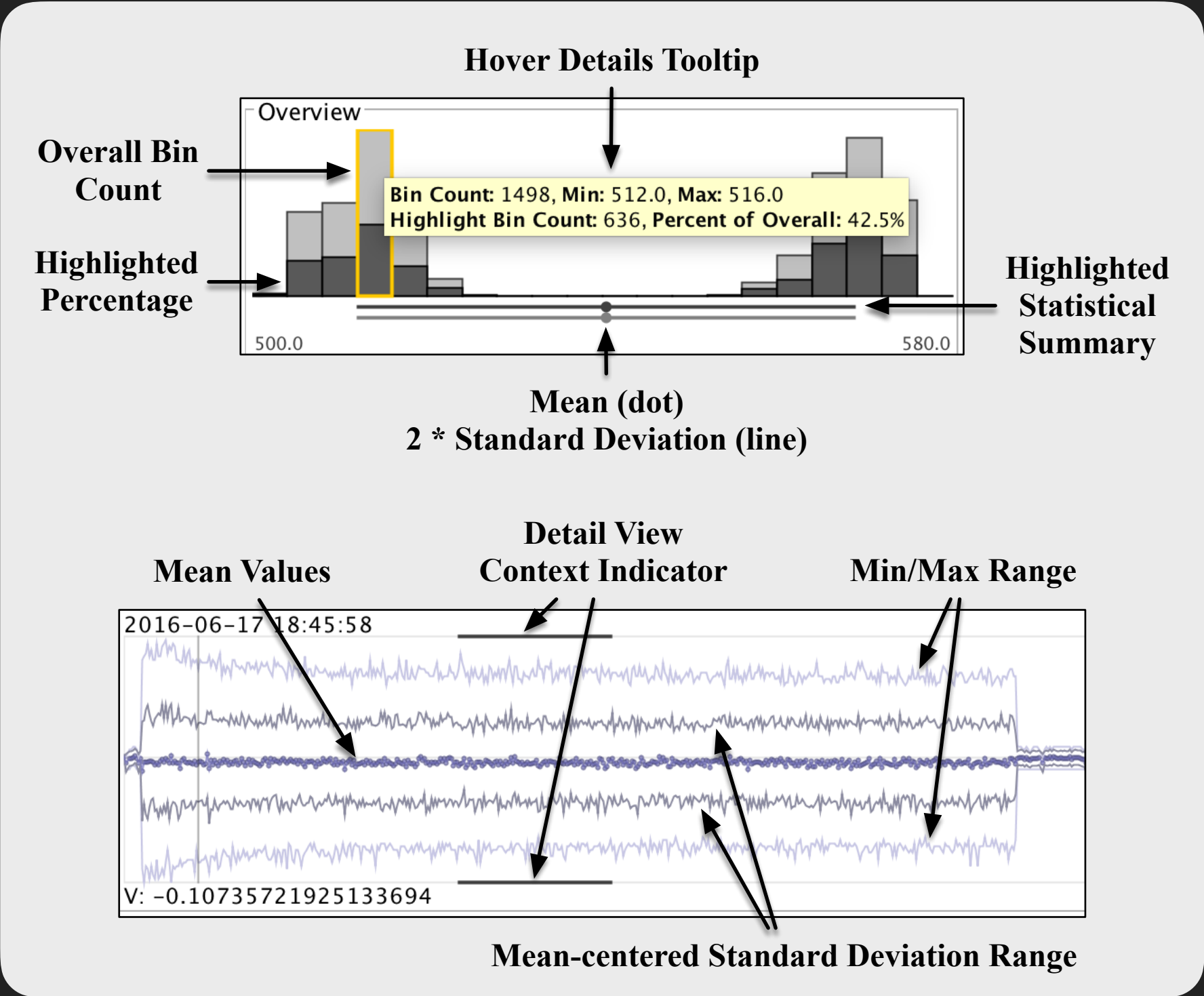
DETAIL TIME SERIES VISUALIZATION DISPLAY MODES
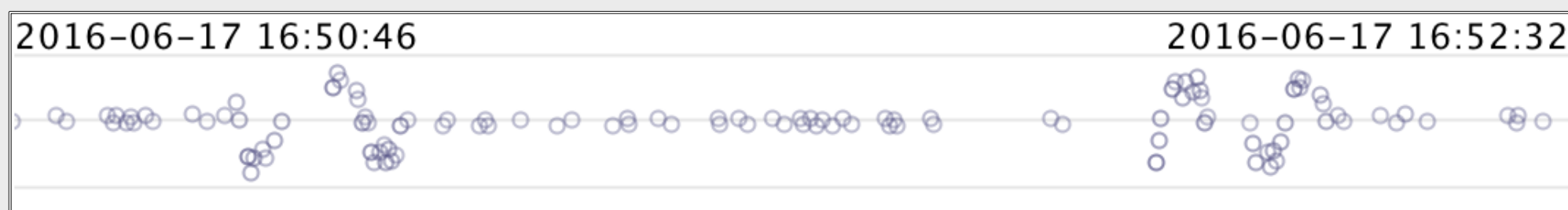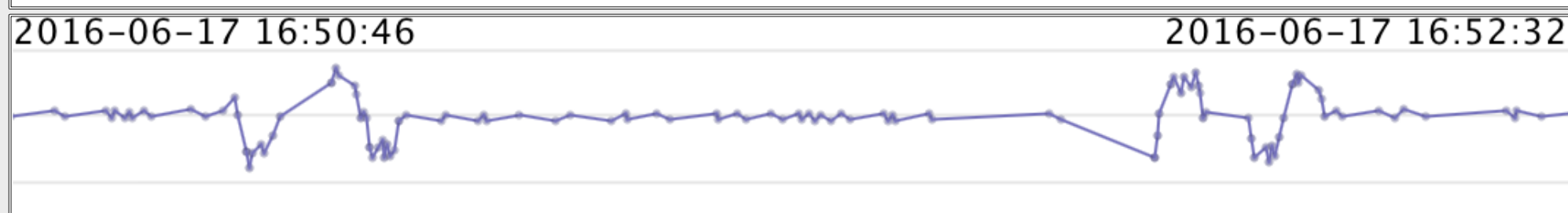
SEGMENTED TIME SERIES VISUALIZATION
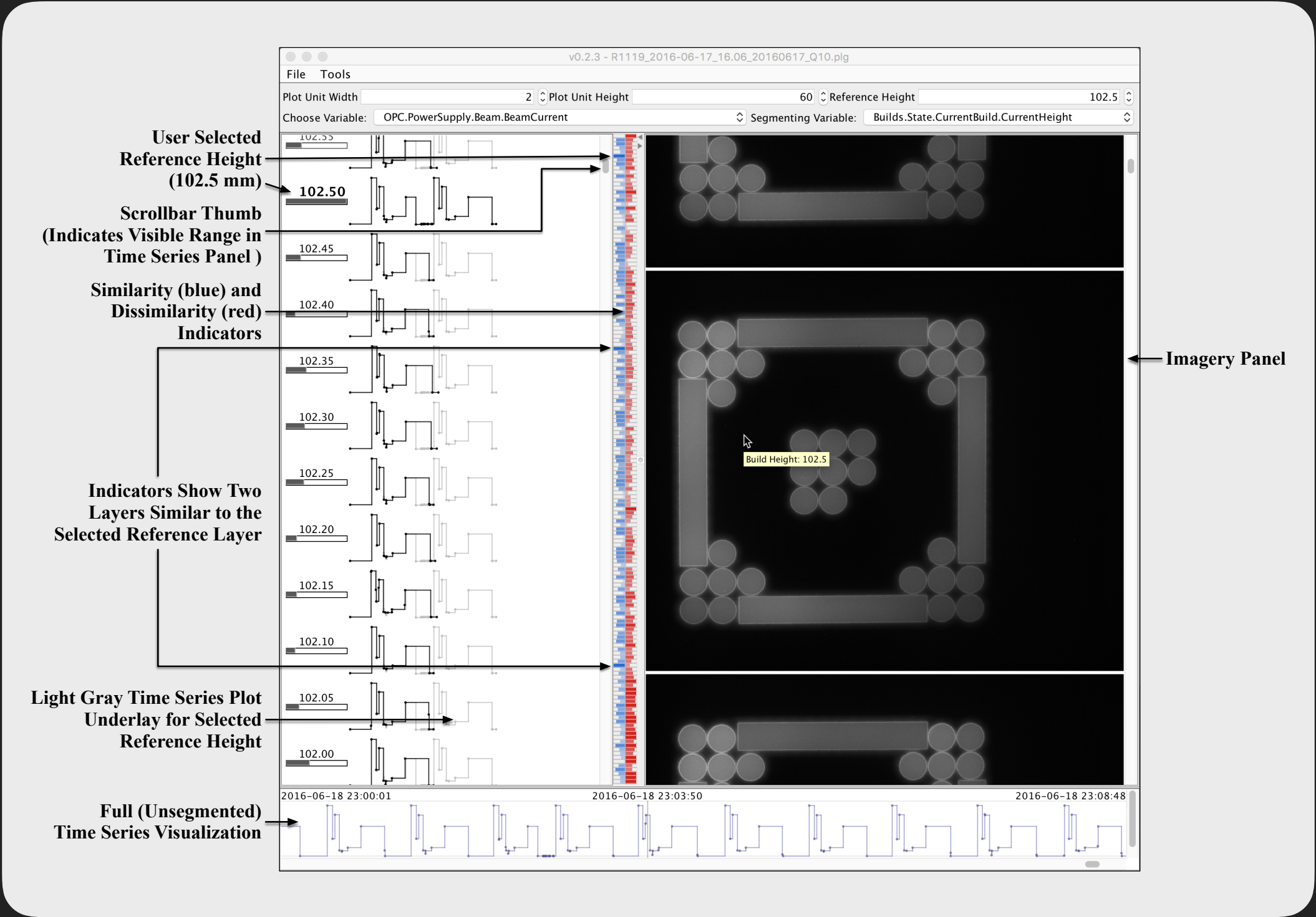
WATERFALL VISUALIZATION
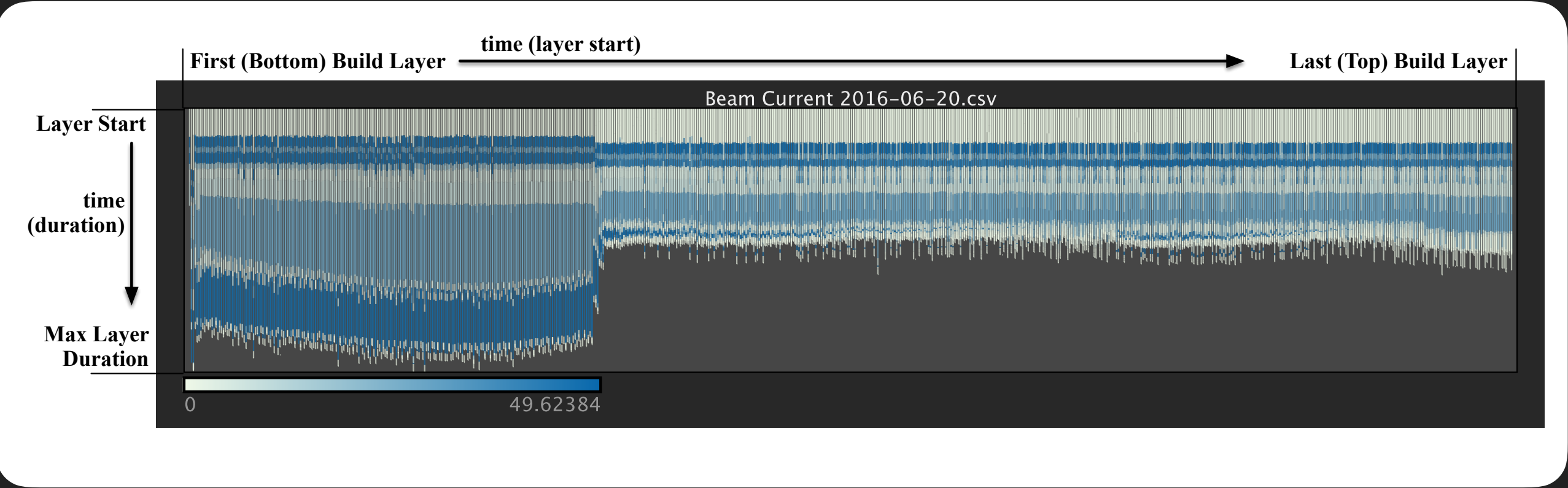
CASE STUDY: ANALYSIS OF LOG DATA FROM A 3D PRINTER BUILD

▸ Arcam Q10 3D Printer System

    ▸ Uses electron beam melting to synthesize metallic objects

▸ Data are 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

GENERAL ANALYSIS STRATEGY USING FALCON

▸ Researchers naturally gravitated toward a workflow that parallels Shneiderman's visual information seeking strategy*

▸ Begin with overview of entire build using a set of key variables

▸ Drill down to explore the patterns by accessing other variables and more detailed views

▸ Along the way, they note interesting patterns

▸ Combine log data with imagery data for big picture

▸ Follow-up with investigations of microstructure with extremely high details (e.g., scanning microscopy)
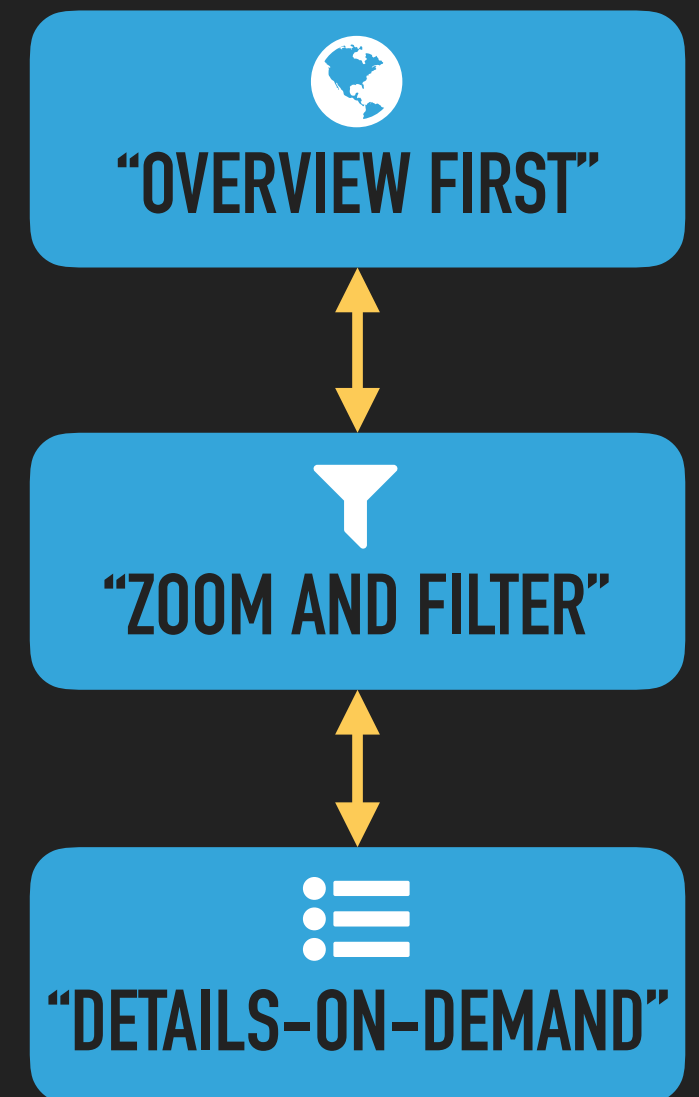
"OVERVIEW FIRST"

"ZOOM AND FILTER"

"DETAILS-ON-DEMAND"

* 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
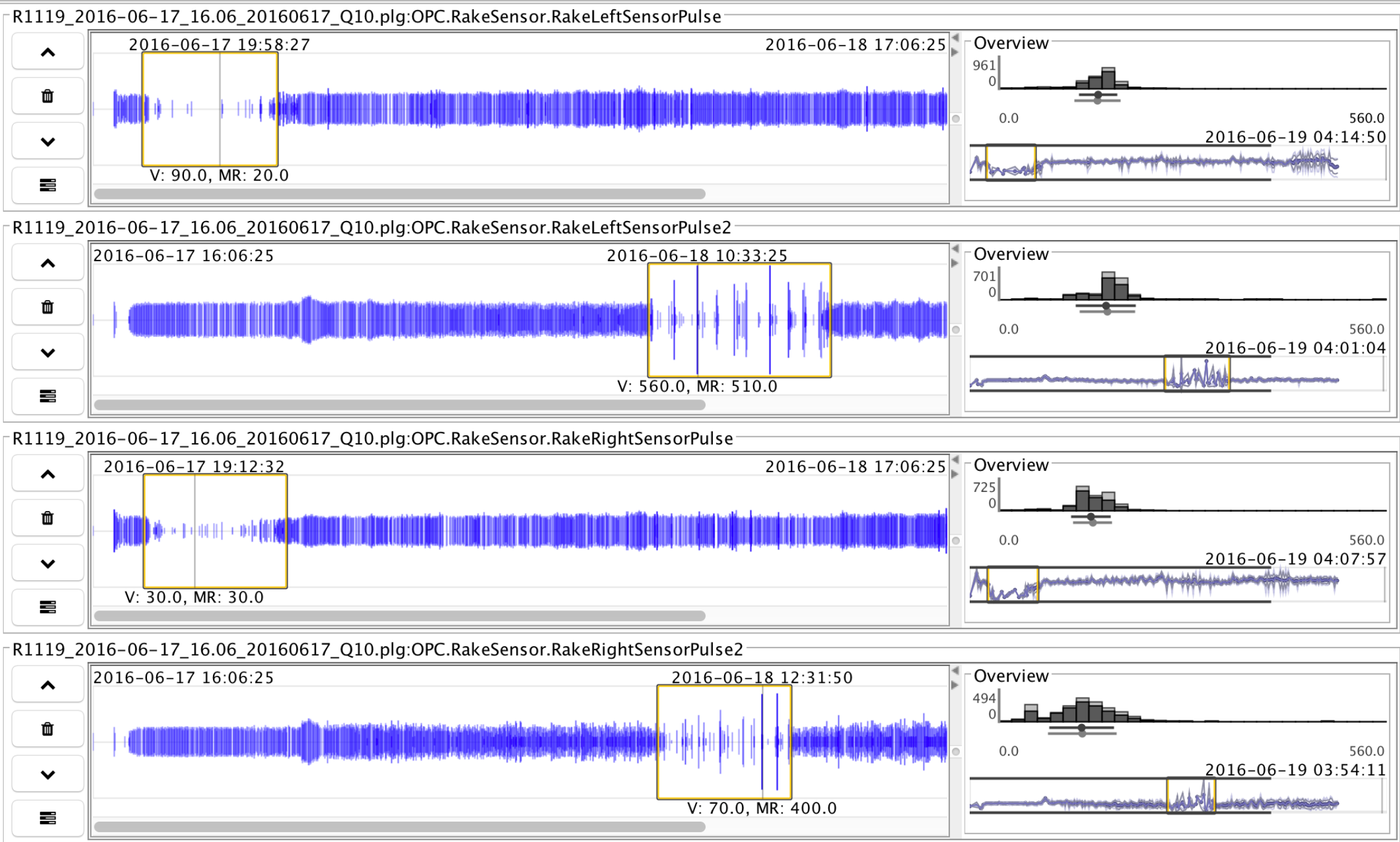
OVERVIEW FIRST

A MORE FOCUSED OVERVIEW

Beam Current 2016-06-17.csv

ZOOM AND FILTER

MORE DETAIL, ON DEMAND

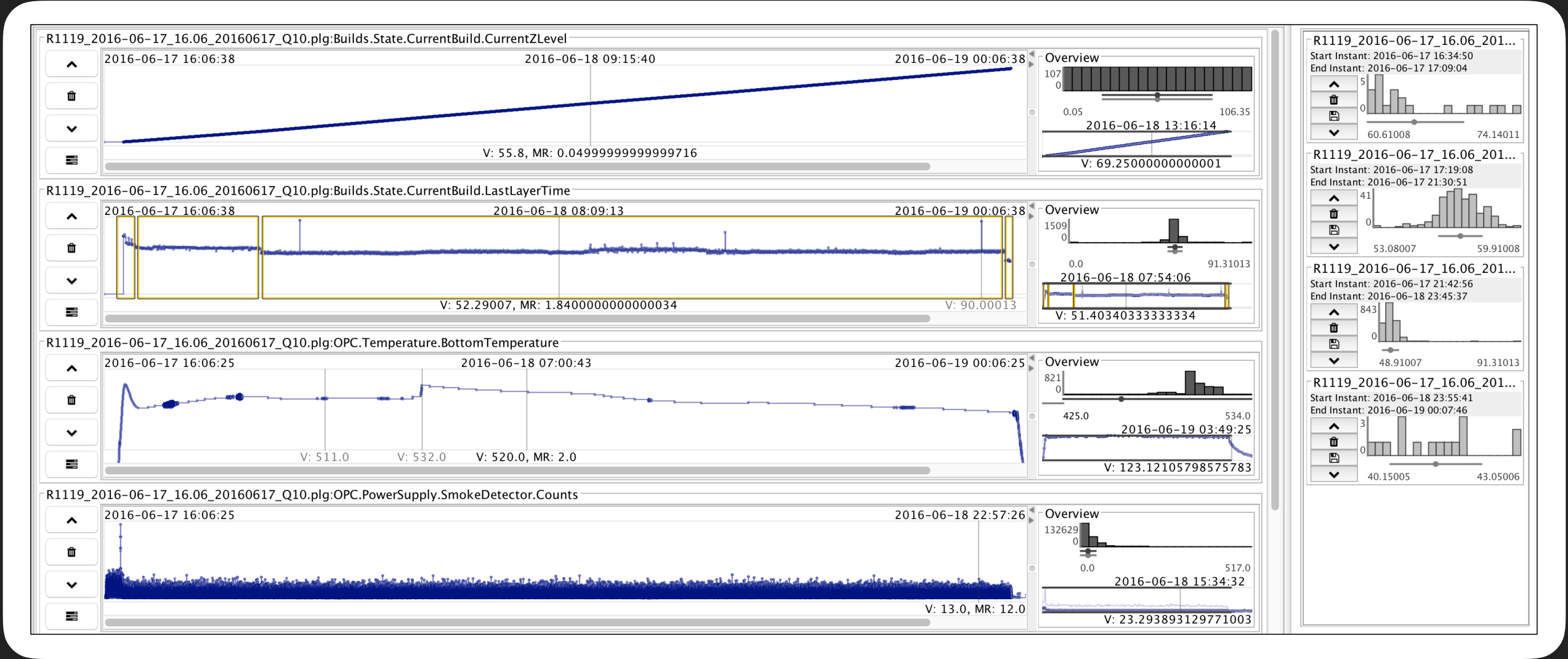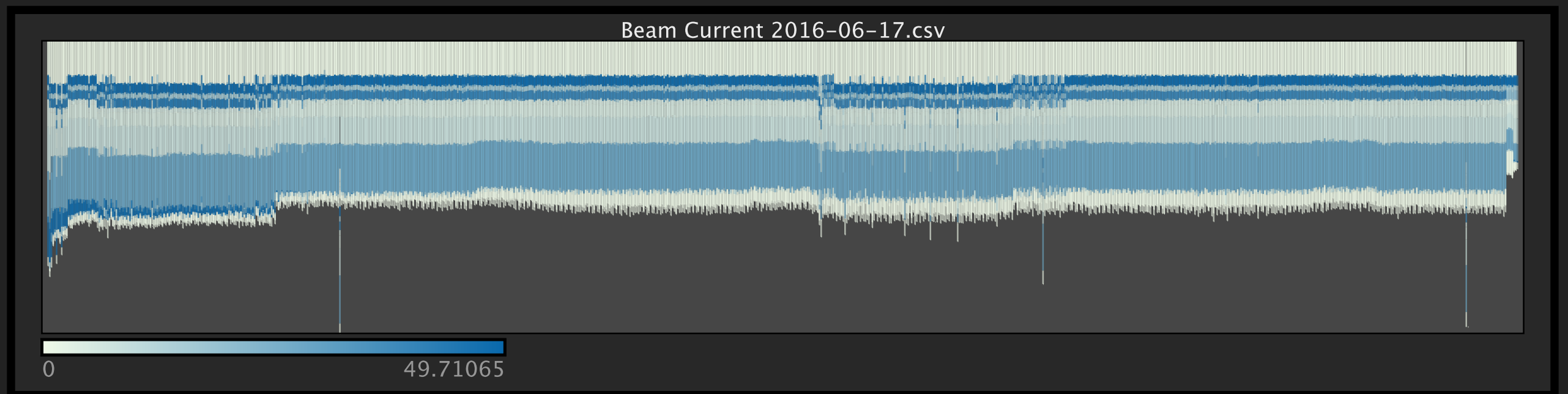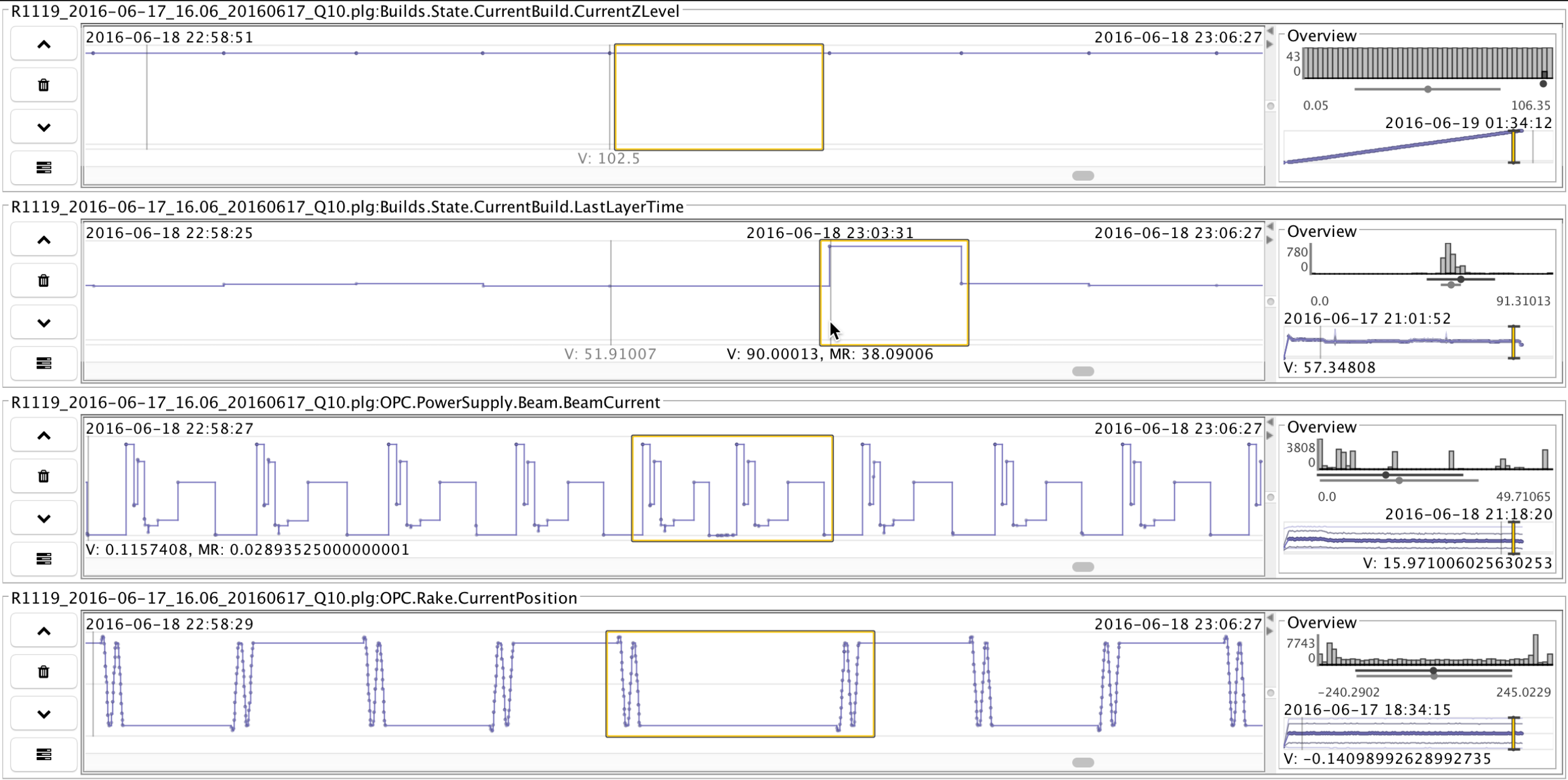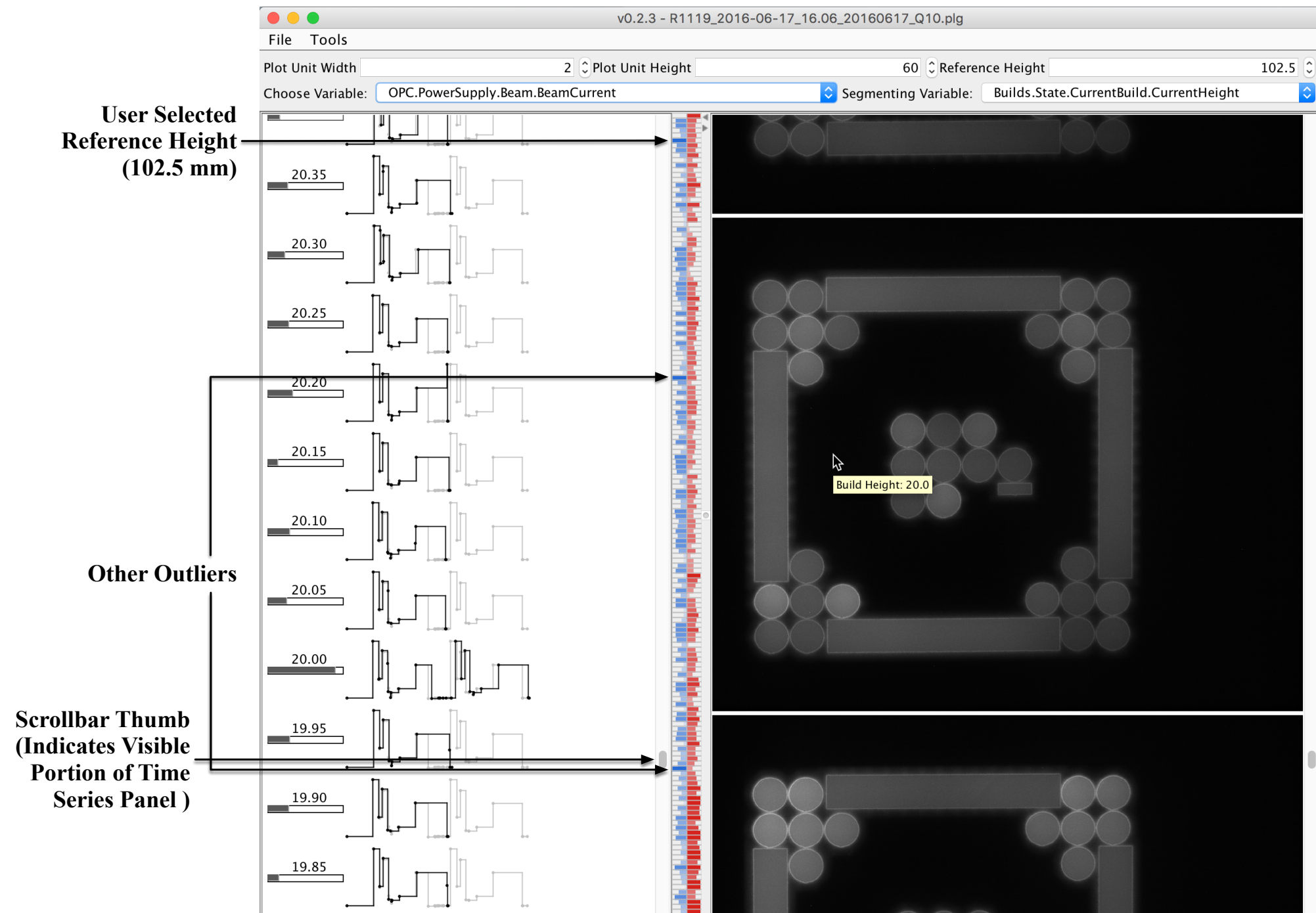# THE CAUSE OF THE OUTLIERS

▸ Two possibilities:

  ▸ Smoke detection reset

  ▸ Arc trip

▸ Both cause signal repeats

▸ Here, arc trip is the cause

▸ This knowledge led to additional study to see how arc trips affect the microstructure of a build.

7_Q10.plg:Builds.State.CurrentBuild.LastLayerTime
2016−06−18 08:09:13   2016−06−19 00:0
V: 52.29007, MR: 1.8400000000000034   V: 90.00

016−06−17_16.06_20160617_Q10.plg:OPC.PowerSupply.SmokeDetector.Counts
2016−06−17 16:06:25
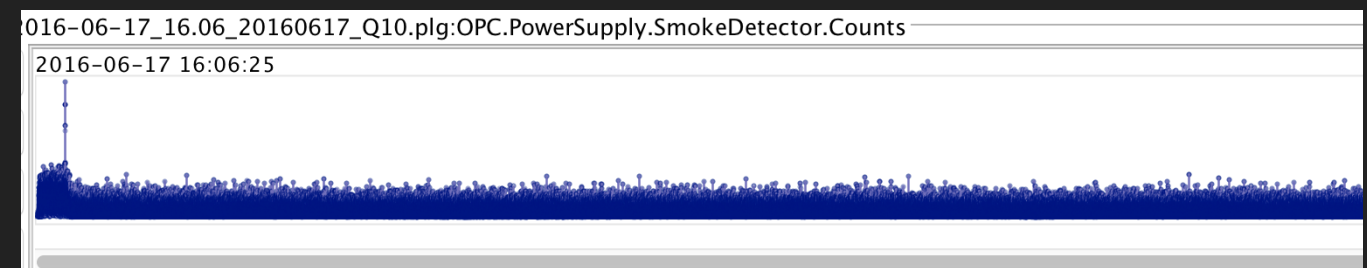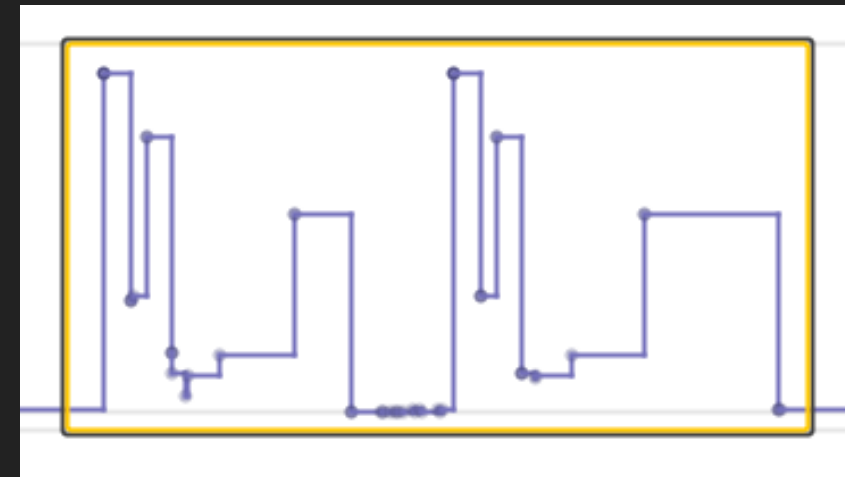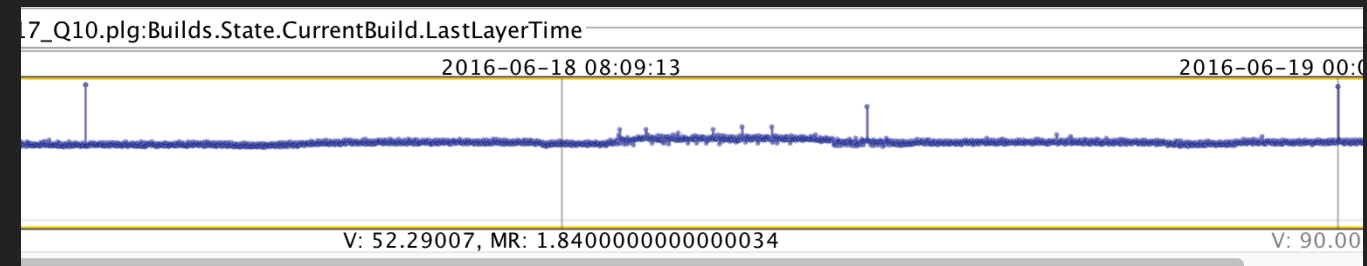
CONCLUSIONS

▸ Falcon enables significant discoveries that:

  ▸ Help us detect certain conditions that impact quality

  ▸ Help us improve the 3D printing process to avoid failures

▸ Practical results demonstrate improvements over traditional, general purpose tools

▸ ProTip: Strive to include domain experts early and often in the design of new data science techniques to improve efficacy

▸ Falcon is applicable to other domains (e.g., cyber security, climate)

▸ Open source base version of Falcon coming soon…

  ▸ http://cda.ornl.gov/projects/falcon/

More information is available about this and my other research at http://csteed.com.

QUESTIONS?