Using Forge to Connect BIM to the Internet of Things

Kean Walmsley

Autodesk

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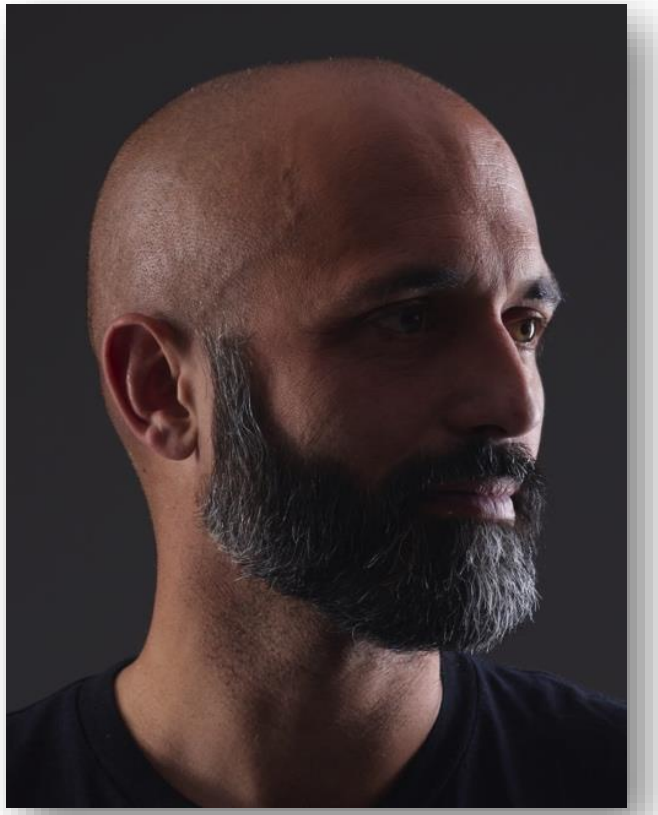
AUTODESK. UNIVERSITY

Class Summary

Autodesk Research's Project Dasher 360 is a building performance management tool that displays historical and real-time sensor data inside a building model. In this session, we'll take a close look at how the Forge platform has been used to implement the Dasher 360 project, leading to a multi-year desktop development project being largely re-created for the web in a matter of months. We'll pay particular attention to the techniques used to contextualize sensor data within intelligent models displayed via the web, explaining the implementation details of reusable Forge Viewer extensions created using JavaScript.



About the speaker

Kean Walmsley | @keanw | keanw.com

Kean works for Autodesk Research as a Platform Architect and Evangelist, focusing on the intersection of BIM with IoT and a little VR/MR. He has worked for Autodesk in a number of roles and in a number of different countries – he's currently based in Switzerland – and spends a significant amount of time engaging with Autodesk's developer community via his popular programming-oriented blog, "Through the Interface".

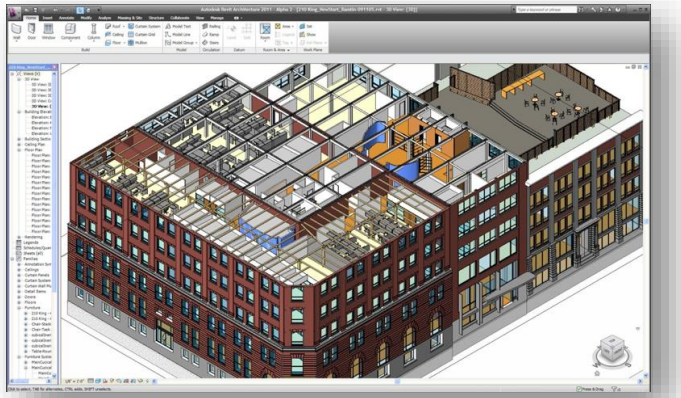
Autodesk Research

- A small team acquired with Alias in Toronto
  - Now 100+ people in 5 countries
- Headed by Gord Kurtenbach
  - Reporting to Jeff Kowalski (OCTO)
- Increasingly focused on technology transfer
  - Meshmixer, Draco, Dreamcatcher

History of Project Dasher

Project Dasher Desktop

Project Dasher began in 2009 as a research project to develop visualization and analytics tools for building operations data in the context of Building Information Models



As-Built BIM
Highly detailed AEC models

+

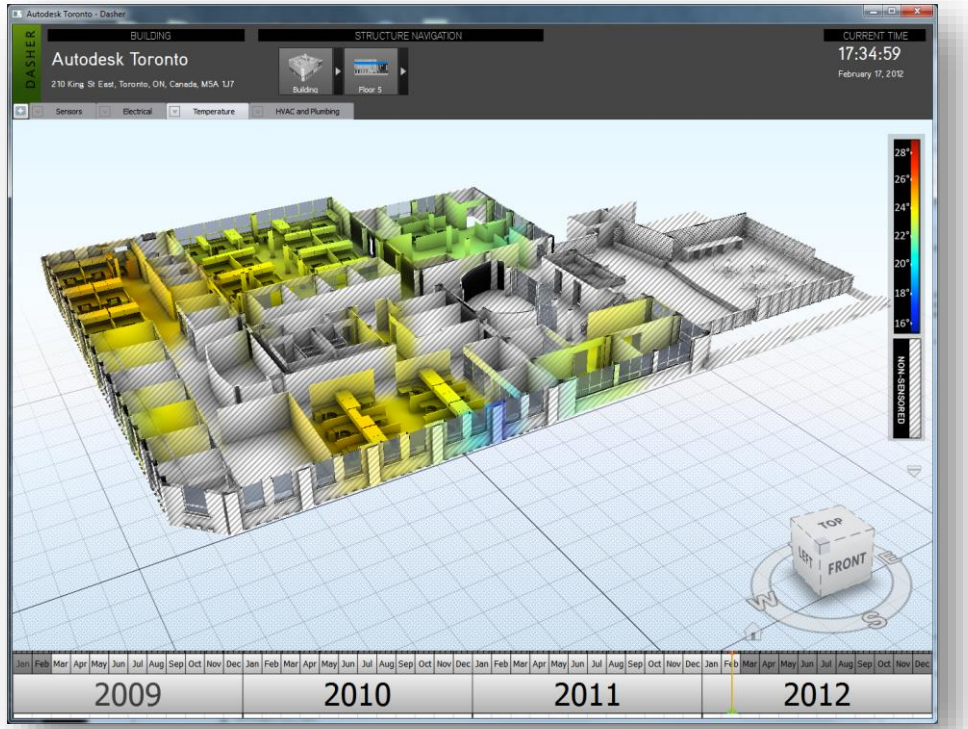
Building Data
Building management systems (BMS) and IoT enabled sensors for operations and management data collection

=

Project Dasher
A visualization to help customers understand their data in context of the 3D model and debug operational issues

Migrating to Dasher 360

C++, **GLSL Shaders**



JavaScript, TypeScript, CSS, HTML, **GLSL Shaders**

Viewer

Authentication

Data Management

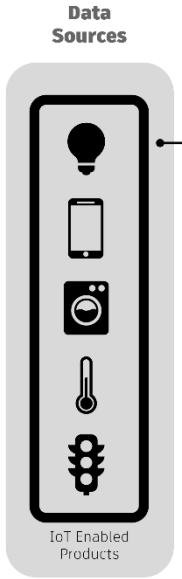
Model Derivative

AUTODESK® FORGE

Dasher 360’s use of Forge

Dasher Forge Usage

AUTODESK® FORGE



Data 360

Viewer

Authentication

Data Management

Model Derivative

DASHER 360

Client Side

TypeScript

Forge Viewer Extensions

Backend

node.js

express

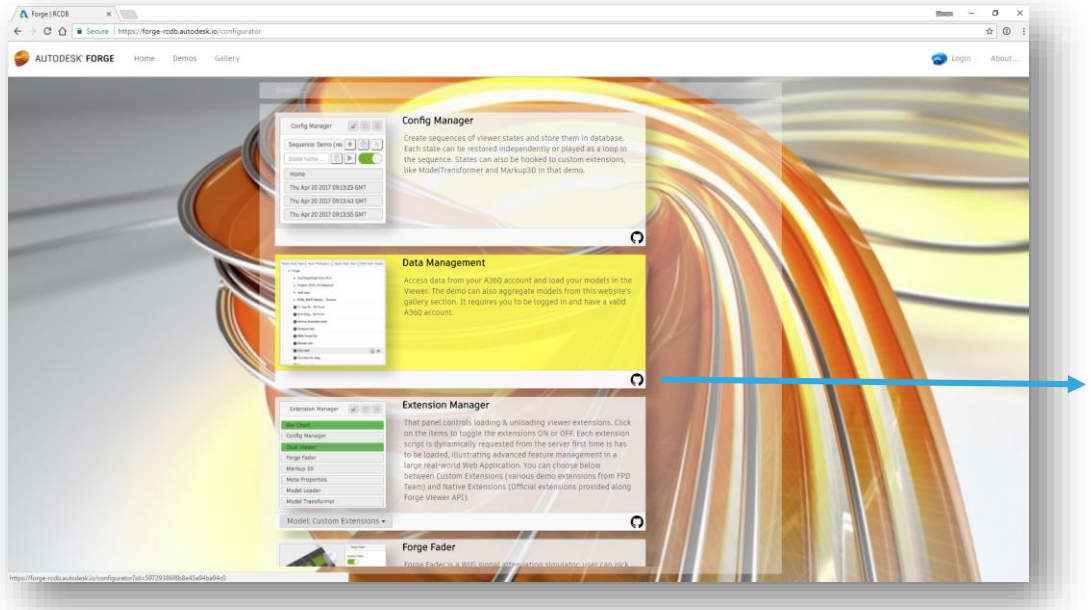
mongoDB.

Forge Examples

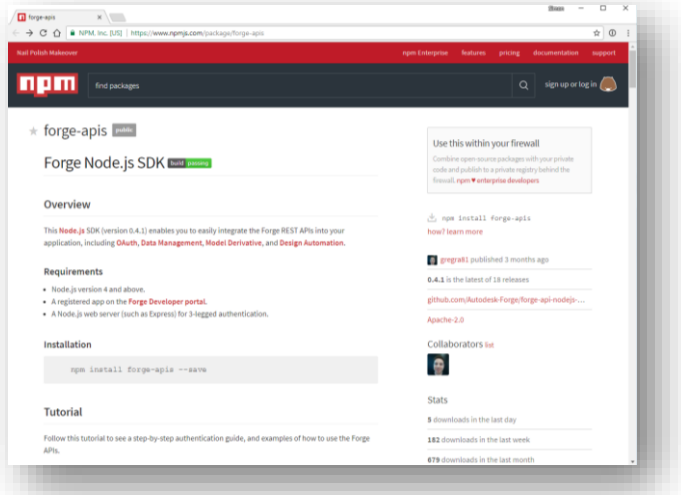
AUTODESK® FORGE

https://github.com/Autodesk-Forge

- model.derivative-nodejs-sample
  - Demo: https://derivatives.autodesk.io
- forge-rcdb.nodejs
  - Demo: https://forge-rcdb.autodesk.io



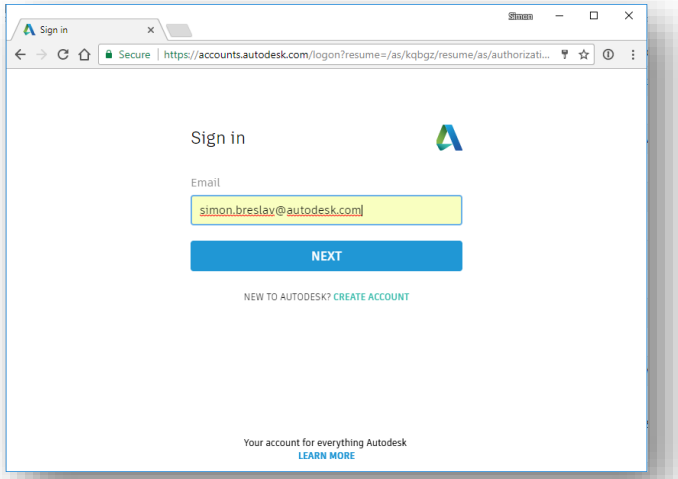
Source Code!



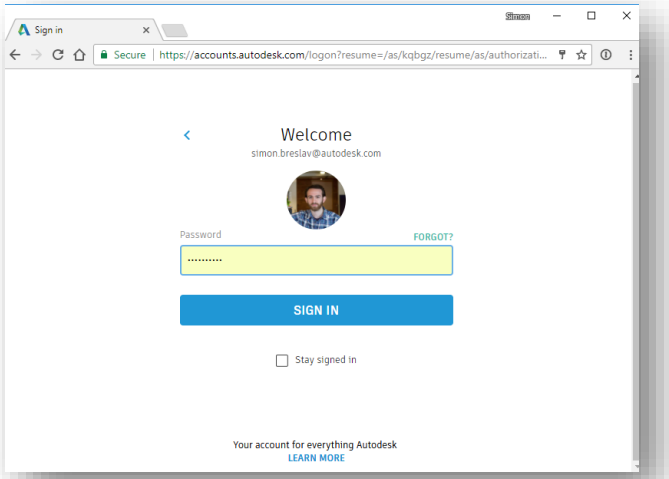
https://www.npmjs.com/package/forge-apis

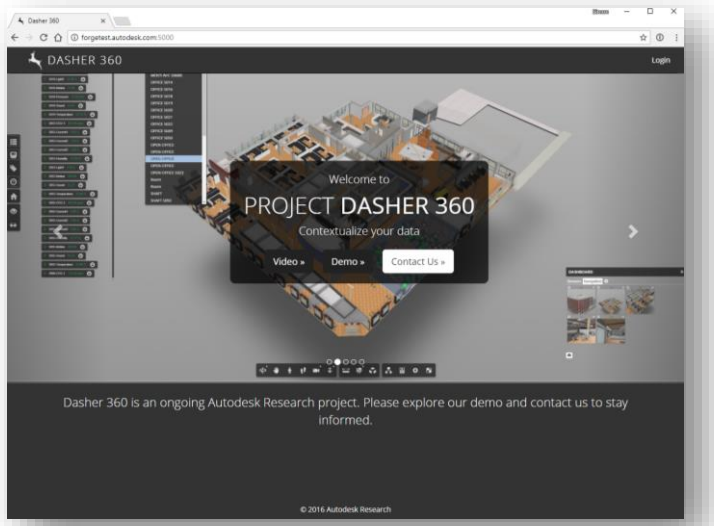
Authentication

Authentication

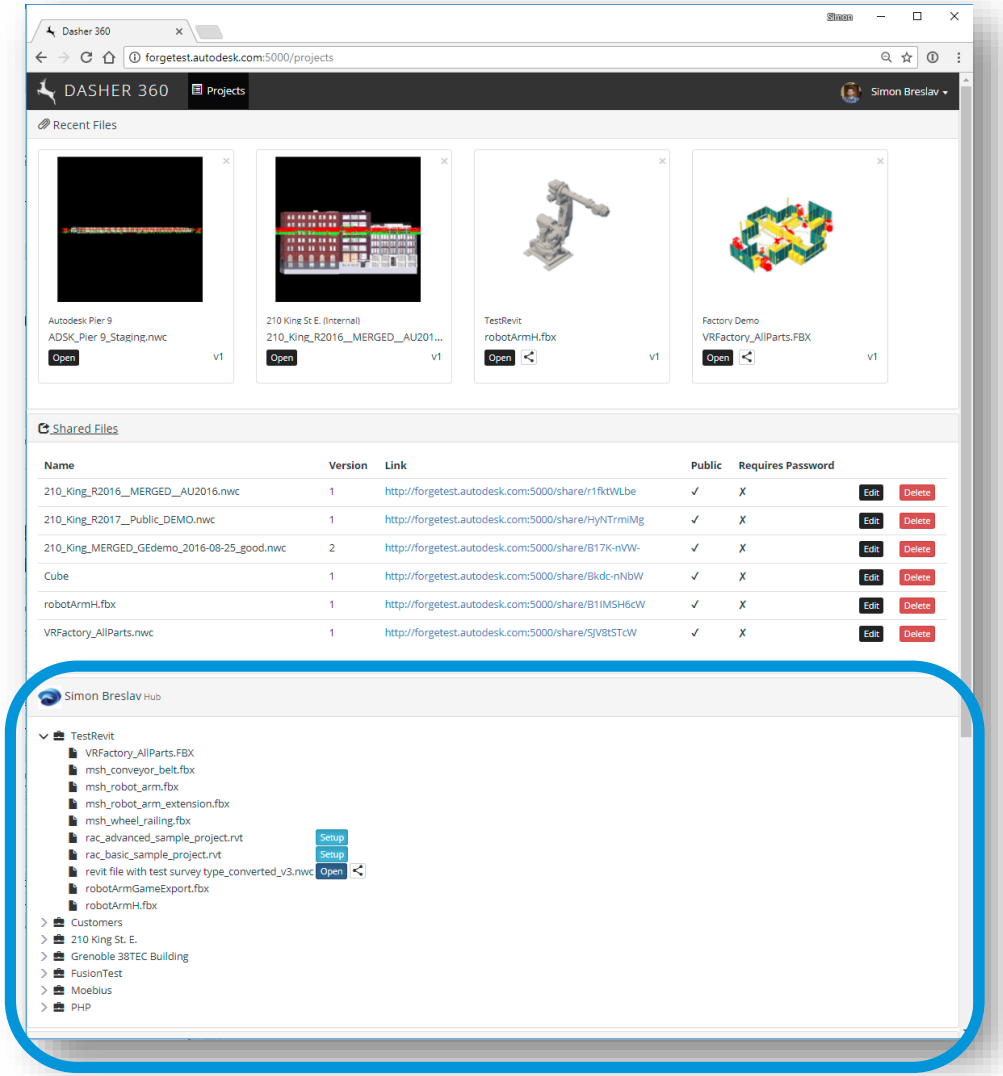


Demo

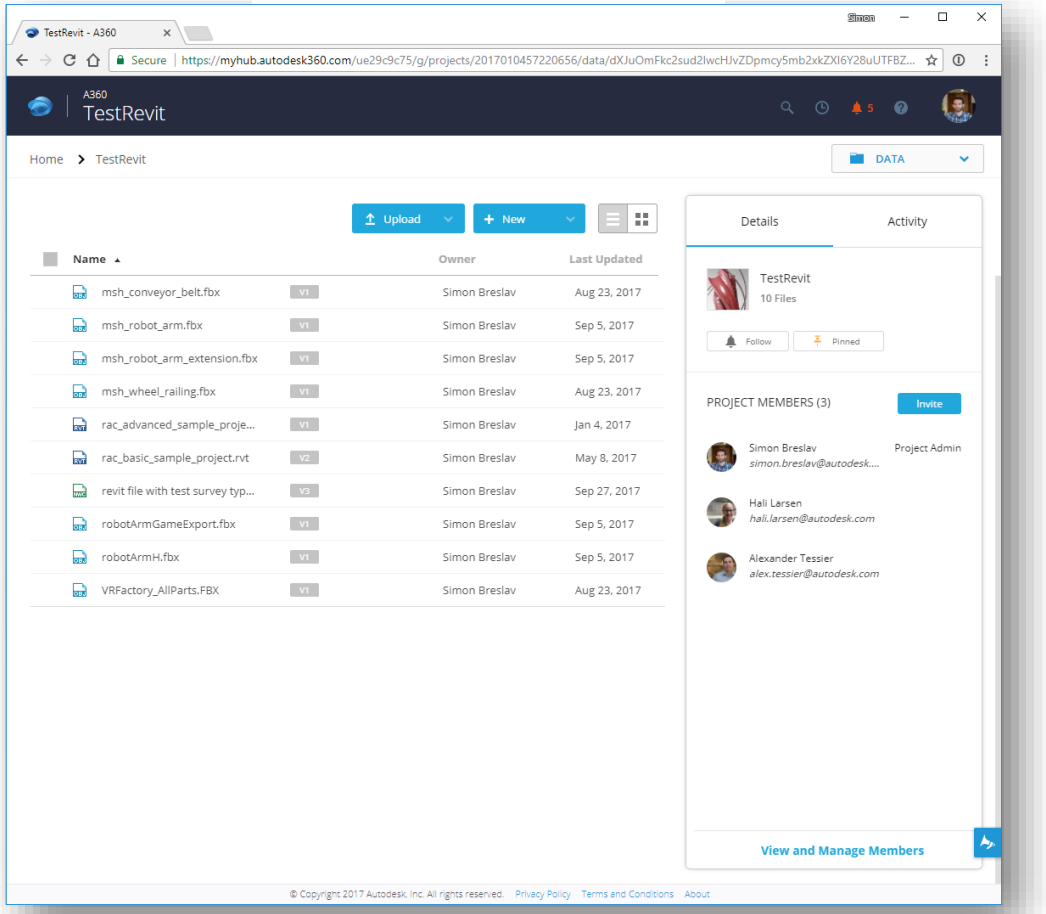




Data Management



A360

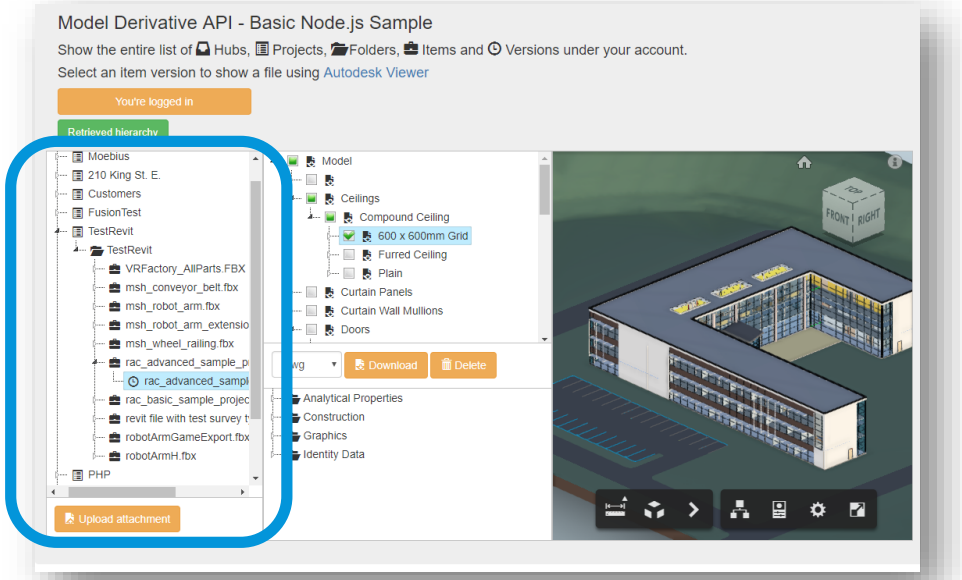


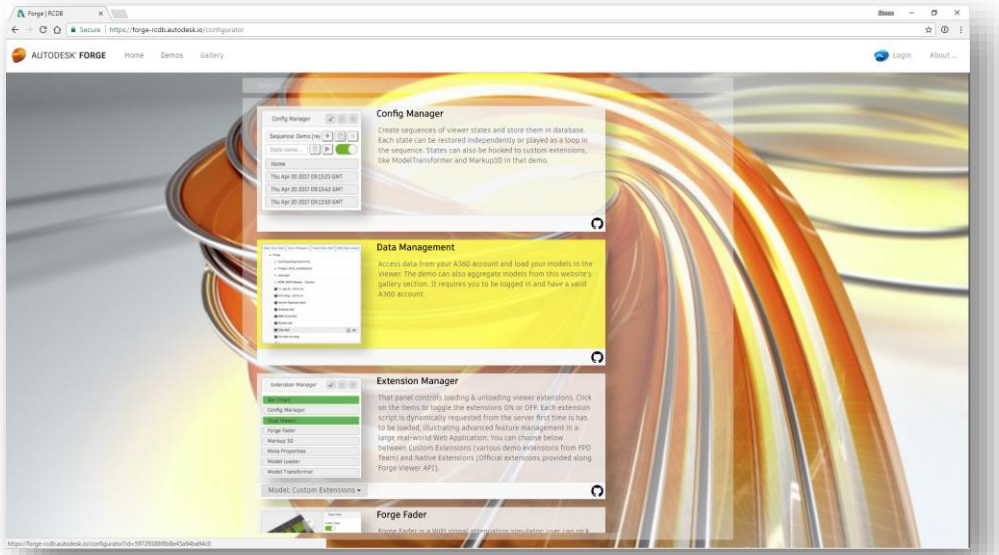
Data Management: Examples

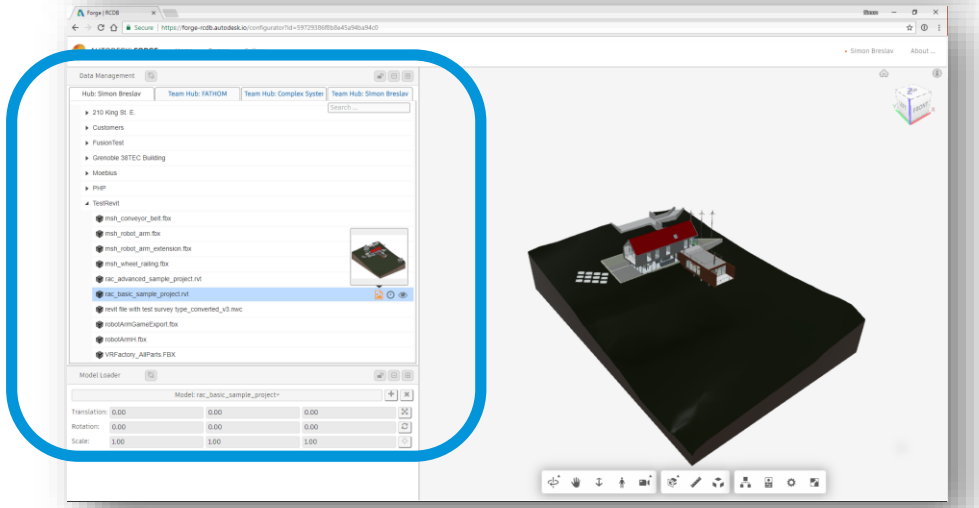
Data Management

https://github.com/Autodesk-Forge

- model.derivative-nodejs-sample
  - Demo: https://derivatives.autodesk.io
- forge-rcdb.nodejs
  - Demo: https://forge-rcdb.autodesk.io





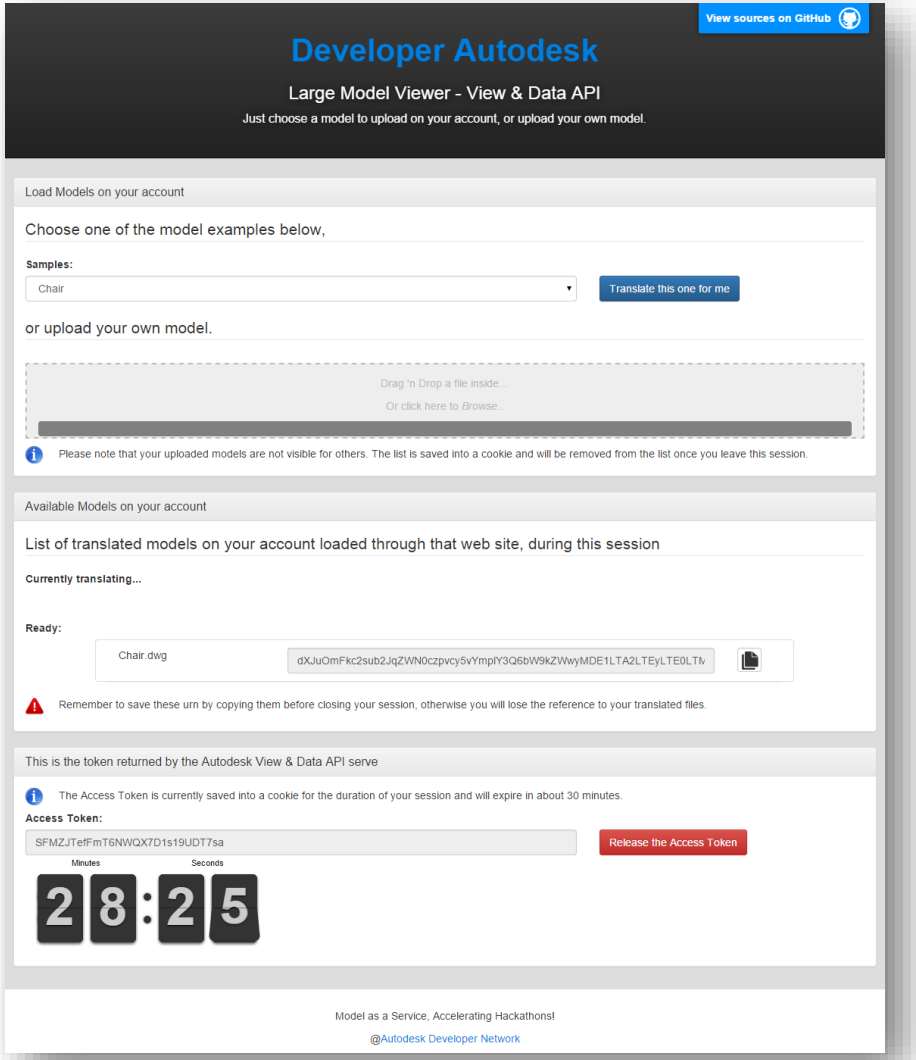


Model Derivative: Example

Model Derivative

https://github.com/Autodesk-Forge

- models.autodesk.io
  - Demo: https://models.autodesk.io



Viewer

Viewer

Viewer + Viewer Extensions

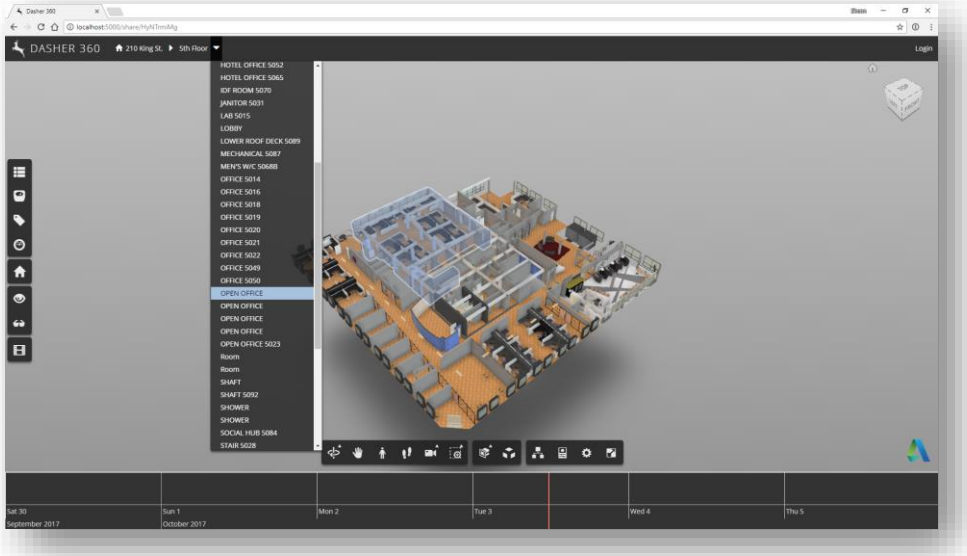
Navigation extensions (demo)

Toolbar

[Creating a vertical toolbar extension for the Autodesk viewer]

http://keanw.com/2016/05/creating-a-vertical-toolbar-extension-for-the-autodesk-viewer.html

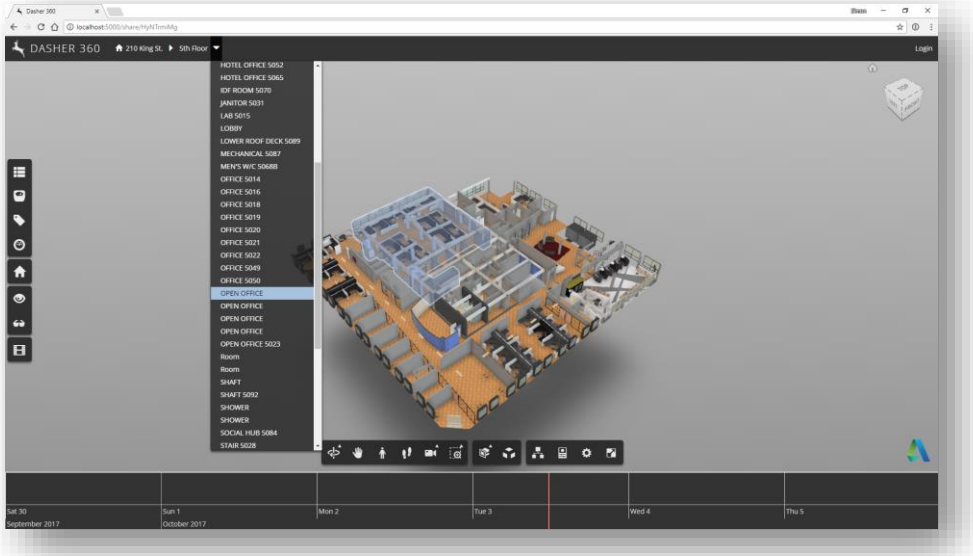
Breadcrumbs: Floor & Room Navigation



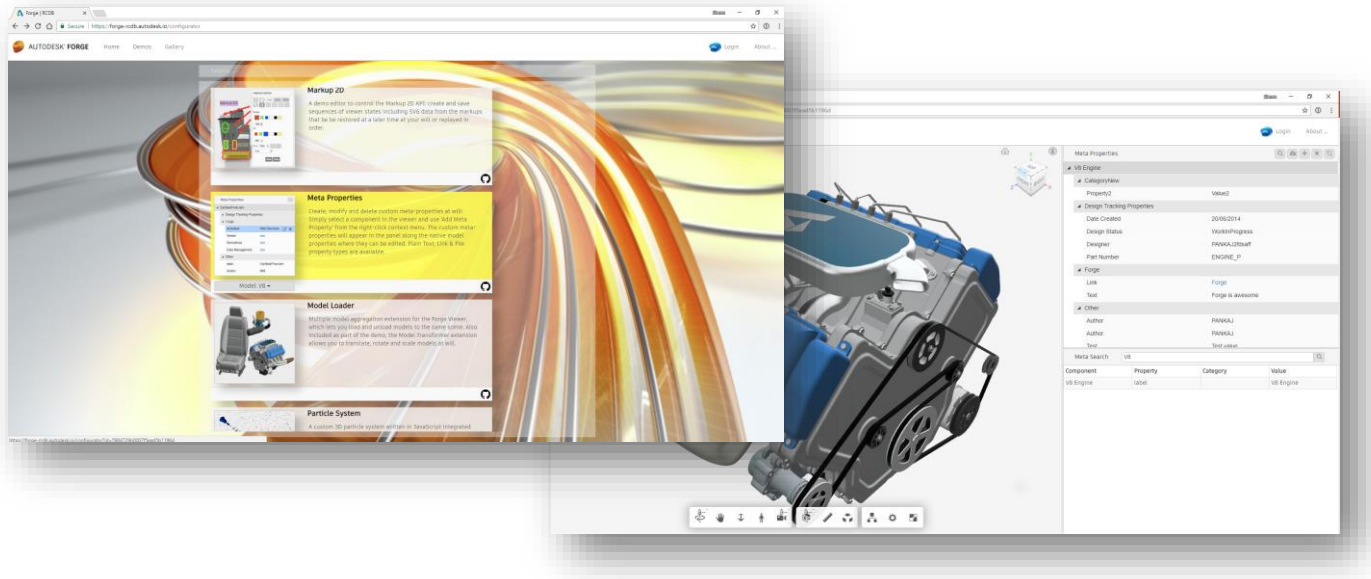
- Breadcrumb navigation widget
- Floor and room hierarchy
  - Combination of settings and property parsing

```
"levels": [
{ "match": "SIXTH FLOOR", "value": 6, "name": "6th Floor" },
{ "match": "FIFTH FLOOR", "value": 5, "name": "5th Floor" },
{ "match": ["LEVEL 4 FLR. FIN.", "FOURTH FLOOR"], "value": 4, "name": "4th Floor"
},
{ "match": ["LEVEL 3 FLR. FIN.", "THIRD FLOOR"], "value": 3, "name": "3rd Floor" },
{ "match": "LEVEL 2 FLR. FIN.", "value": 2, "name": "2nd Floor" },
{ "match": "LEVEL 1 FLR. FIN.", "value": 1, "name": "1st Floor" },
{ "match": "Ground Level", "value": 0, "name": "Ground Floor" }
]
```

Breadcrumbs: Floor & Room Navigation

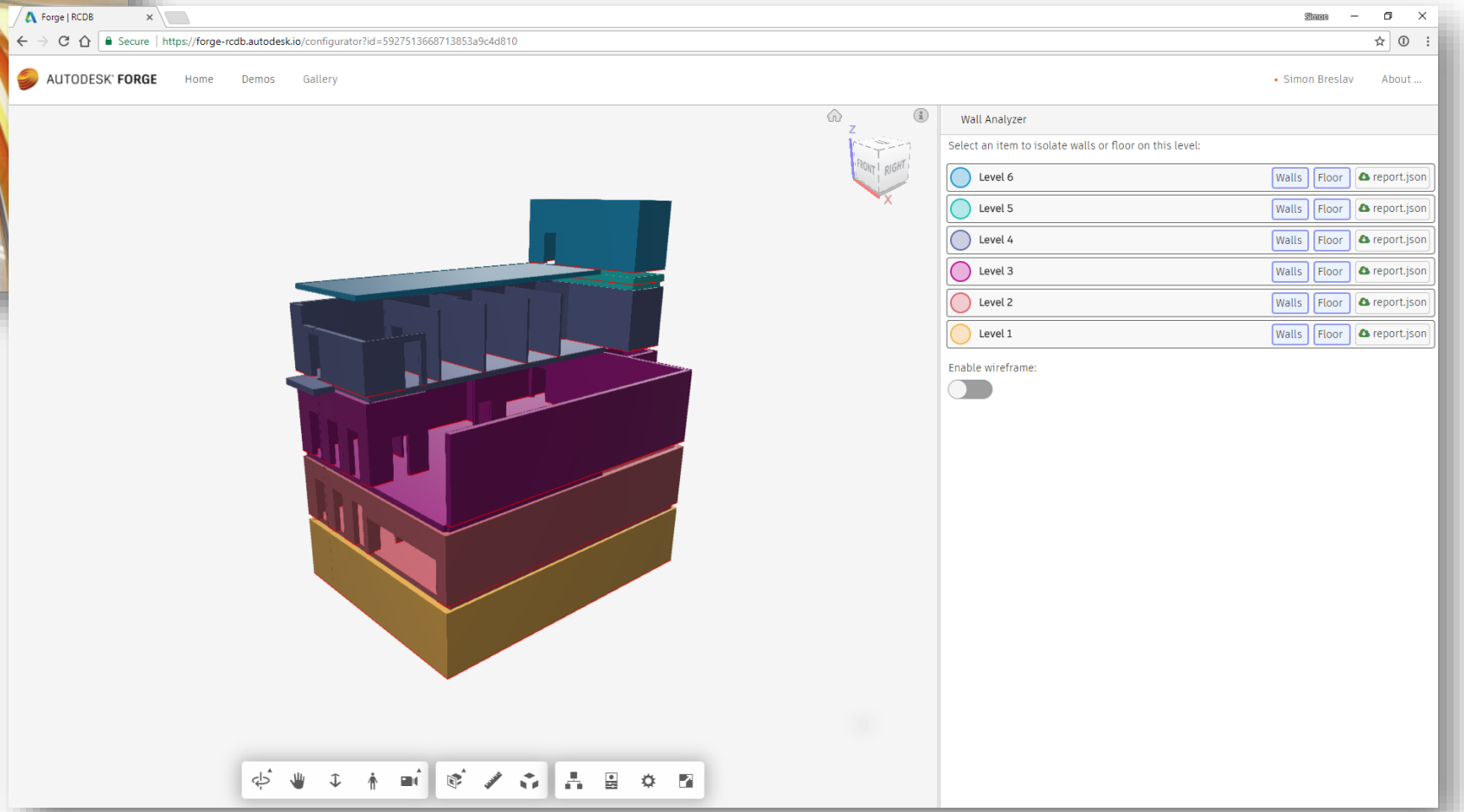


- Breadcrumb navigation widget
- Floor and room hierarchy
  - Combination of settings and property parsing
  - See Meta Properties demo on https://forge-rcdb.autodesk.io



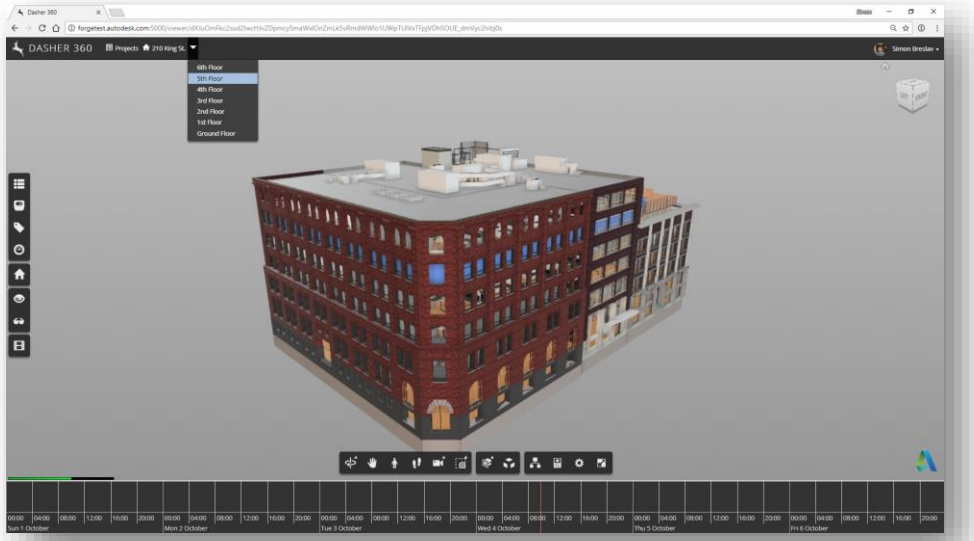
Breadcrumbs: Future Work: Geometric Analysis

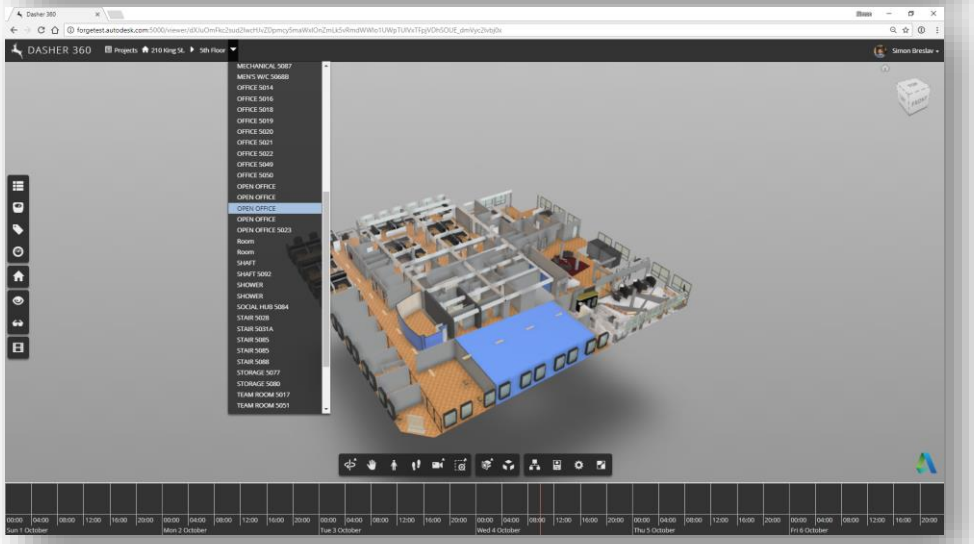
Wall Analyzer Demo!



https://forge-rcdb.autodesk.io

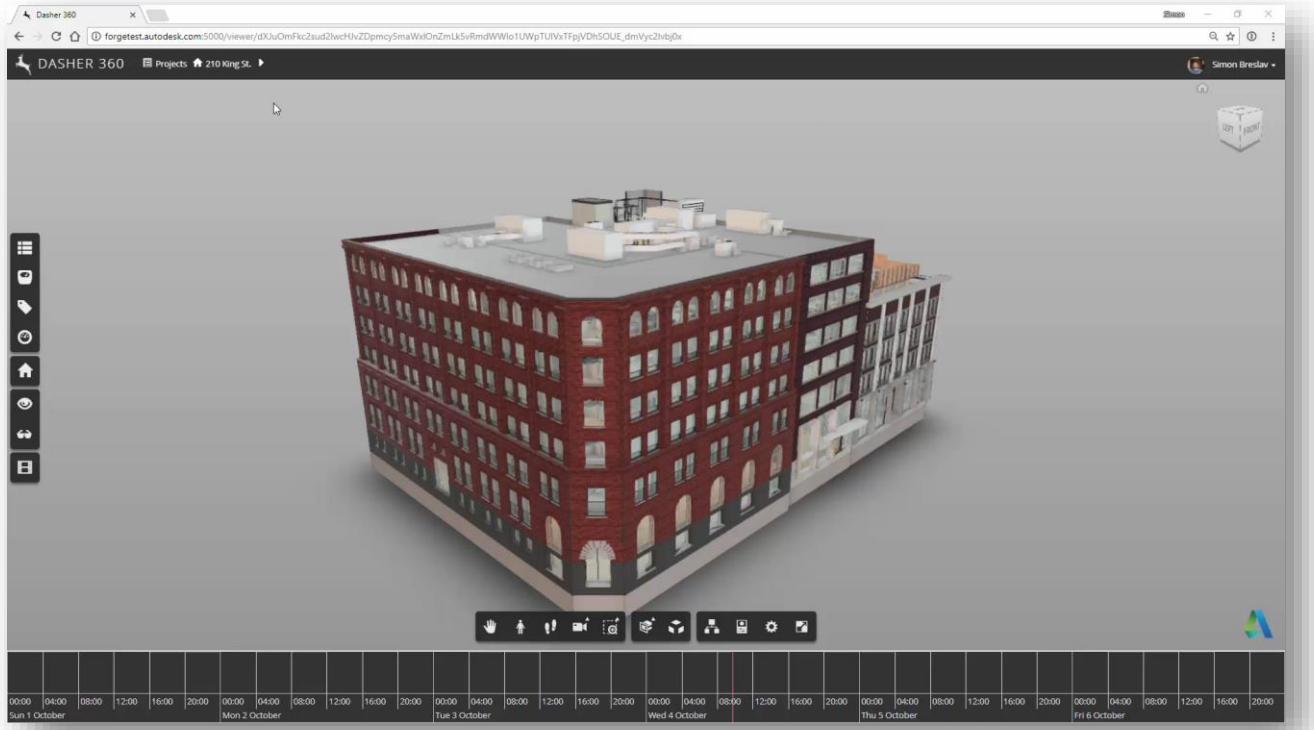
Breadcrumbs: Floor & Room Navigation



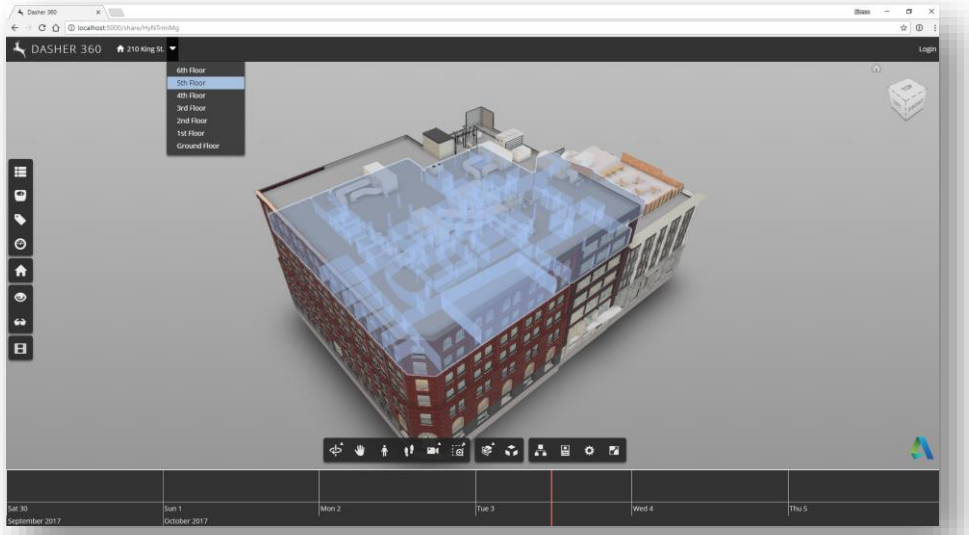


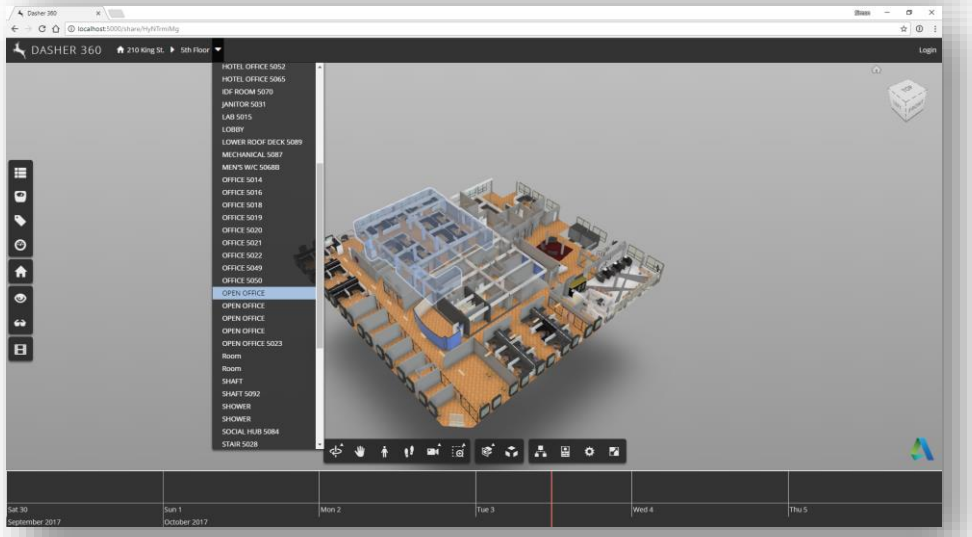
- Breadcrumb navigation widget
- Floor and room hierarchy
- Selection highlight
  - Uses room geometries

```
viewer.select(dbId)
viewer.clearSelection()
```



Breadcrumbs: Floor & Room Navigation





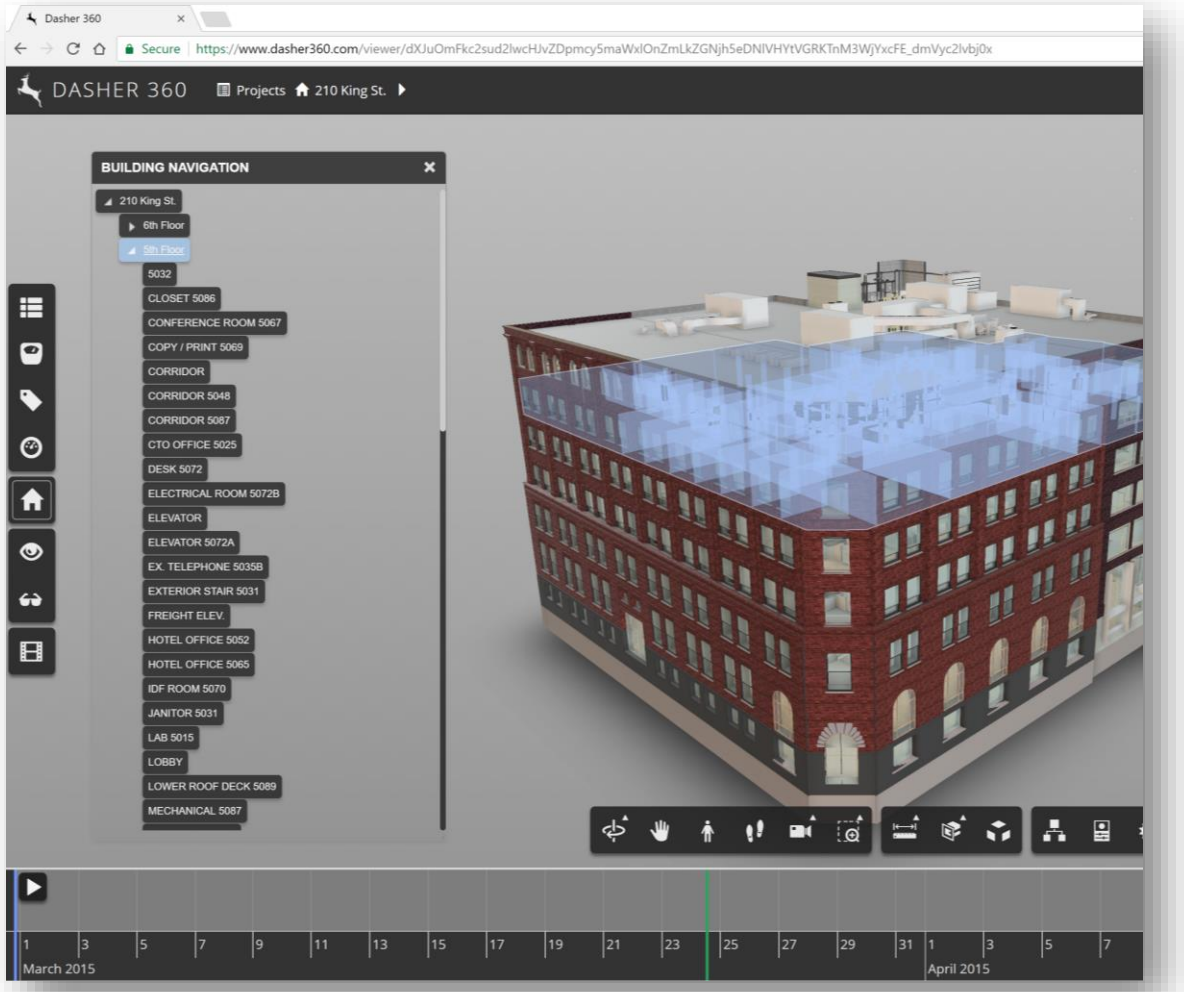
- Breadcrumb navigation widget
- Floor and room hierarchy
- Selection highlight
  - Uses room geometries
  - Avoids building redraw by using overlays
  - WARNING: Undocumented API, use at own risk!

```
let material = new THREE.MeshBasicMaterial(
{color: 0x6e98ee,
 transparent: true,
 opacity: 0.5 });
material.depthWrite = false;
material.depthTest = false;
viewer.impl.createOverlayScene('CustomSelection');

let renderProxy = this.viewer.impl.getRenderProxy(viewer.model, fragId);
let meshProxy = new THREE.Mesh(renderProxy.geometry, material);
meshProxy.matrix.copy(renderProxy.matrixWorld);

viewer.impl.addOverlay('CustomSelection', meshProxy);
viewer.impl.invalidate(false, false, true);
```

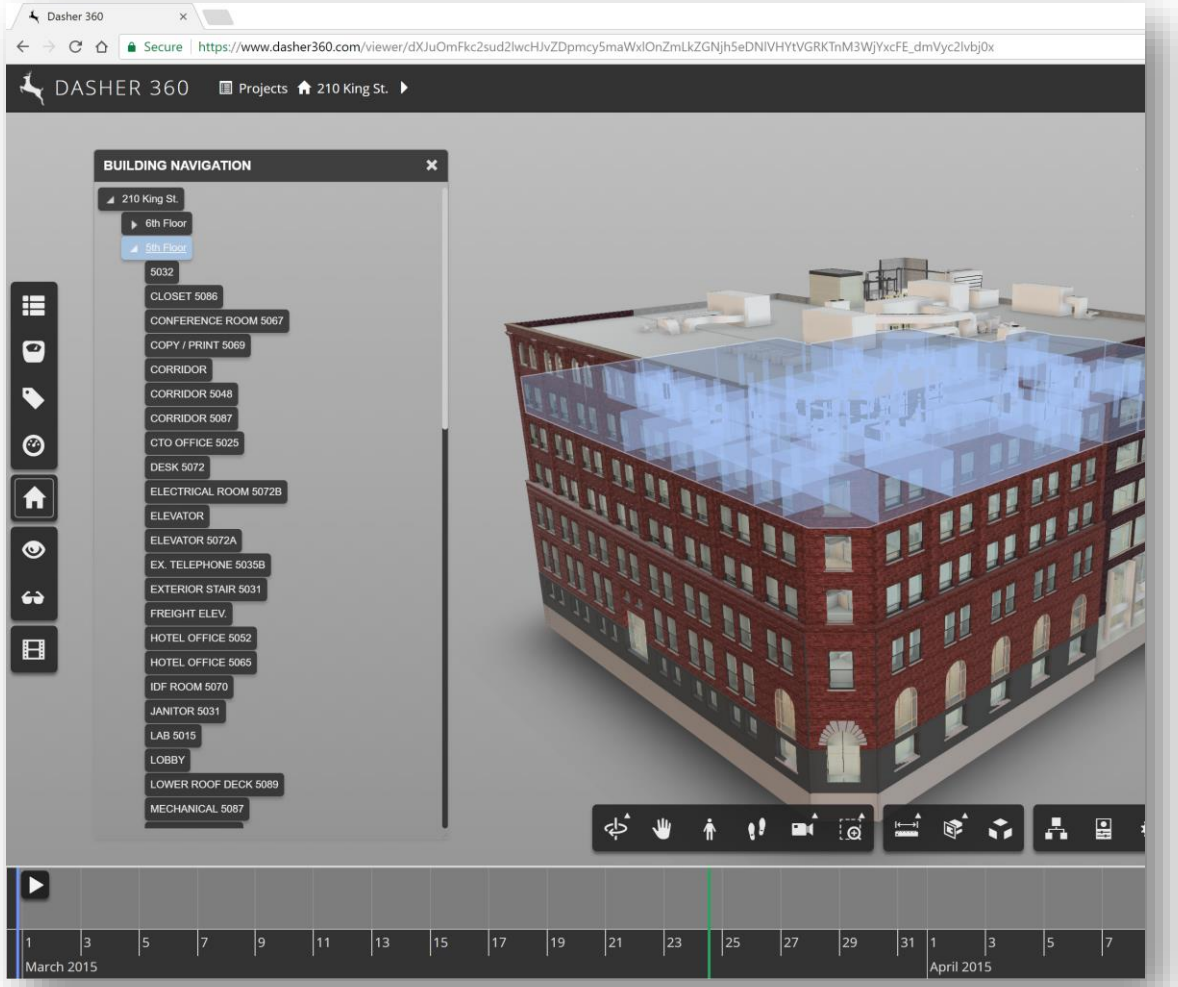
Building Navigation List



Autodesk.Viewing.UI.Tree

Autodesk.Viewing.UI.TreeDelegate

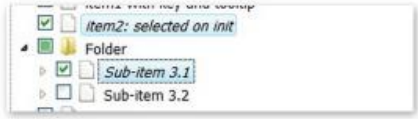
Building Navigation List

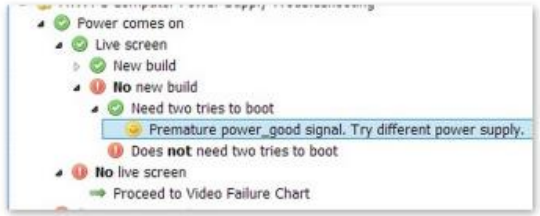


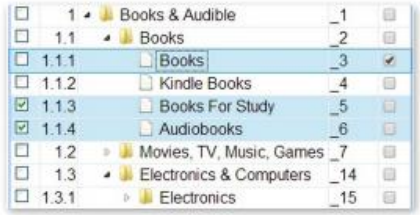
`Autodesk.Viewing.UI.Tree`

`Autodesk.Viewing.UI.TreeDelegate`

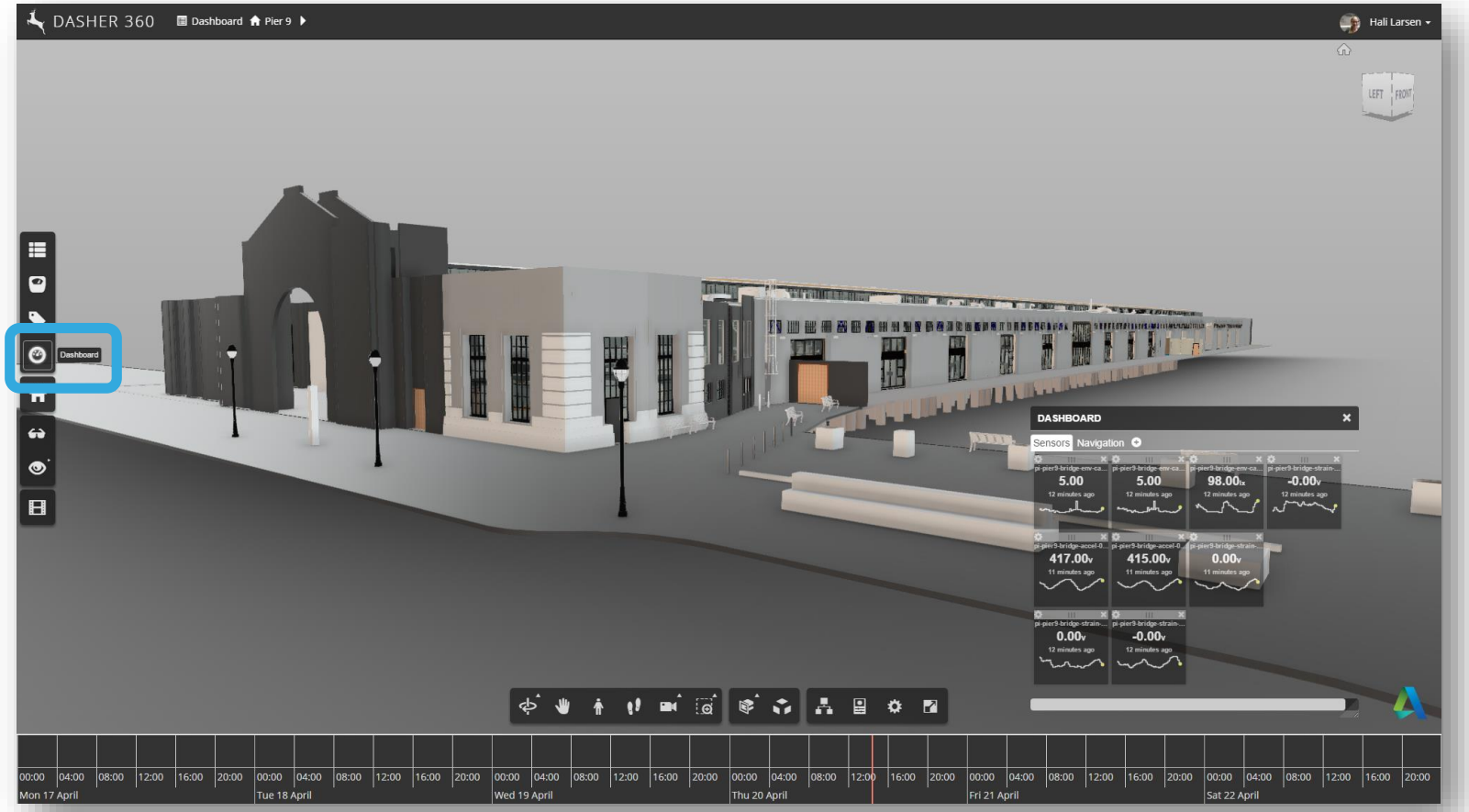
https://github.com/mar10/fancytree

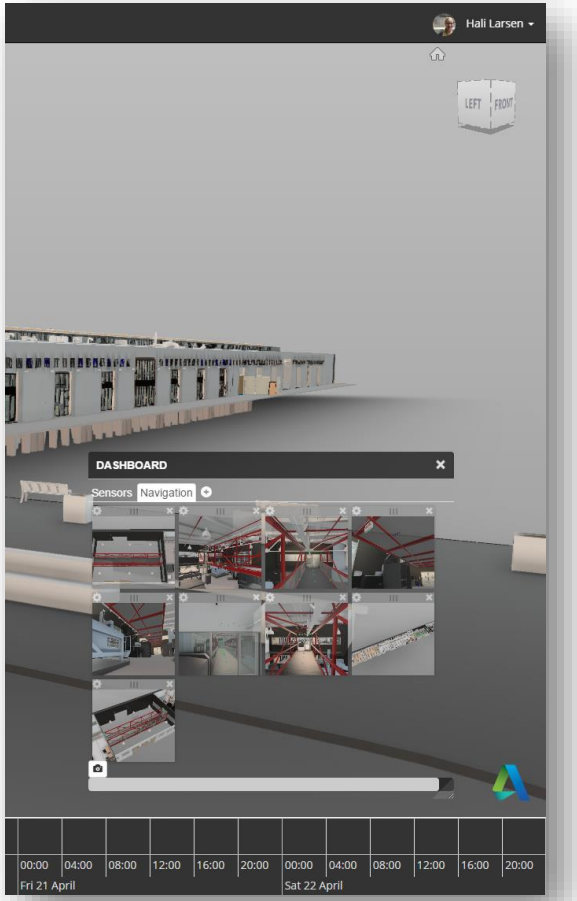




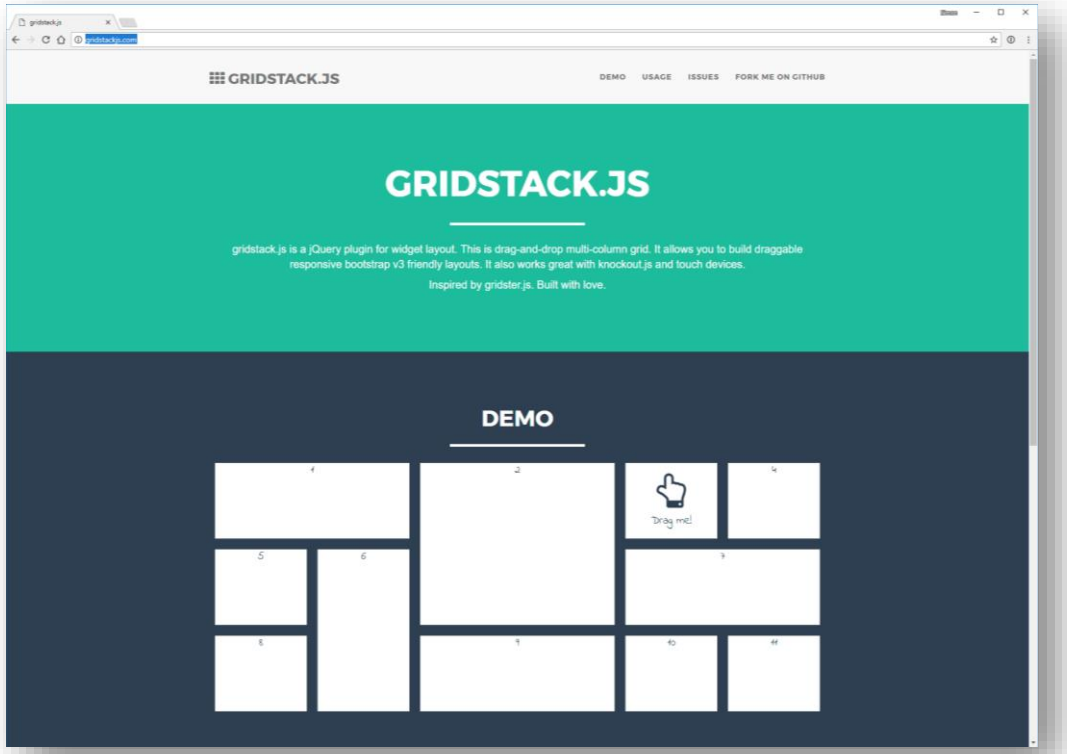


Sensor & View Bookmark Dashboard



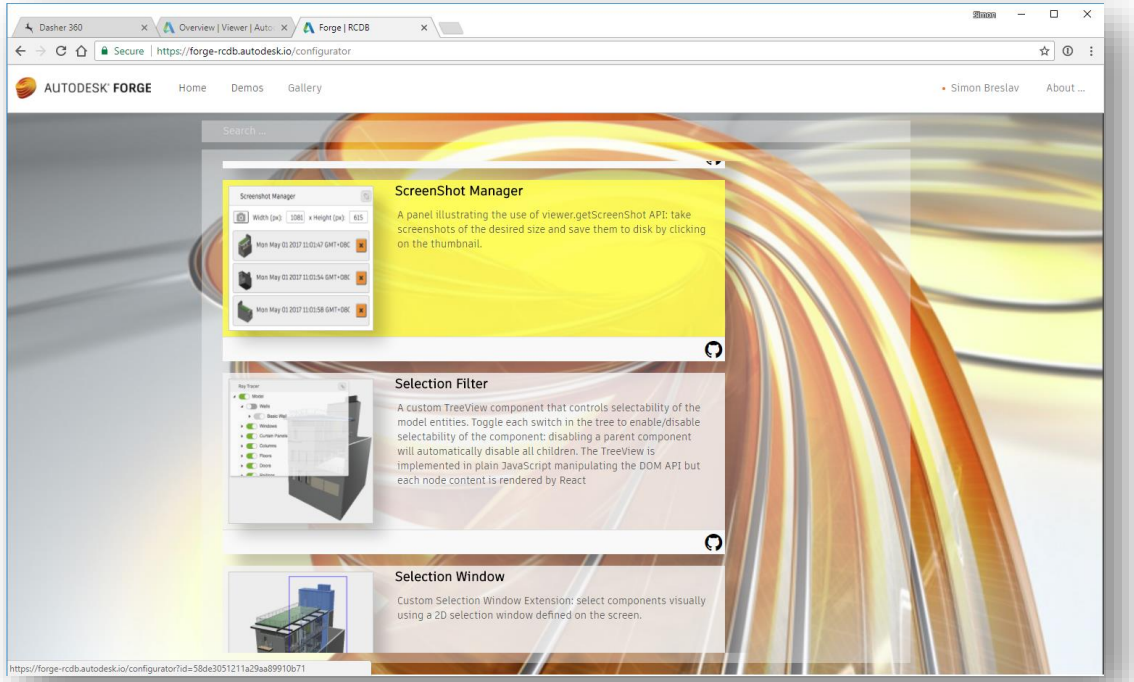


Sensor & View Bookmark Dashboard



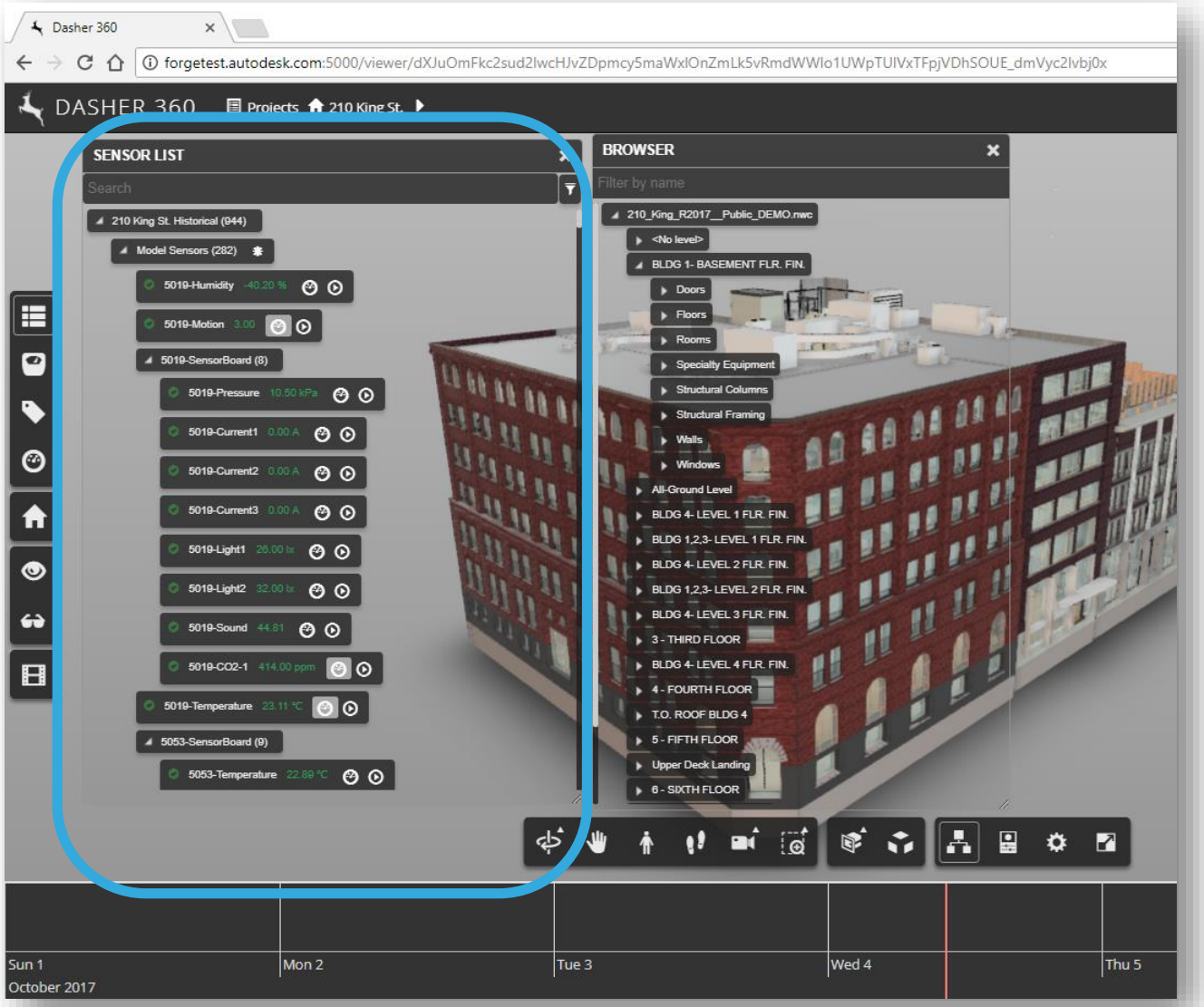
http://gridstackjs.com

```
viewer.getScreenShotBuffer(width, height, callback)
viewer.getState(filter)
viewer.restoreState(viewerState, filter, immediate)
```

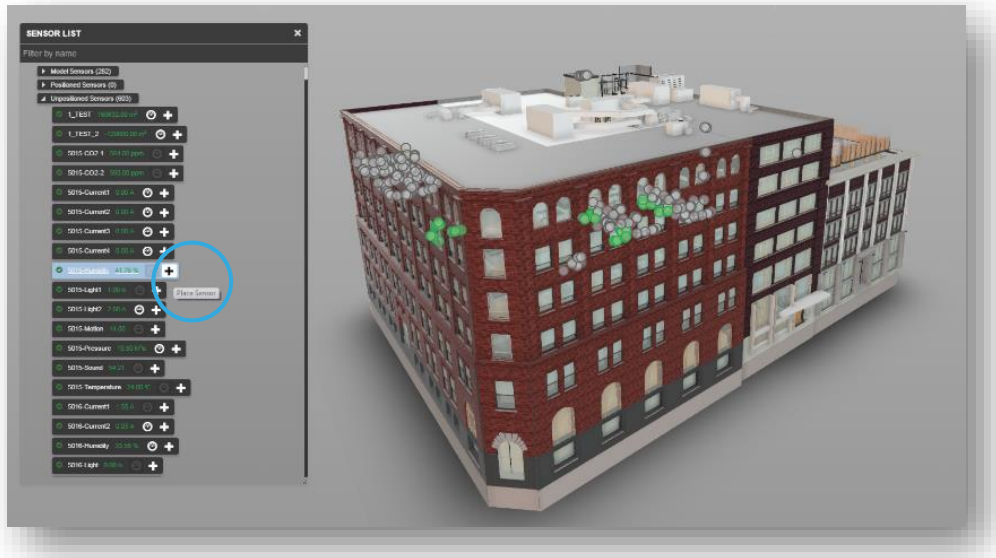


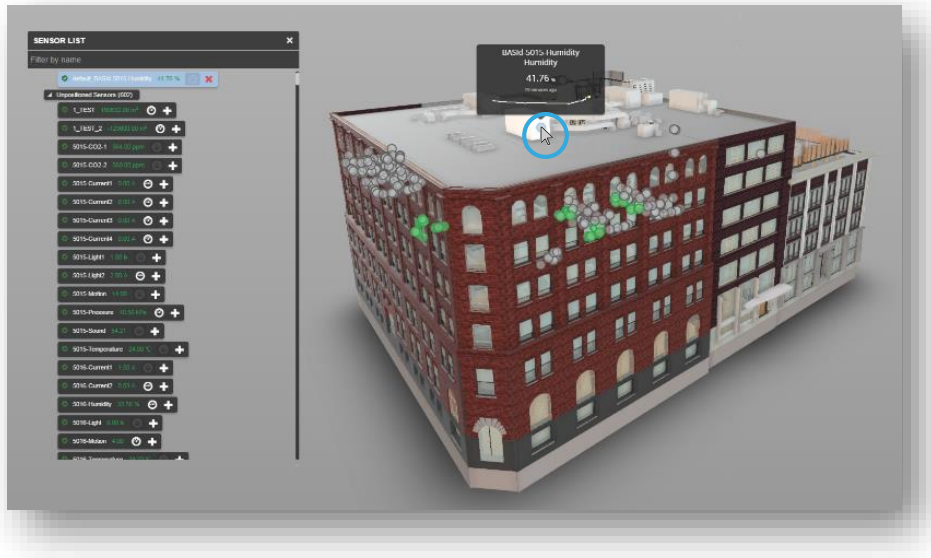
Sensor extensions (demo)

Sensor List


Dasher 360
forgetest.autodesk.com:5000/viewer/dXJuOmFkc2sud2lwcHJvZDpmcy5maWxlOnZmLk5vRmdWWlo1UWpTUlVxTFpjVDhSOUE_dmVyc2lvbj0x
DASHER 360
Projects
210 King St.
SENSOR LIST
Search
210 King St. Historical (944)
Model Sensors (282)
5019-Humidity -40.20 %
5019-Motion 3.00
5019-SensorBoard (8)
5019-Pressure 10.50 kPa
5019-Current1 0.00 A
5019-Current2 0.00 A
5019-Current3 0.00 A
5019-Light1 26.00 lx
5019-Light2 32.00 lx
5019-Sound 44.81
5019-CO2-1 414.00 ppm
5019-Temperature 23.11 °C
5053-SensorBoard (9)
5053-Temperature 22.88 °C
BROWSER
Filter by name
210_King_R2017__Public_DEMO.nwc
<No level>
BLDG 1- BASEMENT FLR. FIN.
Doors
Floors
Rooms
Specialty Equipment
Structural Columns
Structural Framing
Walls
Windows
All-Ground Level
BLDG 4- LEVEL 1 FLR. FIN.
BLDG 1,2,3- LEVEL 1 FLR. FIN.
BLDG 4- LEVEL 2 FLR. FIN.
BLDG 1,2,3- LEVEL 2 FLR. FIN.
BLDG 4- LEVEL 3 FLR. FIN.
3 - THIRD FLOOR
BLDG 4- LEVEL 4 FLR. FIN.
4 - FOURTH FLOOR
T.O. ROOF BLDG 4
5 - FIFTH FLOOR
Upper Deck Landing
6 - SIXTH FLOOR
Sun 1
October 2017
Mon 2
Tue 3
Wed 4
Thu 5

Sensor List: Placing Sensors

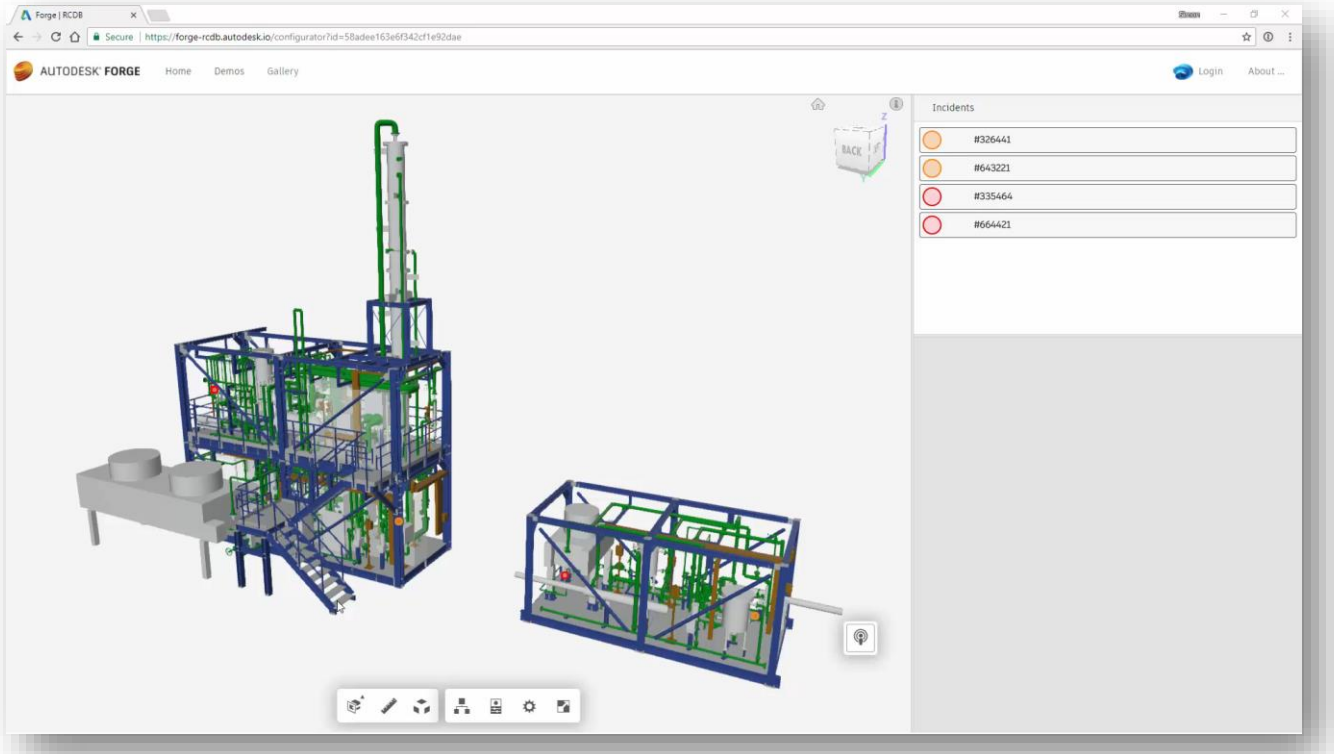




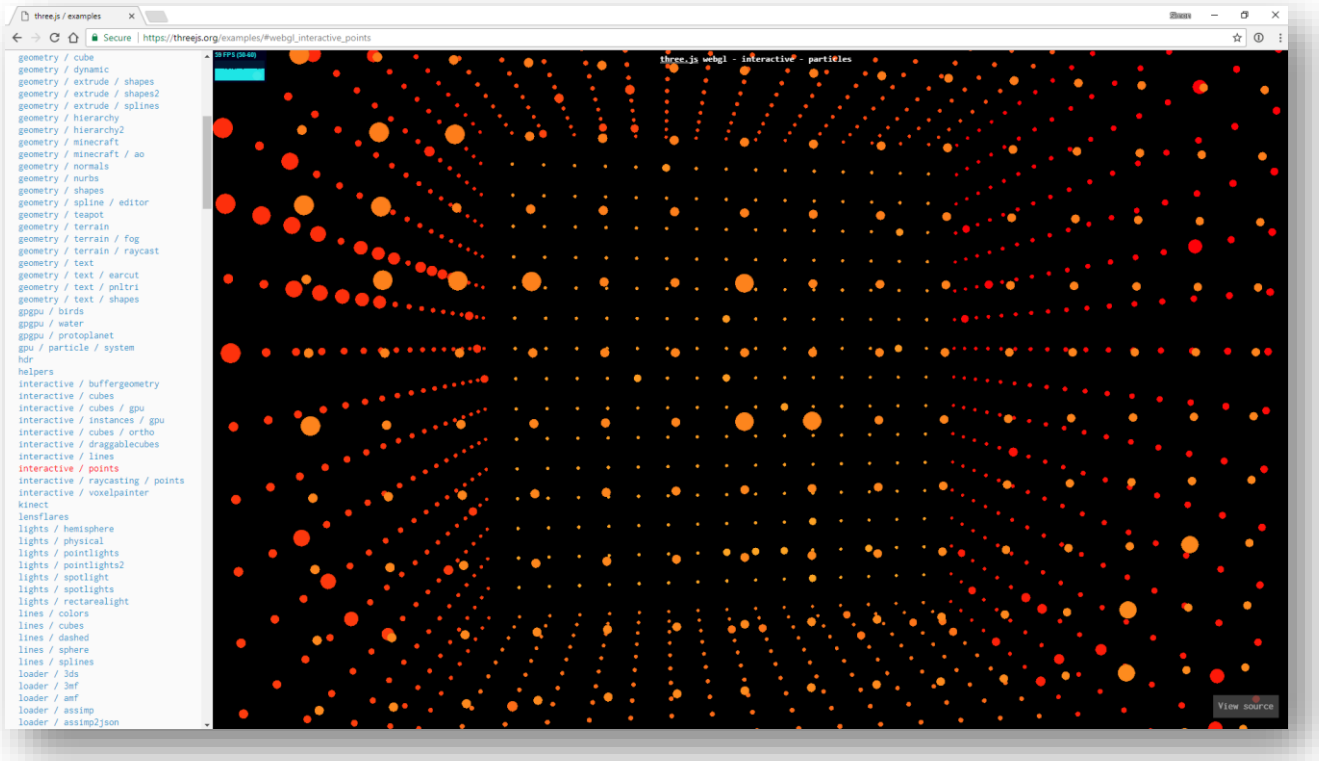

```
viewer.clientToWorld(clientX, clientY, ignoreTransparent)
viewer.clientToWorld(event.canvasX, event.canvasY, false);
```

Sensor Dots

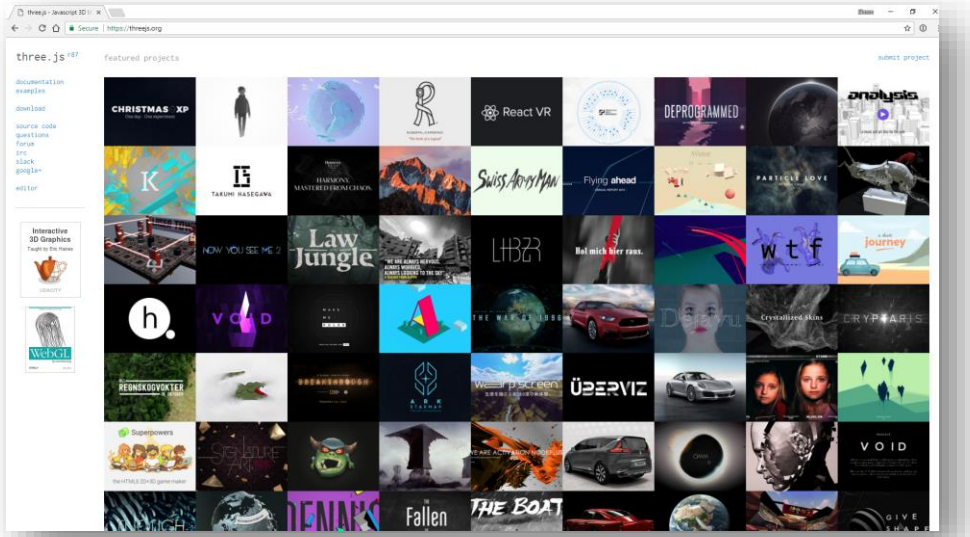
- Sensor Dots were originally SVG elements
  - Easy to animate
  - Easy to make interactive (hover, click)
- Tracks camera movements
- **IoT** Example: https://forge-rcdb.autodesk.io



Sensor Dots: Particle System/Point Cloud



https://threejs.org/examples/#webgl_interactive_points



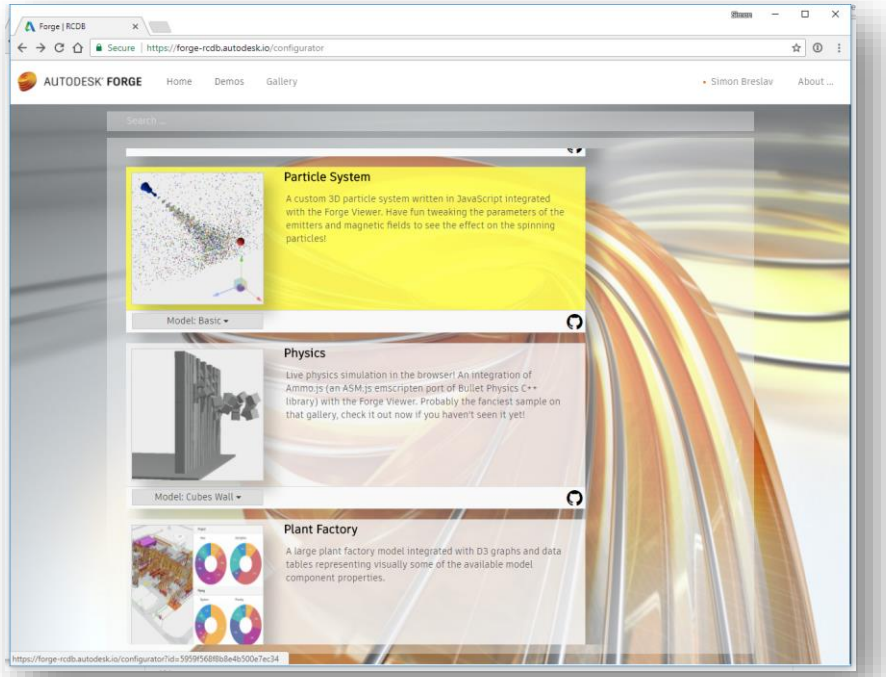
https://threejs.org/

WARNING: Check which version of three.js the Viewer is using, old three.js releases are available on GitHub

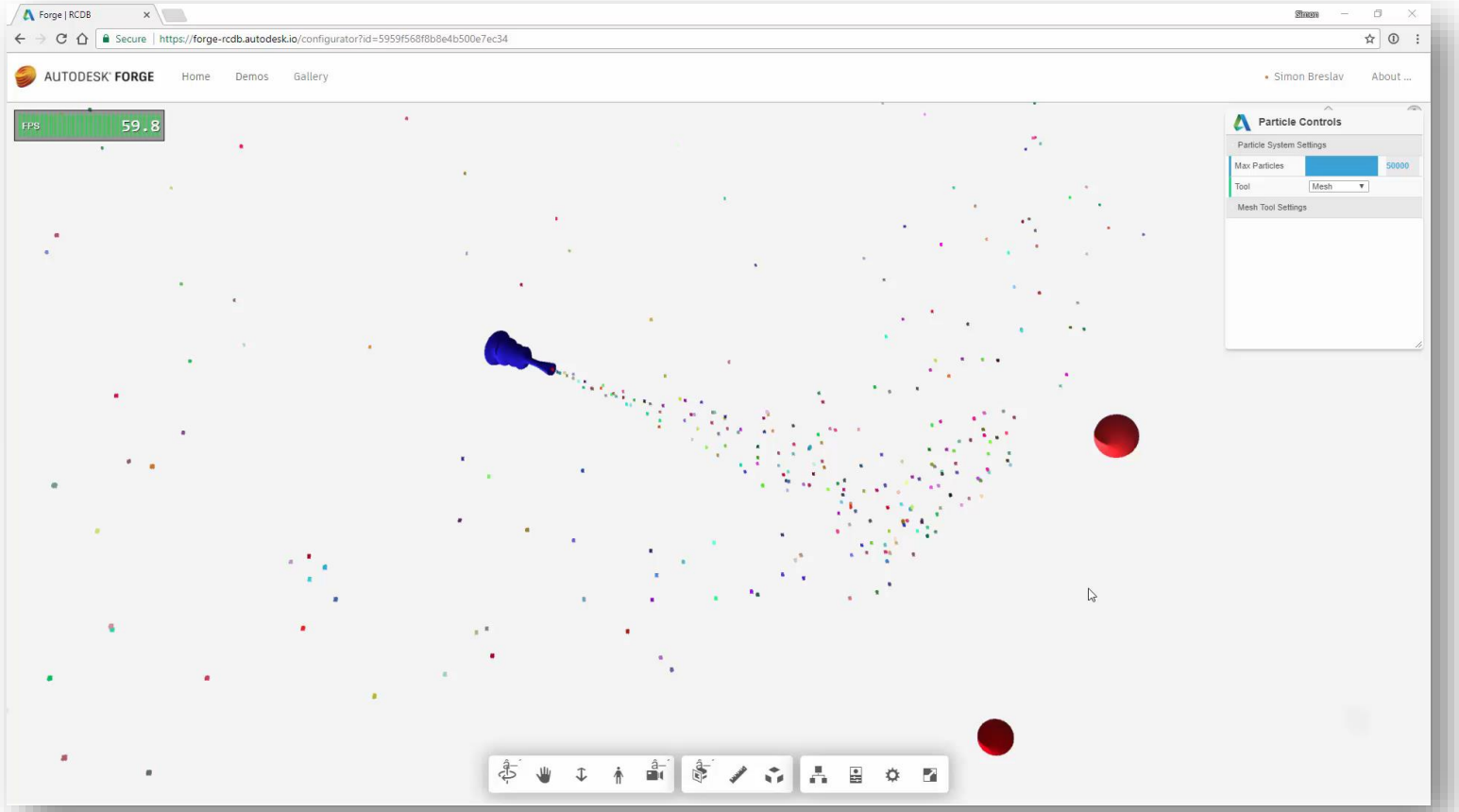
https://github.com/mrdoob/three.js/releases/tag/r71

- Release has the docs and examples!

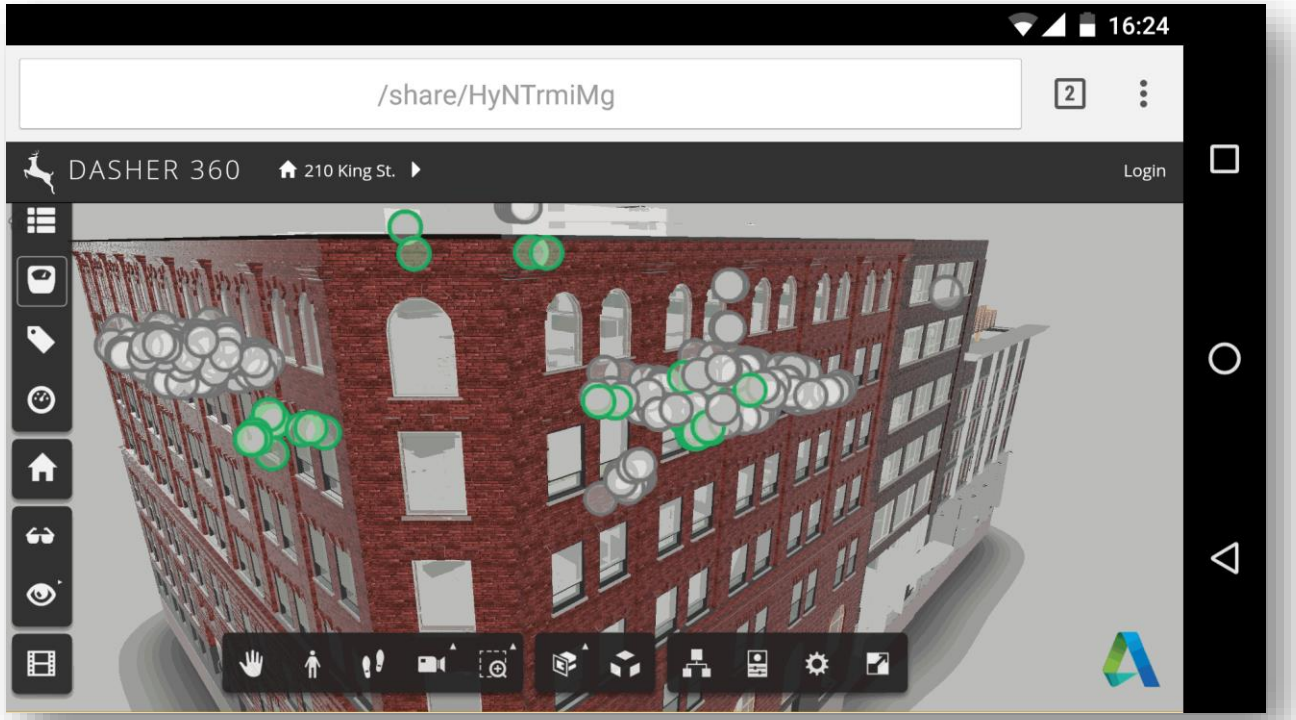
Sensor Dots: Particle System/Point Cloud

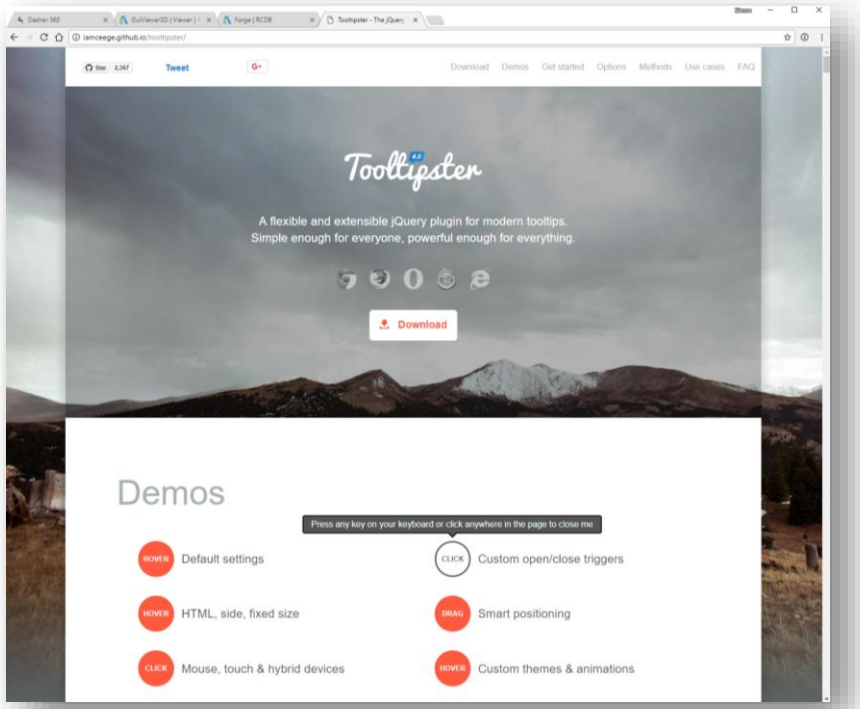


https://forge-rcdb.autodesk.io



Tooltips & Touch



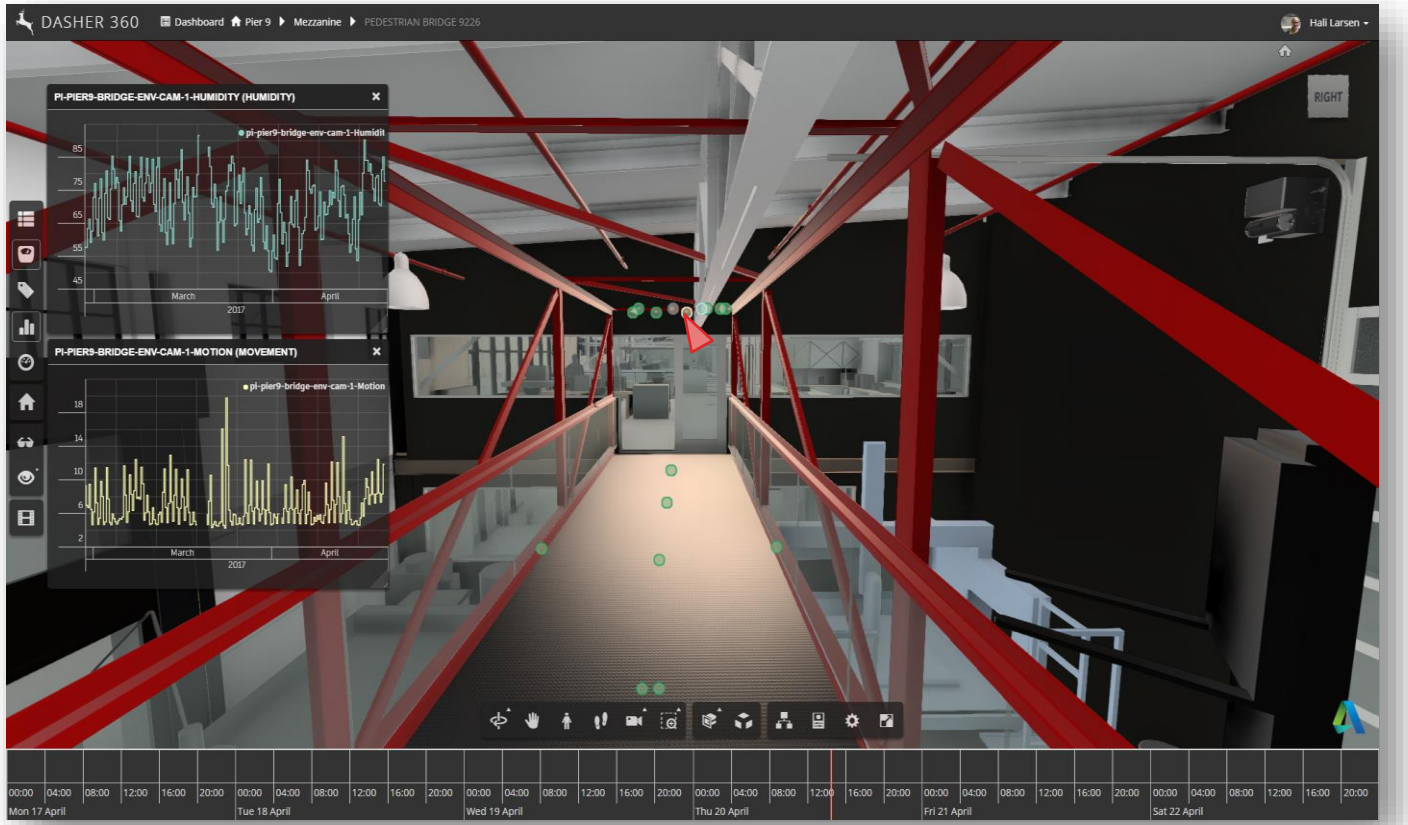


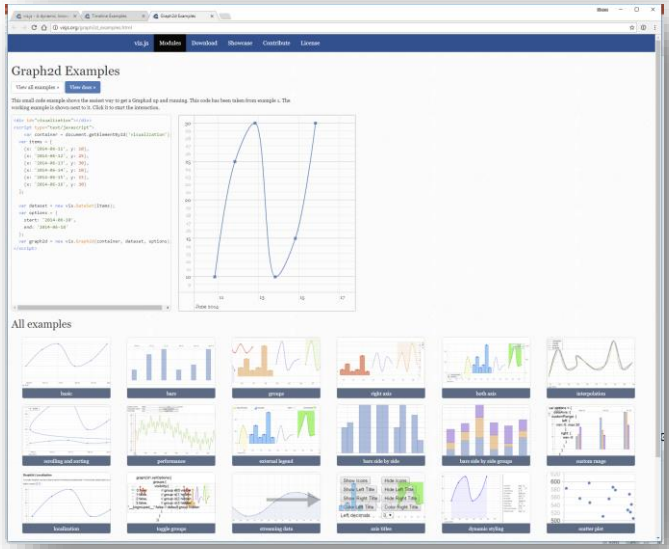
http://iamceege.github.io/tooltipster

Handling both mouse and touch events in Forge viewer applications

http://keanw.com/2017/04/handling-both-mouse-and-touch-events-in-forge-viewer-applications.html

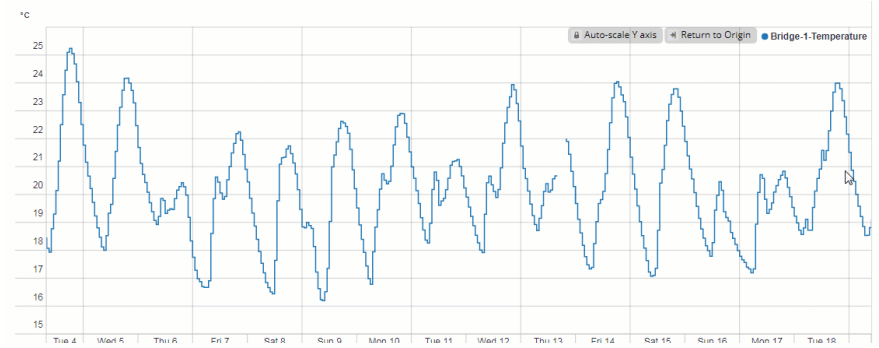
Charts

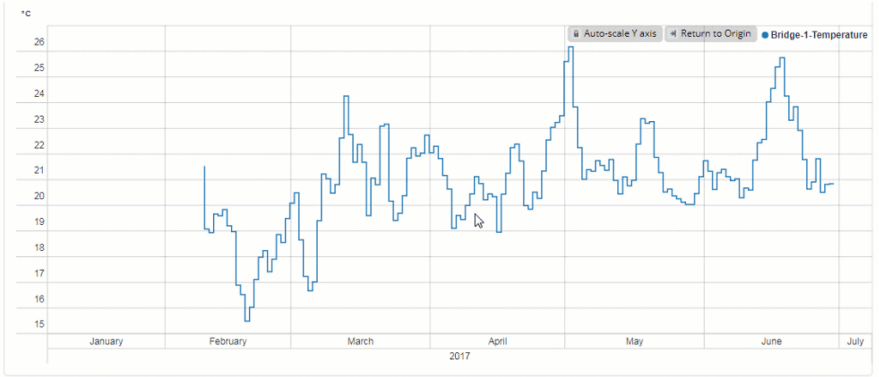


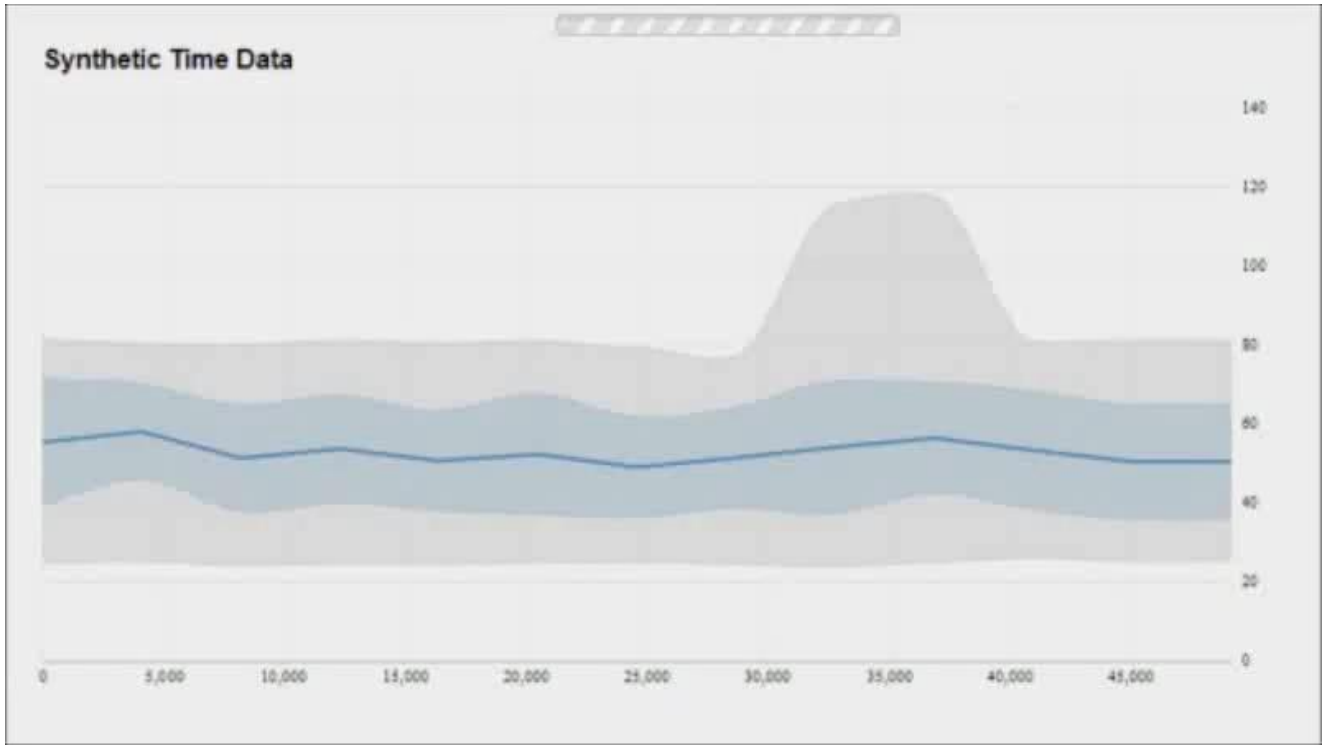


http://visjs.org

Charts: Splash





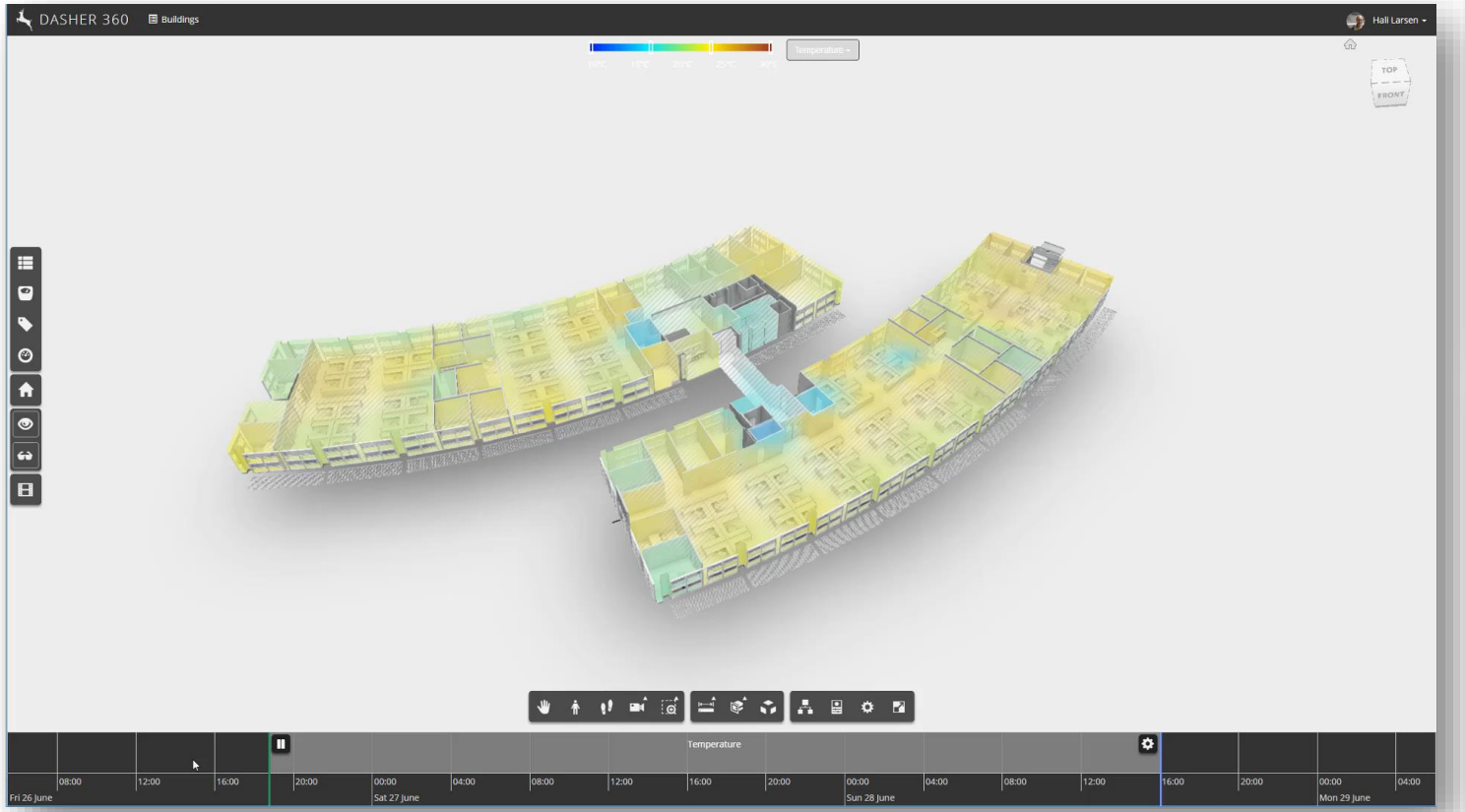


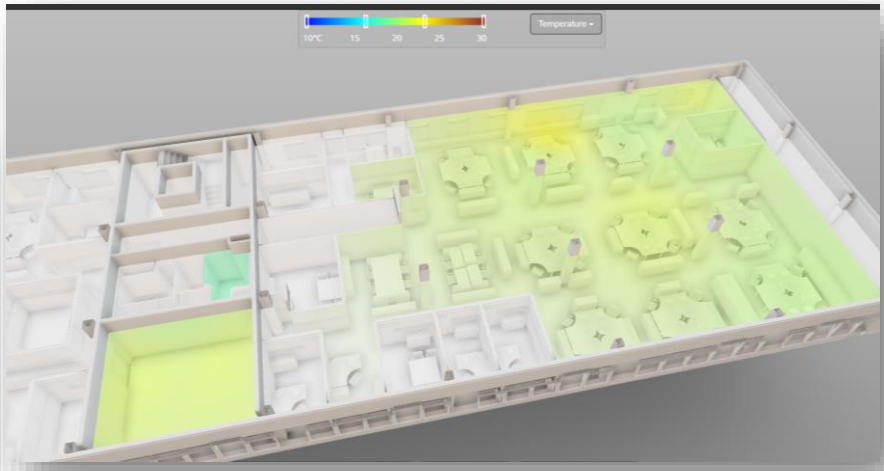
https://autodeskresearch.com/publications/splash

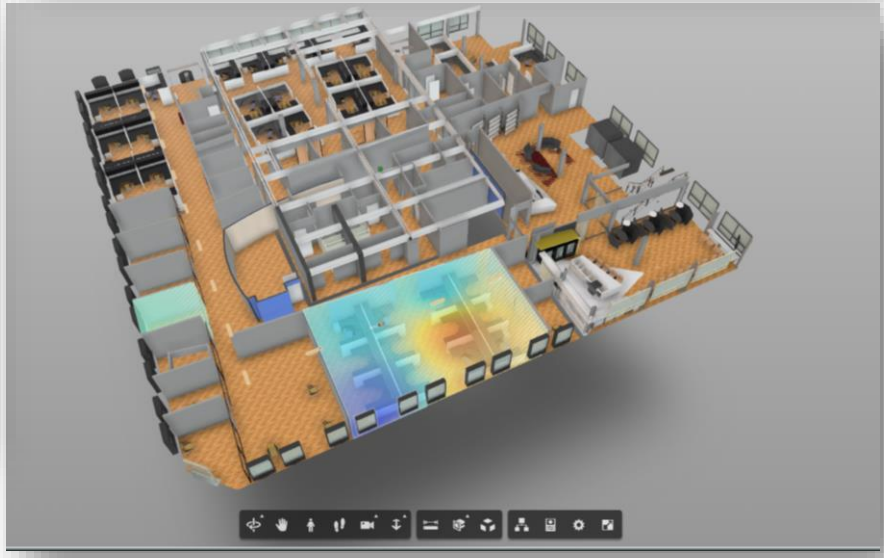
Data is retrieved and loaded a various levels of detail to enable fluid pan and zoom navigation

Sensor extensions II (demo)

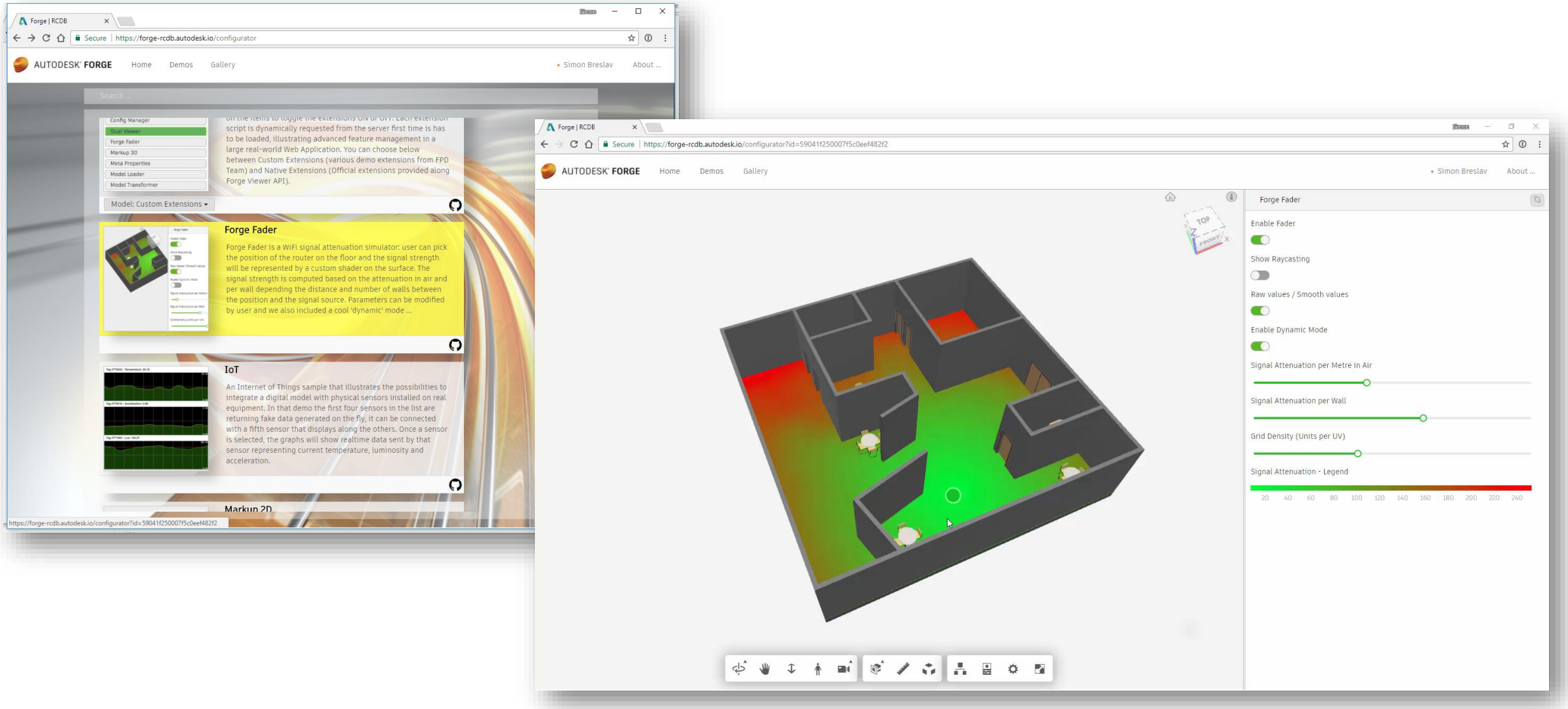
Surface Shading / Heatmap



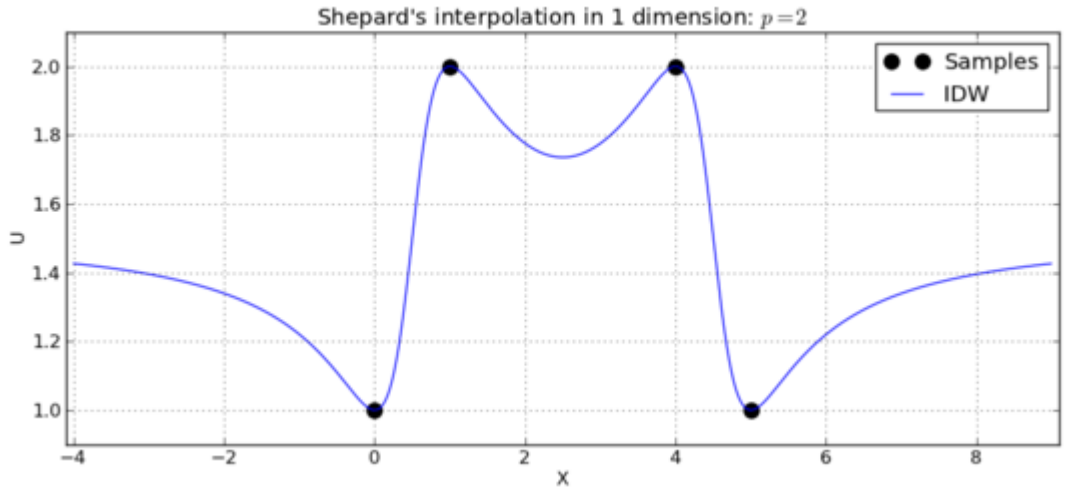




Surface Shading / Heatmap



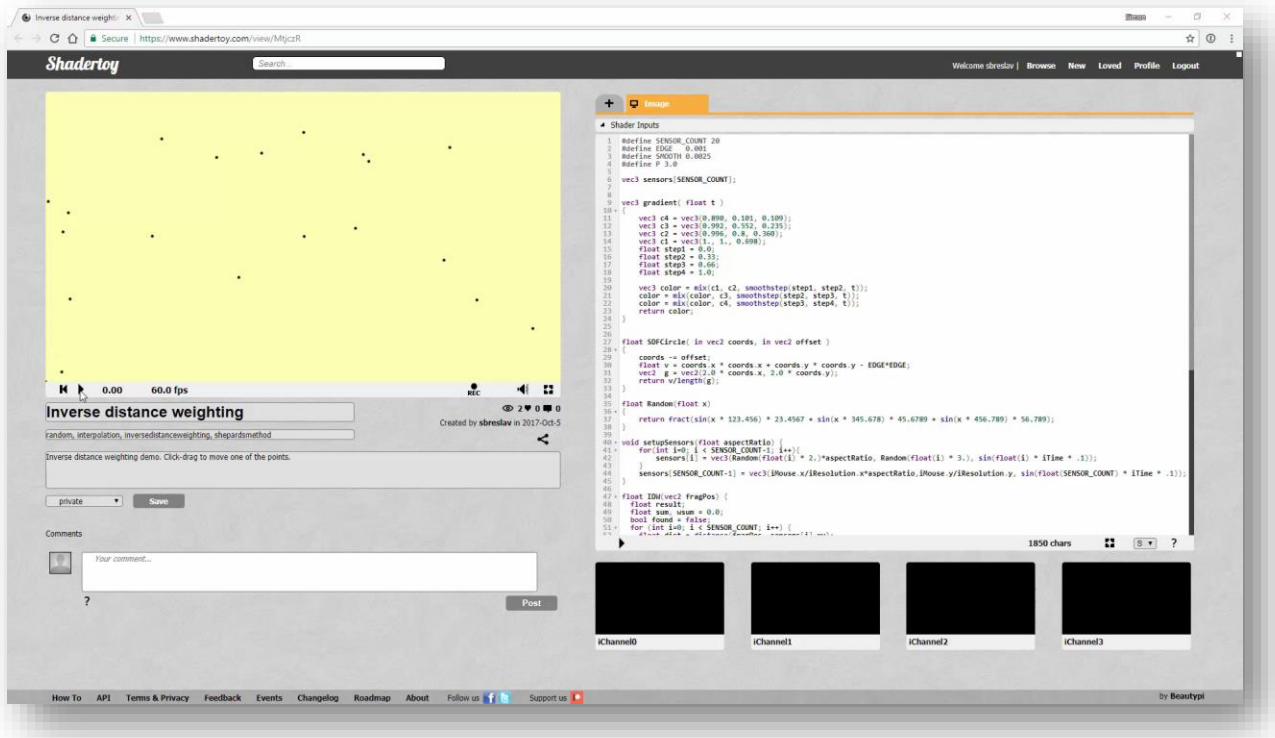
Surface Shading: Inverse distance weighting



- Inverse Distance Weighting (A.K.A Shepard's method)
  - https://en.wikipedia.org/wiki/Inverse_distance_weighting
- Shepard, Donald (1968). "A two-dimensional interpolation function for irregularly-spaced data". *Proceedings of the 1968 ACM National Conference*. pp. 517–524.

Lots of other methods to interpolate values:
https://en.wikipedia.org/wiki/Multivariate_interpolation

Surface Shading: Inverse distance weighting

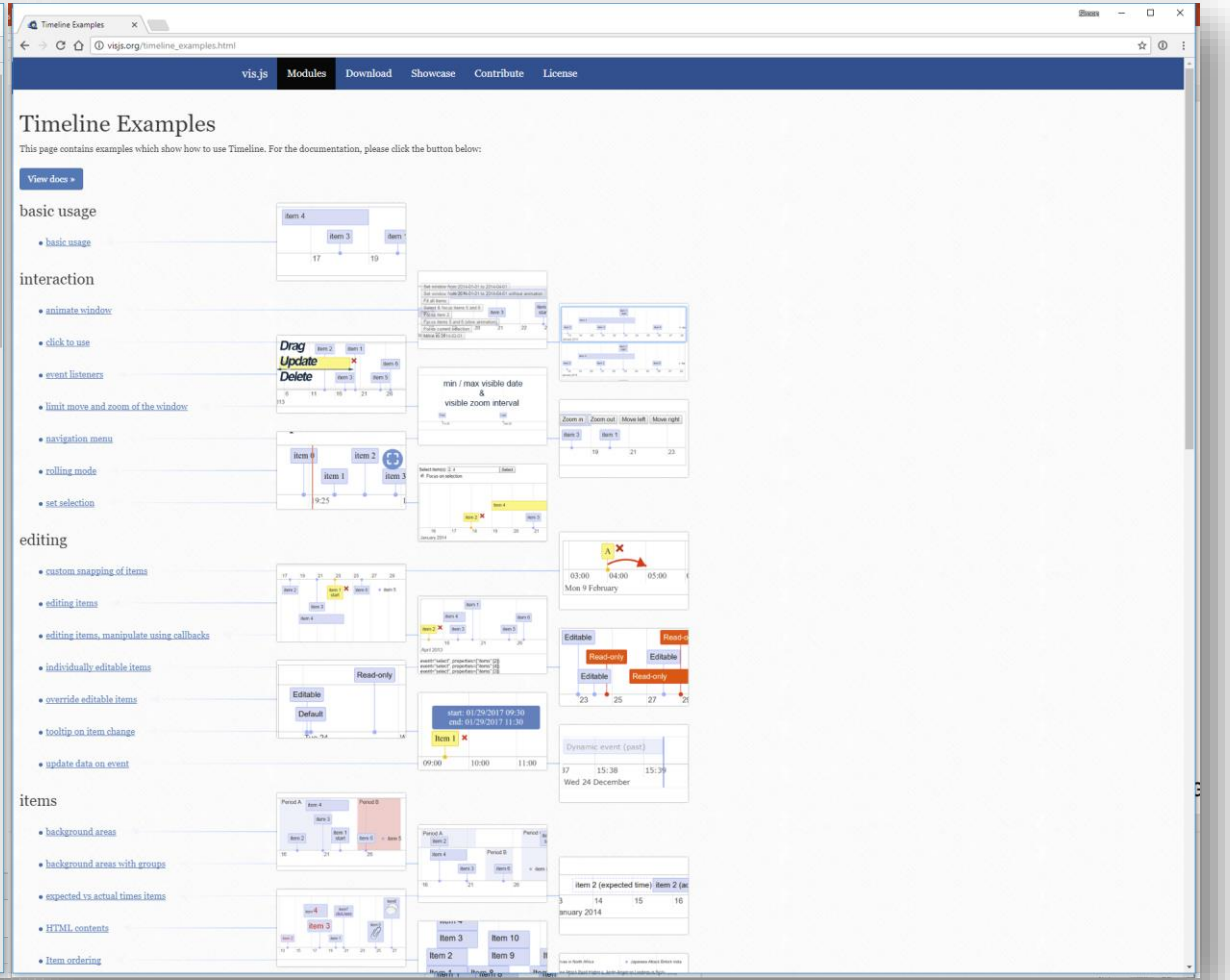


https://www.shadertoy.com/view/MtjczR

GLSL

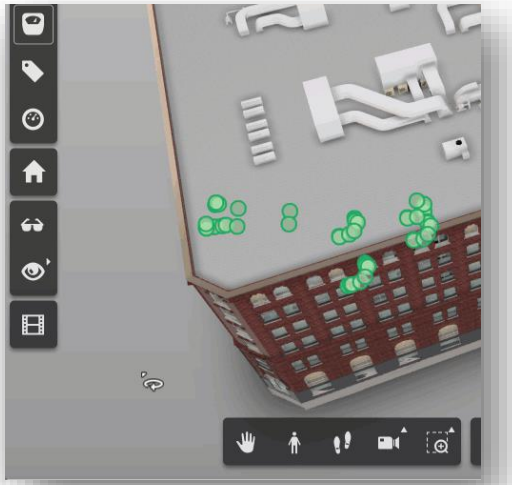
```
...
float IDW(vec2 fragPos) {
  float sum, wsum = 0.0;
  for (int i=0; i < SENSOR_COUNT; i++) {
    float dist = distance(fragPos, sensors[i].xy);
    if( dist > 0.0) {
      float w = (1.0 / pow(dist, P));
      sum += (sensors[i].z * w);
      wsum += w;
    } else {
      return sensors[i].z;
    }
  }
  return sum / wsum;
}
...
```

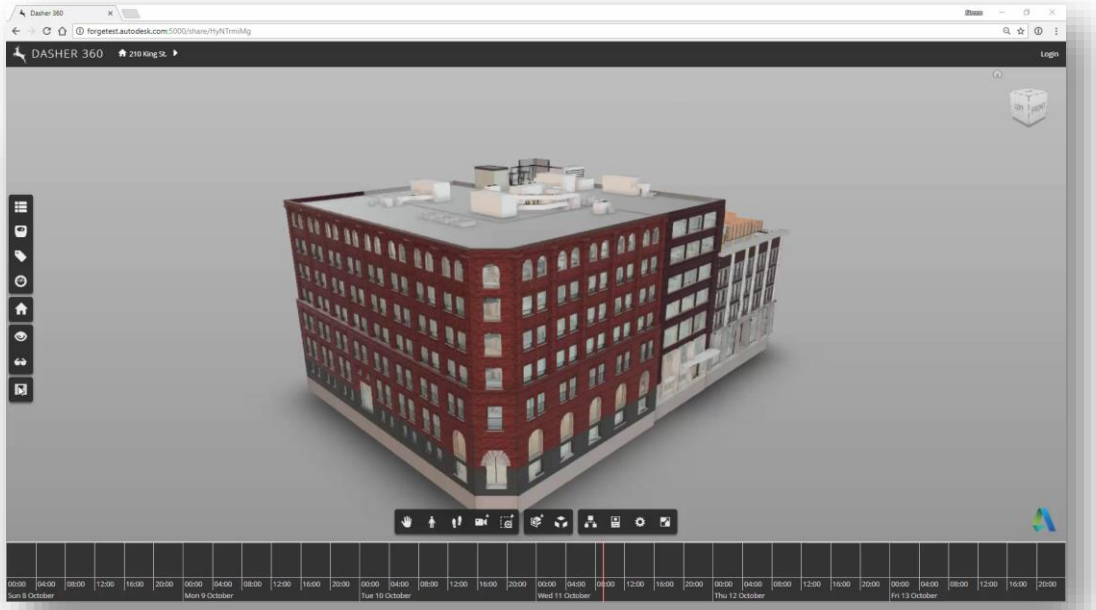
Timeline: visjs.org



Kiosk Mode

- Designed for when you want to leave Dasher 360 in “demo mode”
  - For instance on a large screen in your building lobby
- Displays a fake cursor to simulate the operation of Dasher 360
- Loops through various Dasher 360 features, interruptable by mouse or touch input
- Functional for any screen configuration, view- and model-independent
- Easily extensible



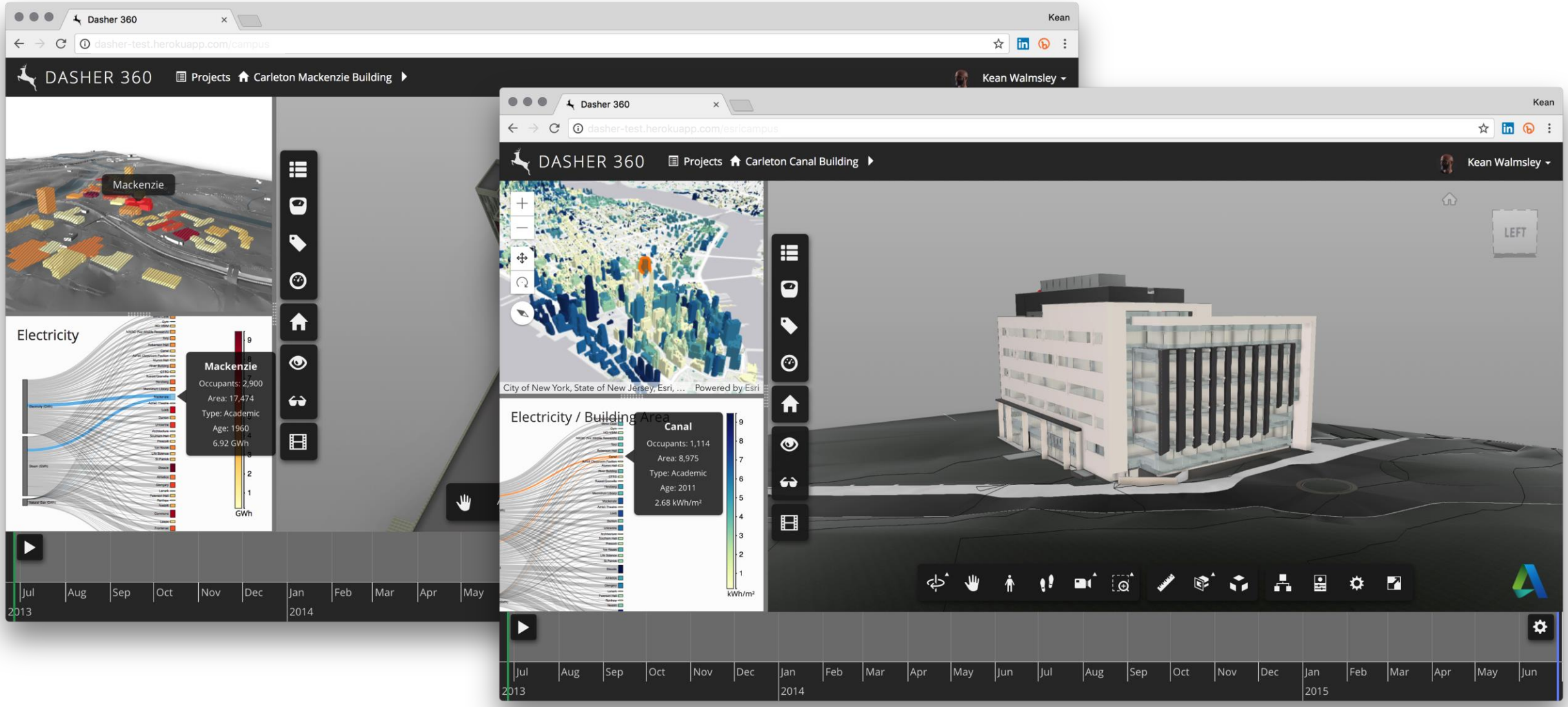


Kiosk Mode

- Implementing a demo mode inside the Forge viewer – Part 1
  - http://keanw.com/2017/03/implementing-a-demo-mode-inside-the-forge-viewer-part-1.html
- Implementing a demo mode inside the Forge viewer – Part 2
  - http:/keanw.com/2017/03/implementing-a-demo-mode-inside-the-forge-viewer-part-2.html
- Implementing a demo mode inside the Forge viewer – Part 3
  - http://keanw.com/2017/03/implementing-a-demo-mode-inside-the-forge-viewer-part-3.html
- Uses a fake cursor
- The various extensions define their areas of interest
  - Location of on/off button
  - Interesting locations where cursor should visit plus actions to perform on hover, click and unhover

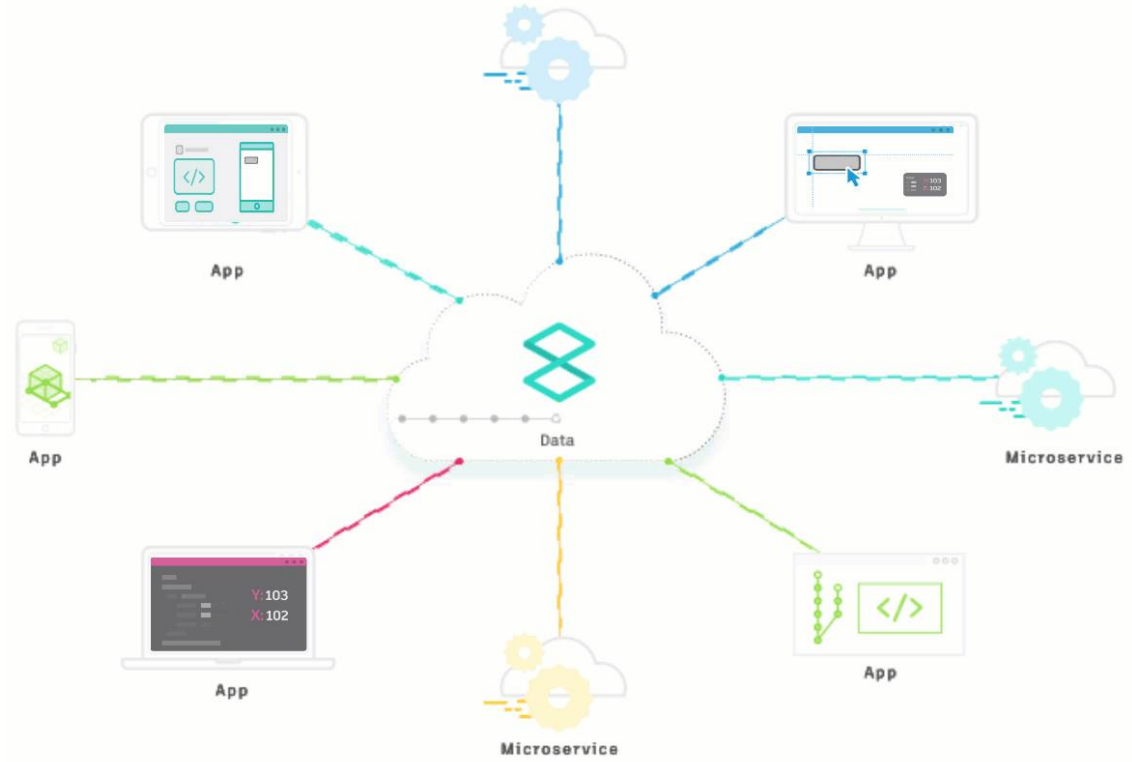
What’s next for Dasher?

Campus and City Views



Forge NextGen

- The Forge team is providing a set of “next generation” services…
  - HFDM
  - App Framework
- A good fit for dealing with “dynamic” data?
  - Models that move or change, over time
  - Sensors that change location, over time
- Needed for dealing with construction and factory use-cases



Dasher 360

forgetest.autodesk.com:5000/viewer/dXJuOmFkc2sud2lwcHJvZDpmcy5maWxlOnZmLjhyZC1JN2ItVFIyeHkzUWxxS3lEc2c_dmVyc2lvbj0x#

DASHER 360 | Projects | Robot 753 | Simon Breslav

SENSOR LIST

Search

- Current-Sensor-1 9.74 A
- Current-Sensor-2 9.68 A
- Current-Sensor-3 9.84 A
- Current-Sensor-4 10.30 A
- State-Sensor-0 0.00
- State-Sensor-1 0.00
- State-Sensor-2 0.00
- State-Sensor-3 0.00
- State-Sensor-4 0.00
- Temperature-Sensor-0 20.00 °C
- Temperature-Sensor-1 20.30 °C
- Temperature-Sensor-2 19.31 °C
- Temperature-Sensor-3 20.05 °C
- Temperature-Sensor-4 20.23 °C

Unpositioned Sensors (0)

10°C 15°C 20°C 25°C 30°C

Temperature | Enable

FRONT | RIGHT

DASHBOARD

Sensors | Navigation

Current-Sensor-1 9.74A a minute ago

Current-Sensor-2 9.68A a minute ago

Current-Sensor-3 10.69A a minute ago

Temperature-Sensor-0 20.00°C a minute ago

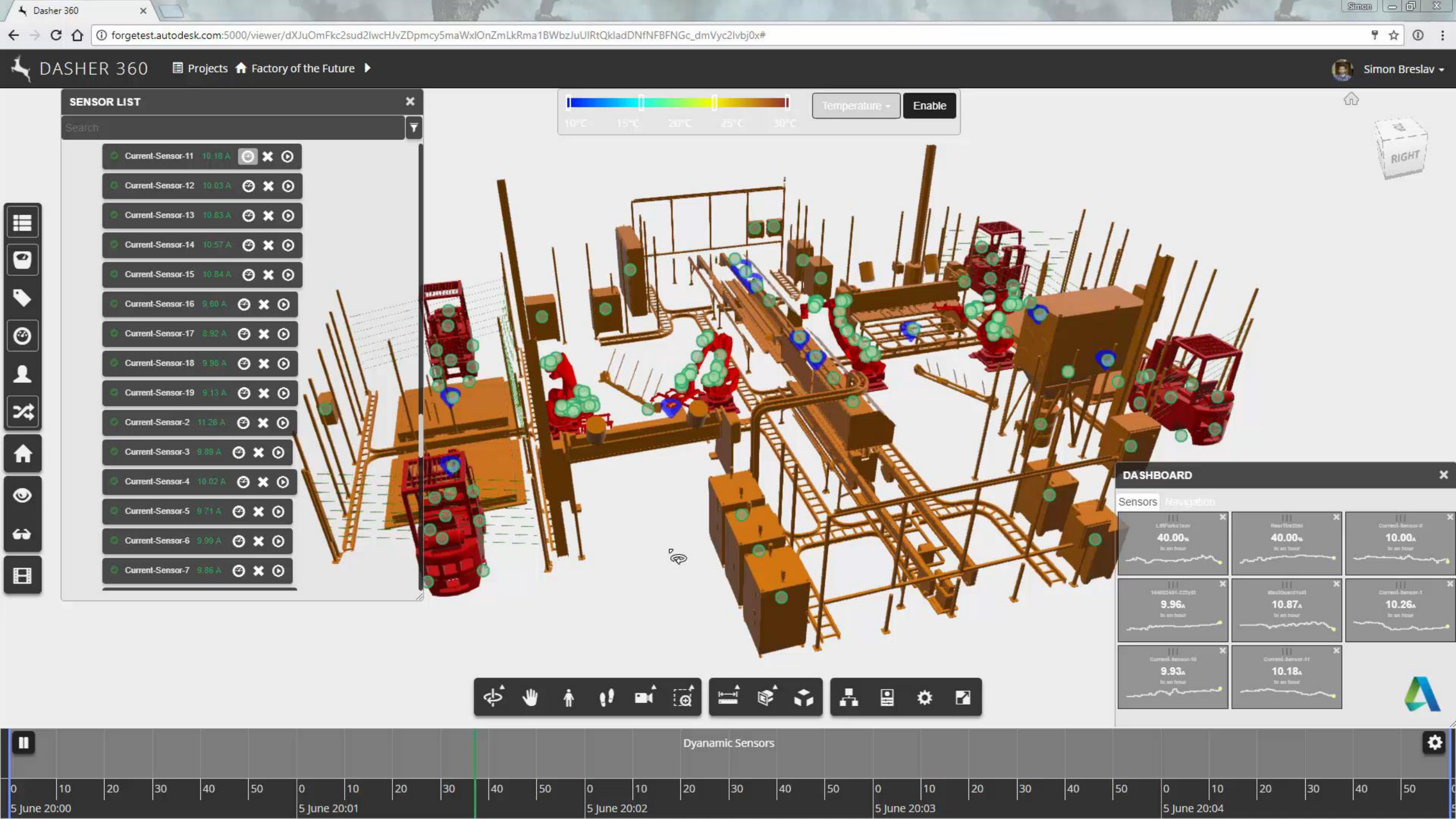
Temperature-Sensor-1 20.30°C a minute ago

Temperature-Sensor-2 19.31°C a minute ago

Dyanamic Sensors

20:00 20:05 20:10 20:15 20:20 20:25 20:30 20:35 20:40 20:45 20:50 20:55

Mon 5 June


Dasher 360
forgetest.autodesk.com:5000/viewer/dXJuOmFkc2sud2lwcHJvZDpmcy5maWxlOnZmLkRma1BWbzJuUlRtQkladDNfNFBFNGc_dmVyc2lvbj0x#
DASHER 360
Projects
Factory of the Future
Simon Breslav
SENSOR LIST
Search
Current-Sensor-11 10.18 A
Current-Sensor-12 10.03 A
Current-Sensor-13 10.83 A
Current-Sensor-14 10.57 A
Current-Sensor-15 10.84 A
Current-Sensor-16 9.60 A
Current-Sensor-17 8.92 A
Current-Sensor-18 9.98 A
Current-Sensor-19 9.13 A
Current-Sensor-2 11.26 A
Current-Sensor-3 9.89 A
Current-Sensor-4 10.02 A
Current-Sensor-5 9.71 A
Current-Sensor-6 9.99 A
Current-Sensor-7 9.86 A
10°C 15°C 20°C 25°C 30°C
Temperature
Enable
RIGHT
DASHBOARD
Sensors
40.00%
40.00%
10.00A
9.96A
10.87A
10.26A
9.93A
10.18A
Dyanamic Sensors
5 June 20:00
5 June 20:01
5 June 20:02
5 June 20:03
5 June 20:04

DASHER 360
Projects
Metro Green III
Hali Larsen
LEFT
FRONT
SENSOR LIST
Pillar
PillarTech-42948-8-Dust 9.25 µg/m³
PillarTech-42948-8-Humidity 36.21 %
PillarTech-42948-8-Pressure 30.17 Pa
PillarTech-42948-8-Temp 72.52 °F
PillarTech-42949-8-Dust 144.66 µg/m³
PillarTech-42949-8-Humidity 35.97 %
PillarTech-42949-8-Pressure 30.17 Pa
PillarTech-42949-8-Temp 71.13 °F
PillarTech-42950-8-Dust 19.24 µg/m³
PillarTech-42950-8-Humidity 29.98 %
PillarTech-42950-8-Pressure 30.20 Pa
PillarTech-42950-8-Temp 74.17 °F
DASHBOARD
Sensors
Navigation
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
Tue 7 March
Wed 8 March

Conclusions

- Forge helped us move a complex desktop application to the web
  - It was both easy and fun!
- Lots of existing examples were available as references
- We used various, off-the-shelf JavaScript libraries in addition to Forge
- Viewer extensions allowed us to create separate (but sometimes connected) features
  - These can be combined to create versions with different capabilities

Kiosk mode, Q&A

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