Getting started with Generative Design for AEC

Kean Walmsley

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About the speaker

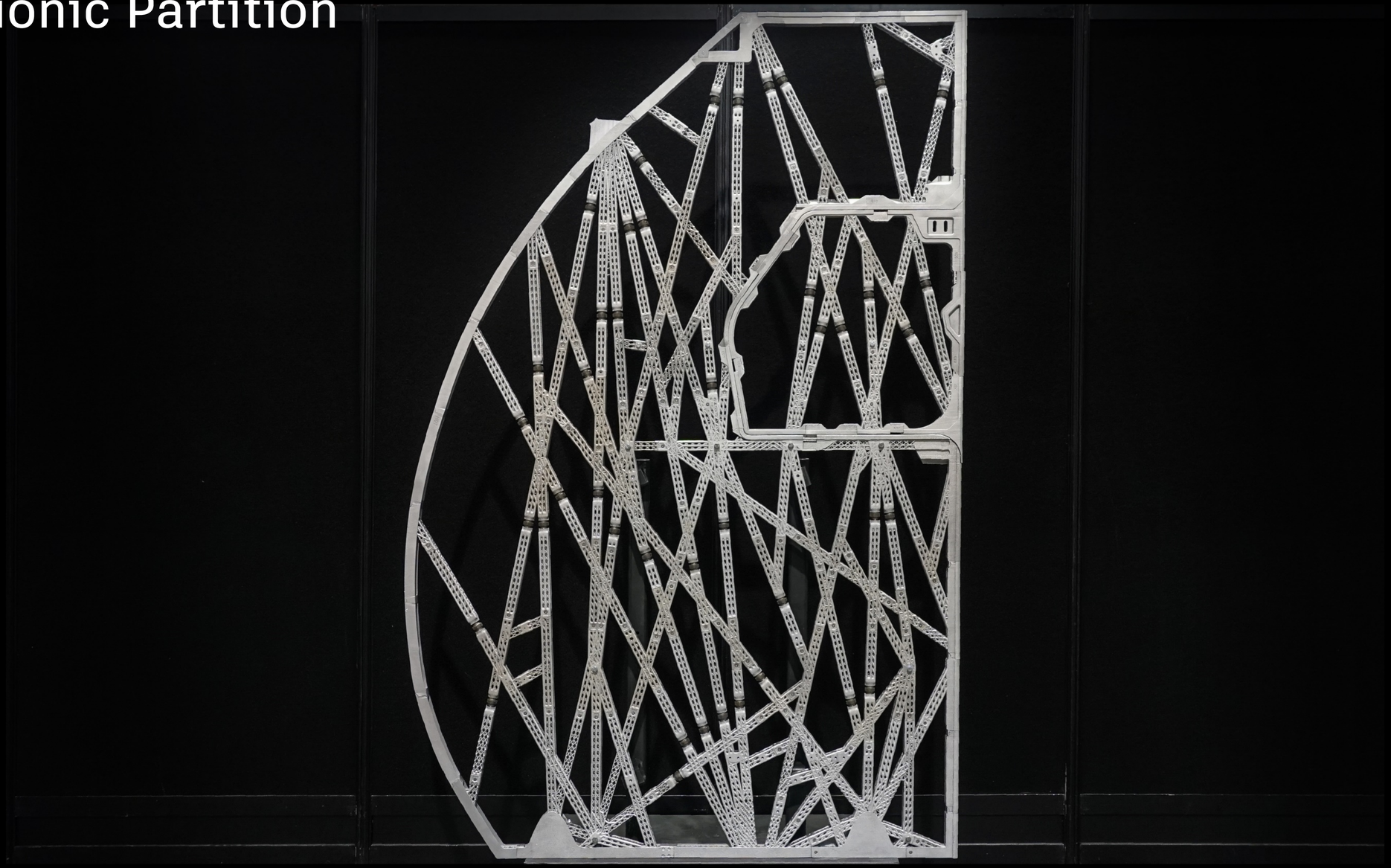
Kean Walmsley

1995-2012	ADN	1995-1998	UK
2012-2016	AutoCAD	1998-2000	Switzerland
2016- ...	Research	2000-2003	USA
		2003-2005	India
		2006- ...	Switzerland

2006- ...	Through the Interface

Autodesk Research into Generative Design

A320 Bionic Partition



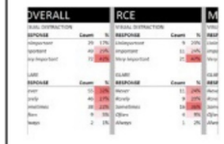
A320 Bionic Partition

GENERATIVE DESIGN

QUANTITATIVE

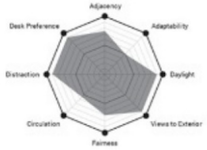
QUALITATIVE

DATA



GENERATE

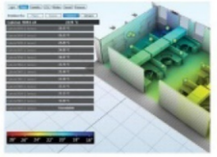
EVALUATE



EVOLVE

SELECT

MONITOR



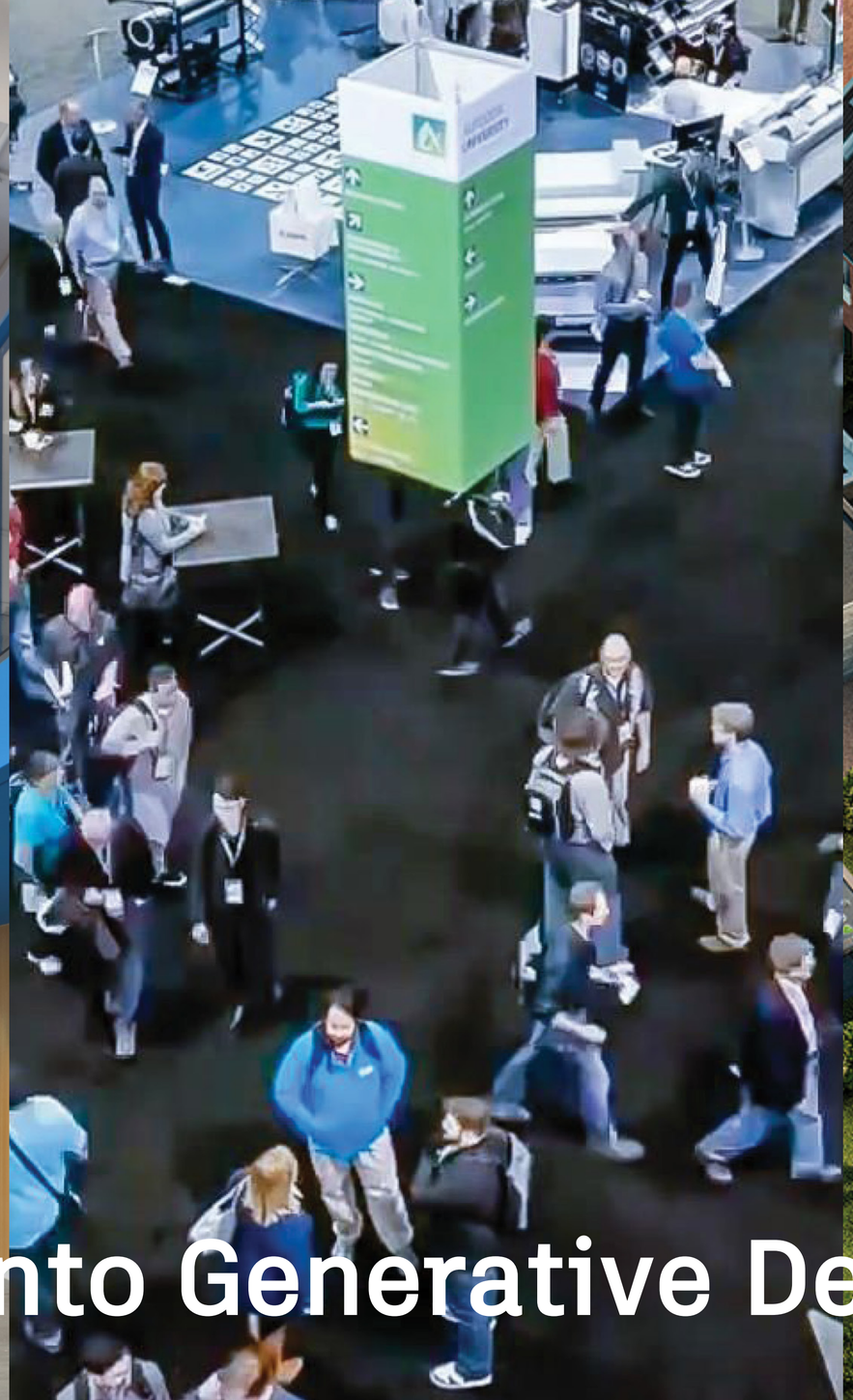
DESIGN

VISUALIZE

REFINE

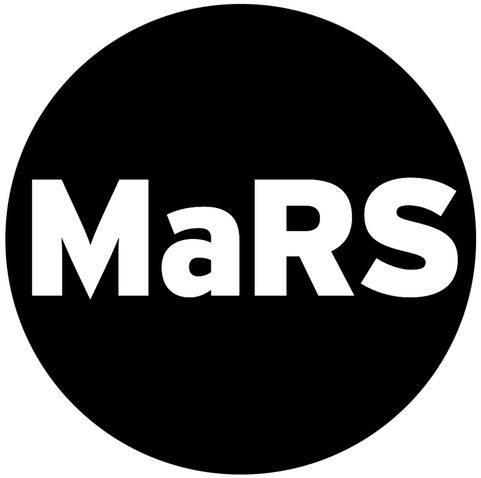
INTERNET OF THINGS

VIRTUAL REALITY

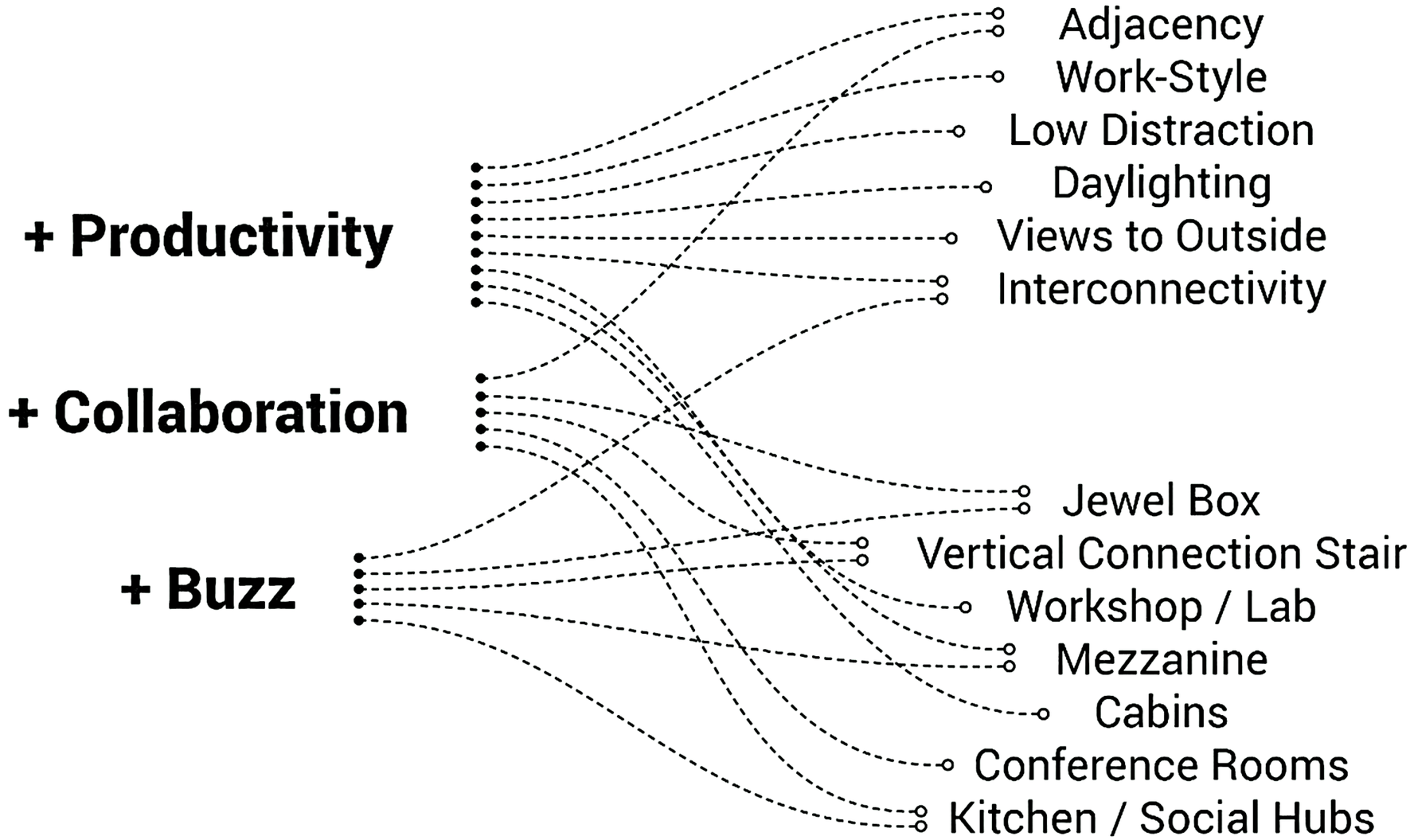


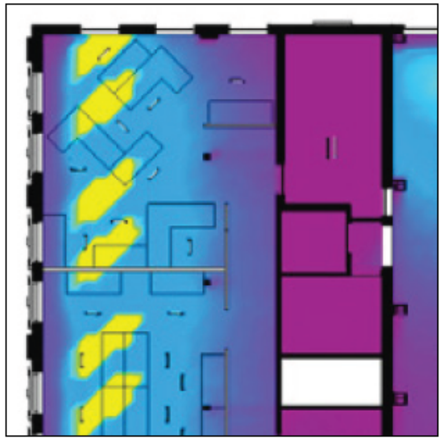
Research into Generative Design for AEC

Generative Architectural Layout
Autodesk Toronto at MaRS

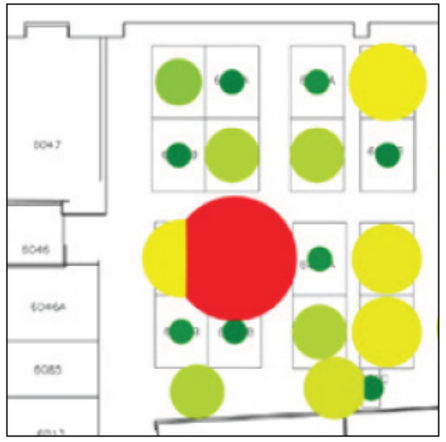


MaRS office by The Living, Autodesk Inc.

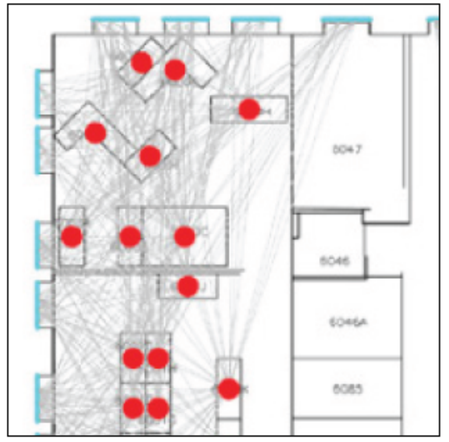

+ Productivity
+ Collaboration
+ Buzz
Adjacency
Work-Style
Low Distraction
Daylighting
Views to Outside
Interconnectivity
Jewel Box
Vertical Connection Stair
Workshop / Lab
Mezzanine
Cabins
Conference Rooms
Kitchen / Social Hubs



1. Daylight

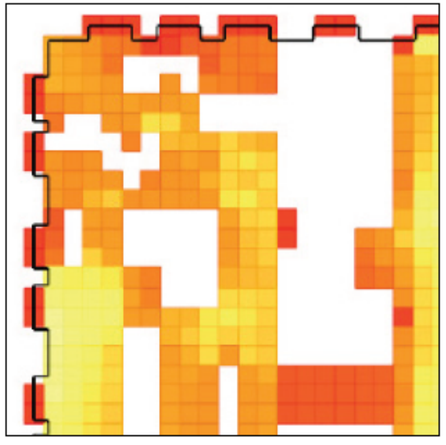


2. Low Visual Distraction



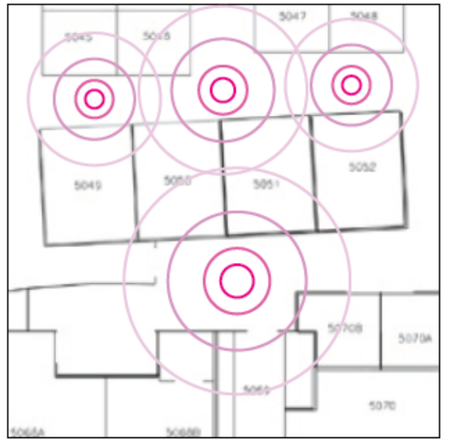
3. Views to Outside

4. Adjacency Preference

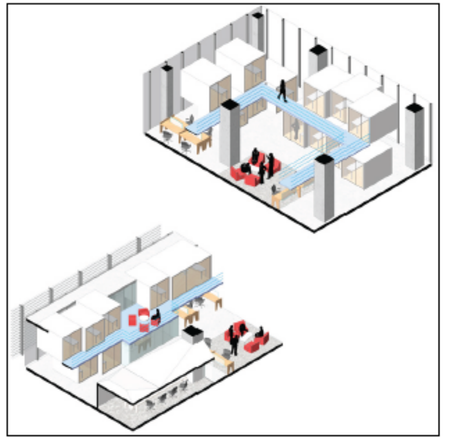


5. Circulation

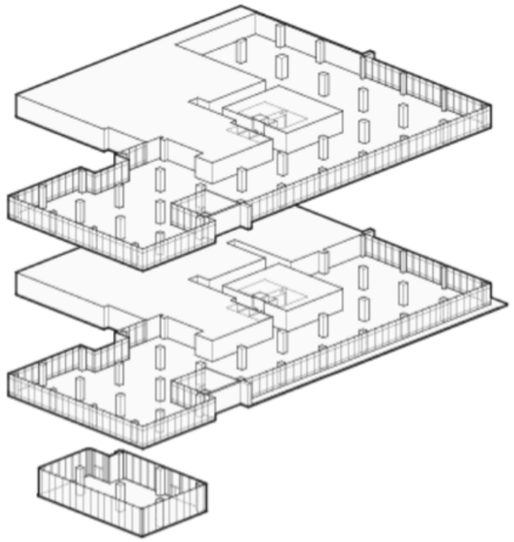
6. Work Styles



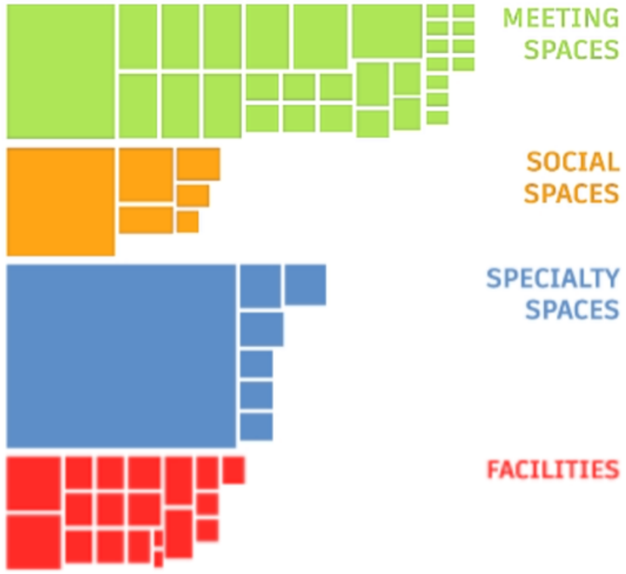
7. Low Acoustic Distraction



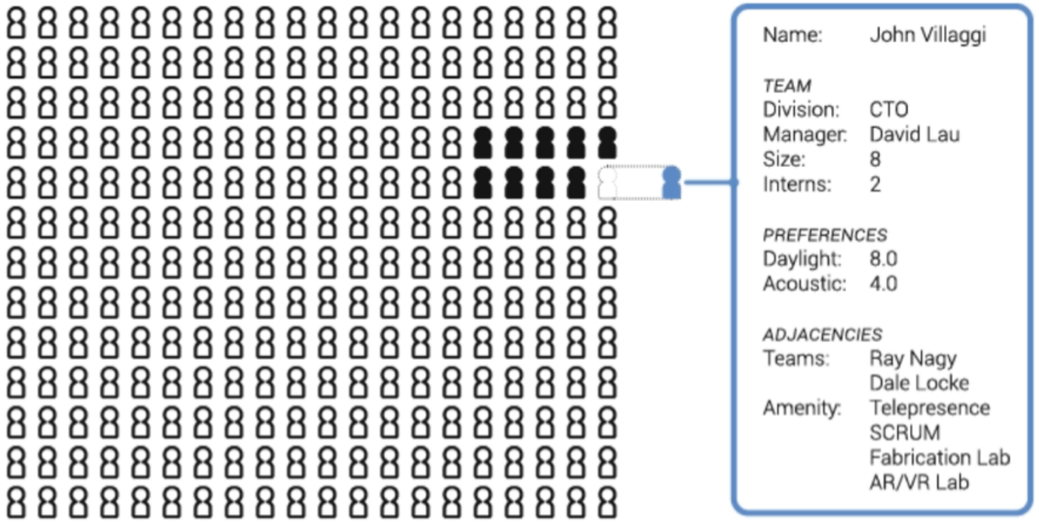
8. Low Density



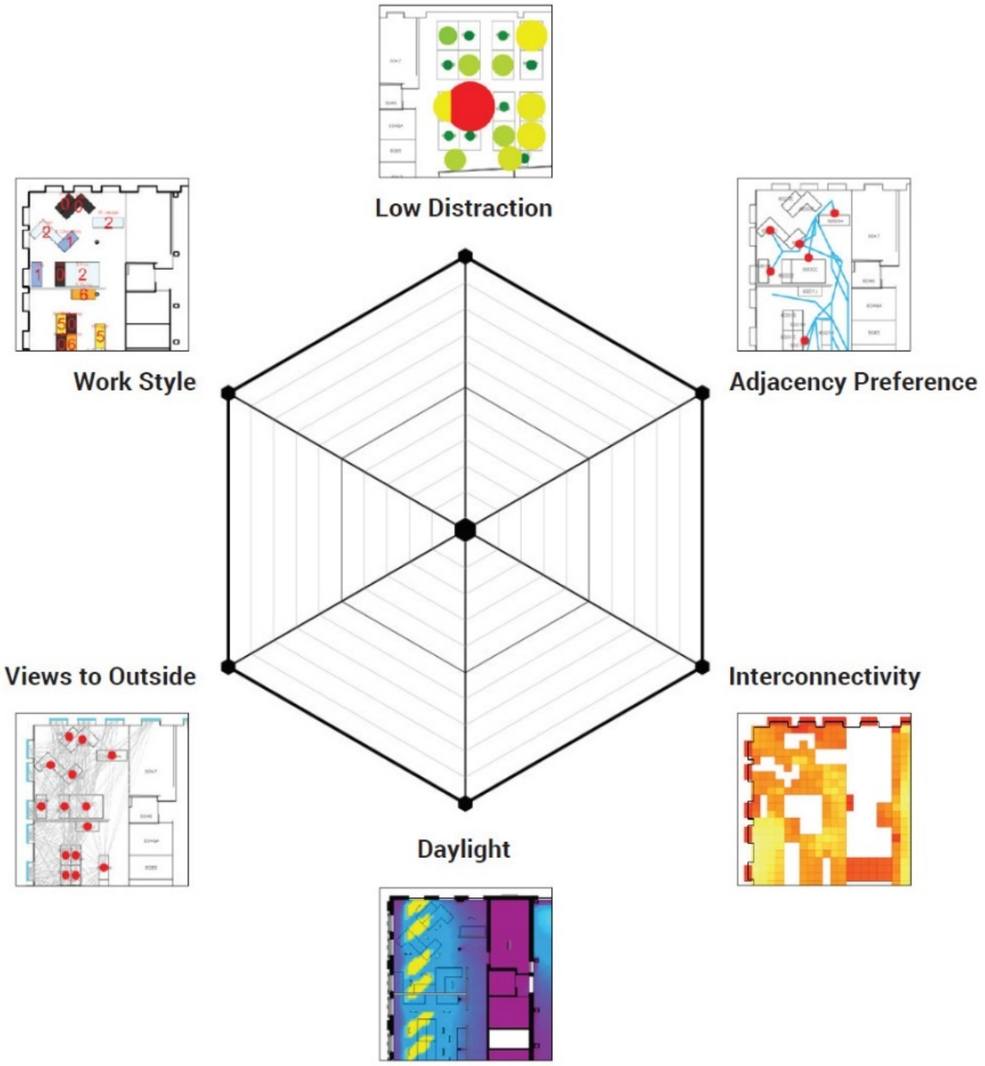
3 floors
48,000 square feet

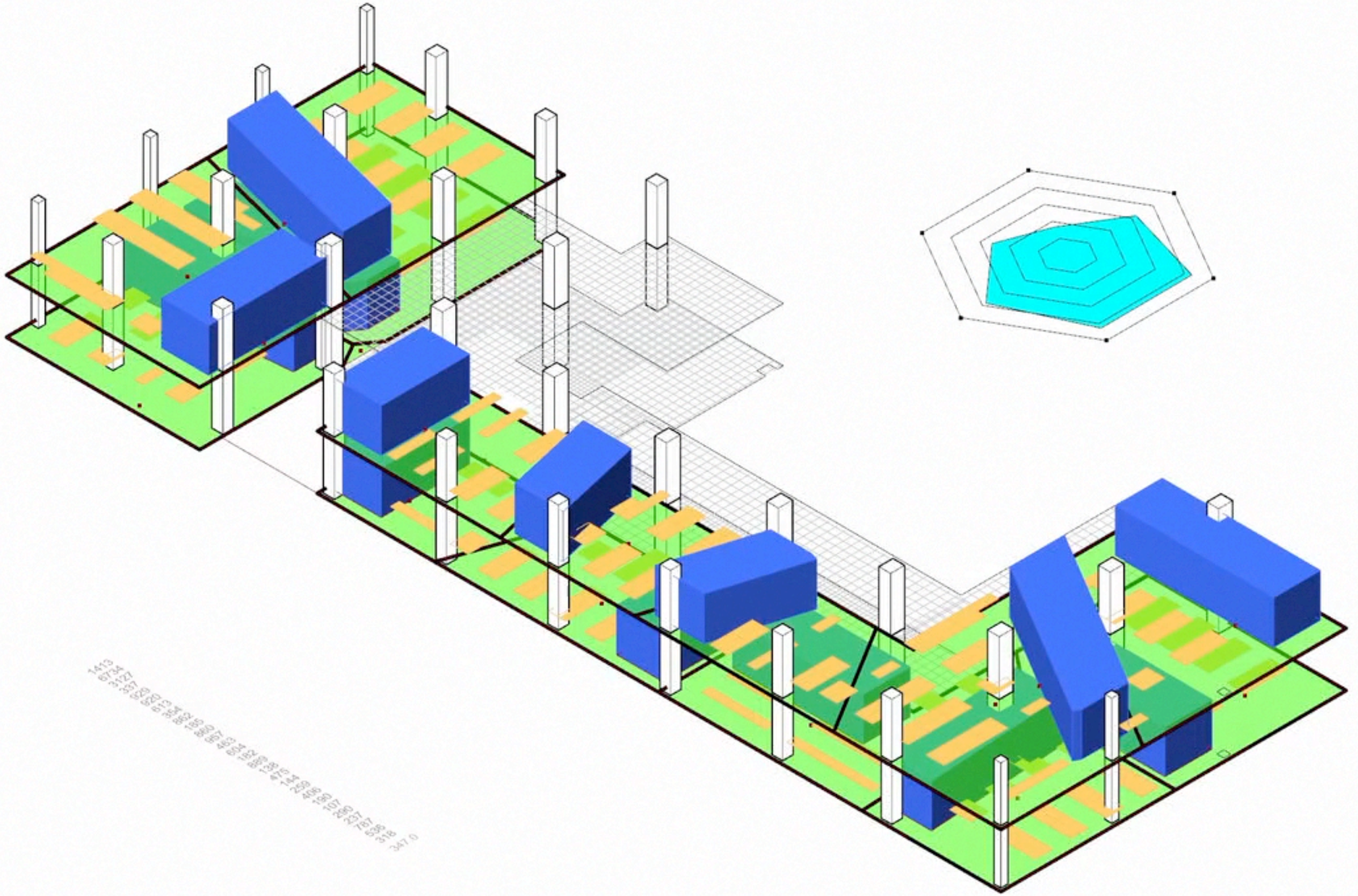


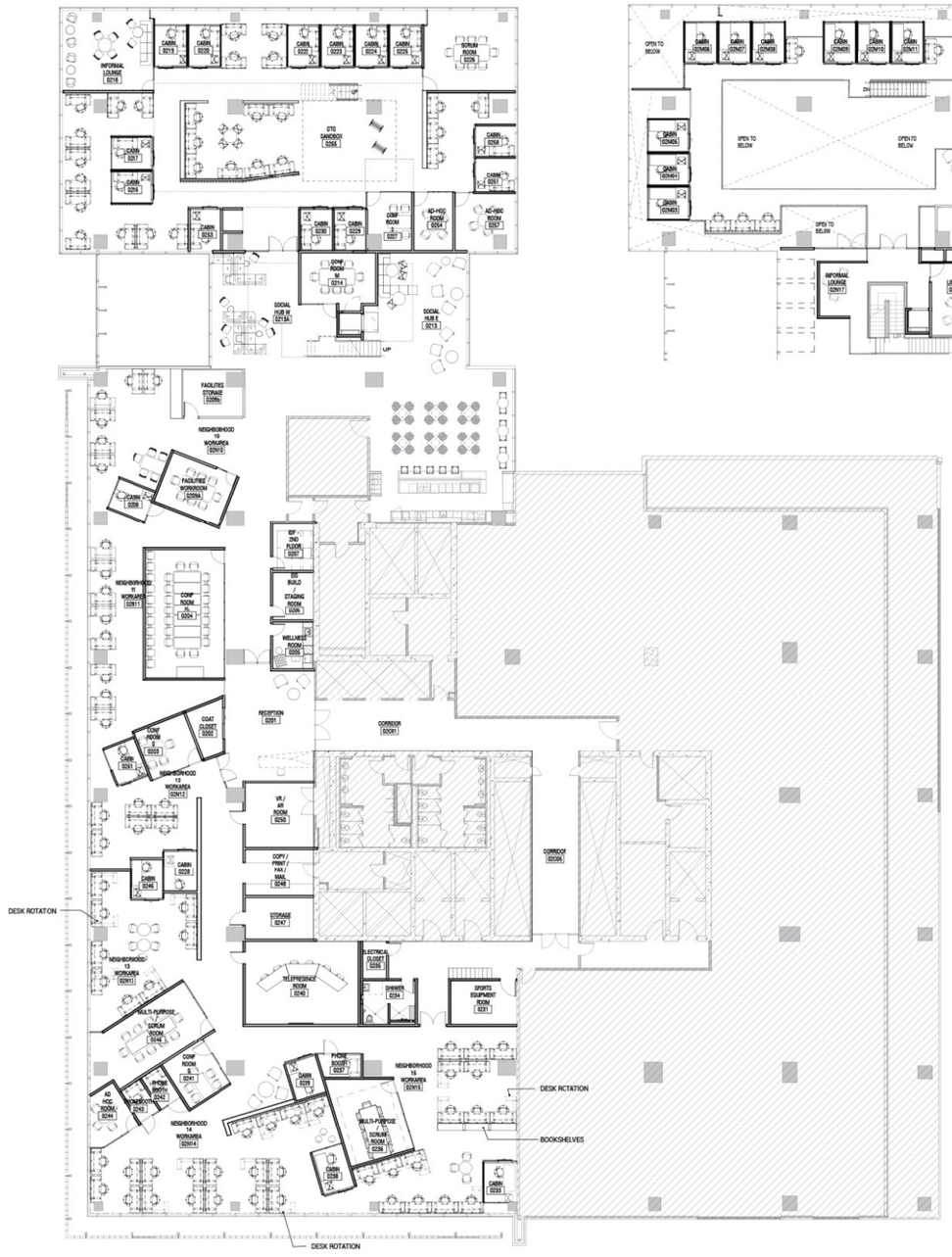
11 meeting rooms
6 multi-purpose rooms
11 phone booths



250+ people
25+ teams

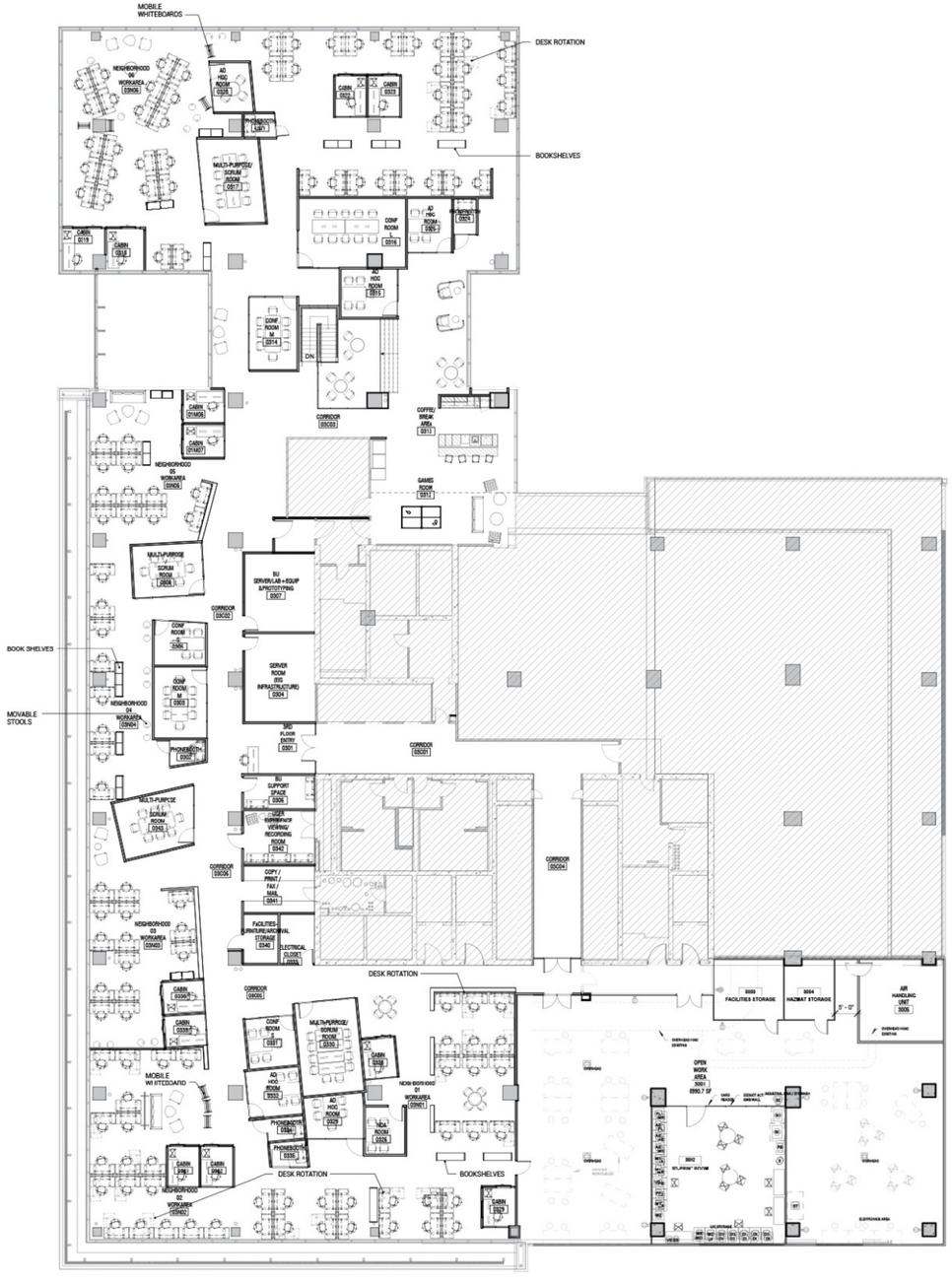

Low Distraction
Work Style
Adjacency Preference
Views to Outside
Interconnectivity
Daylight





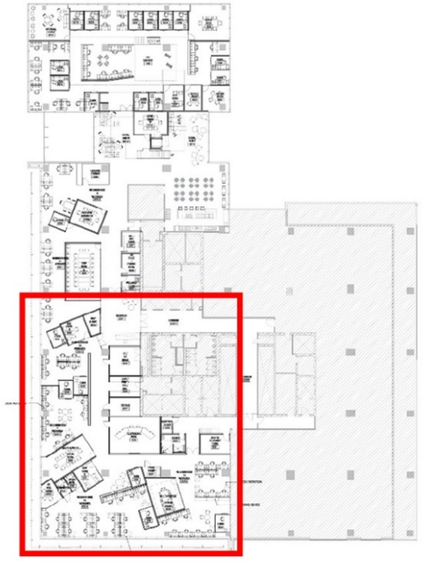
MaRS AUTODESK RELOCATION

SECOND FLOOR PLAN - 20160916



MaRS AUTODESK RELOCATION

THIRD FLOOR PLAN - 20160916



1. Multiple types and sizes of amenity spaces surround each neighborhood to break up space and reduce distraction, leading to better scoring for productivity

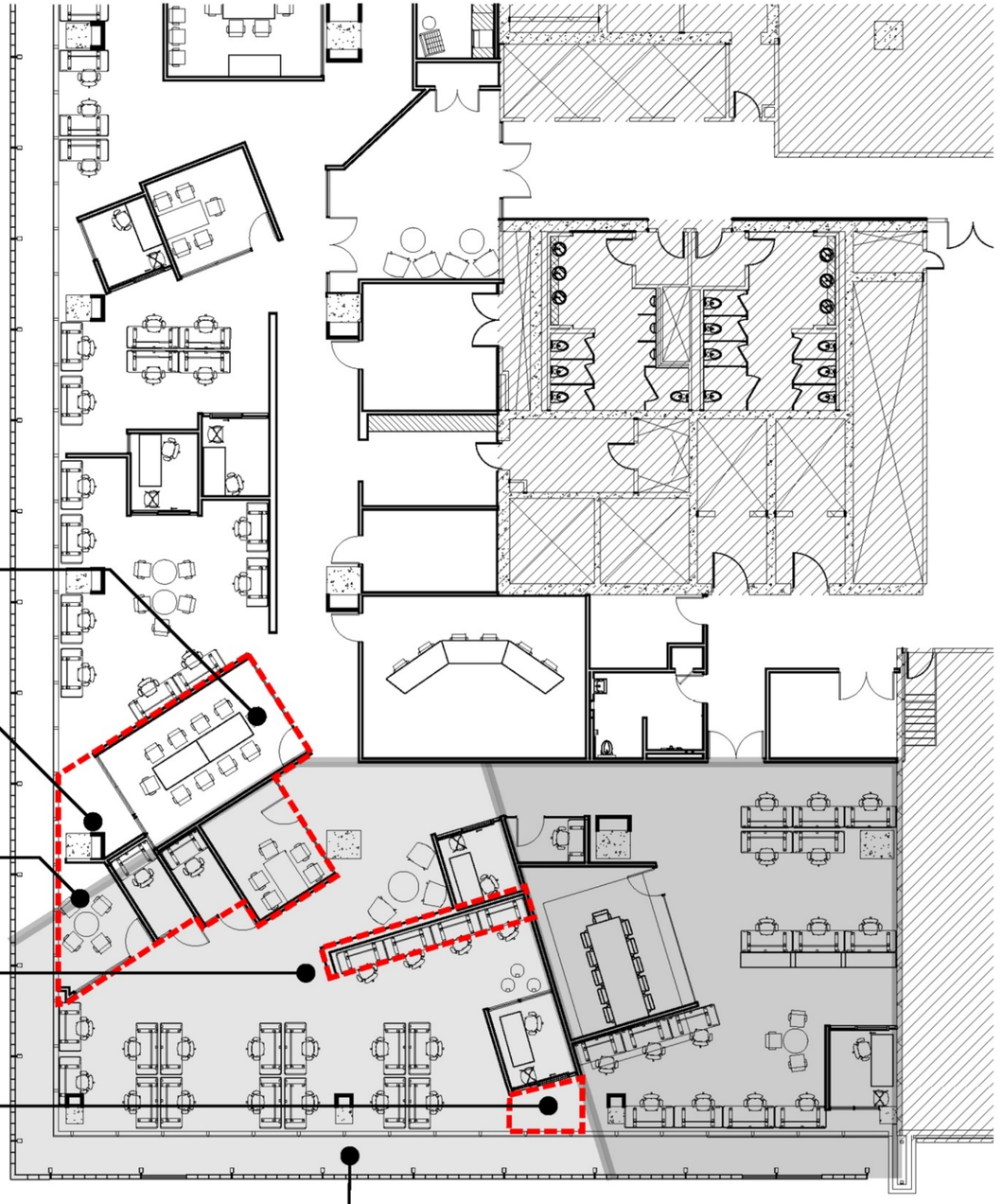
2. Residual irregular-shaped areas become semi-private informal social spaces that, while performance neutral, were unexpected, interesting design elements and well-recieved by the clients

3. Diagonal line between neighborhoods allows fitting more meeting rooms while giving each neighborhood its own character

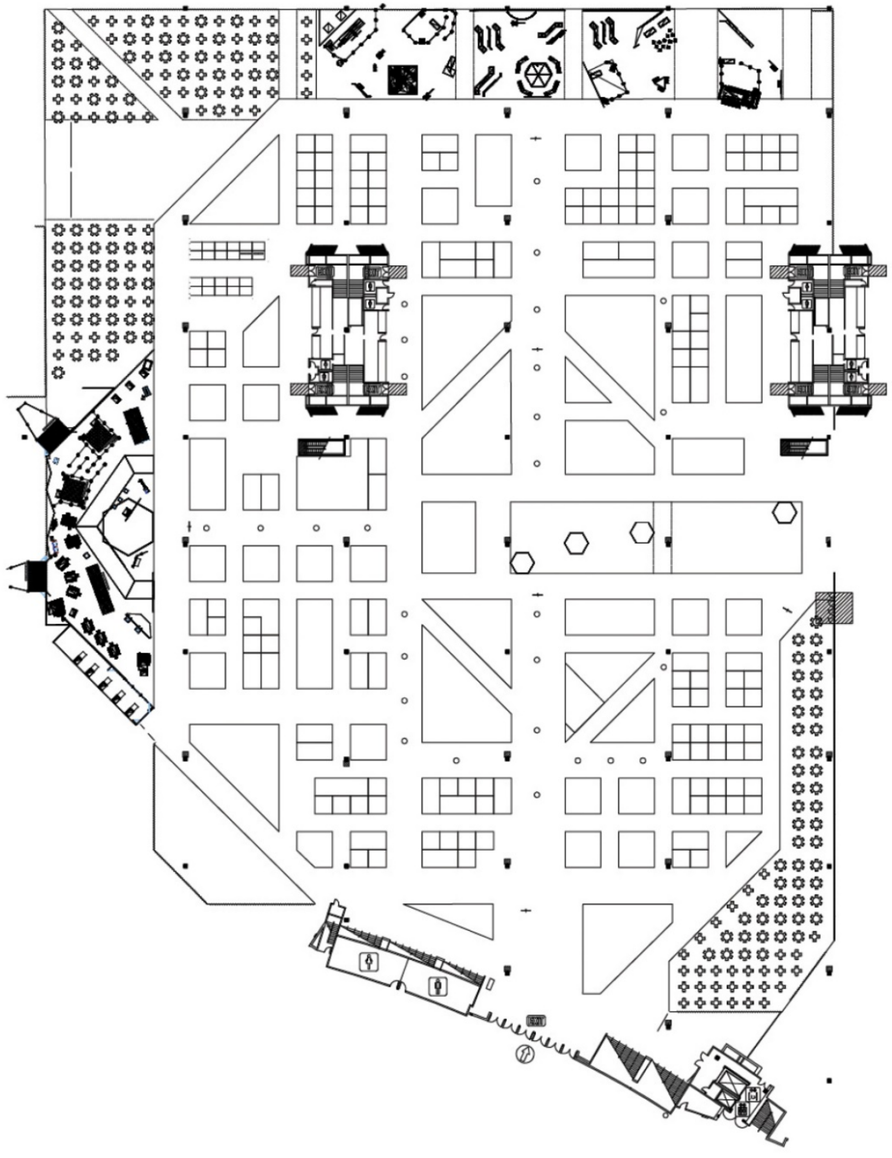
4. Non-orthogonal, non-parallel boundaries obscure sources of distraction (desks in adjacent neighborhoods & high buzz corridors) to improve productivity scores.

5. Back alley connection between neighborhoods, leading to better score for adjacency preference

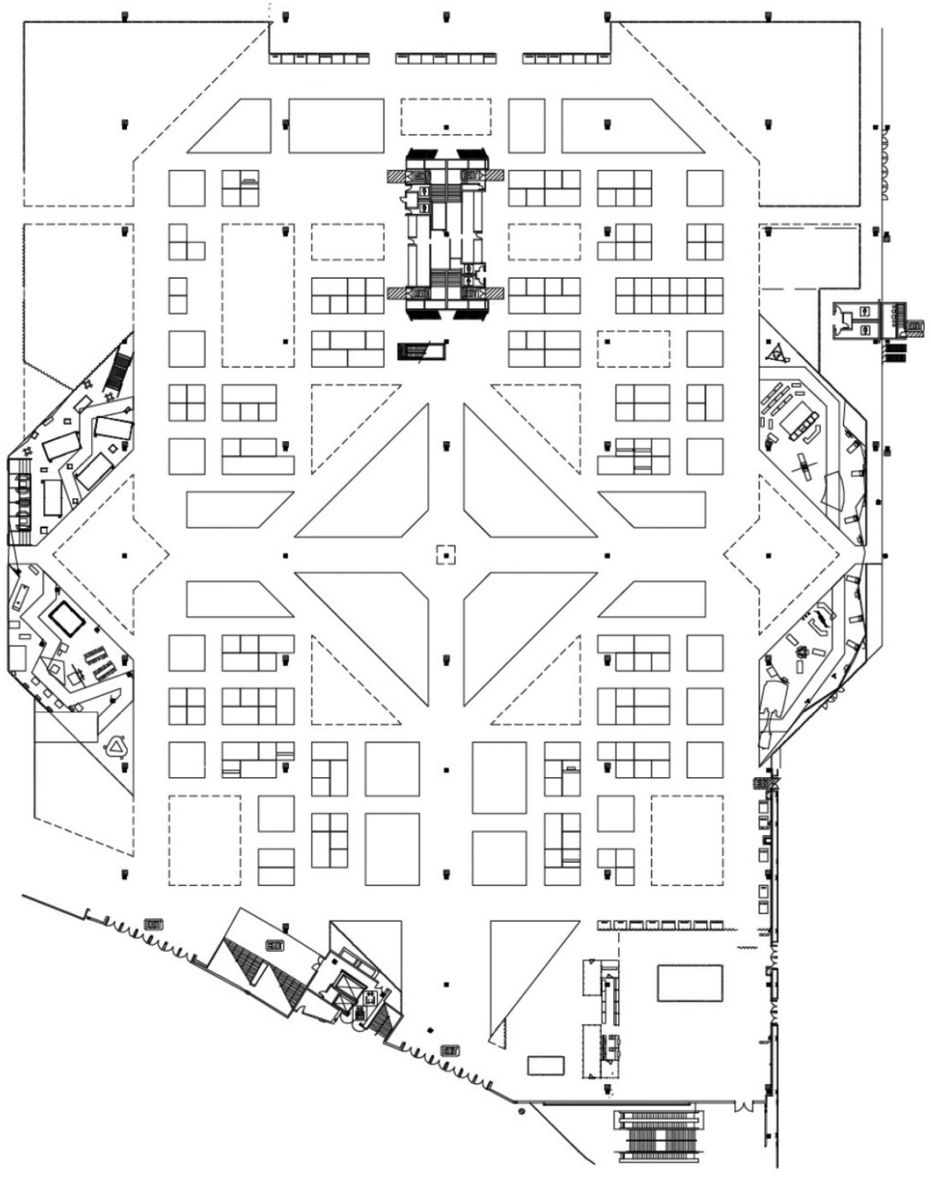
6. Neighborhood expanding out toward window because team prefers natural light



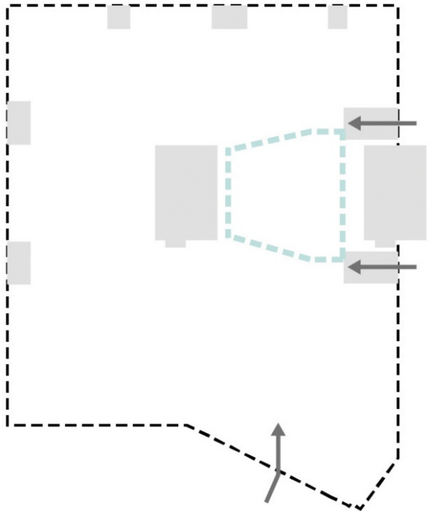
Generative Space Planning
AU 2017 Exhibit Hall



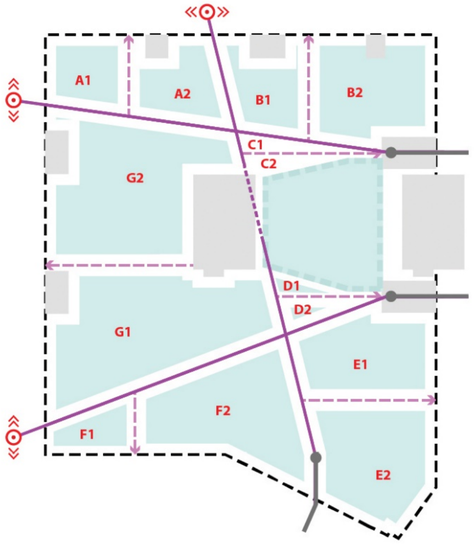
2015



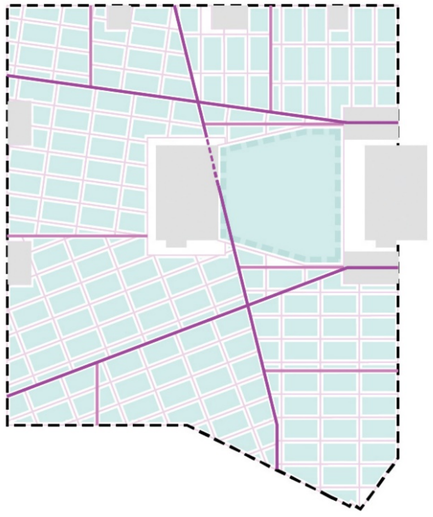
2016



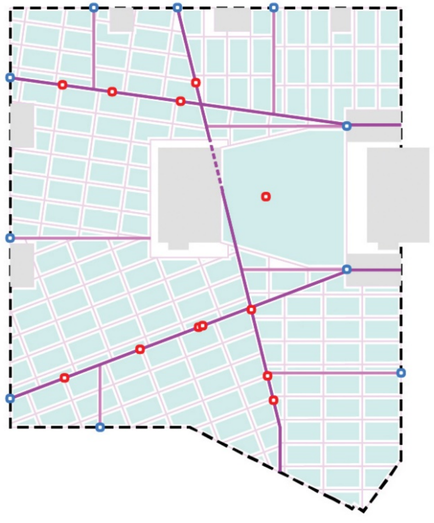
1) Define boundary conditions



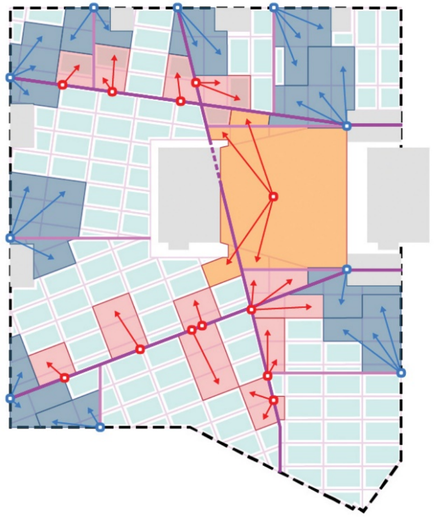
2) Generate primary routes



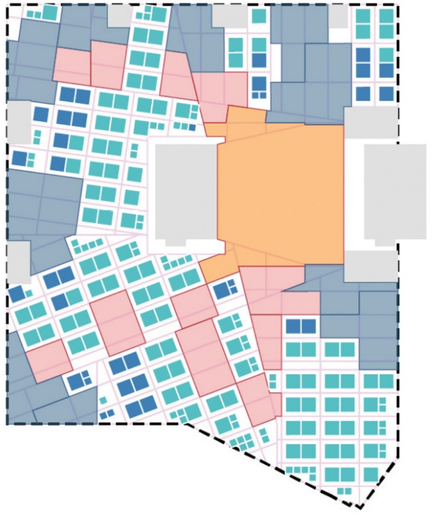
3) Subdivide regions with minimal grid



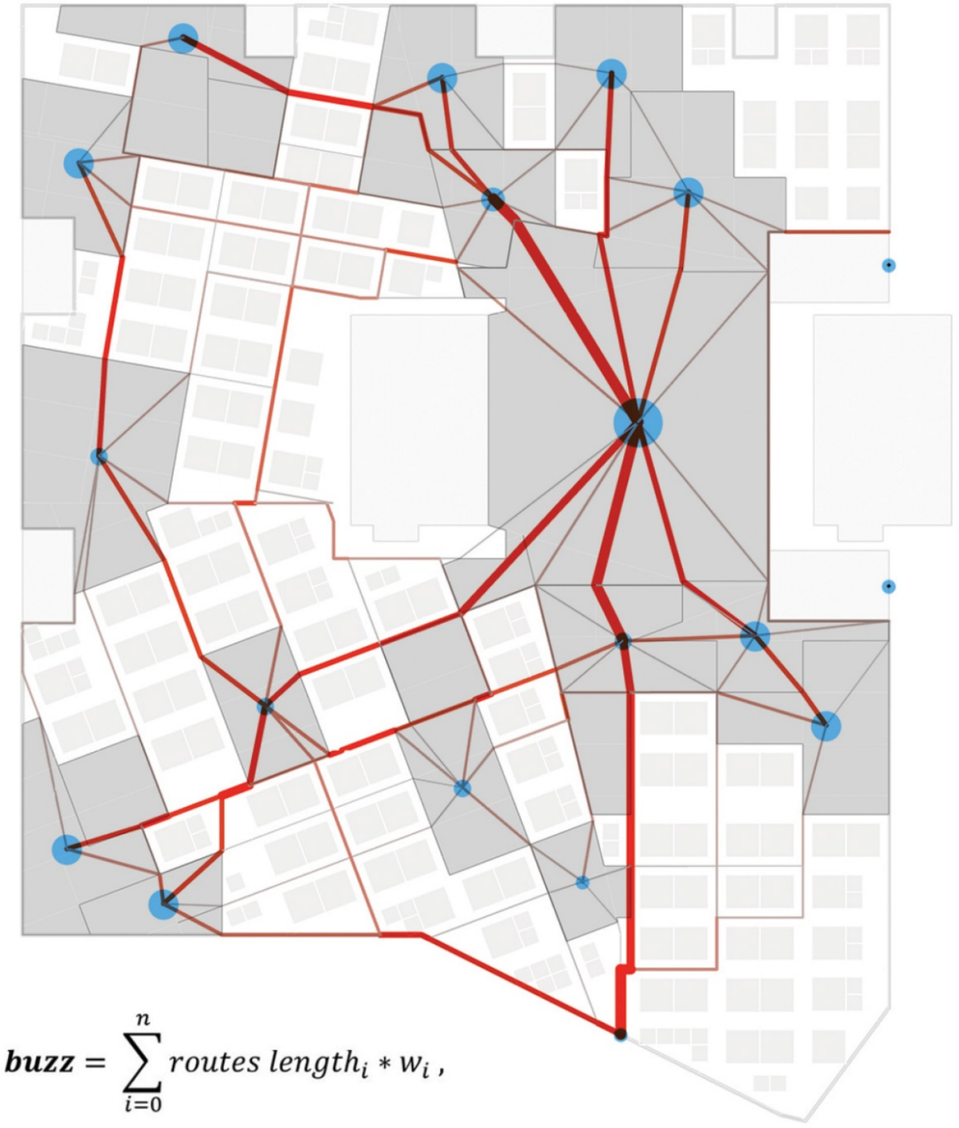
4) Locate anchor programs



5) Join grid cells to accommodate anchor program area requirements



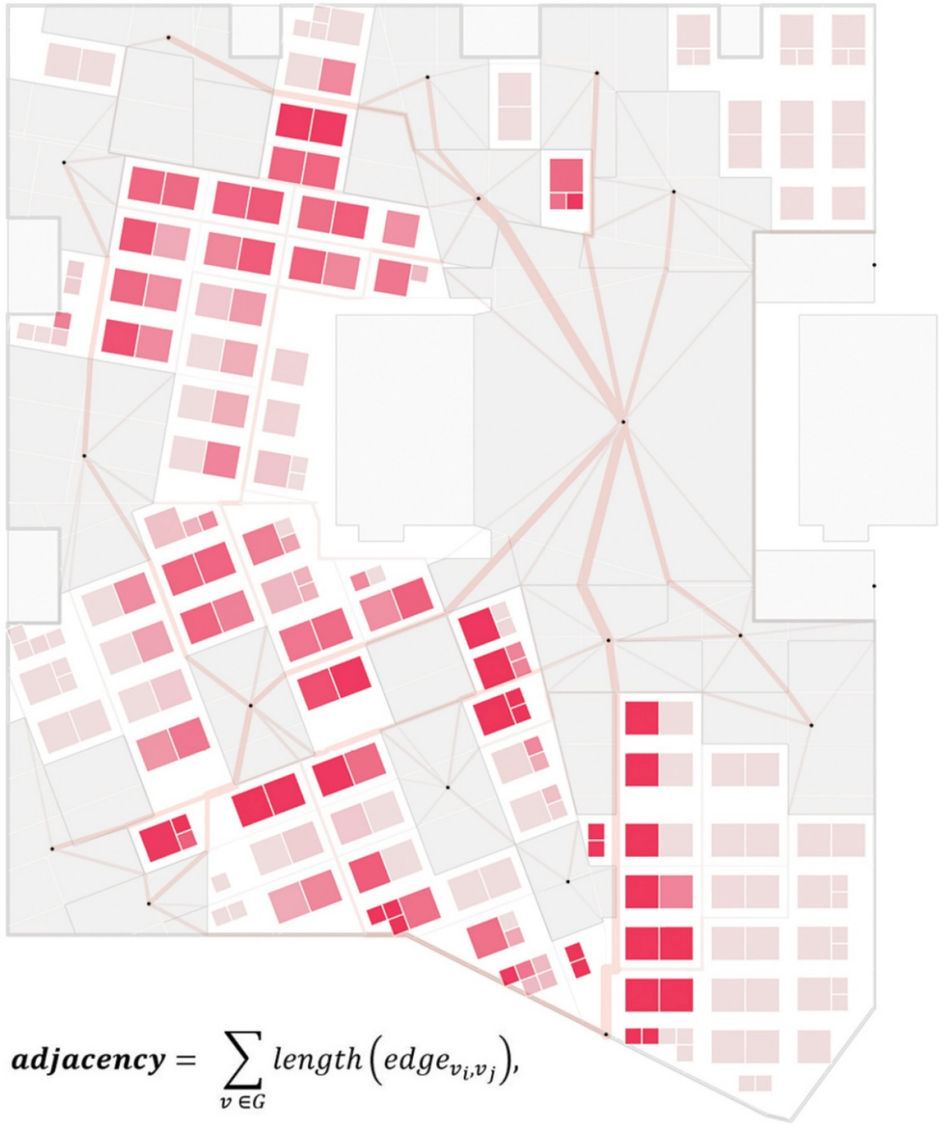
6) Allocate remaining cells to small programs



$$\textbf{buzz} = \sum_{i=0}^{n} routes\ length_i * w_i\ ,$$

$w = amount\ of\ traversals\ in\ each\ route$

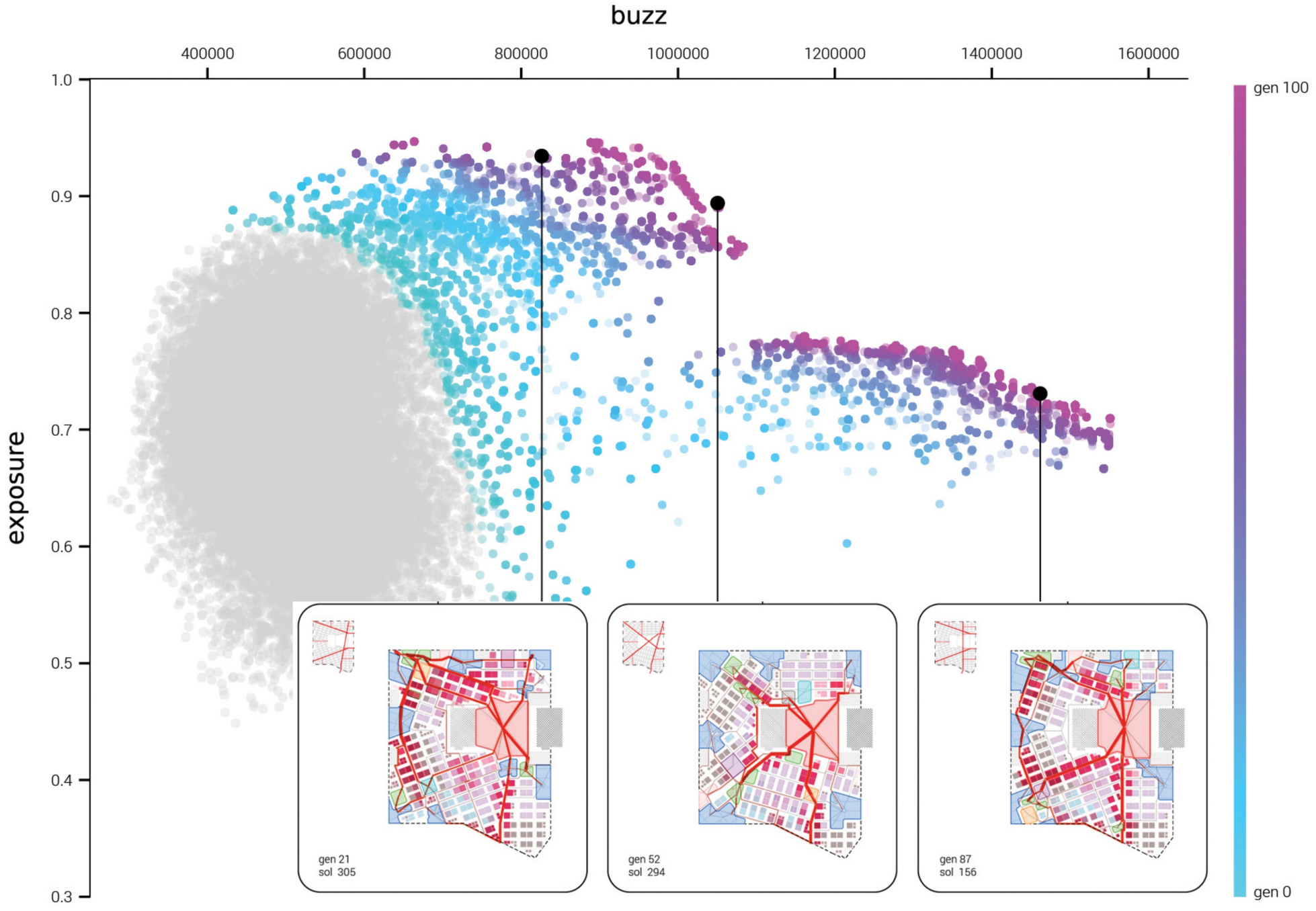
$n = number\ of\ nodes$

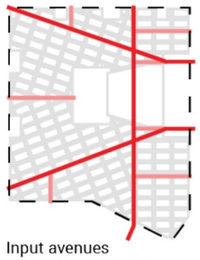


$$\textbf{adjacency} = \sum_{v\ \in G} length\left(edge_{v_i,v_j}\right),$$

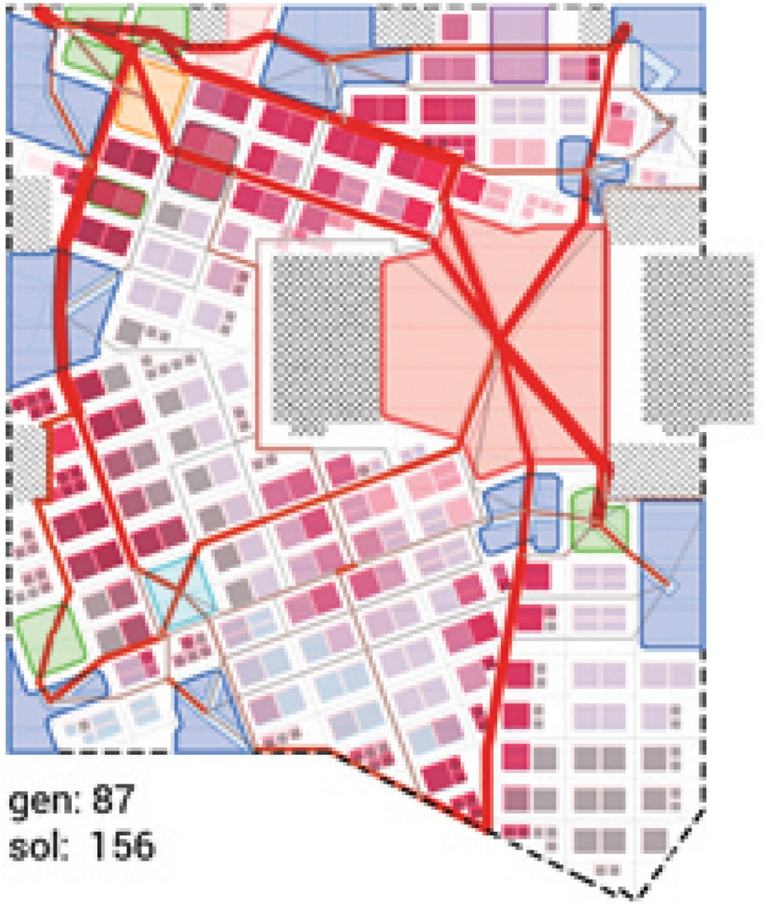
$v = vertices$

$G = graph\ of\ all\ sites\ with\ adjacency\ requirements$


buzz
400000
600000
800000
1000000
1200000
1400000
1600000
exposure
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
gen 100
gen 0
gen 21
sol 305
gen 52
sol 294
gen 87
sol 156

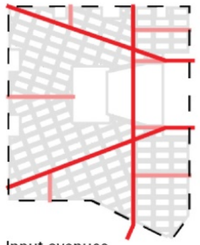


Input avenues
and regions subdivision



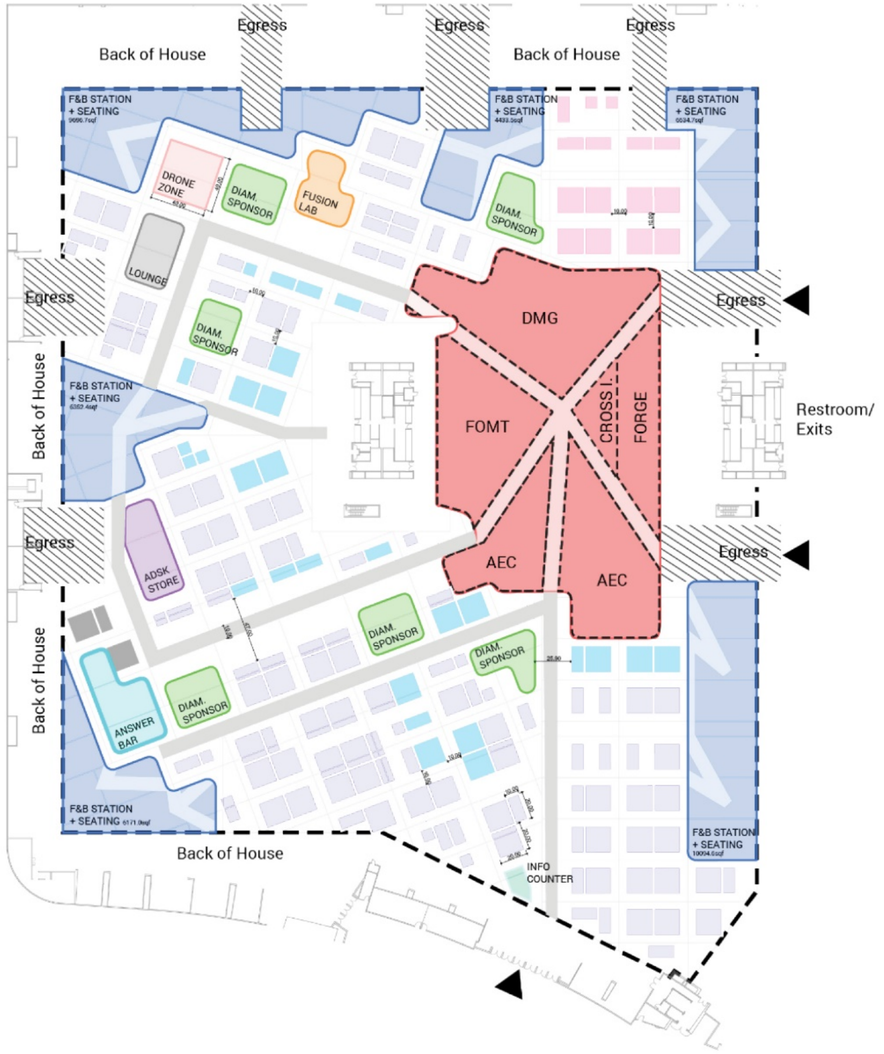
gen: 87
sol: 156

b: 9.5
e: 8.9



Input avenues
and regions subdivision

low buzz
high buzz
high booth exposure
low booth exposure
F&B Seats + Stations
Fusion 360 Lab
ADSK
ADSK Store
Diam/Platinum Sponsors
Lounge
Drone Zone
Answer Bar



- Autodesk areas
- Future of Making Things Customer exhibits
- Sponsor booths
- Building design & fabrication exhibitors
- Construction & operations exhibitors
- General design & technology exhibitors
- Product design & manufacturing exhibitors
- Food and beverage areas

Video Start: 2017-04-27T16:11:17.593Z
Video End: 2017-04-27T16:11:24.113Z
Video Time: 983 / 6520
Time: 2017-04-27T16:11:18.575Z
Network: IDLE
Paused: true
Toggle cam-0 sensor labels
pi-pier9-bridge-strain-2-left-s-0
pi-pier9-bridge-accel-5-9-a-7
pi-pier9-bridge-strain-2-right-s-0
pi-pier9-bridge-accel-5-9-a-6
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pi-pier9-bridge-strain-1-left-s-0
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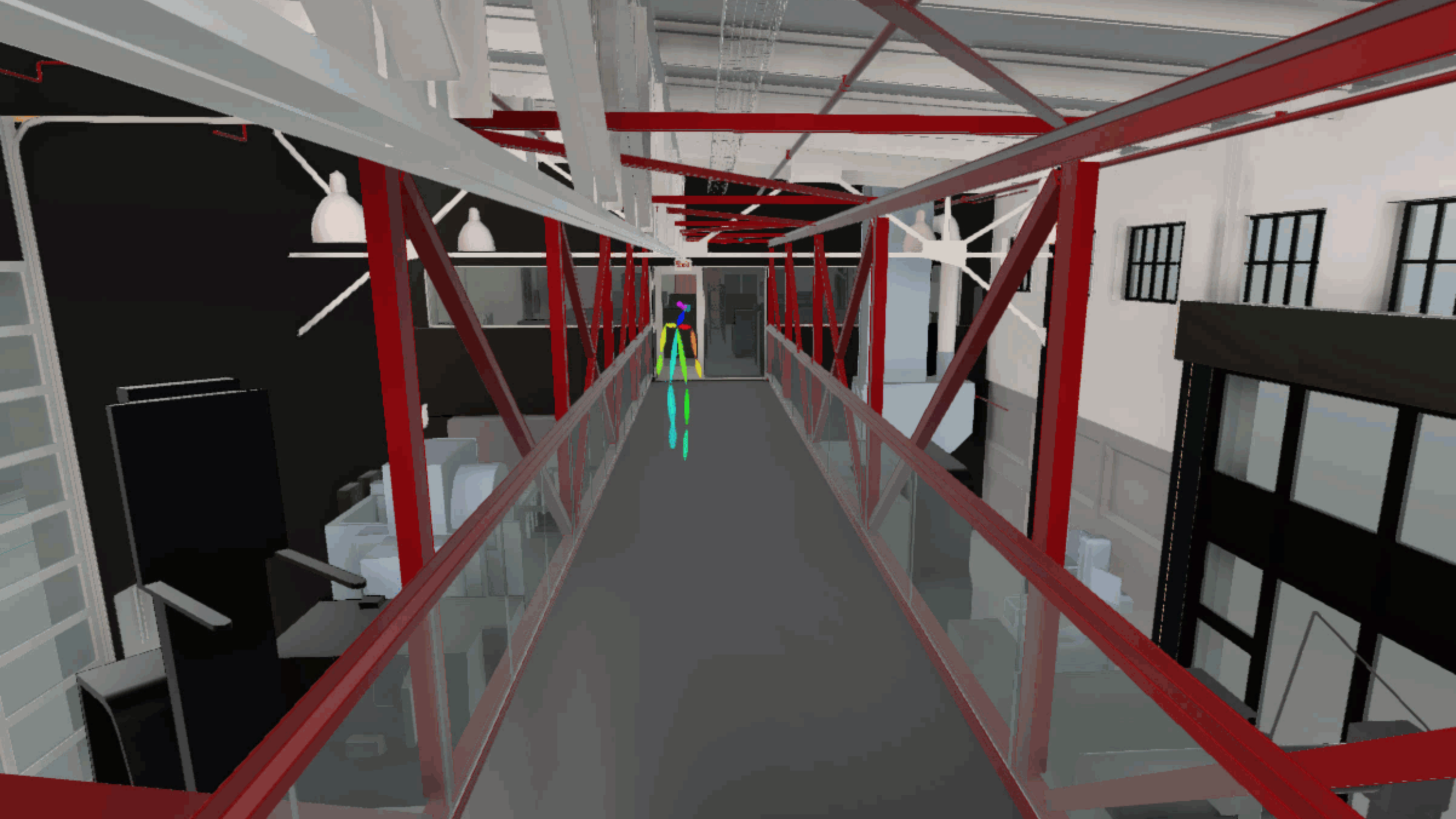
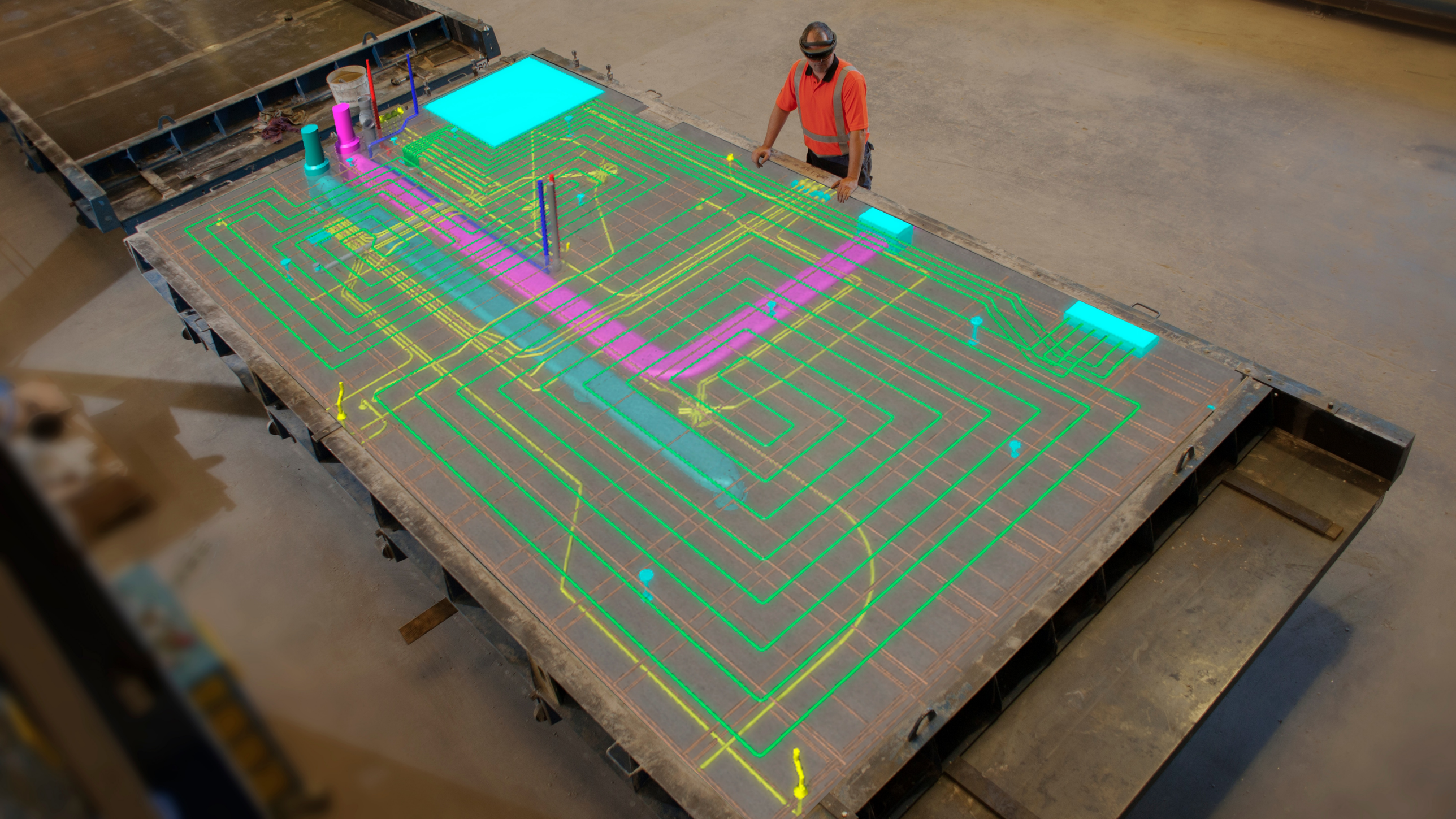
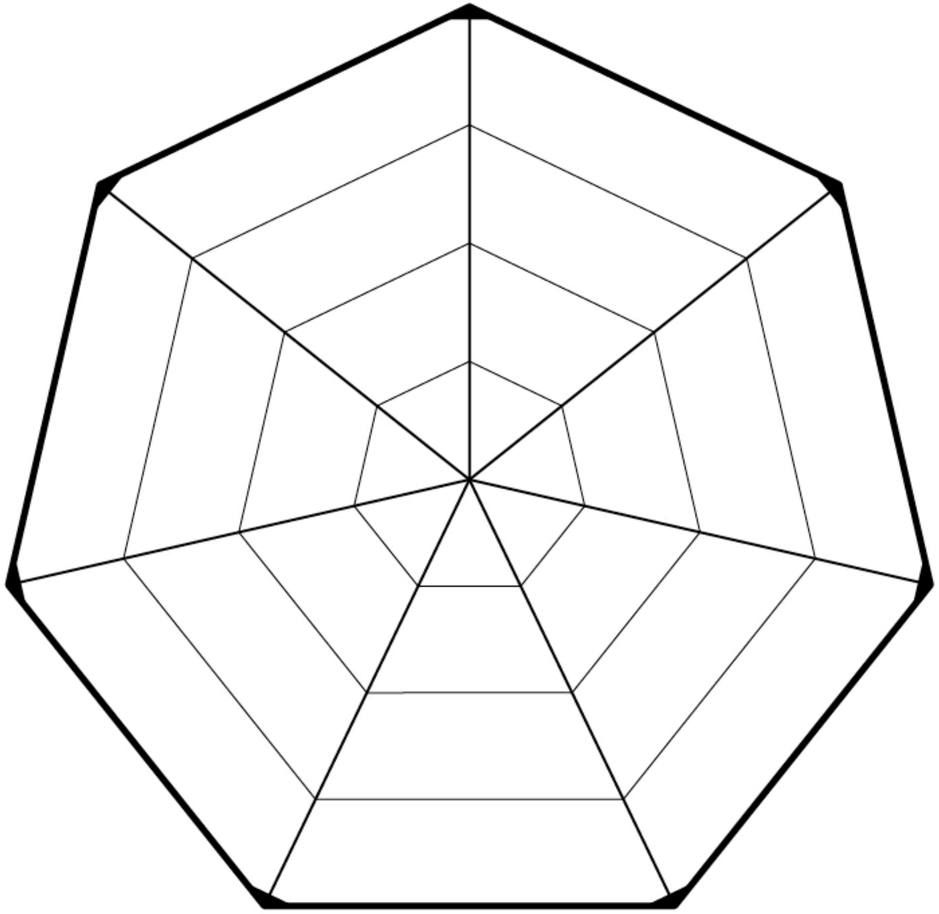
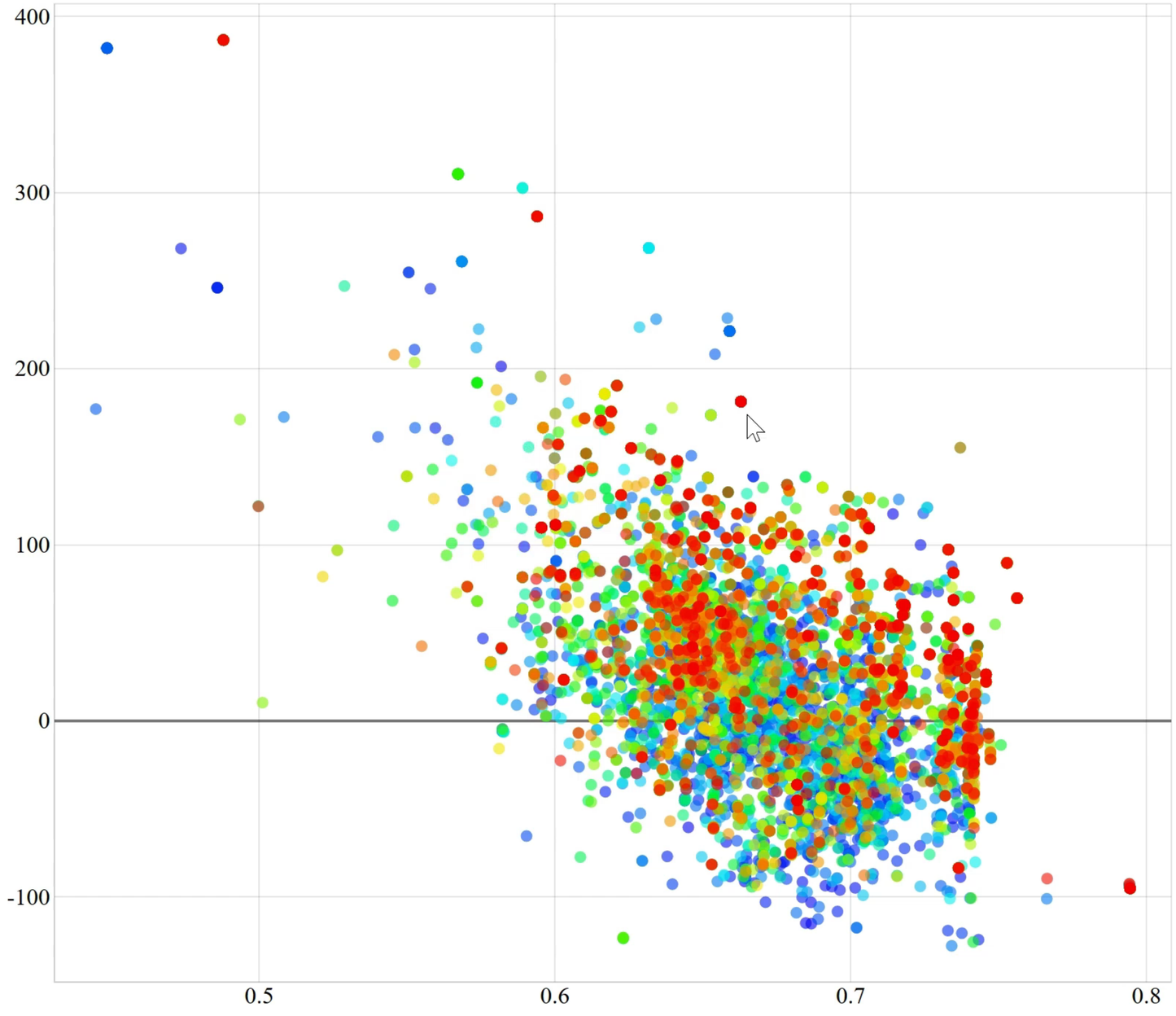


Generative Urban Design Van Wijnen

VAN WIJNEN







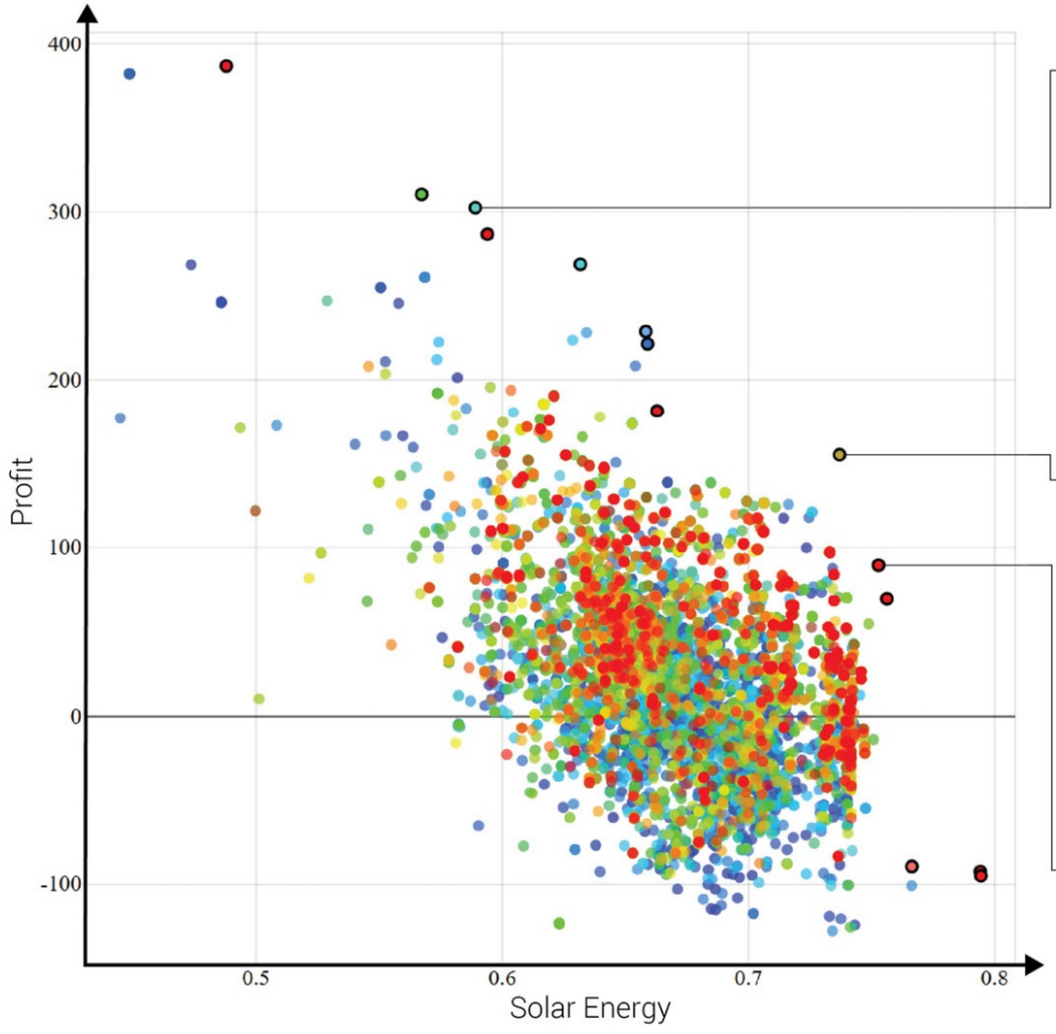
Reload data | Isolate optimal designs | Isolate selected designs | Reset zoom

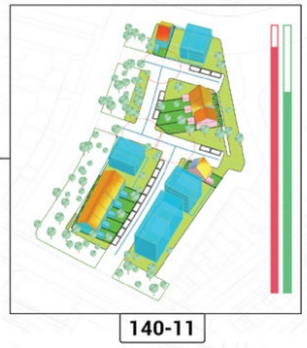
X-axis	Y-axis	Selected designs
id	id	
generation	generation	
[in] avenue	[in] avenue	
[in] street_1	[in] street_1	
[in] street_2	[in] street_2	
[in] street_3	[in] street_3	
[in] street_4	[in] street_4	
[max] solar_radiation	[max] solar_radiation	
[max] revenue	[max] revenue	

Reset | Reset

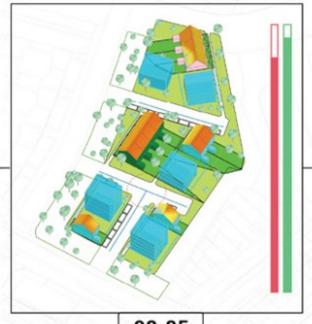
Size	Color
id	id
generation	generation
[in] avenue	[in] avenue
[in] street_1	[in] street_1
[in] street_2	[in] street_2
[in] street_3	[in] street_3
[in] street_4	[in] street_4
[max] solar_radiation	[max] solar_radiation
[max] revenue	[max] revenue

Reset | Export

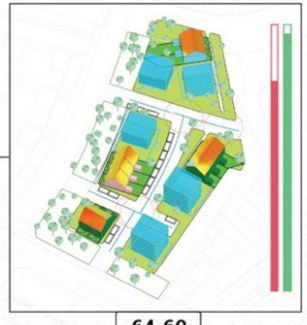




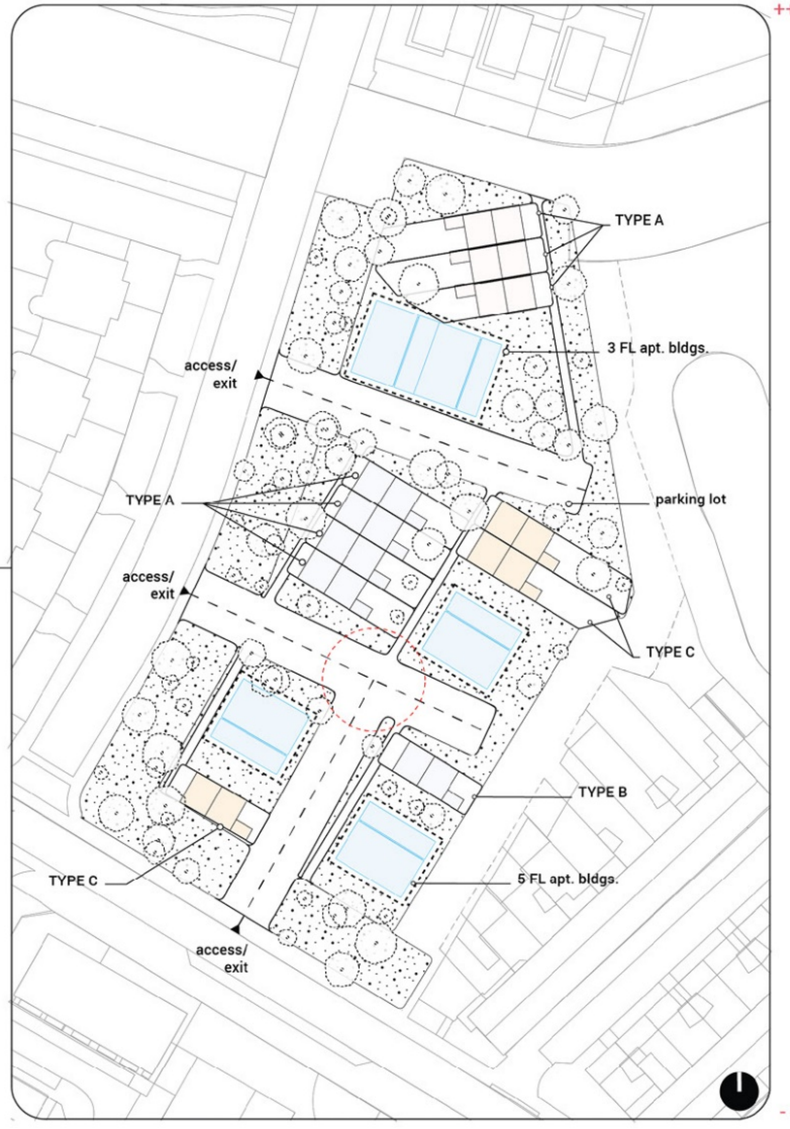
140-11



98-85

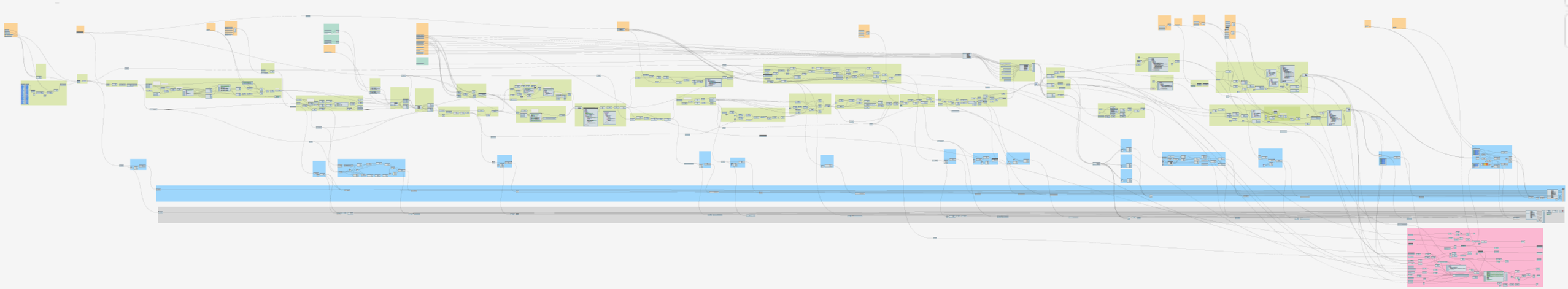


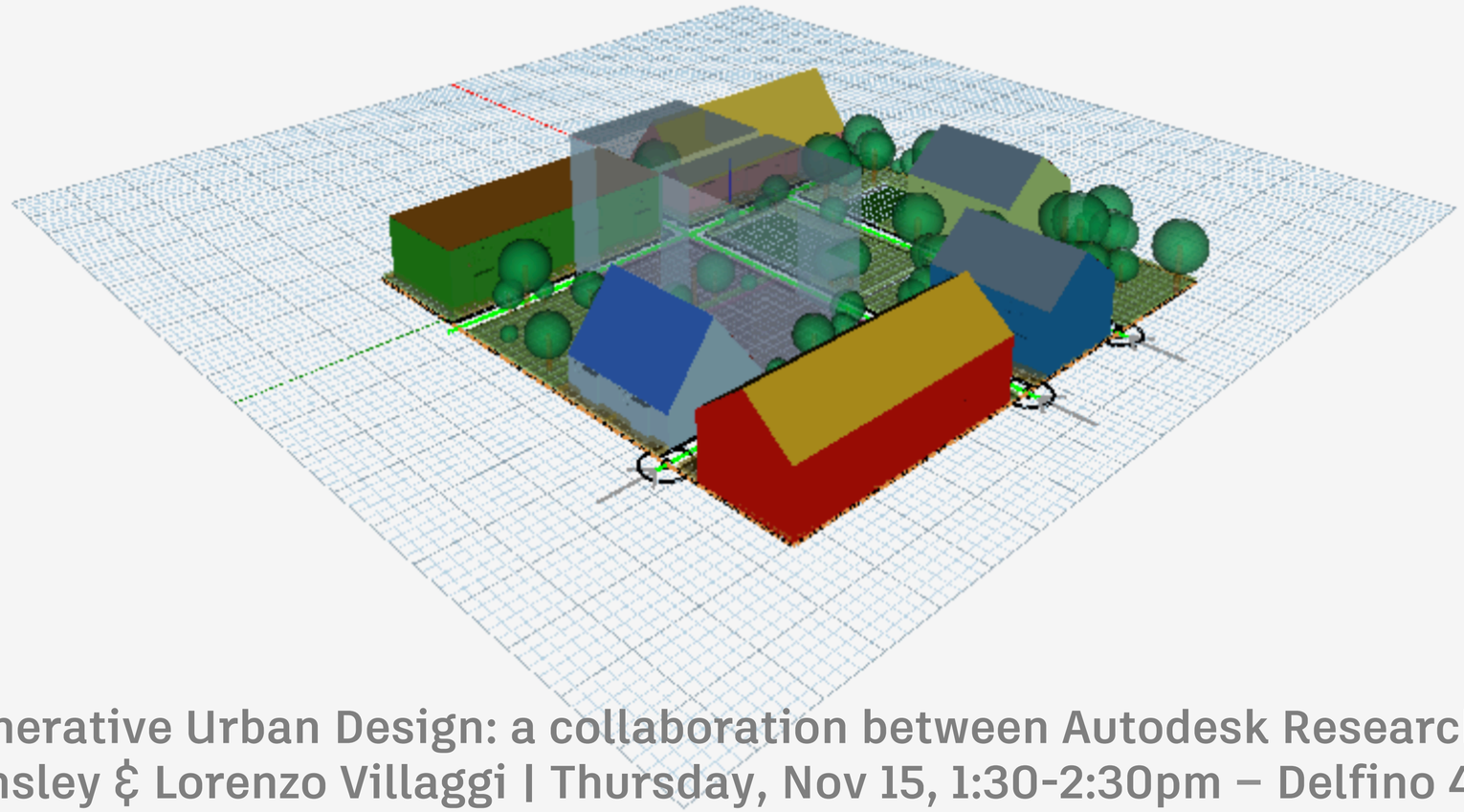
64-60



id# 98 - 85

house: TYPE A count: 3	**house: TYPE C** count: 3
house: TYPE B count: 5	**apartment units** count: 19 - 4438 sqm





CS239262 – Generative Urban Design: a collaboration between Autodesk Research and Van Wijnen

Kean Walmsley & Lorenzo Villaggi | Thursday, Nov 15, 1:30-2:30pm – Delfino 4004, Level 4

Building

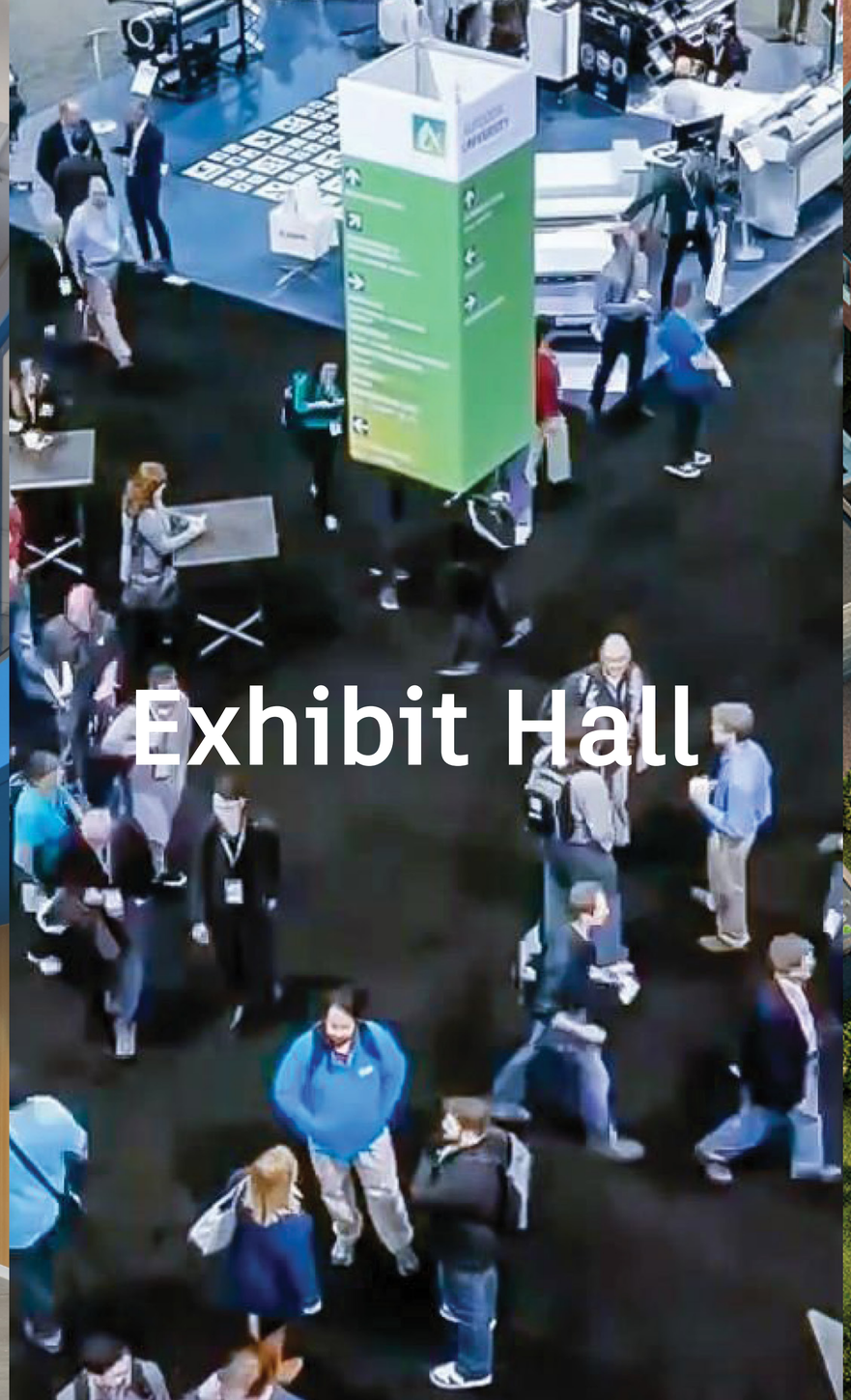


Exhibit Hall

Neighborhood

Autodesk tools for Generative Design in the AEC space

TRADITIONAL DESIGN

RECORDING DECISIONS

GENERATIVE DESIGN

DESCRIBING GOALS + CONSTRAINTS

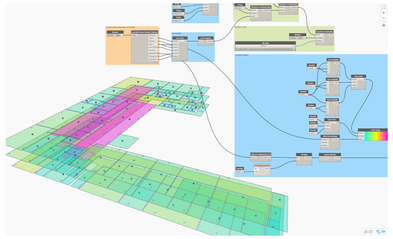
PARAMETRIC MODELING

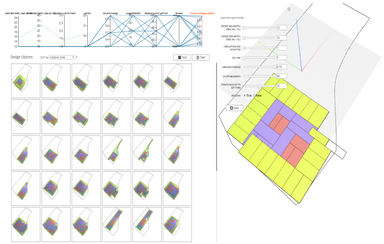
VISUAL PROGRAMMING

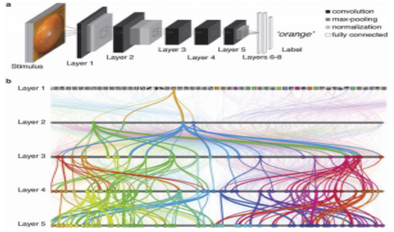
OPTION GENERATION

DESIGN OPTIMIZATION

MACHINE LEARNING







Evolutionary algorithm outperf

https://www.technologyreview.com/s/6115...

MIT Technology Review

Menu

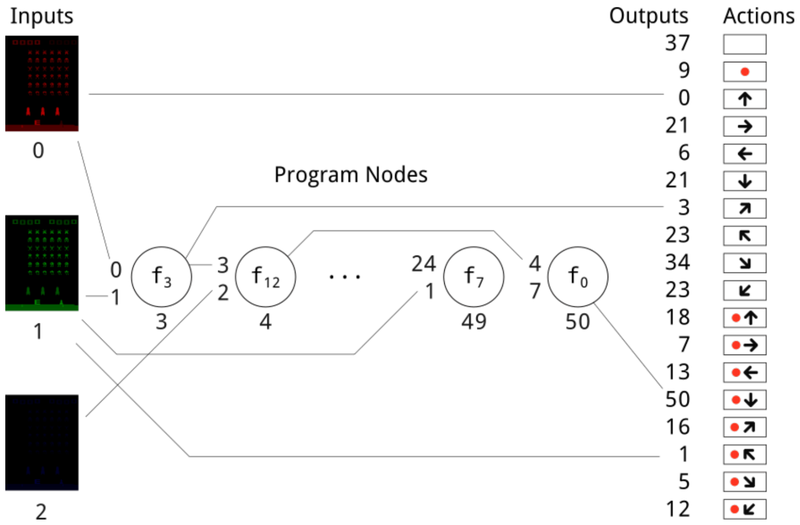
MIT Technology Review Innovation Leaders Summit
Breakthrough to Impact
November 30, 2018
Paris, France
Attend →

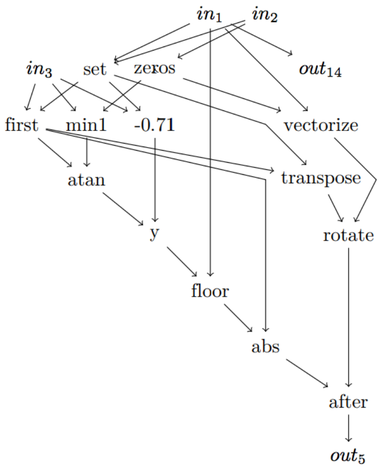
Intelligent Machines

Evolutionary algorithm outperforms deep-learning machines at video games

Neural networks have garnered all the headlines, but a much more powerful approach is waiting in the wings.

by Emerging Technology from the arXiv July 18, 2018





REFINERY: OPTIMIZATION AND OPTIONEERING FOR DYNAMO

Refinery’s Optimization Engine

- Based on the O2 engine developed by Autodesk Research’s The Living
  - Used successfully for the various projects shown previously
- Employs the NSGA-II genetic algorithm
  - Meta-heuristic algorithm for multi-objective optimization
- Relies on bio-inspired operators such as mutation, crossover and selection
  - Population-based, so maintains & improves candidate solutions

REFINERY'S OPTIMIZATION ENGINE

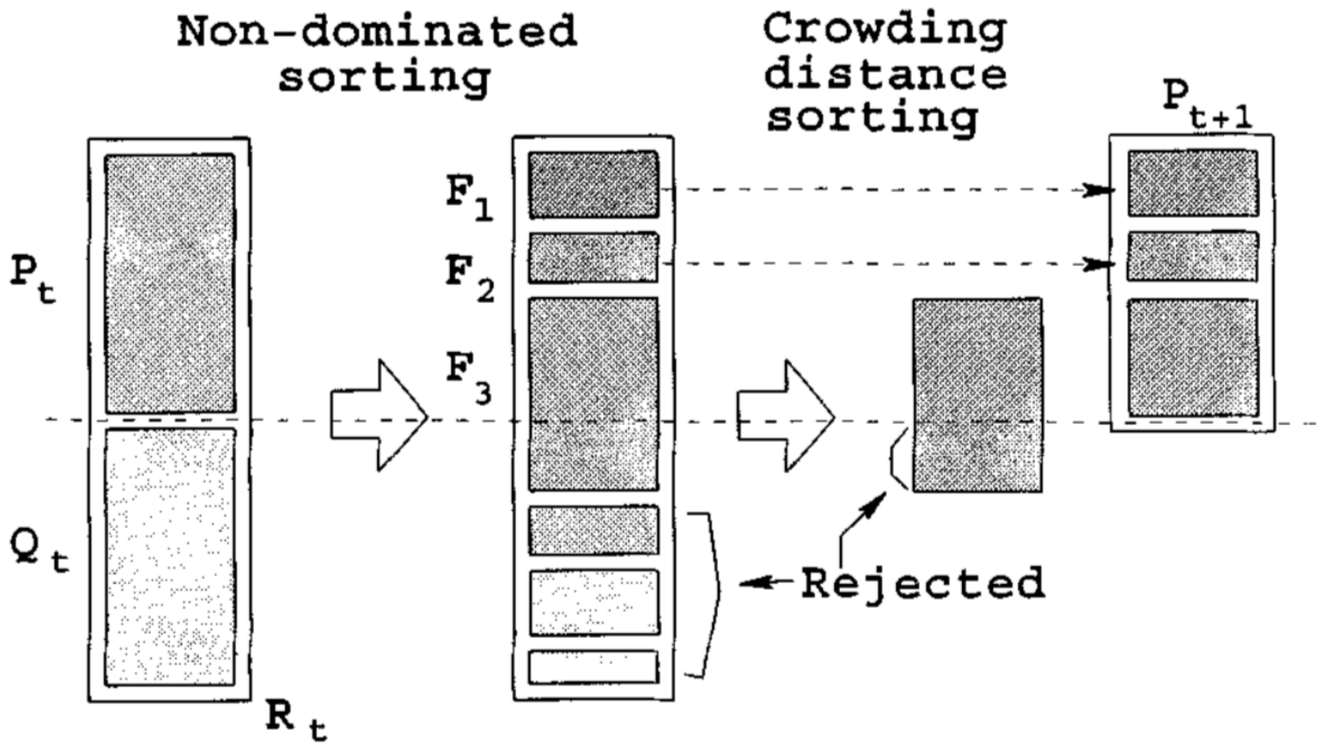


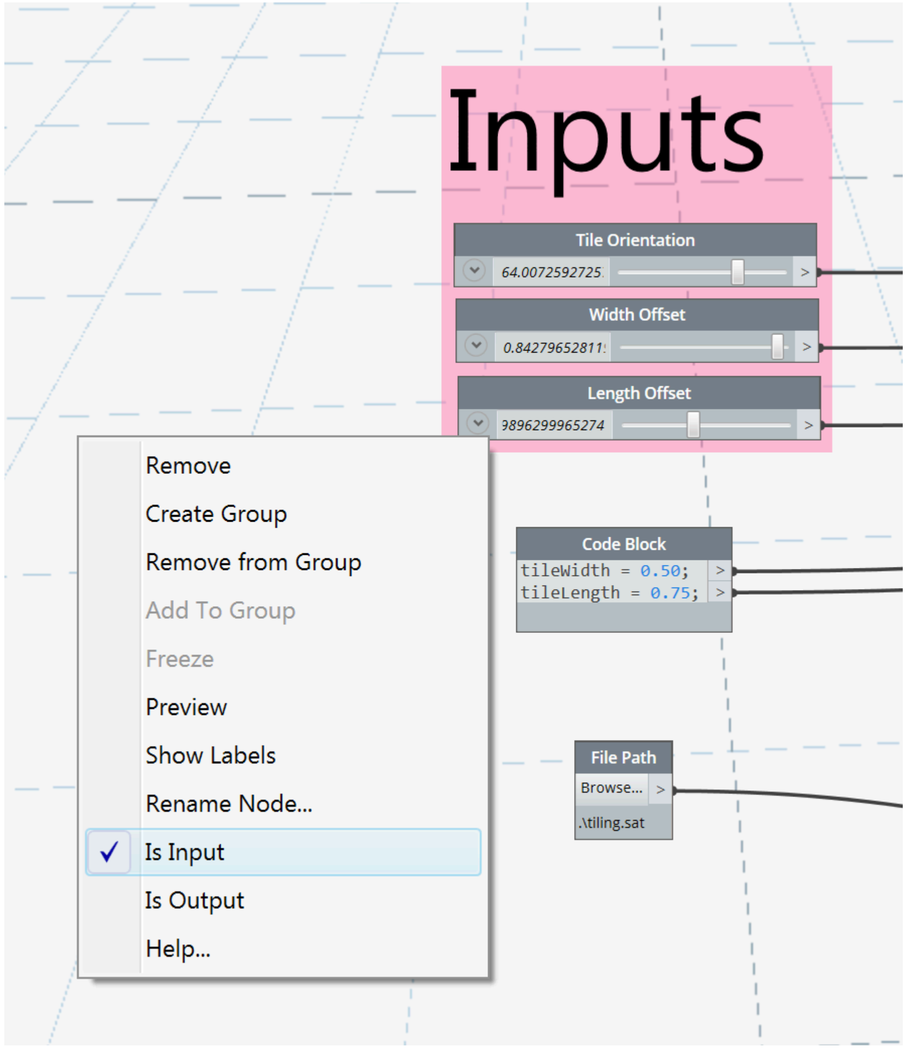
Fig. 2. NSGA-II procedure.

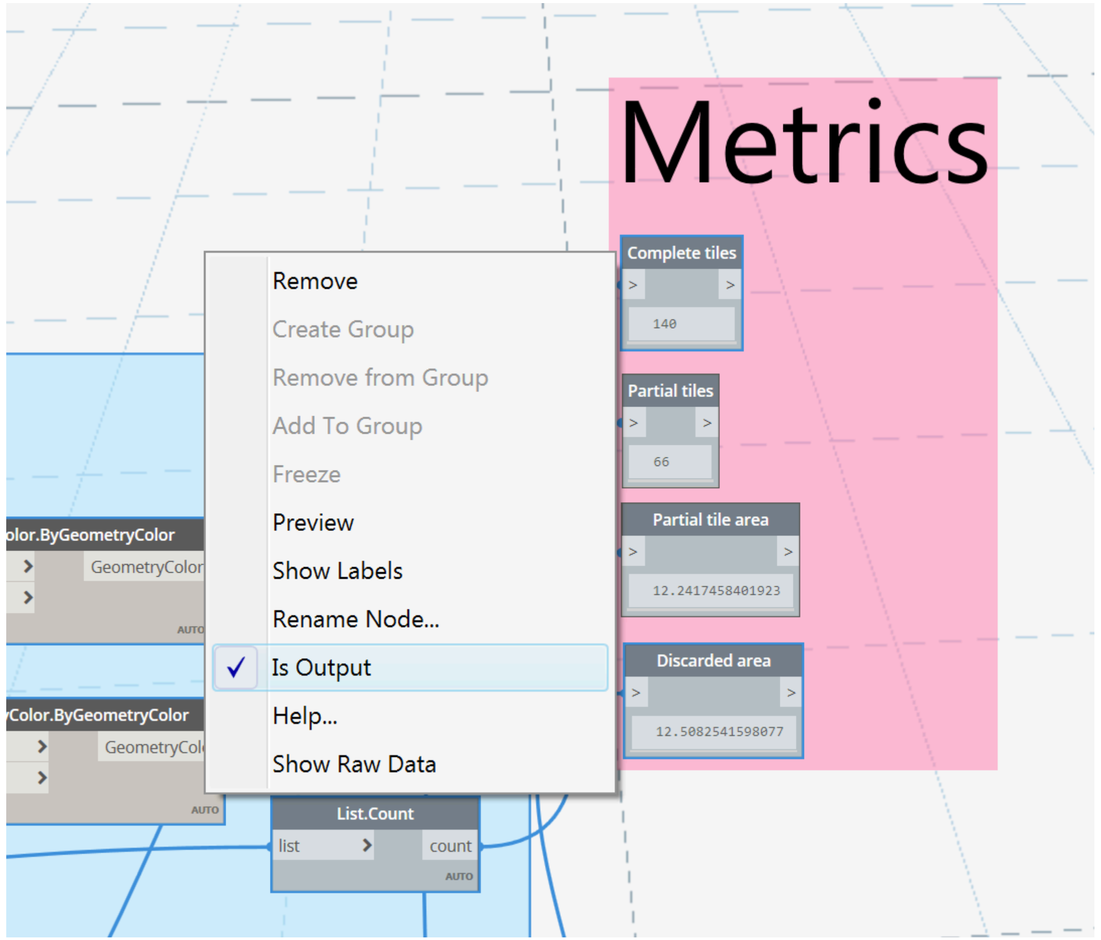
IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTATION, VOL. 6, NO. 2, APRIL 2002

https://www.iitk.ac.in/kangal/Deb_NSGA-II.pdf

Implementing your own generative workflows

Your Dynamo graph needs to tell Refinery about its inputs and outputs





LIKE THIS
RANDOMIZE
CROSS PRODUCT
OPTIMIZE

Create Study

Generation Method

Optimize

Generate

Inputs

Tile Orientation

64.0072592725752

0 90

Width Offset

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0 0.9

Length Offset

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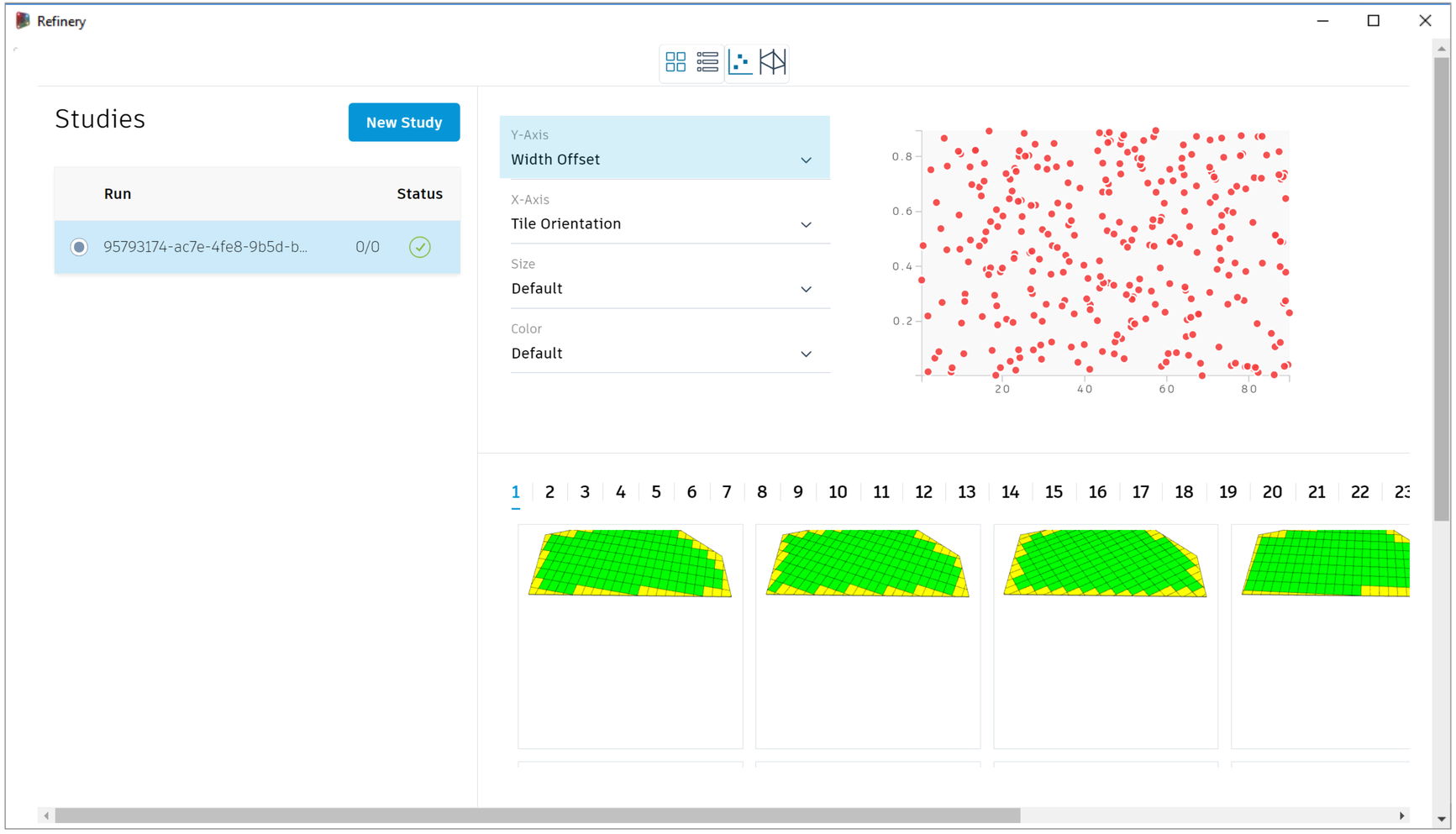
0 0.9

RANDOMIZE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New Study
Run
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0/0
Y-Axis
Width Offset
X-Axis
Tile Orientation
Size
Default
Color
Default
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0.4
0.2
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40
60
80
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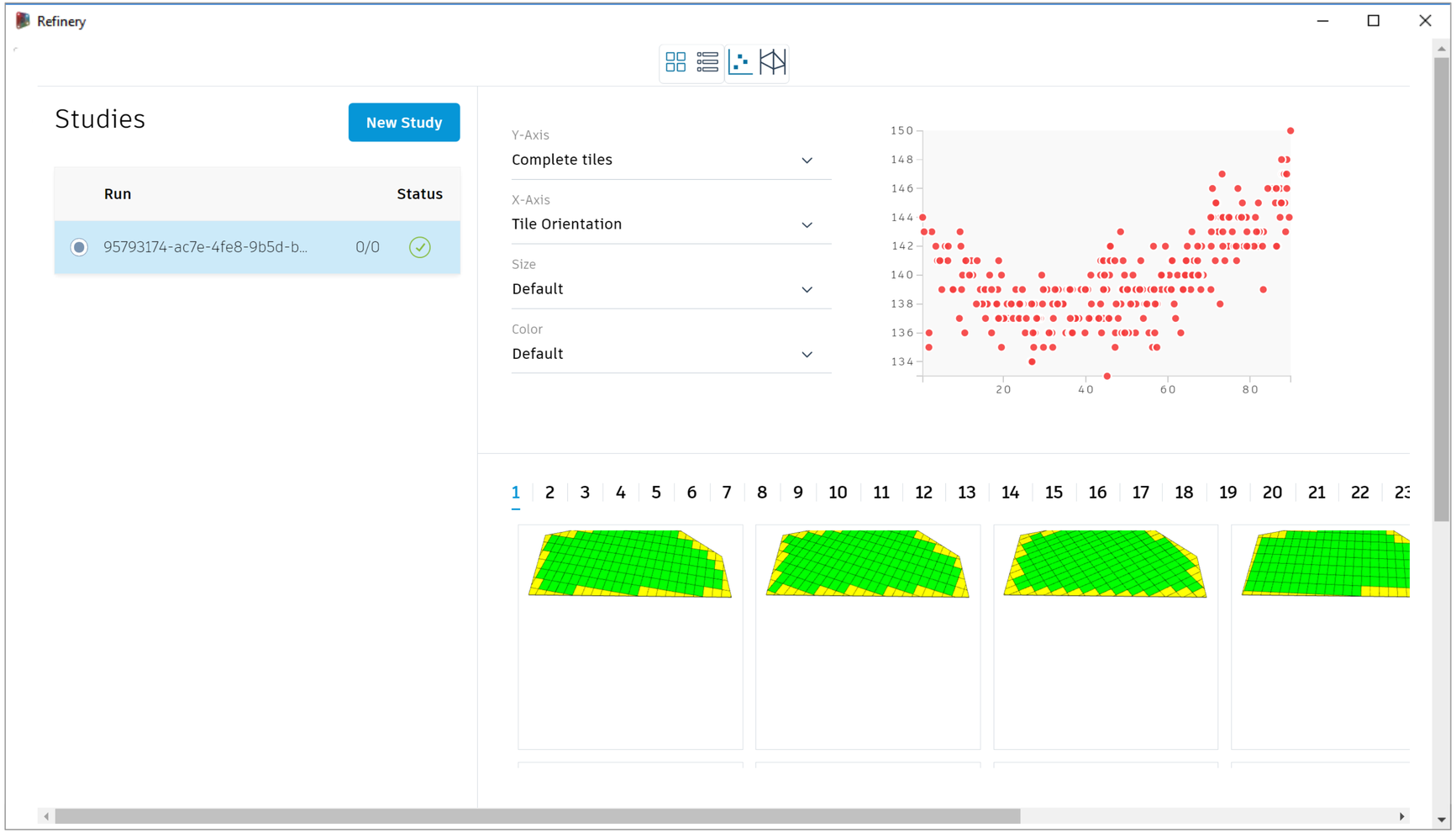
RANDOMIZE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Complete tiles
X-Axis
Tile Orientation
Size
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Color
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60
80
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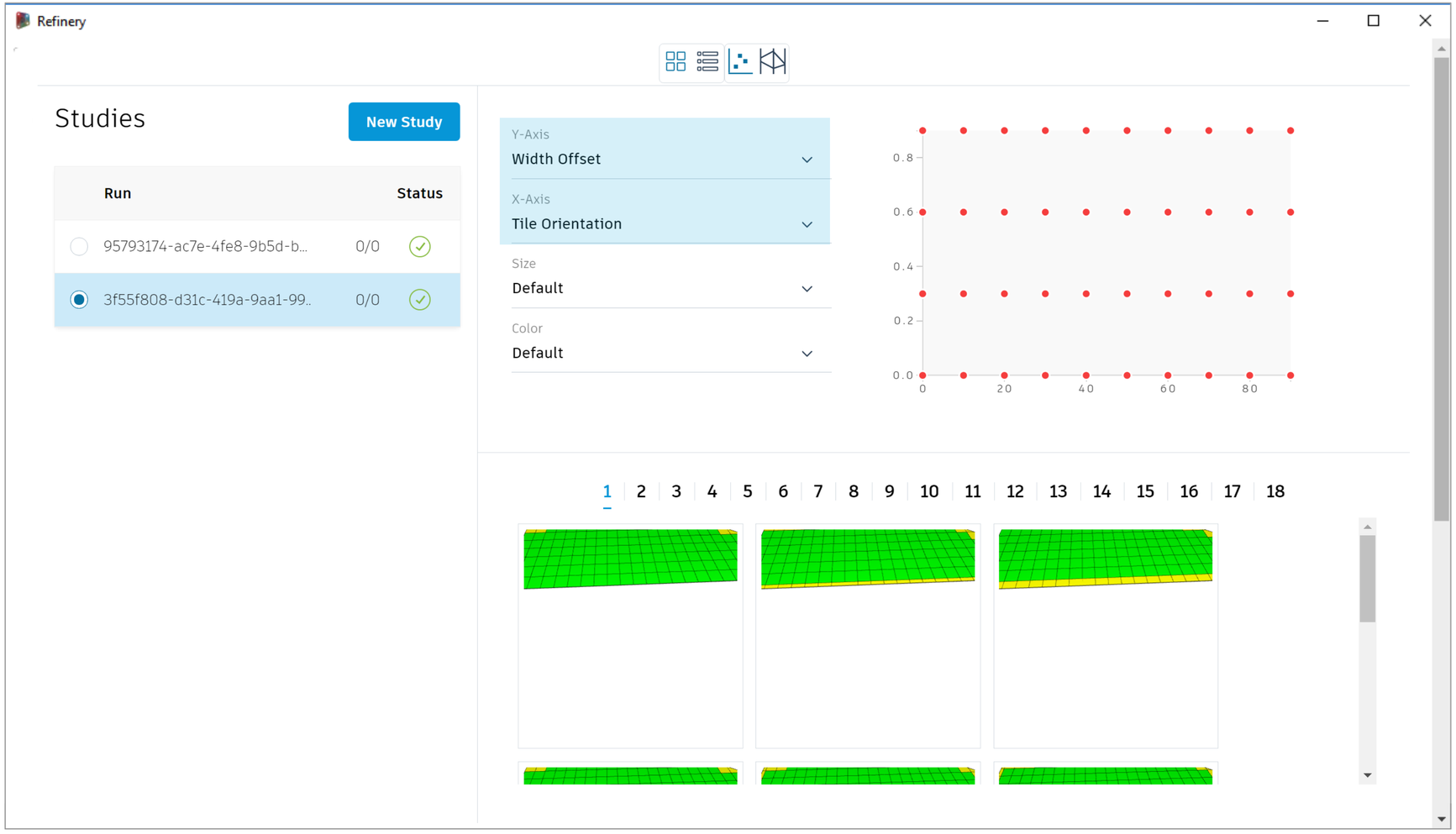
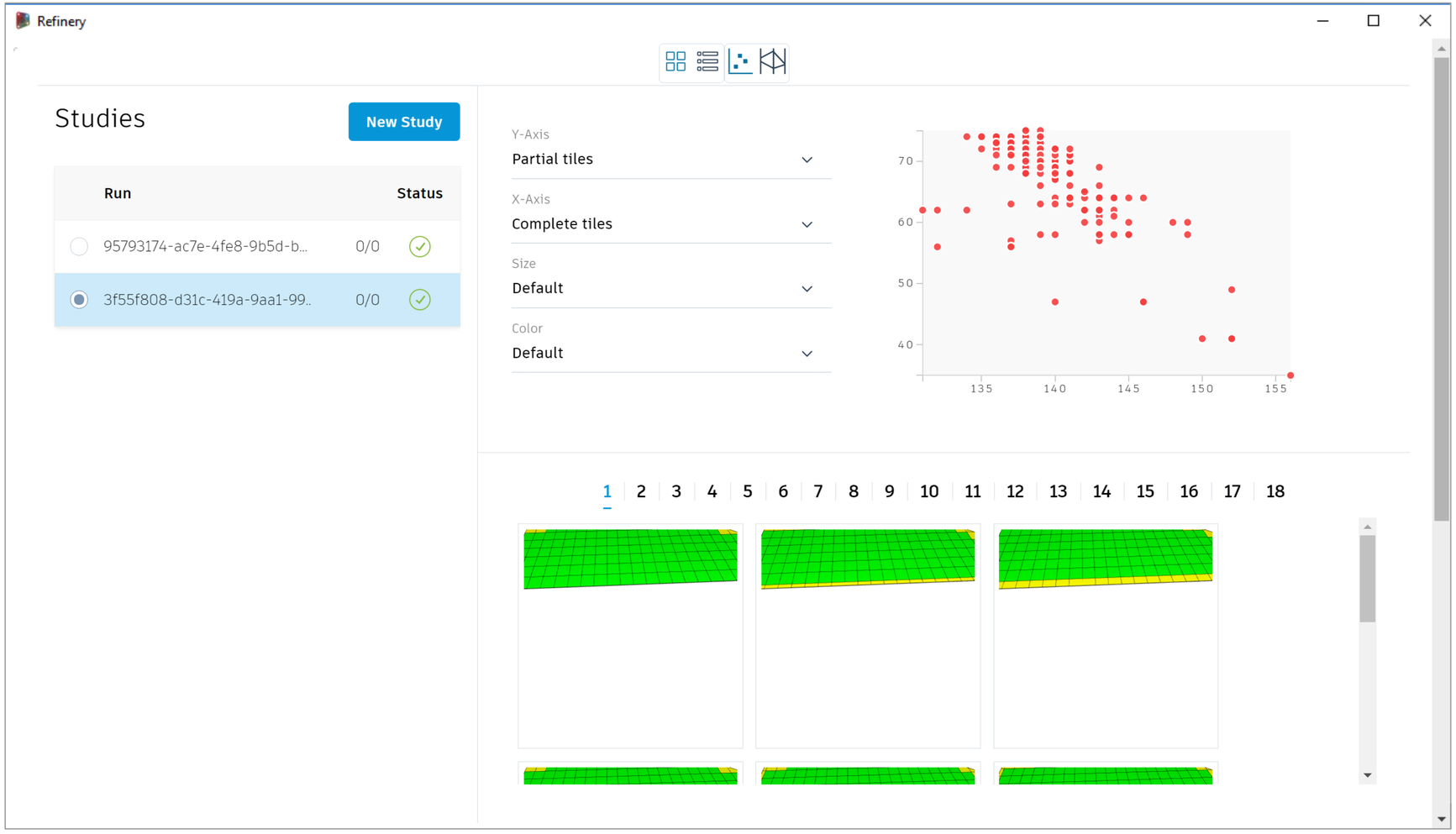
CROSS PRODUCT



CROSS PRODUCT



OPTIMIZE

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10/10
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0/0
Y-Axis
Width Offset
X-Axis
Tile Orientation
Size
Default
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10
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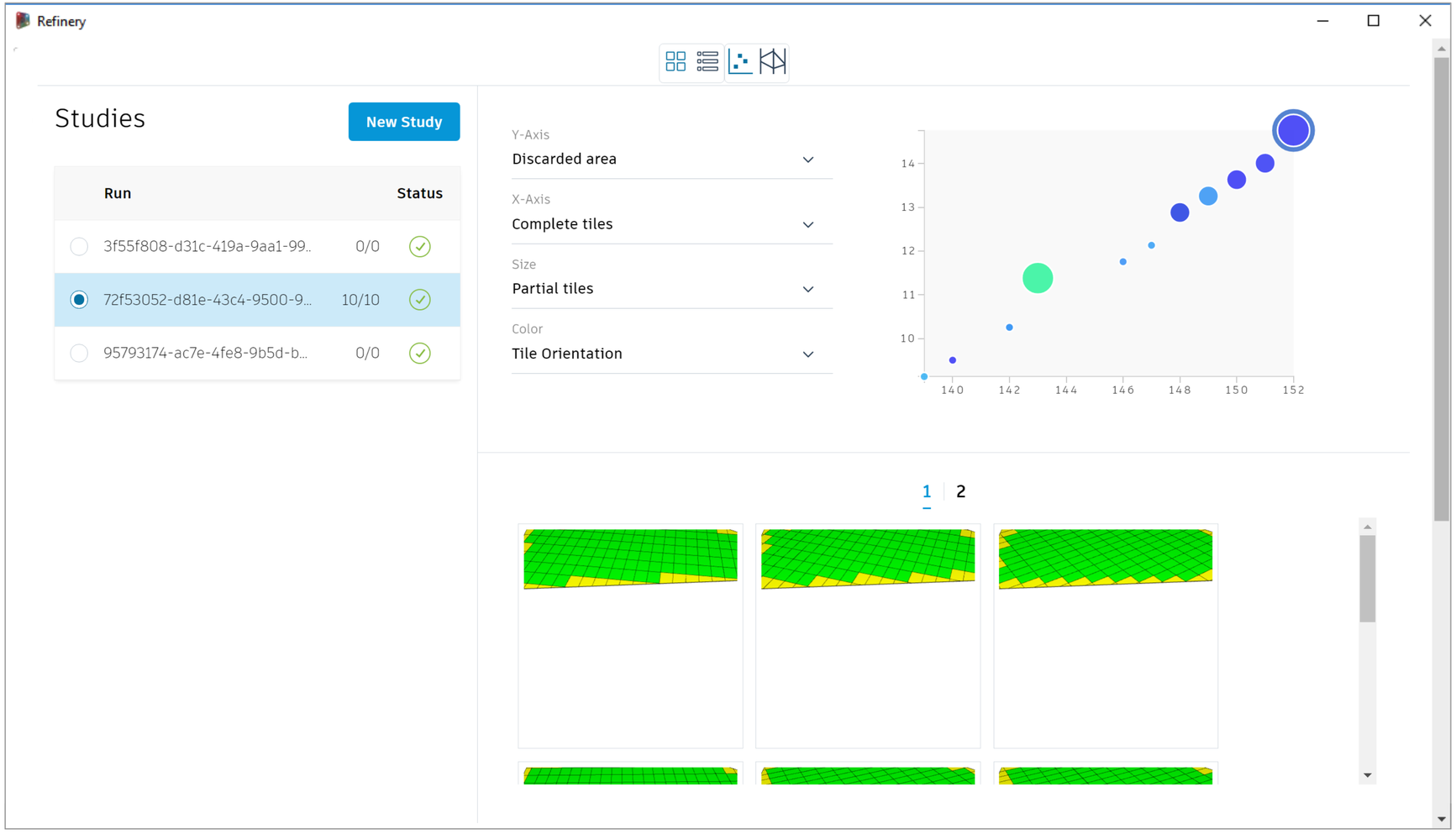
70
80
1
2

OPTIMIZE


Refinery
Studies
New Study
Run
Status
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0/0
72f53052-d81e-43c4-9500-9...
10/10
95793174-ac7e-4fe8-9b5d-b...
0/0
Y-Axis
Discarded area
X-Axis
Complete tiles
Size
Partial tiles
Color
Tile Orientation
14
13
12
11
10
140
142
144
146
148
150
152
1
2

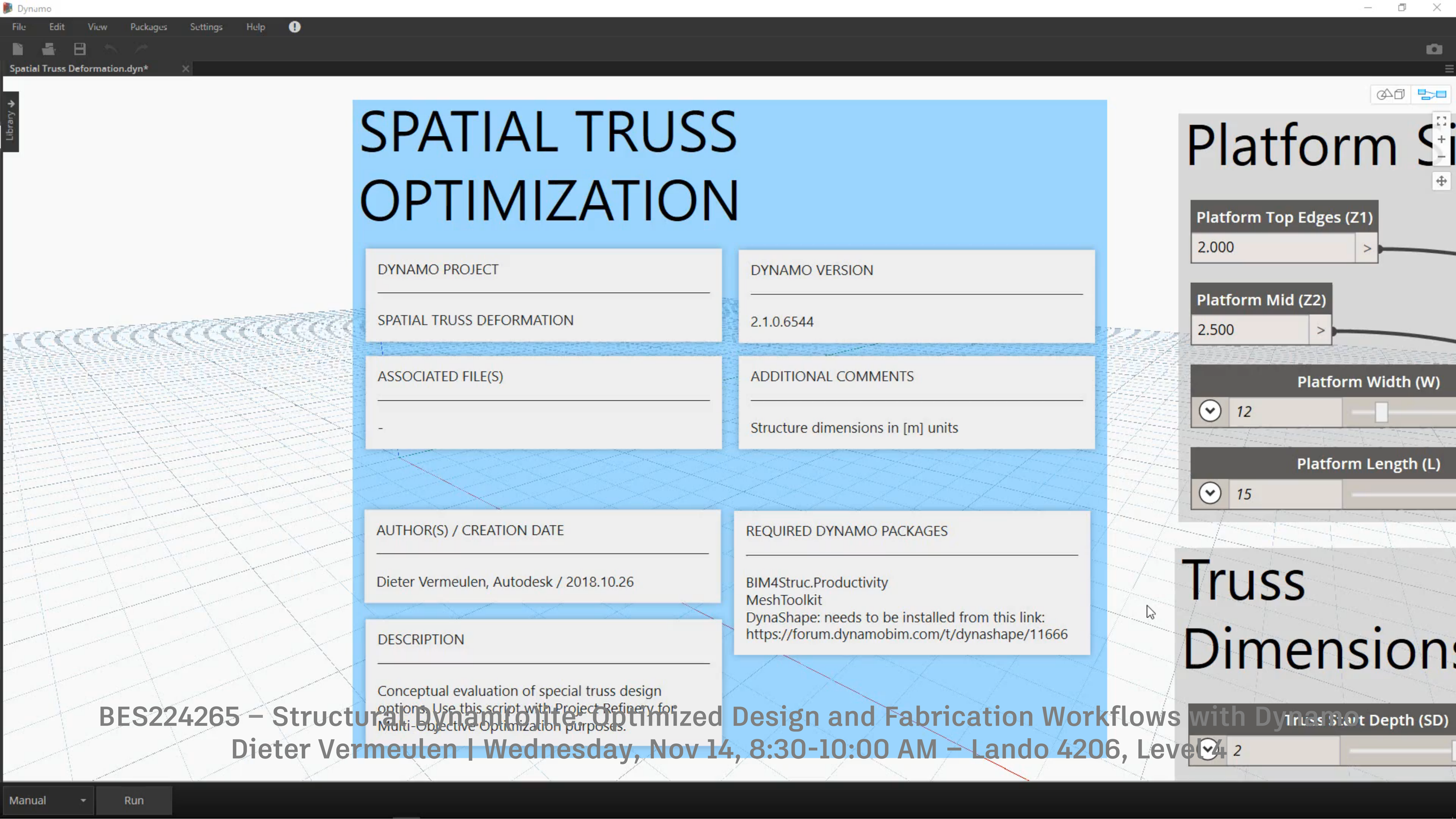
How it works

- You can run Refinery from Dynamo for Revit or Dynamo Sandbox
  - Tasks are executed by Refinery server using DynamoCLI
    - Limits what can be accessed or performed inside Revit
      - Use Data.Remember nodes to cache inputs into the graph
    - Refinery server currently runs locally but will move to the cloud
- Selecting a solution sets the parameters in Dynamo (for Revit)

Demo

Getting started

- Download Refinery from the Beta site
  - https://beta.autodesk.com/key/refinery
  - Works with Dynamo 2.0.2 or daily builds of 2.1
- Still in Beta, so expect some quirks
  - Known issues include a large amount of graphical data generated
    - Check *%appdata%/Refinery* if running out of diskspace
  - Provide feedback on where you want us to go with it!



BES224265 – Structural Dynamofile: Optimized Design and Fabrication Workflows with Dynamo

Dieter Vermeulen | Wednesday, Nov 14, 8:30-10:00 AM – Lando 4206, Level 4

Recommendations

- Get started now on building up skills and IP for generative workflows
  - Dynamo expertise will be even more valuable in the future
    - There's a thriving DynamoBIM community to tap into
  - Start small, such as with today's tiling example
  - Graphs get complicated quickly
  - Maintaining discipline will help
    - Relevant learnings from the Van Wijnen project in Thursday's 1:30pm class
      - *CS239262 - Generative Urban Design: a collaboration between Autodesk Research and Van Wijnen (Delfino 4004, Level 4)*
- Think about "closing the loop": gathering data to help future iterations

Q&A

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