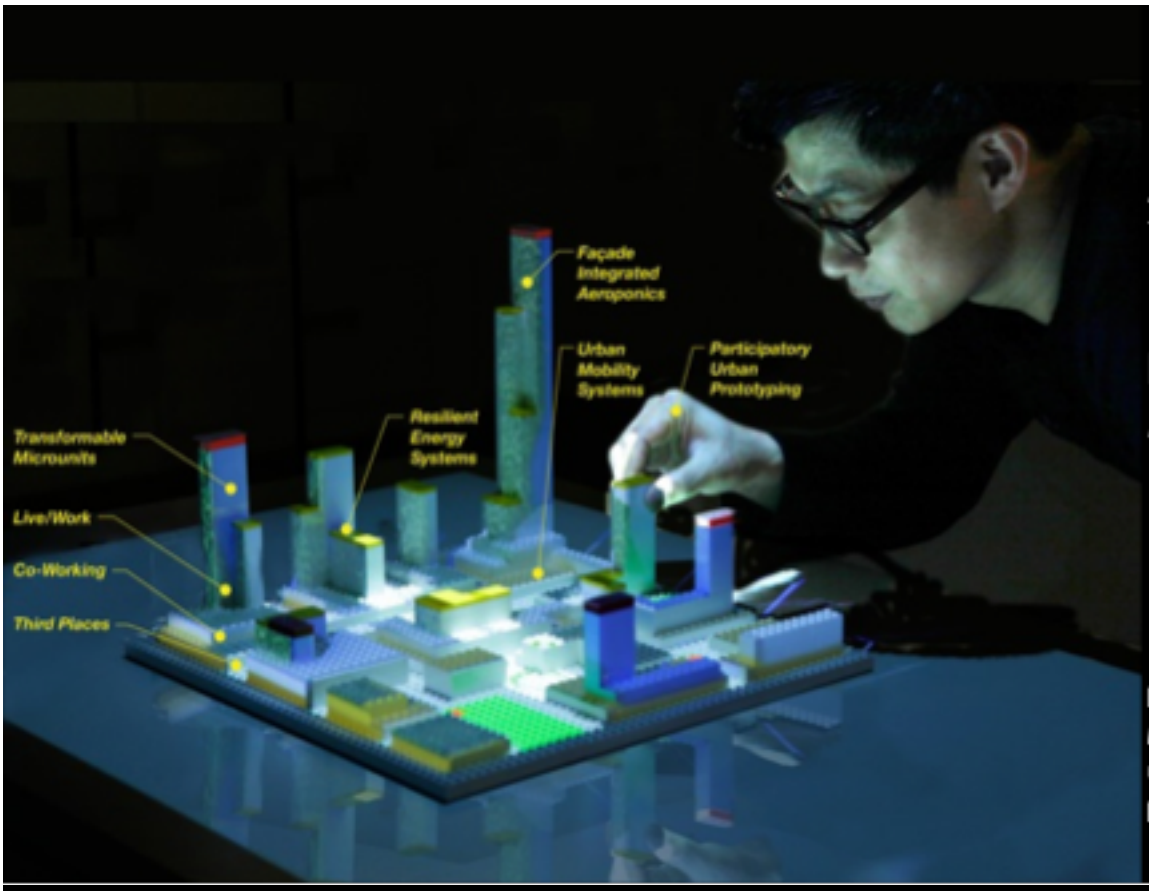
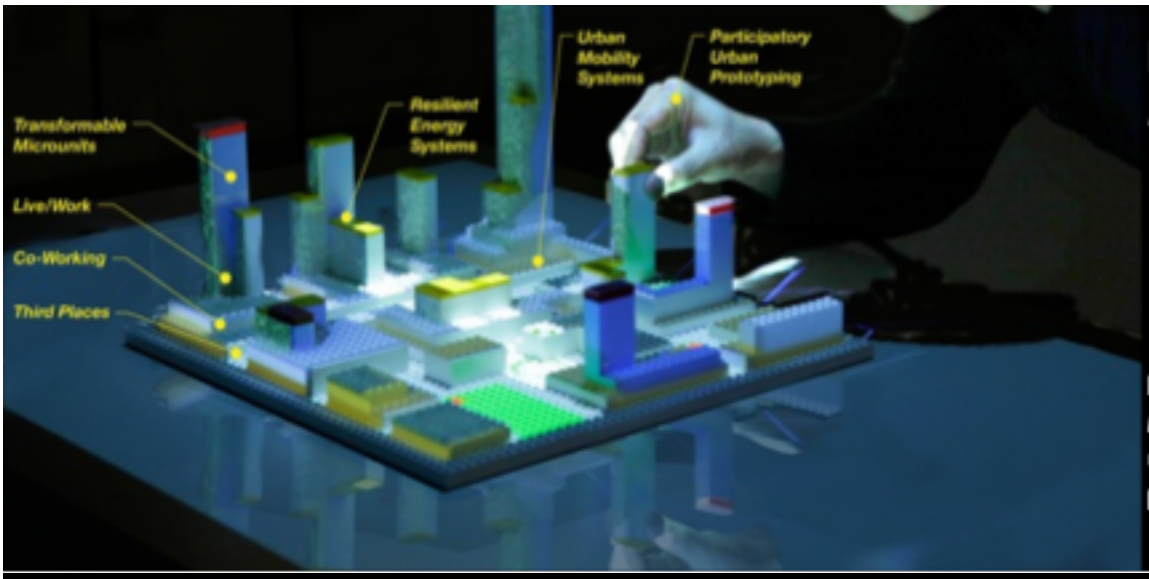


Responsive Cities

2014 NSF Cyber-Physical Systems Principal Investigators' Meeting

Kent Larson
MIT Media Lab
@Larson_MIT
kll@mit.edu

What enables innovative entrepreneurial,



Principal Investigators' Meeting

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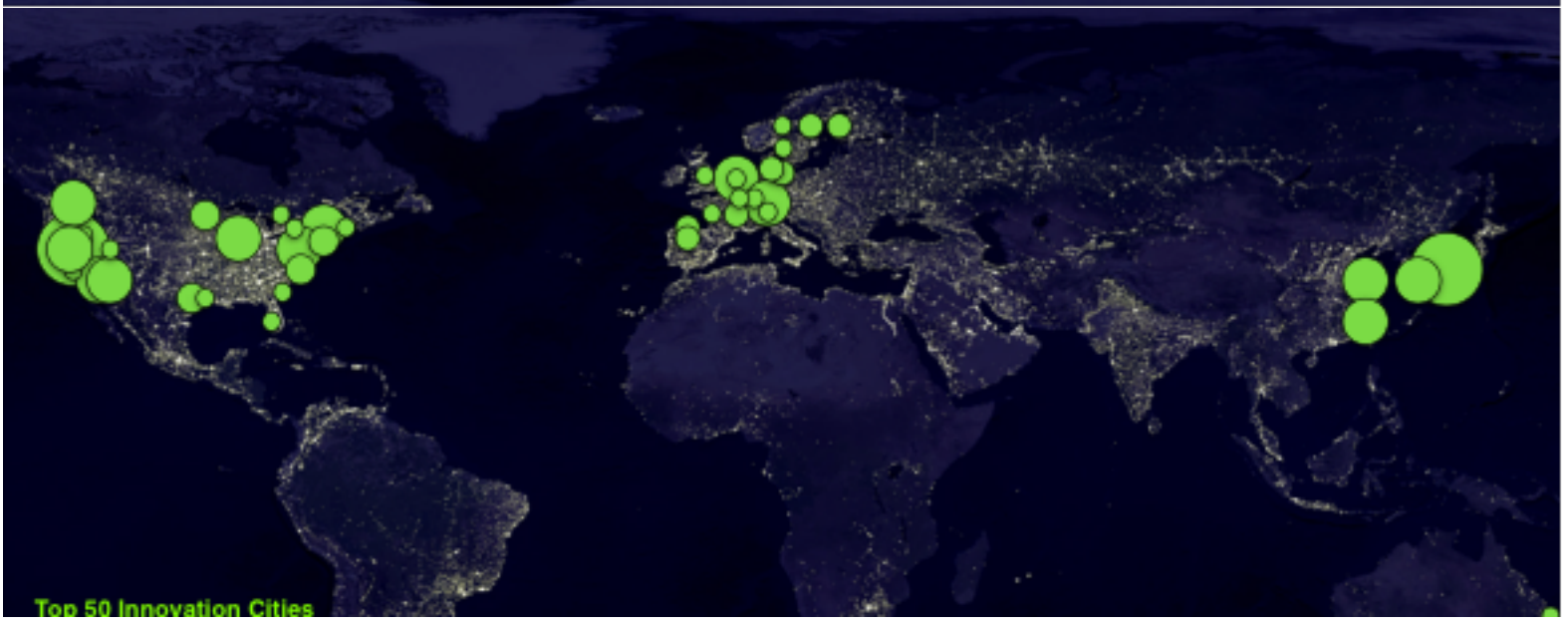
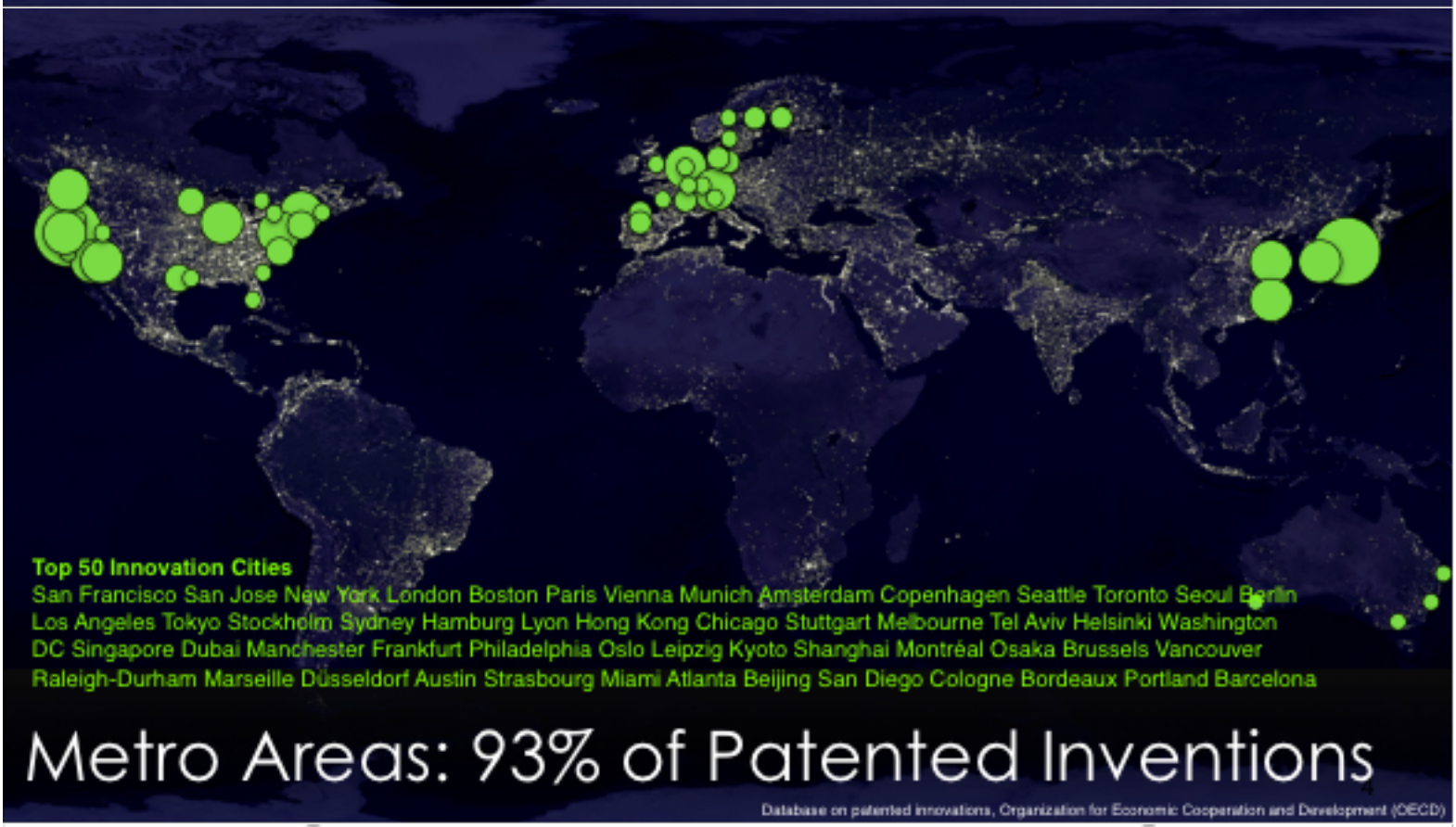
What enables innovative entrepreneurial, high-performance cities?

innovative entrepreneurial, high-performance cities?





Density

Residential
Employment
Cafes, shops, restaurants
Cultural venues …

+

Proximity

Home to workplace
… to recreation, nature
… to shopping, eating
… to schools, healthcare …

+

Diversity

Demographic
Enterprise
Housing
Activity …

+

New Urban Systems

Top 50 Innovation Cities

San Francisco San Jose New York London Boston Paris Vienna Munich Amsterdam Copenhagen Seattle Toronto Seoul Berlin Los Angeles Tokyo Stockholm Sydney Hamburg Lyon Hong Kong Chicago Stuttgart Melbourne Tel Aviv Helsinki Washington DC Singapore Dubai Manchester Frankfurt Philadelphia Oslo Leipzig Kyoto Shanghai Montréal Osaka Brussels Vancouver Raleigh-Durham Marseille Düsseldorf Austin Strasbourg Miami Atlanta Beijing San Diego Cologne Bordeaux Portland Barcelona

Metro Areas: 93% of Patented Inventions

Database on patented innovations, Organization for Economic Cooperation and Development (OECD)

Density

Residential
Employment
Cafes, shops, restaurants
Cultural venues …

+

Proximity

Home to workplace
… to recreation, nature
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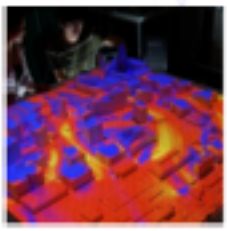
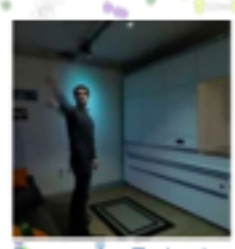
New Urban Systems



Simulation/Integration



Responsive Technology

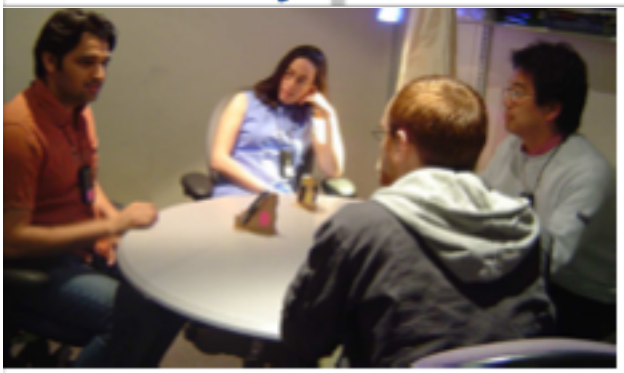
New Model: Mobility

New Model: Food

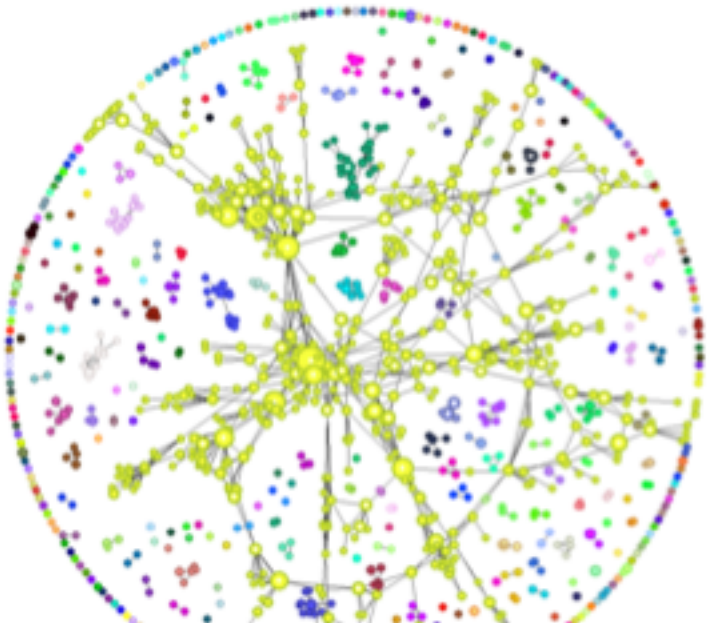
New Model: Housing

=

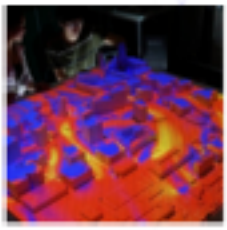
Quality of Life + Jobs + Resource Reduction



Waber, et al.2010; Pan et al, 2011; Cebrian et al. 2011. Ductor, 2010.



New Urban Systems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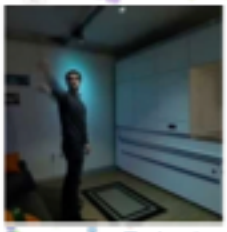
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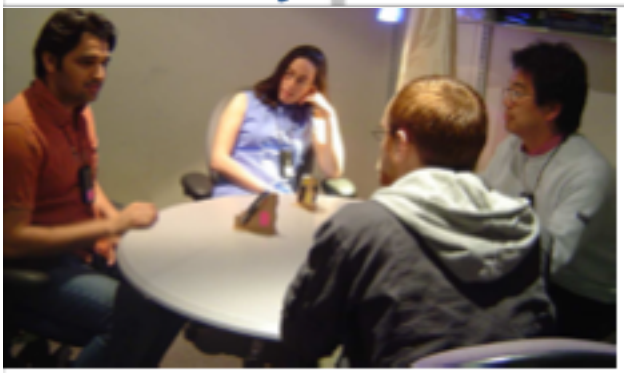

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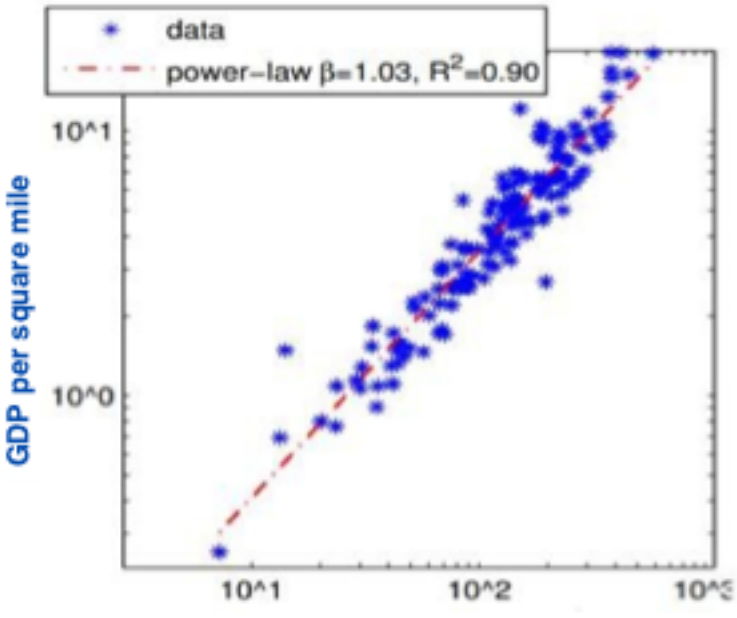
Social Ties Increase Productivity

Human Dynamics Group, MIT Media Lab



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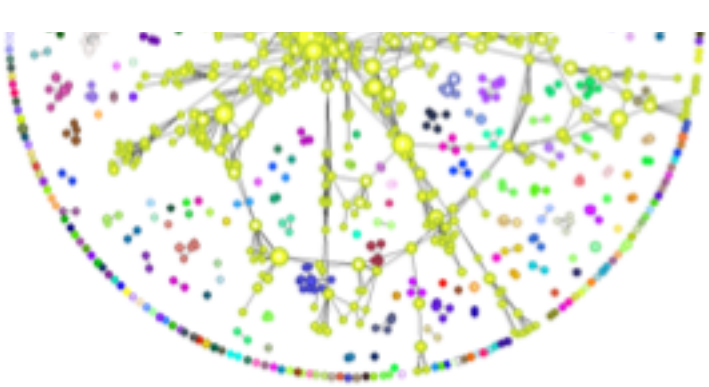

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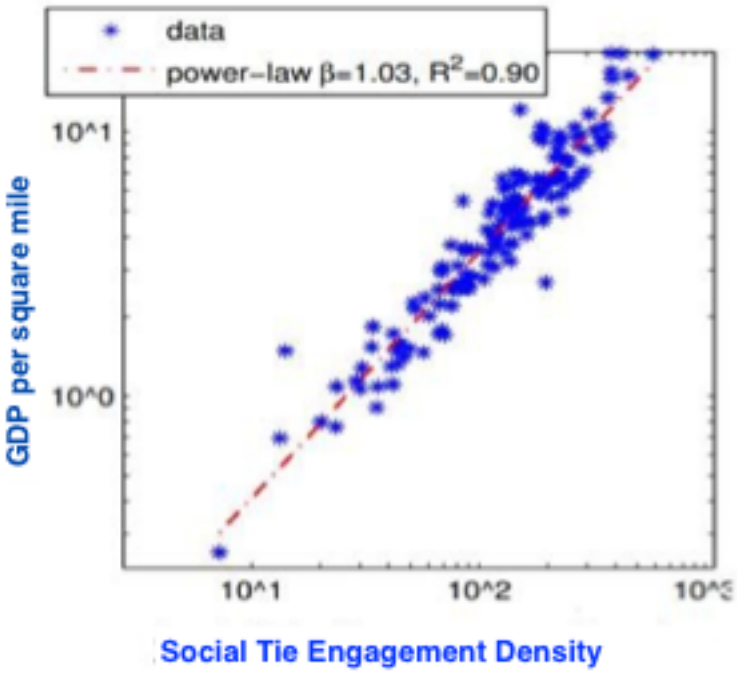
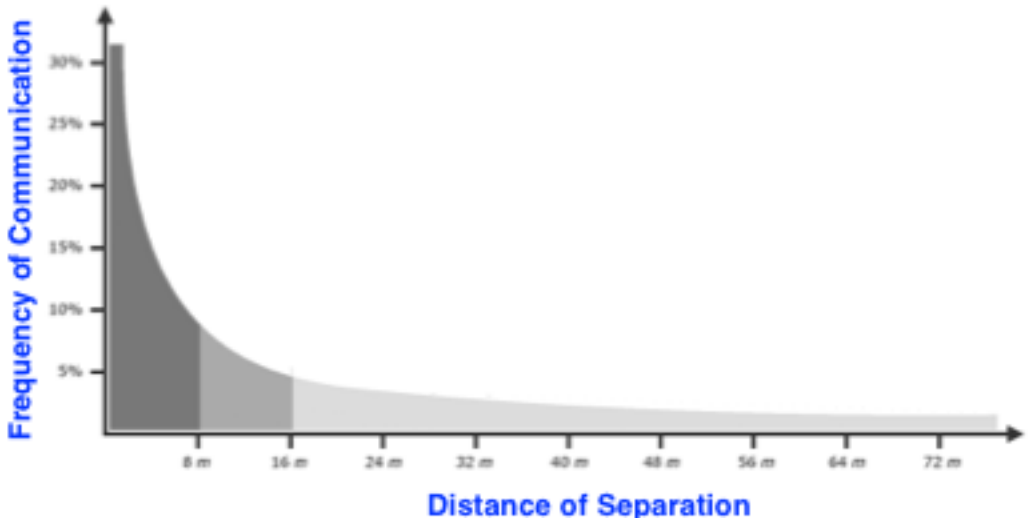
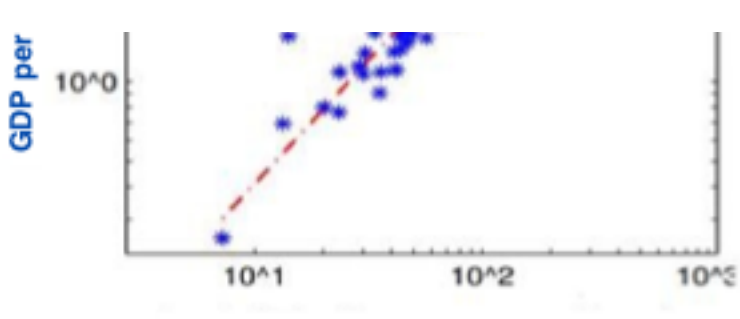


Social Tie Density Increases GDP

Human Dynamics Group, MIT Media Lab



Thomas J. Allen
(MIT Professor of Management Emeritus)
Allen Curve: Proximity brings greater frequency of Communication



Social Tie Density Increases GDP

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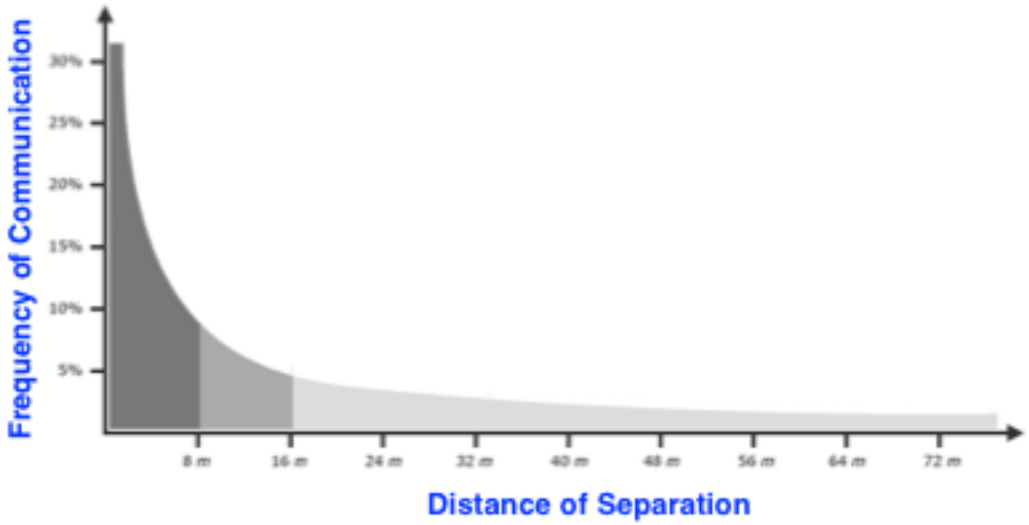

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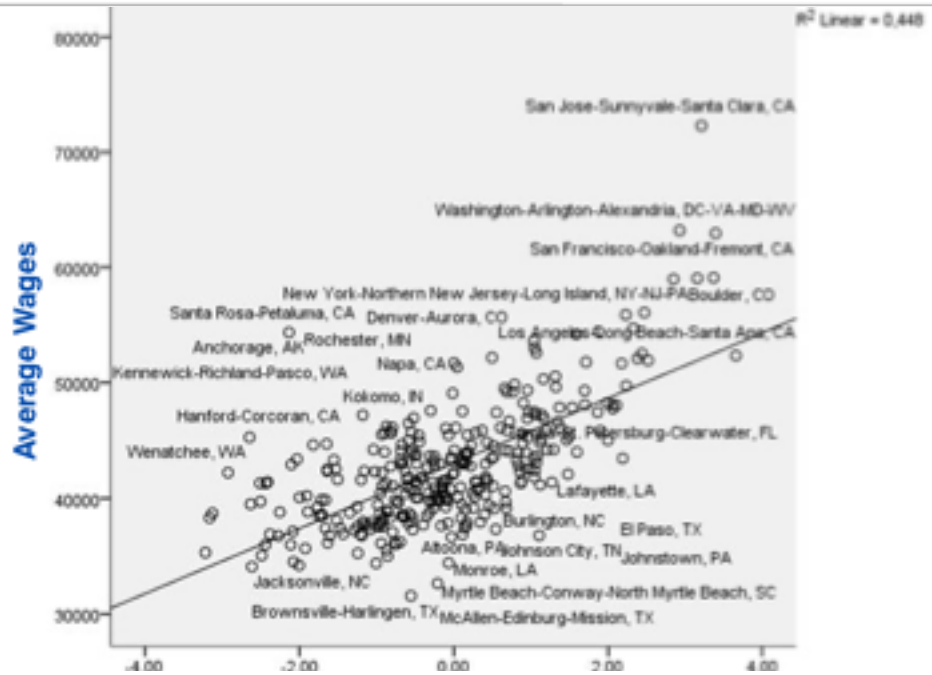
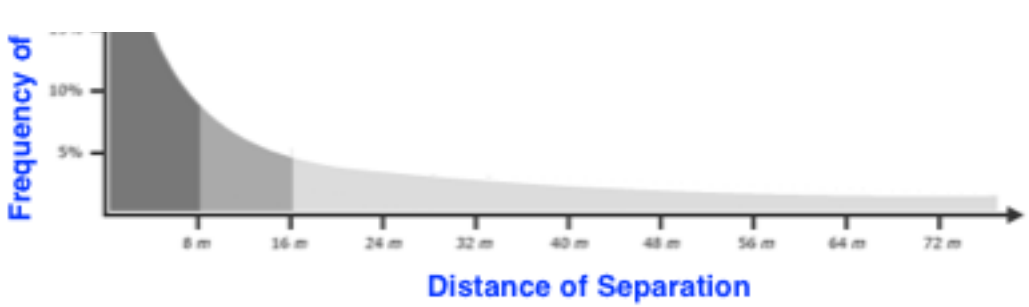
Proximity Increases Communication





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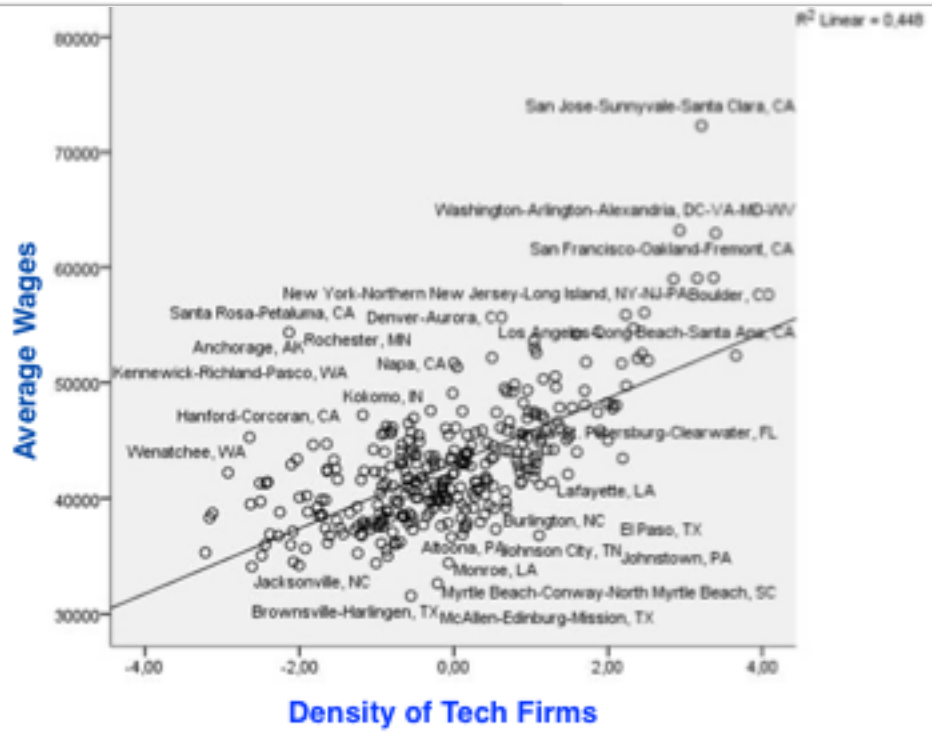
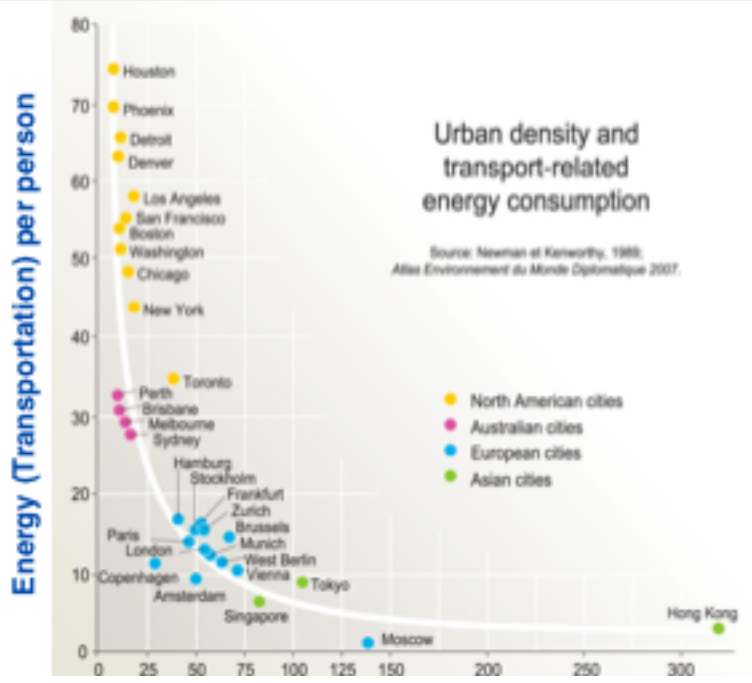
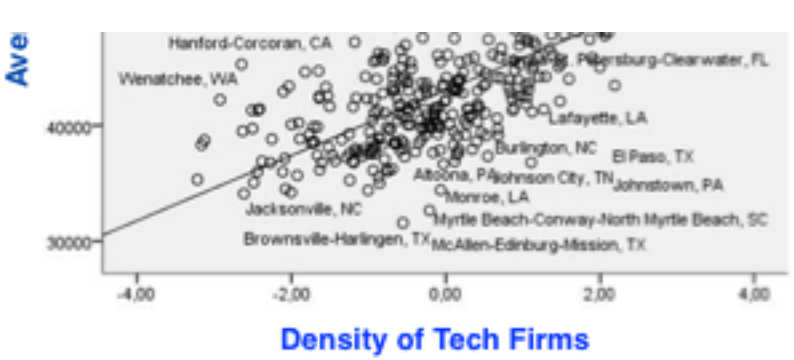


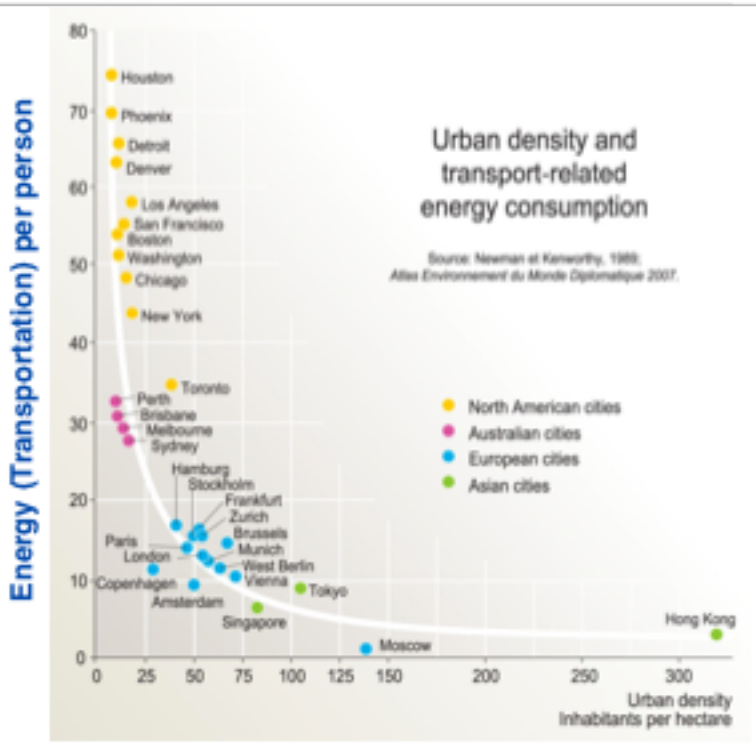
Firm Density Increases Wages





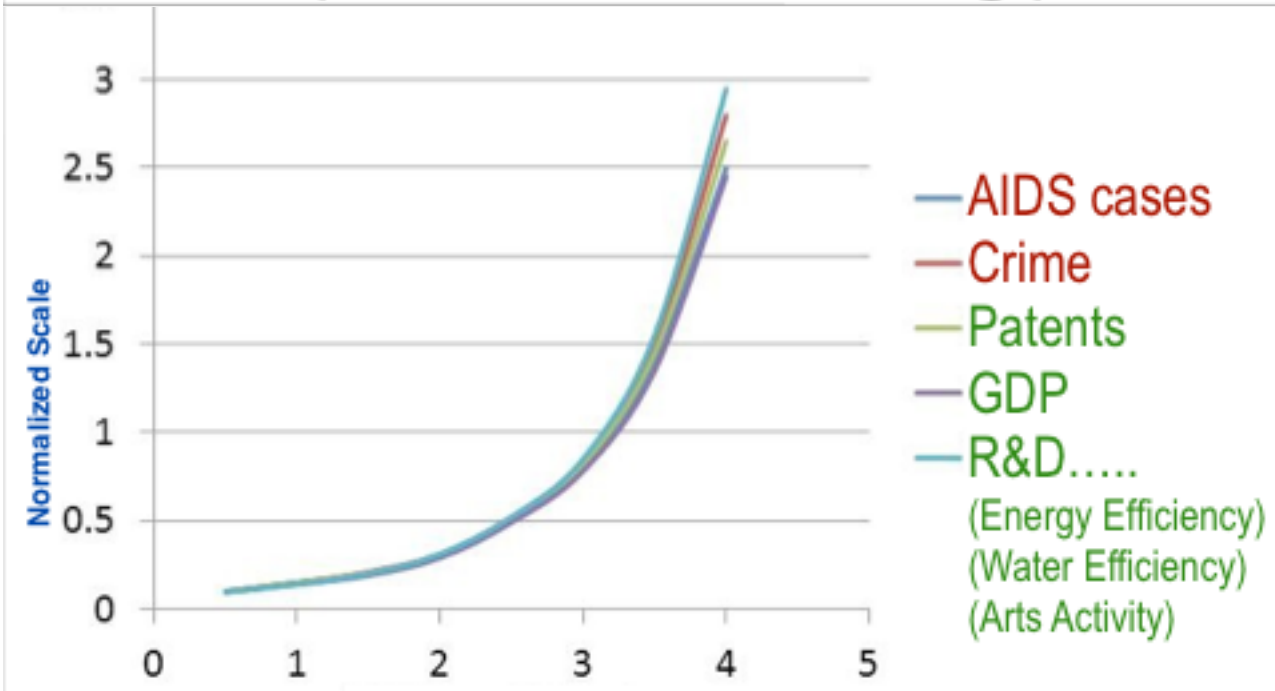
Density of Tech Firms

Firm Density Increases Wages



Population Density

Density Reduces Energy/Person



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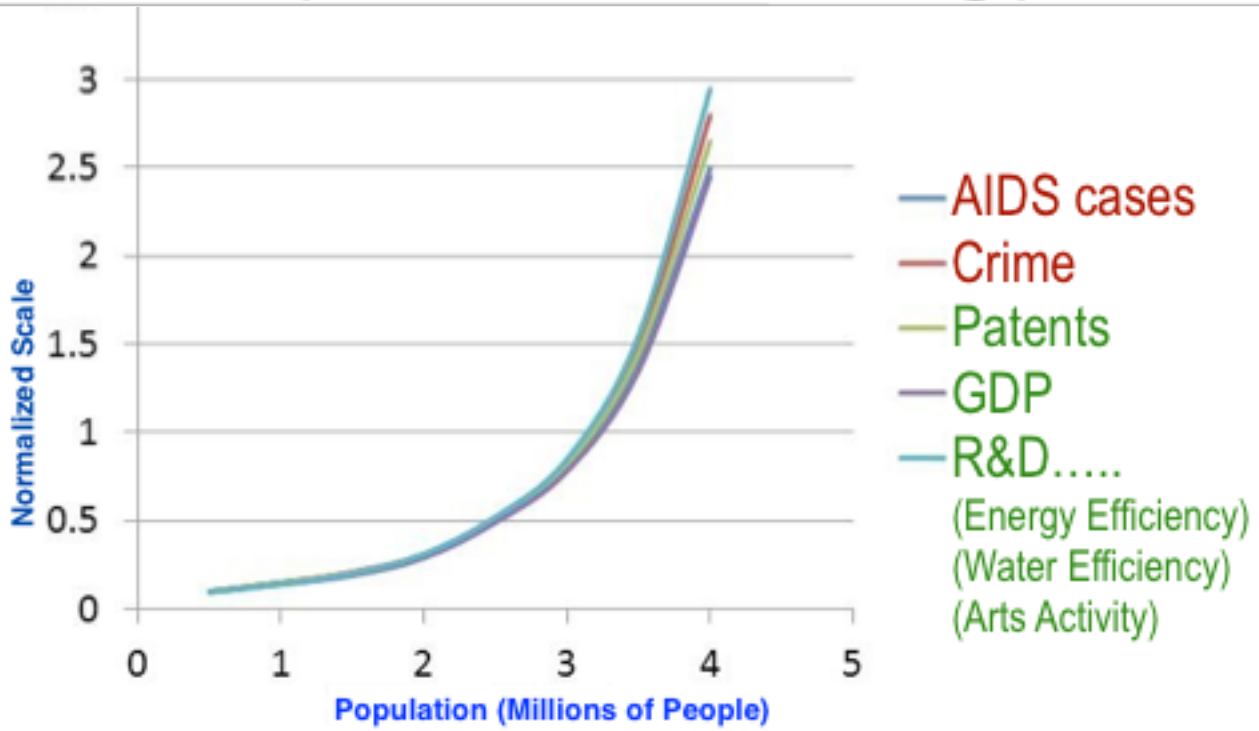
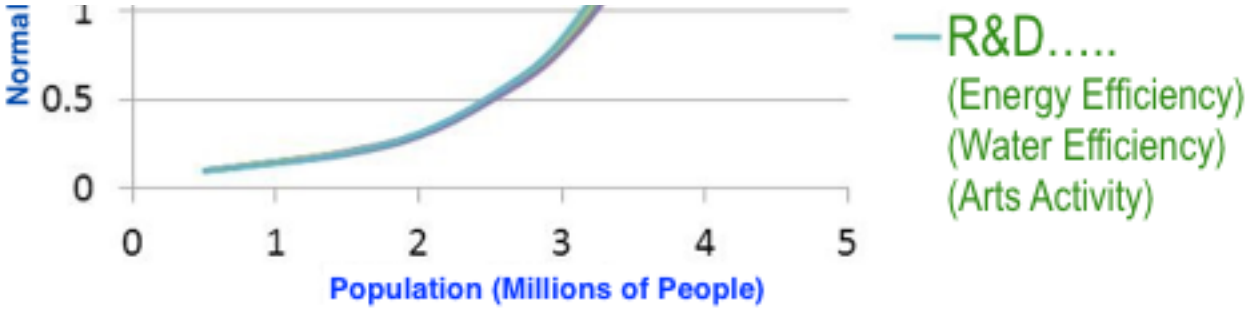


Population Density: Good & Bad

© 2013 Centre for Liveable Cities and Urban Land Institute



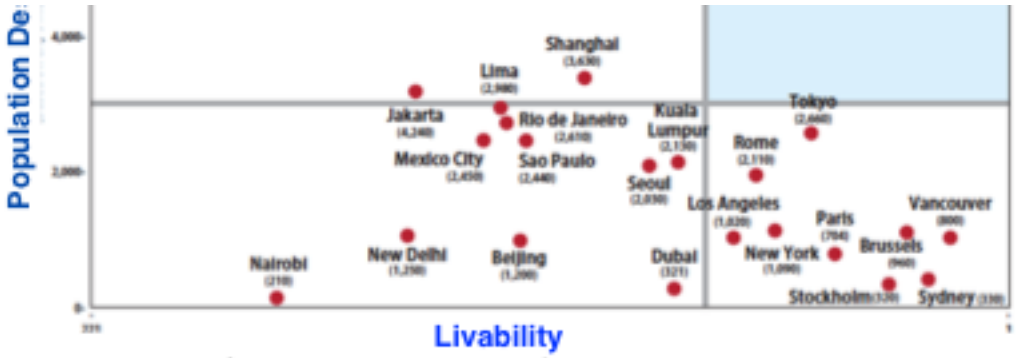
Population Density: Good & Bad

Population Density: Good & Bad Livability

1

Urban Modeling, Simulation, and Decision Support

(Compact, Dense, Diverse, Walkable Districts

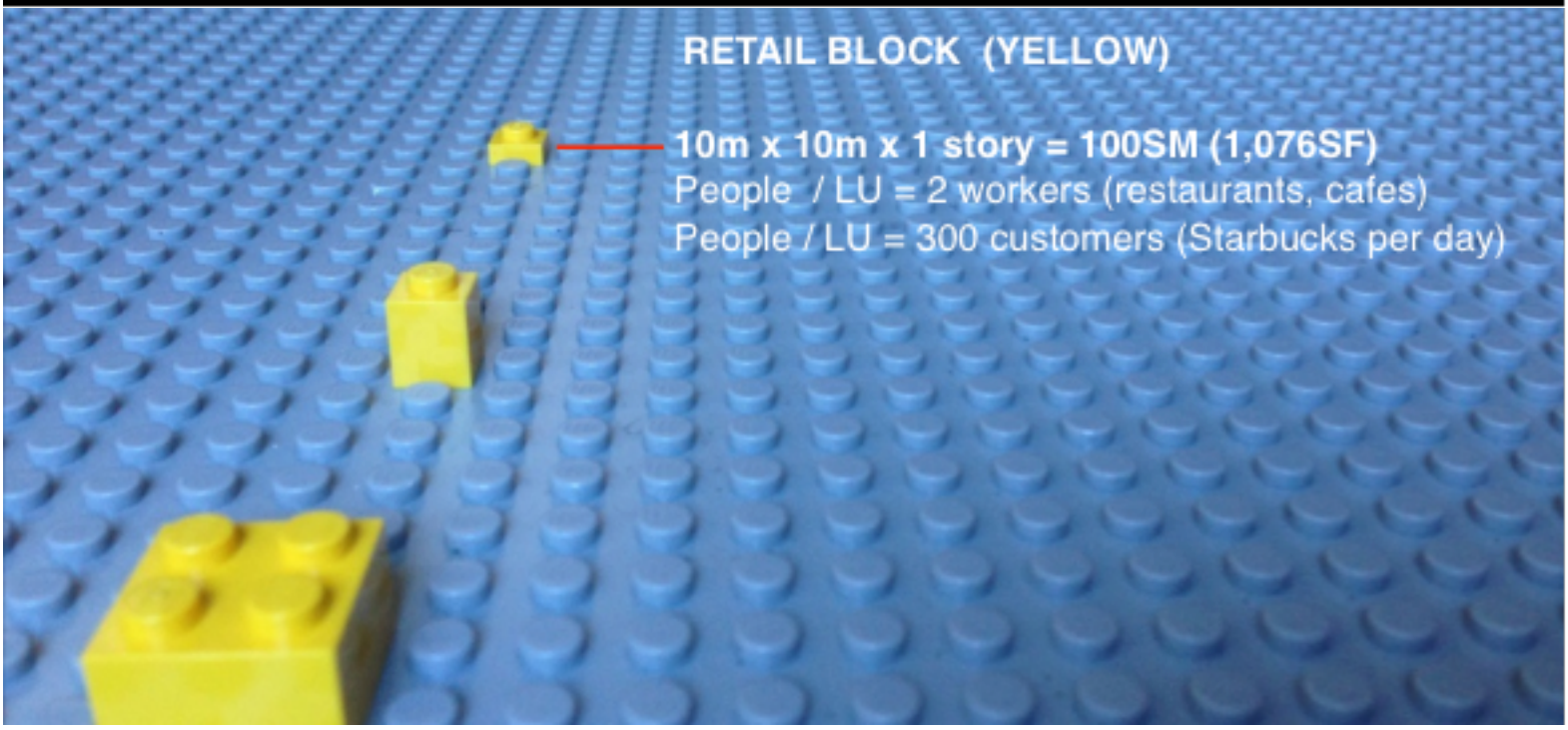


Population Density: Good & Bad Livability

1

Urban Modeling, Simulation, and Decision Support

(Compact, Dense, Diverse, Walkable Districts to promote creative interactions and exchange of ideas)



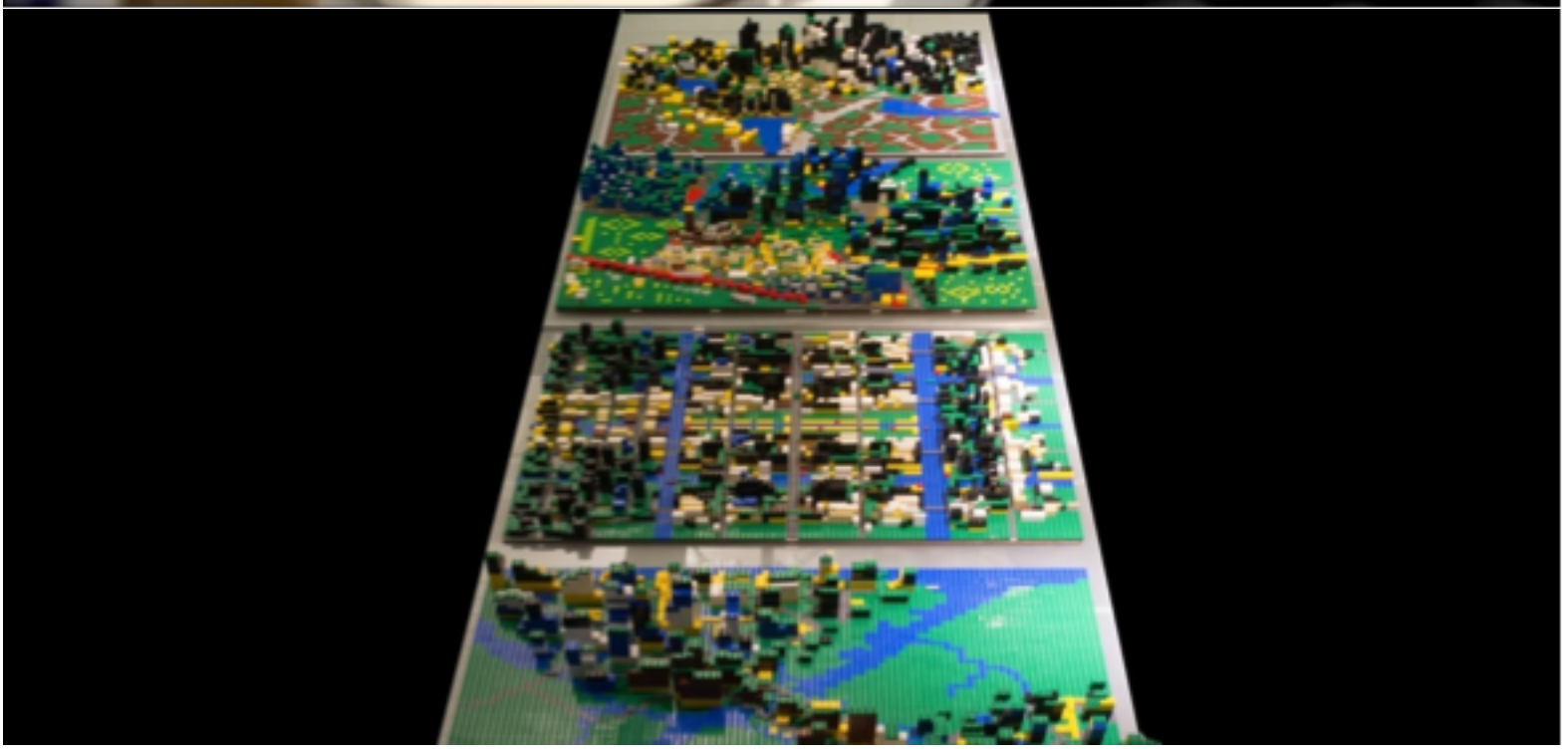
Decision Support

(Compact, Dense, Diverse, Walkable Districts to promote creative interactions and exchange of ideas)

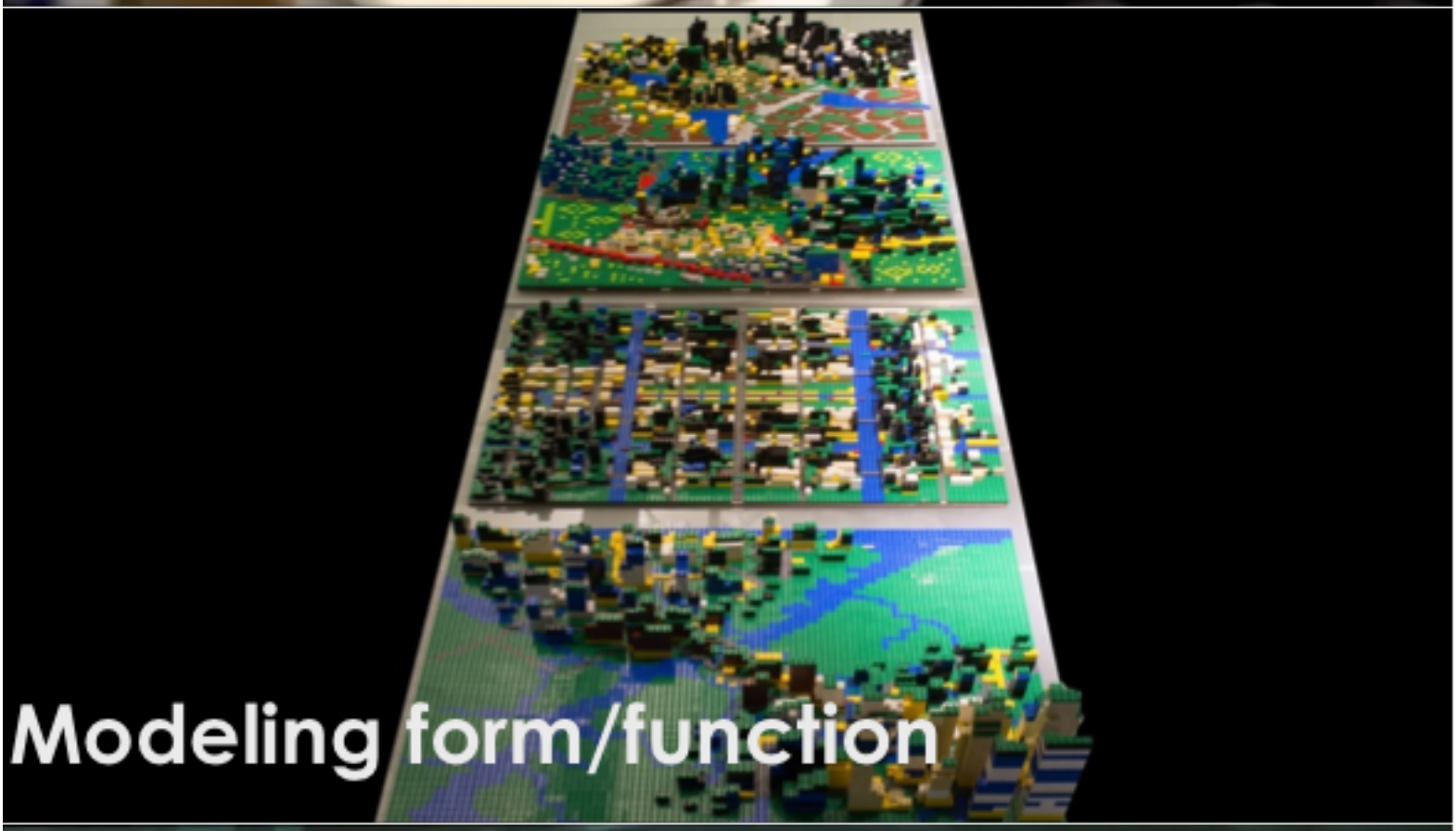
Modeling with Data (LEGO) Units

Modeling form/function

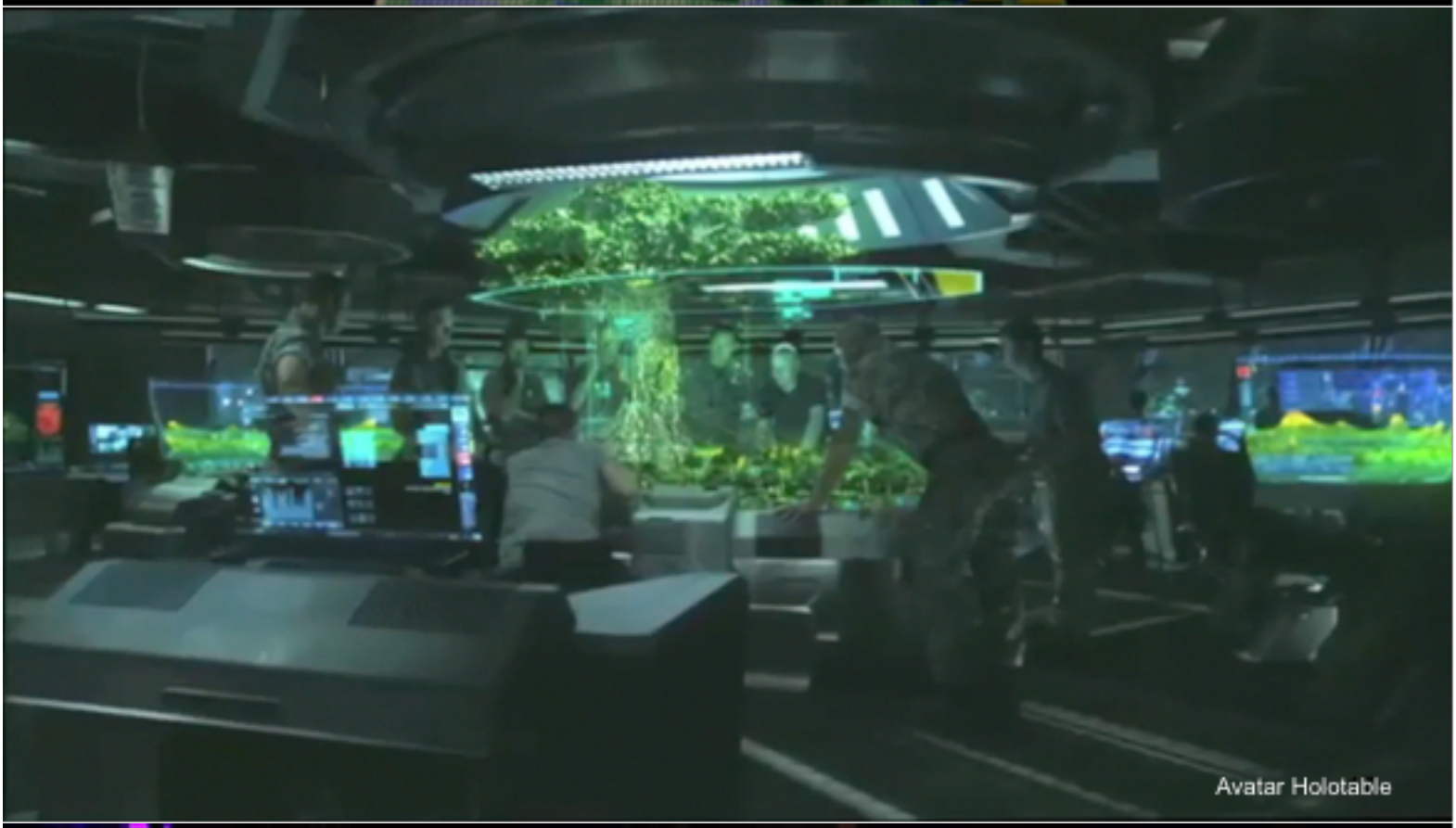
Changing Places Group, MIT Media Lab



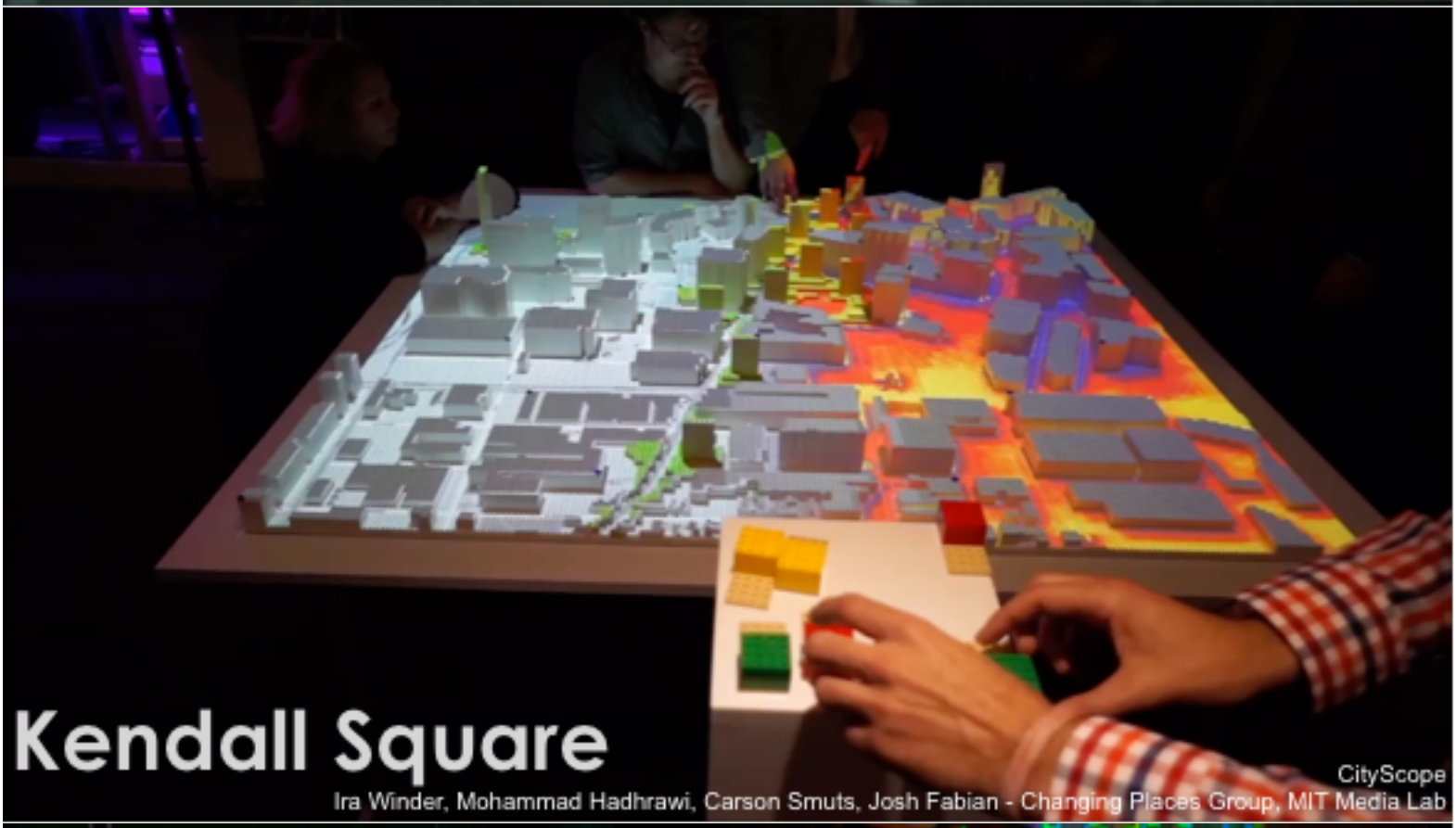
Modeling form/function
Changing Places Group, MIT Media Lab


Modeling form/function

Modeling form/function



Avatar Holotable



Kendall Square

CityScope

Ira Winder, Mohammad Hadhrawi, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab

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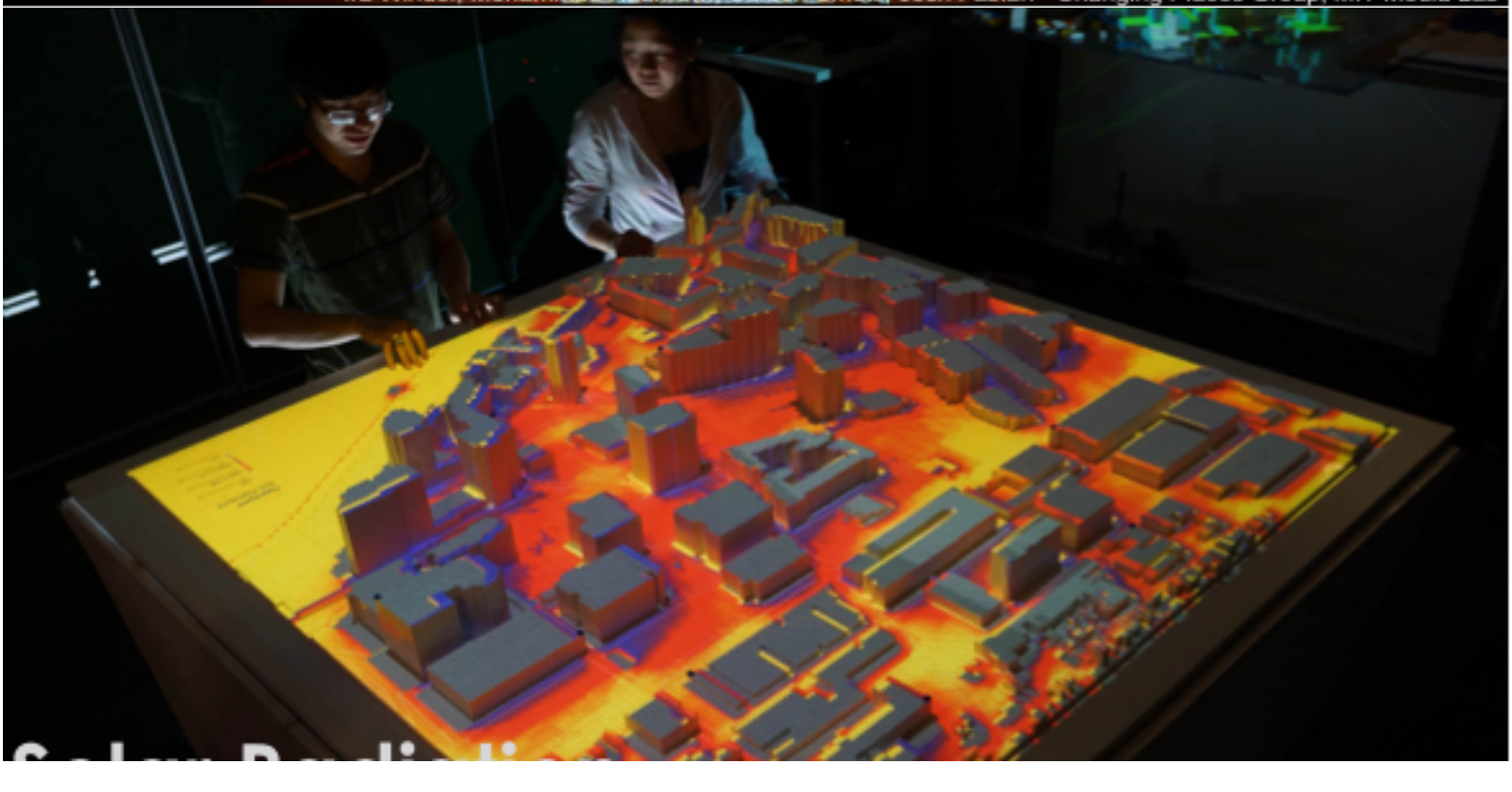

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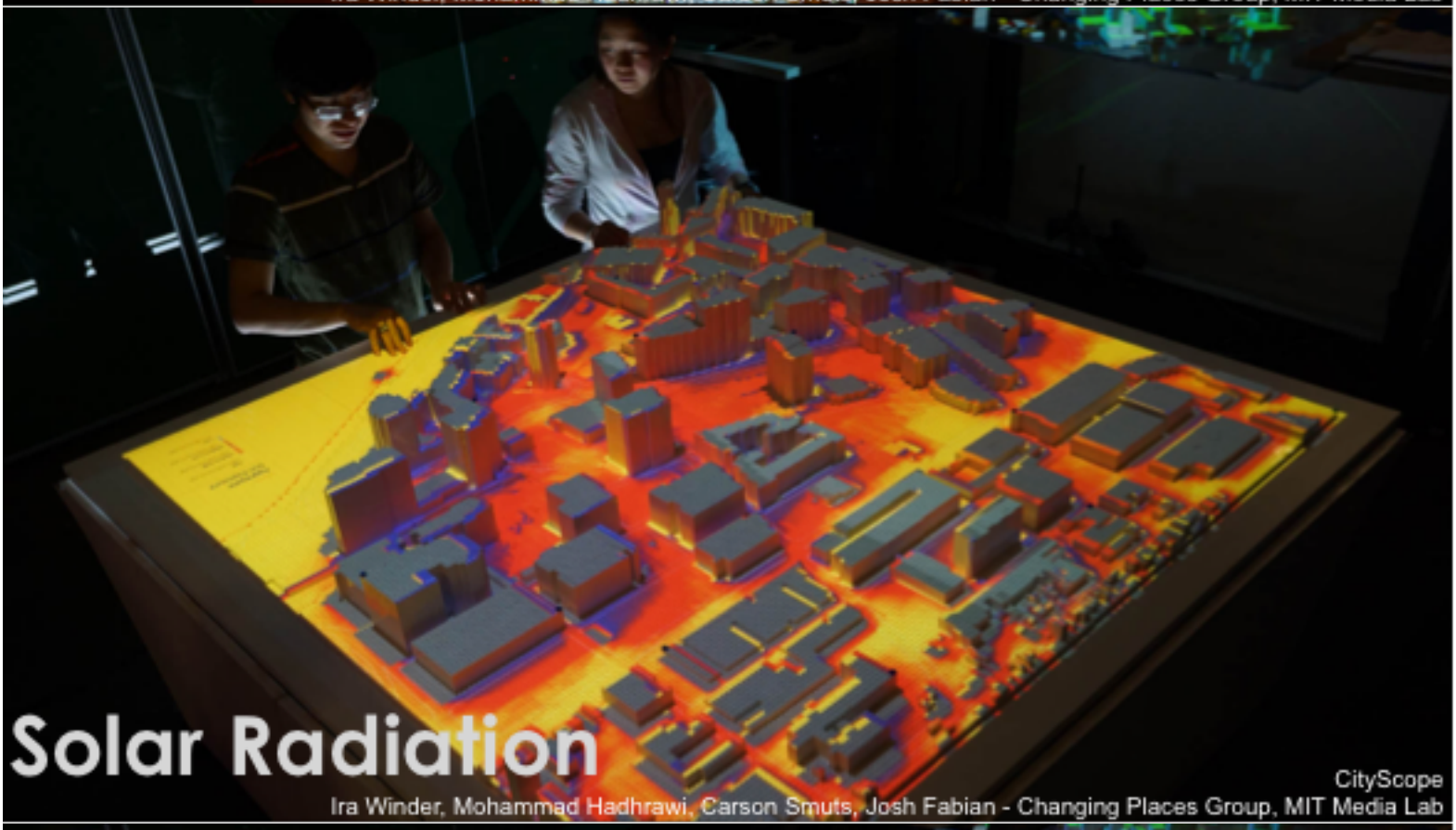

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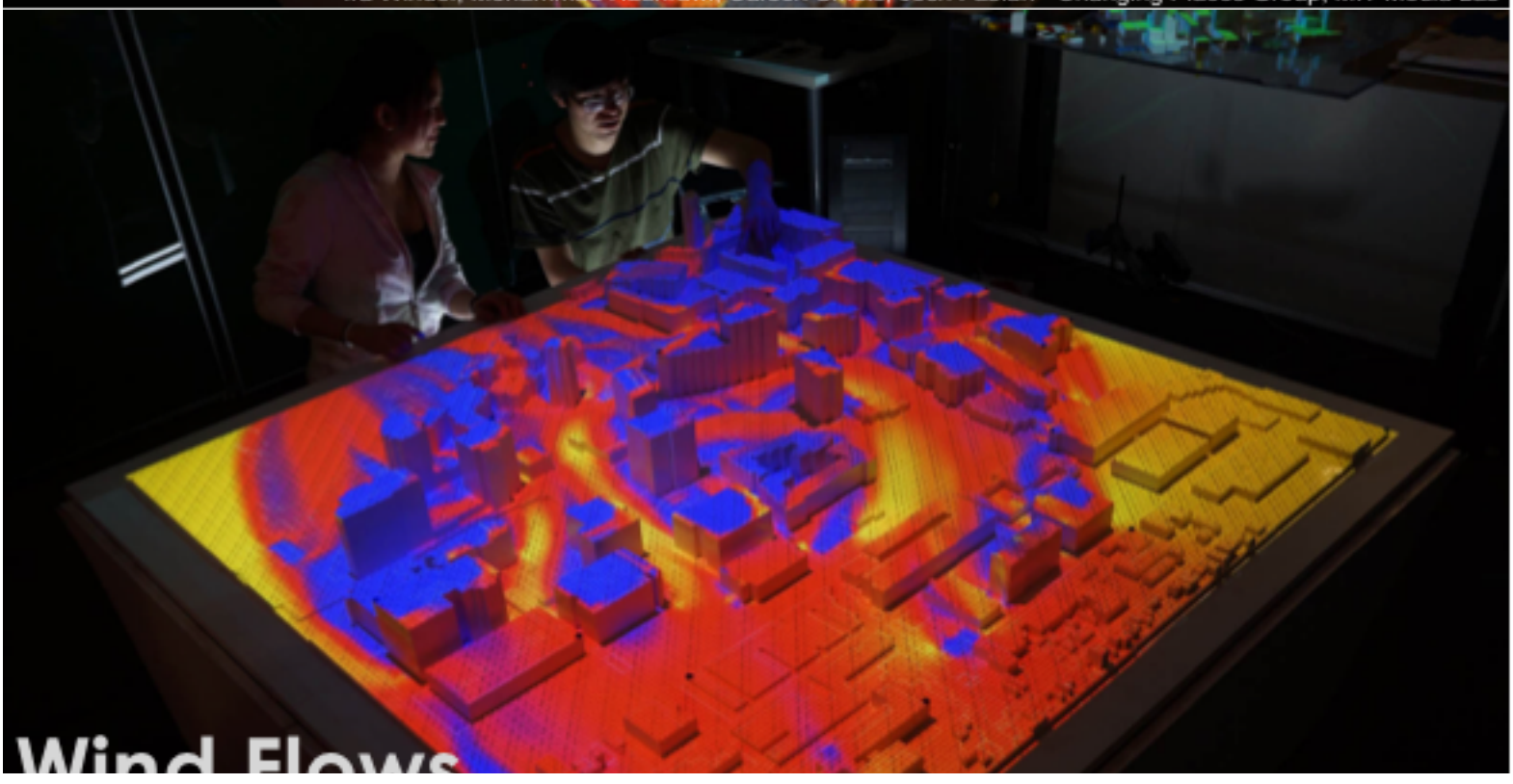

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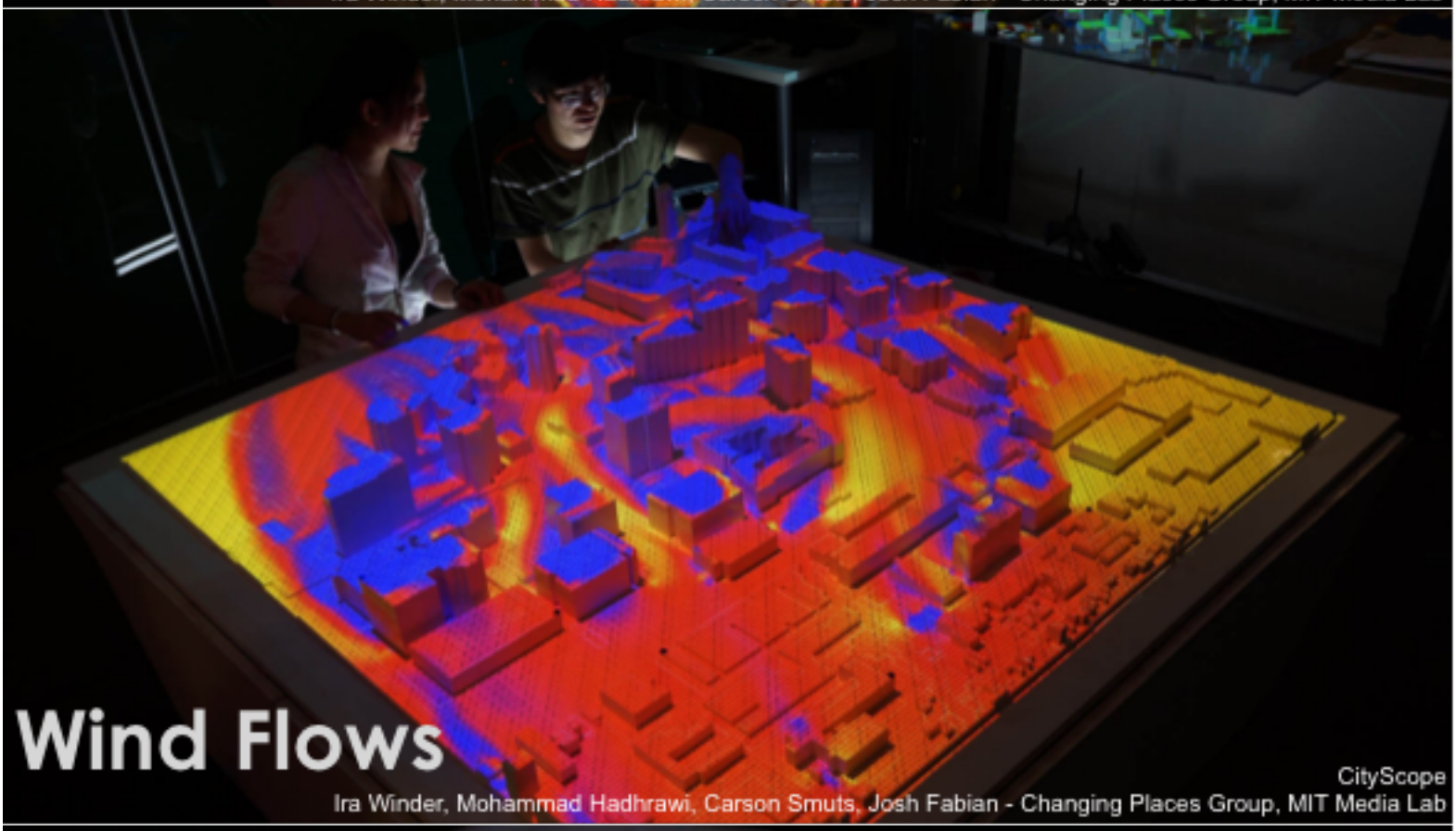

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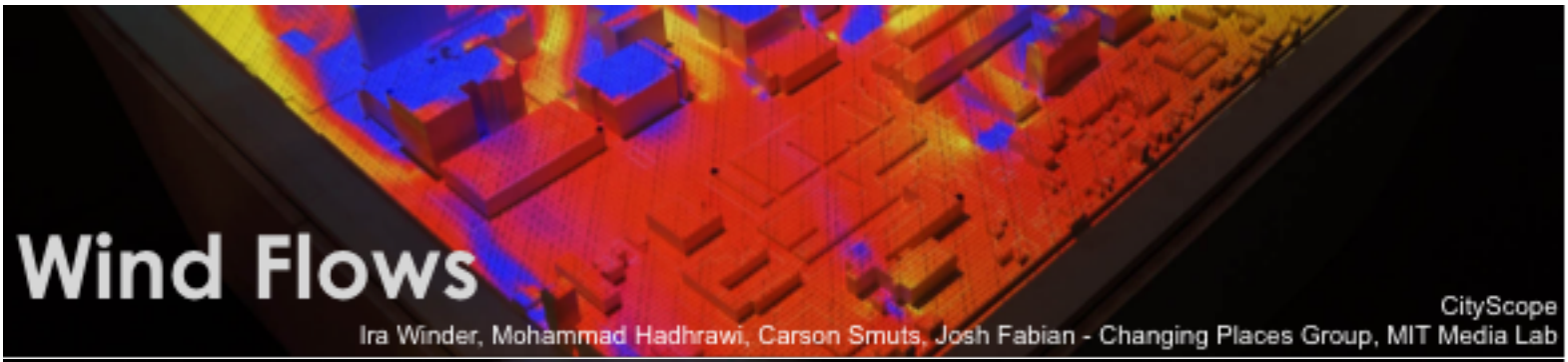

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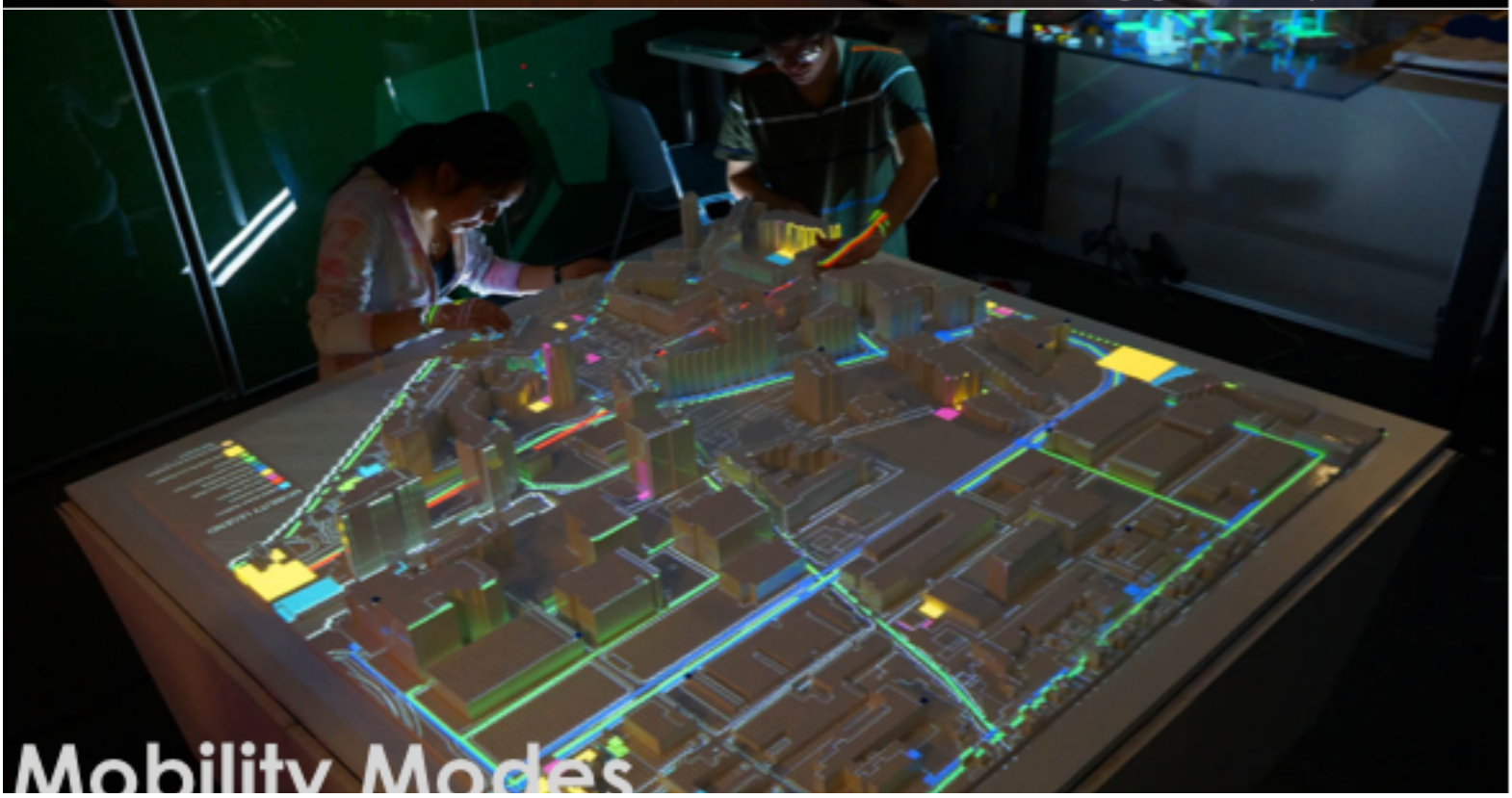

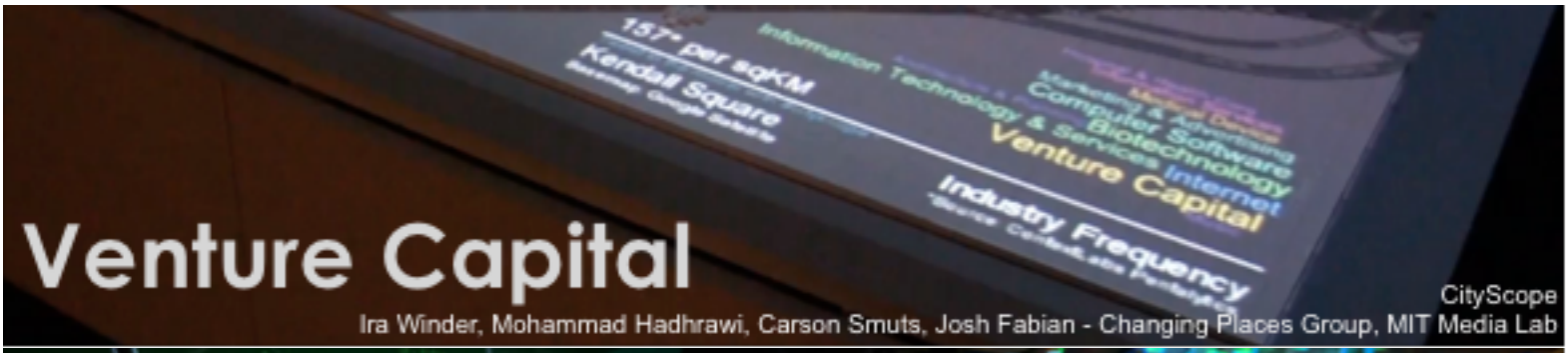

Venture Capital

CityScope
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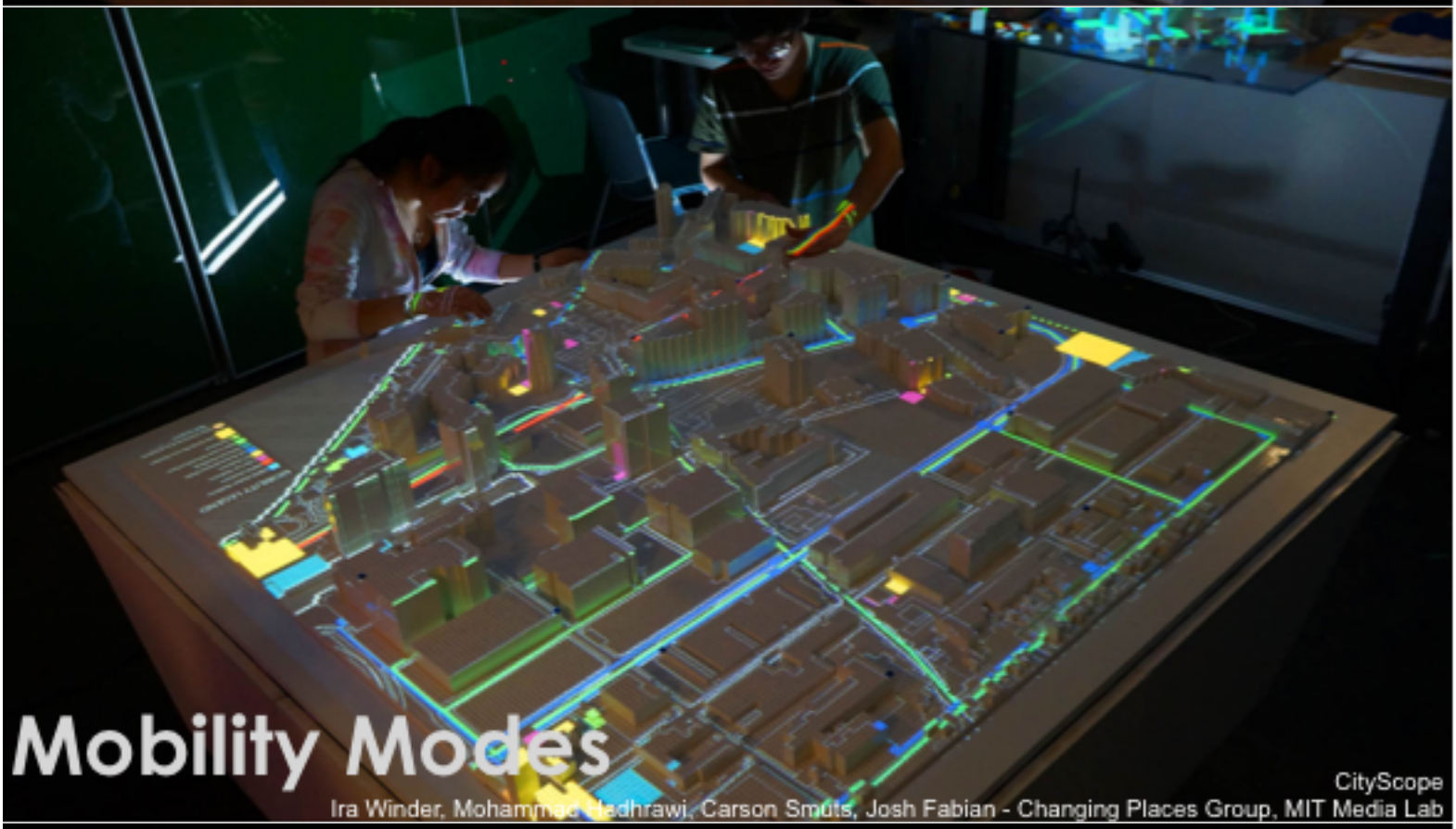

Mobility Modes

CityScope
Ira Winder, Mohammad Hadhrawi, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab

Tweets

CityScope
Ira Winder, Mohammad Hadhrawi, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab

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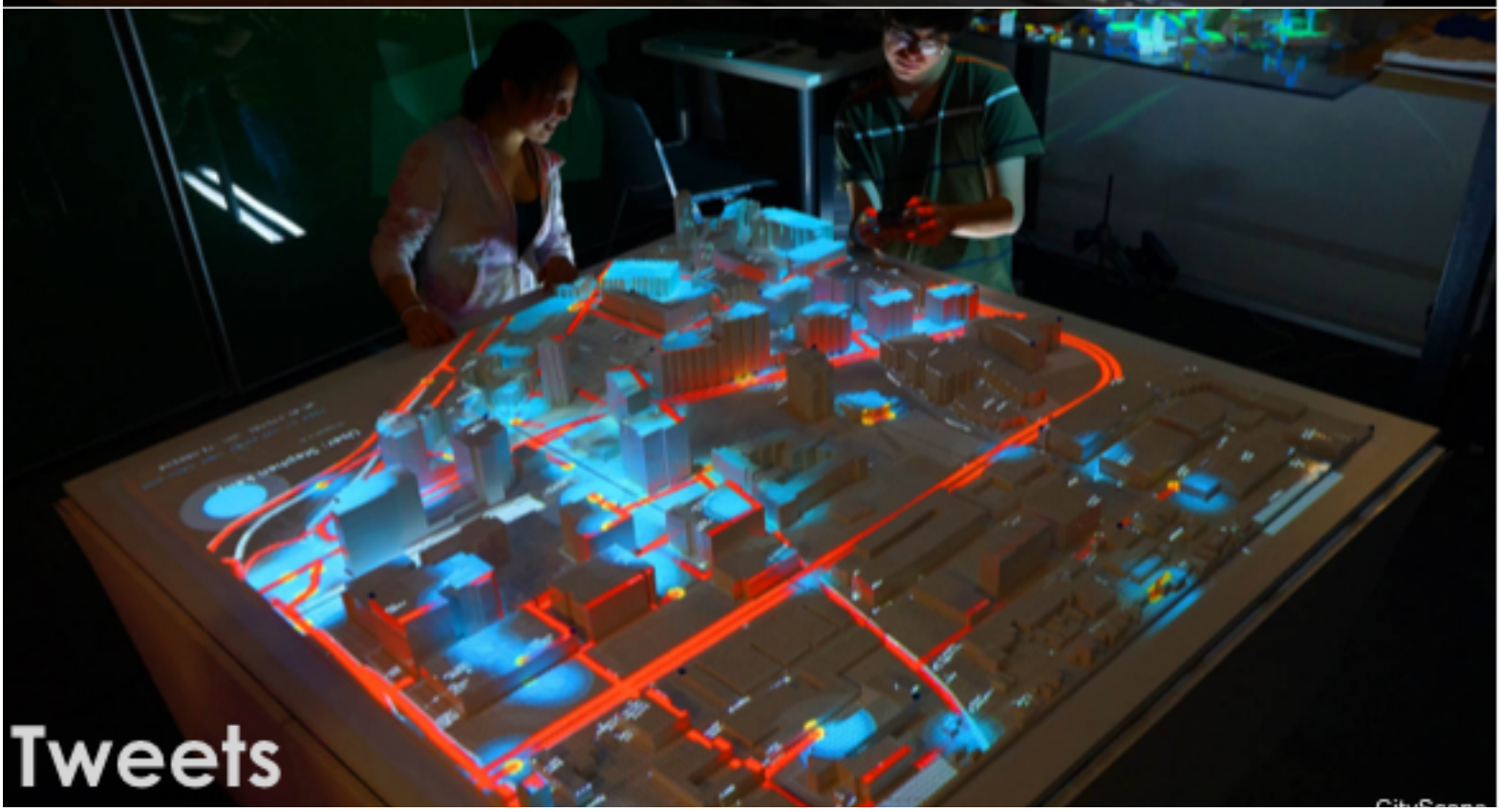

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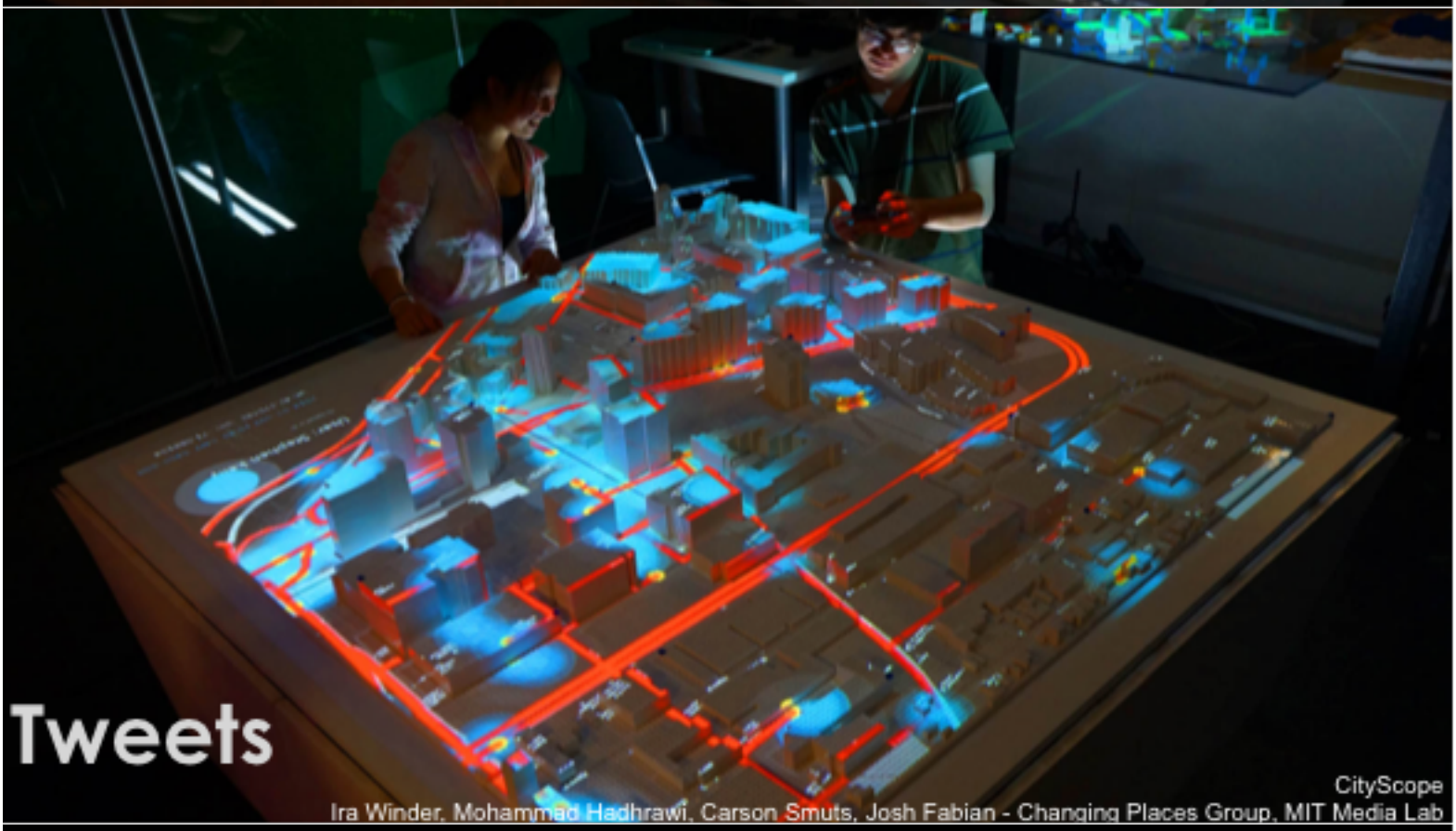

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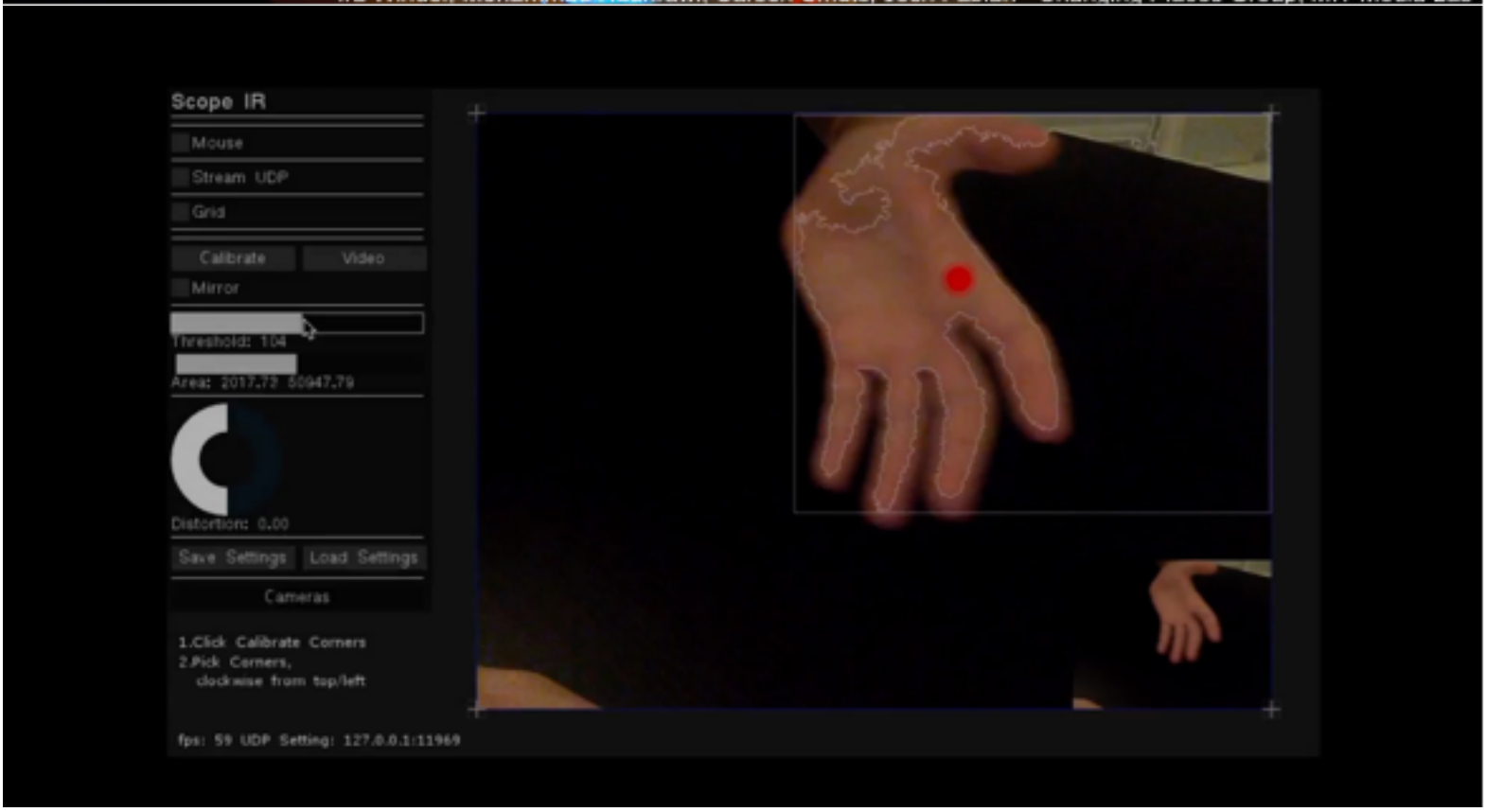

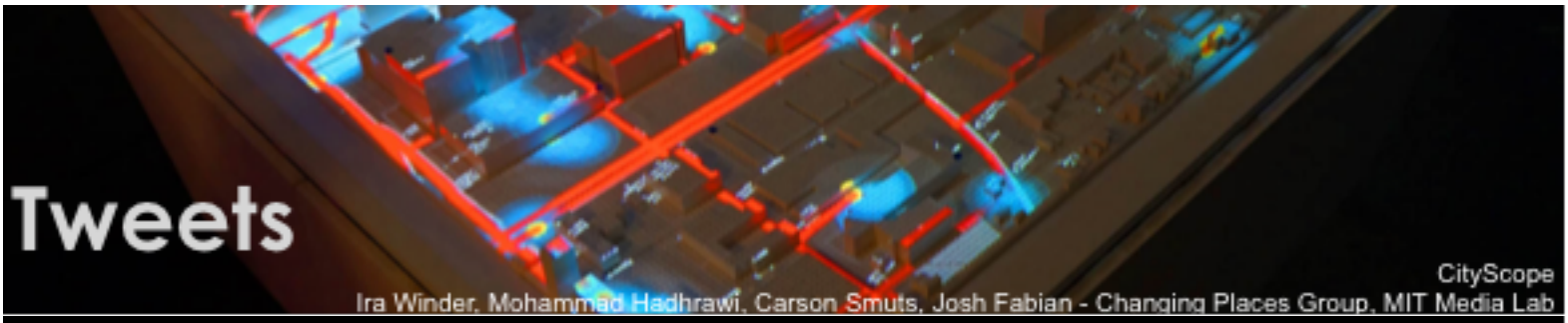
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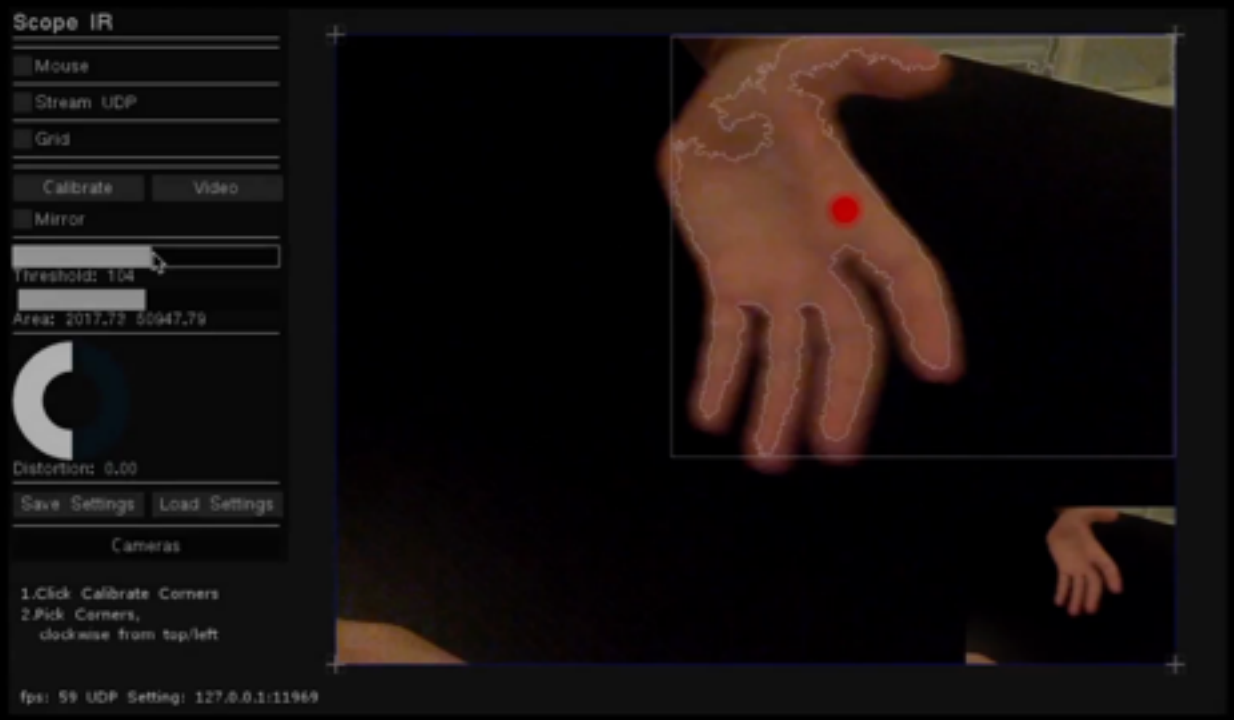
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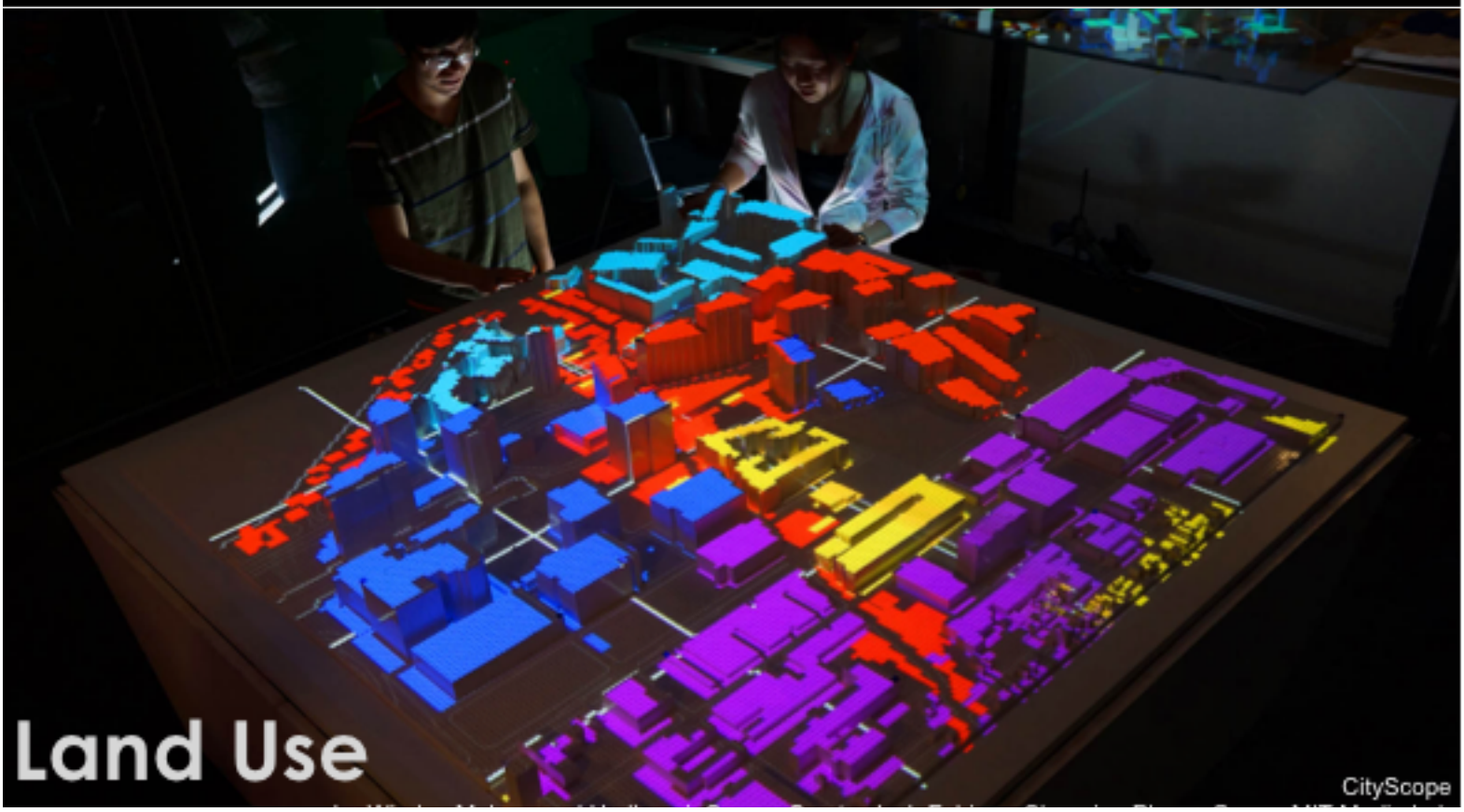
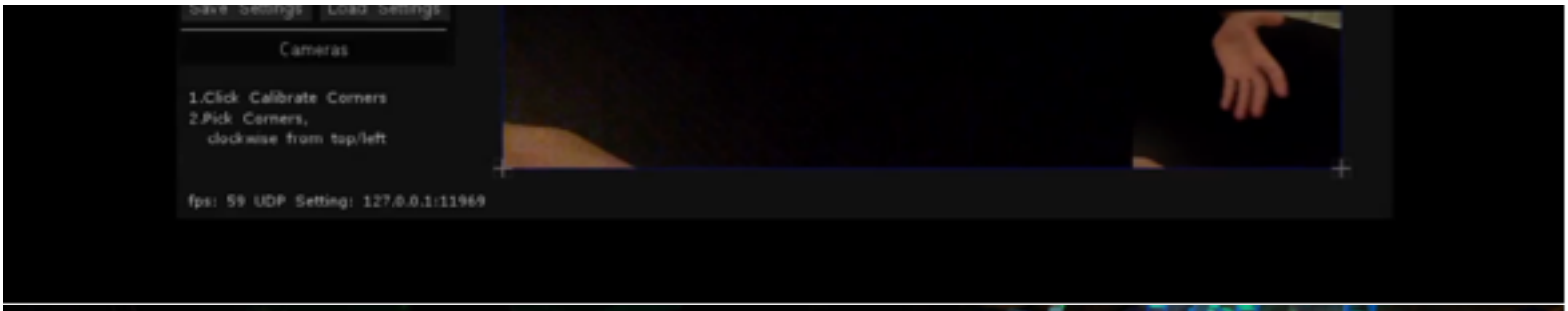
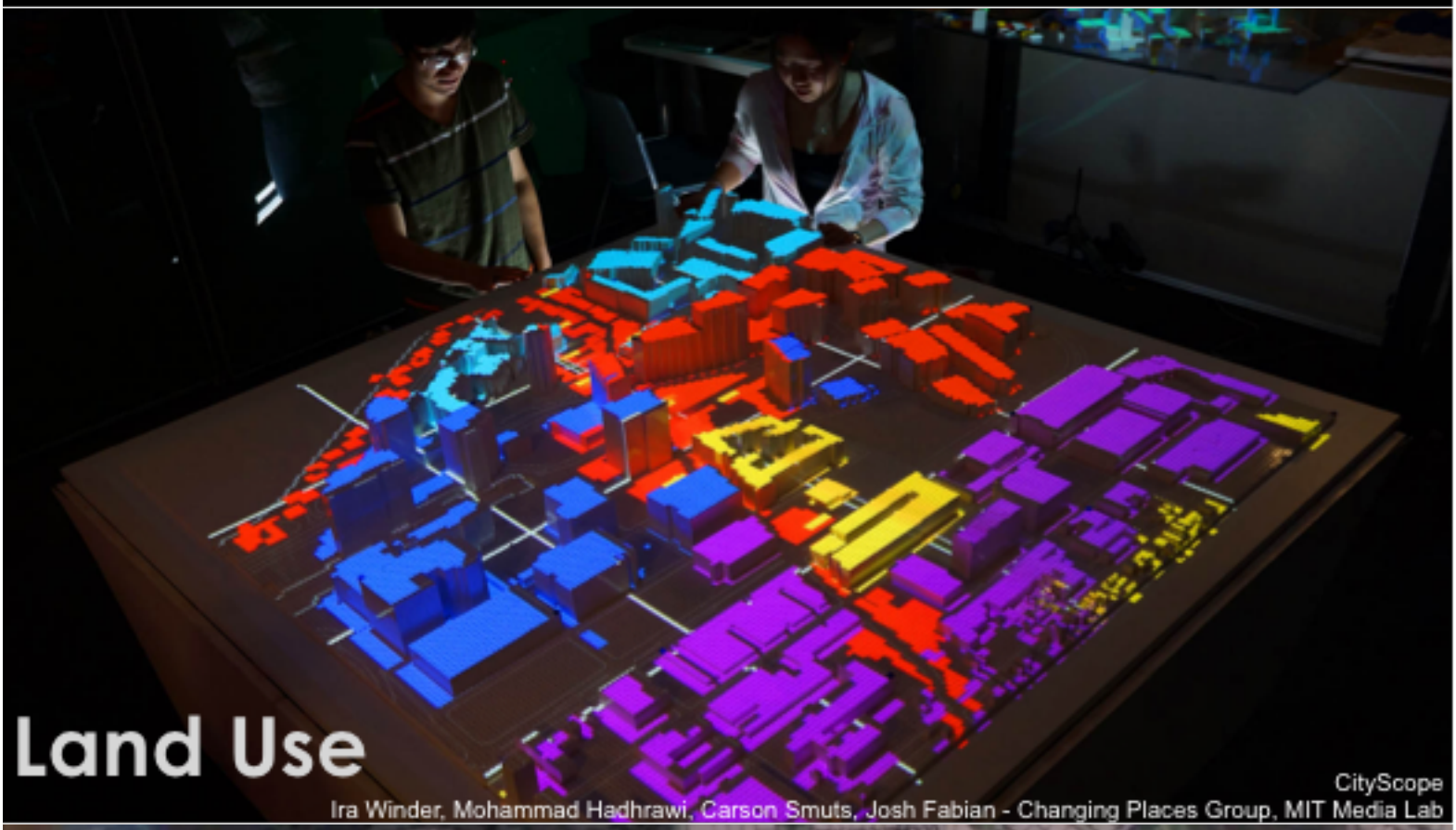
Mouse
Stream UDP
Grid
Calibrate
Video
Mirror
Threshold: 104
Area: 2017.75 50947.79
Distortion: 0.00
Save Settings
Load Settings
Cameras
1.Click Calibrate Corners
2.Pick Corners,
clockwise from top/left
fps: 59 UDP Setting: 127.0.0.1:11969


Land Use
CityScope





CityScope
Ira Winder, Mohammad Hadhrawi, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab

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CityScope, New City, Brisbane Urban Design Use Case

CityScope
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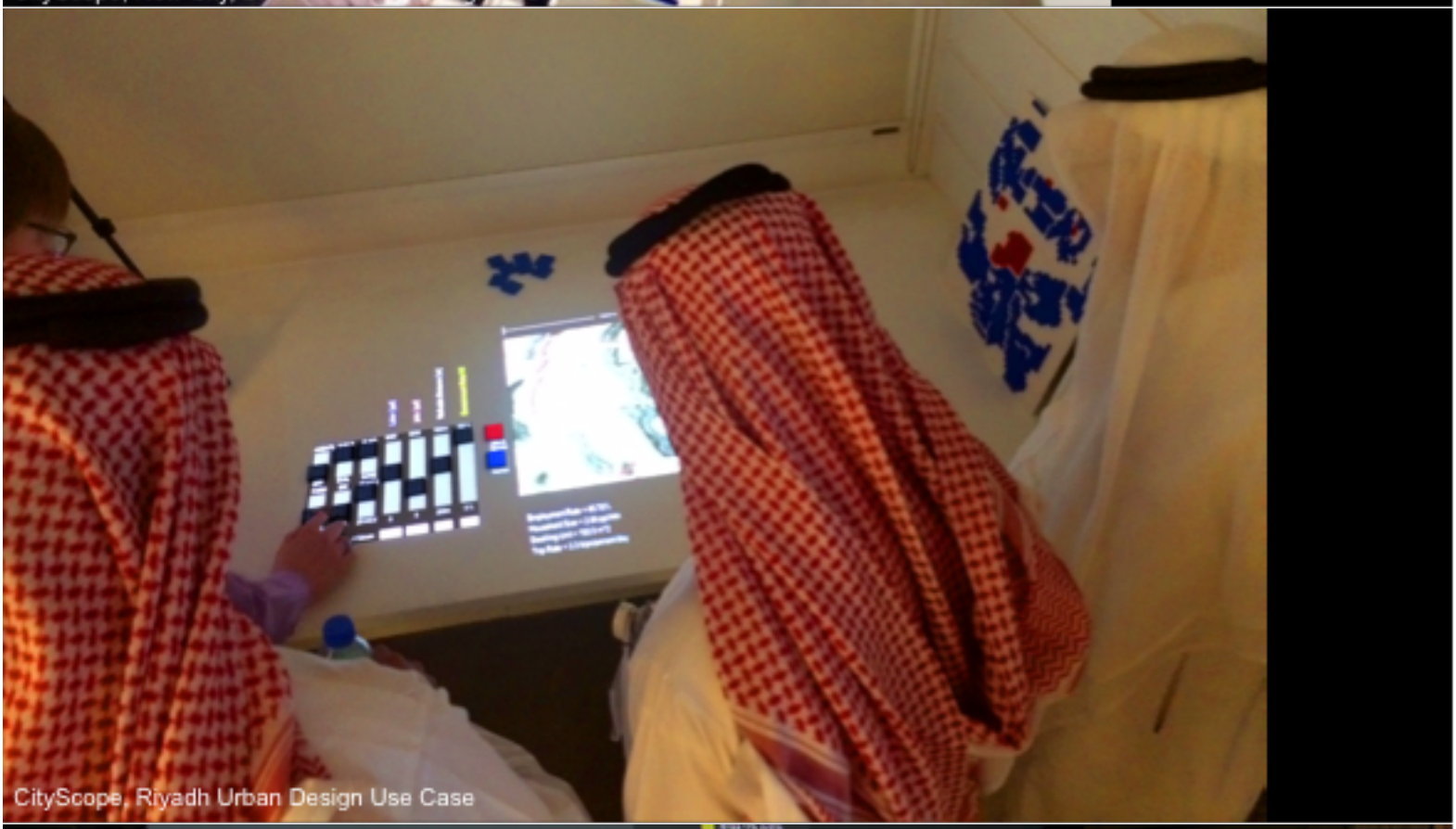
CityScope, New City, Brisbane Urban Design Use Case

CityScope, Riyadh Urban Design Use Case

CityScope, New City, Brisbane Urban Design Use Case

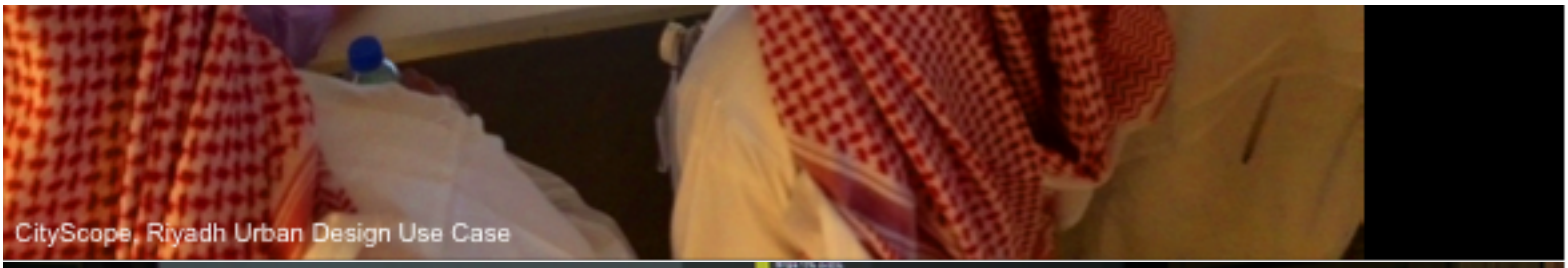


CityScope, Riyadh Urban Design Use Case

3D Planning and Land Use

CityScope

Ira Winder, Mohammad Hadhrawi, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab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3D Planning and Land Use
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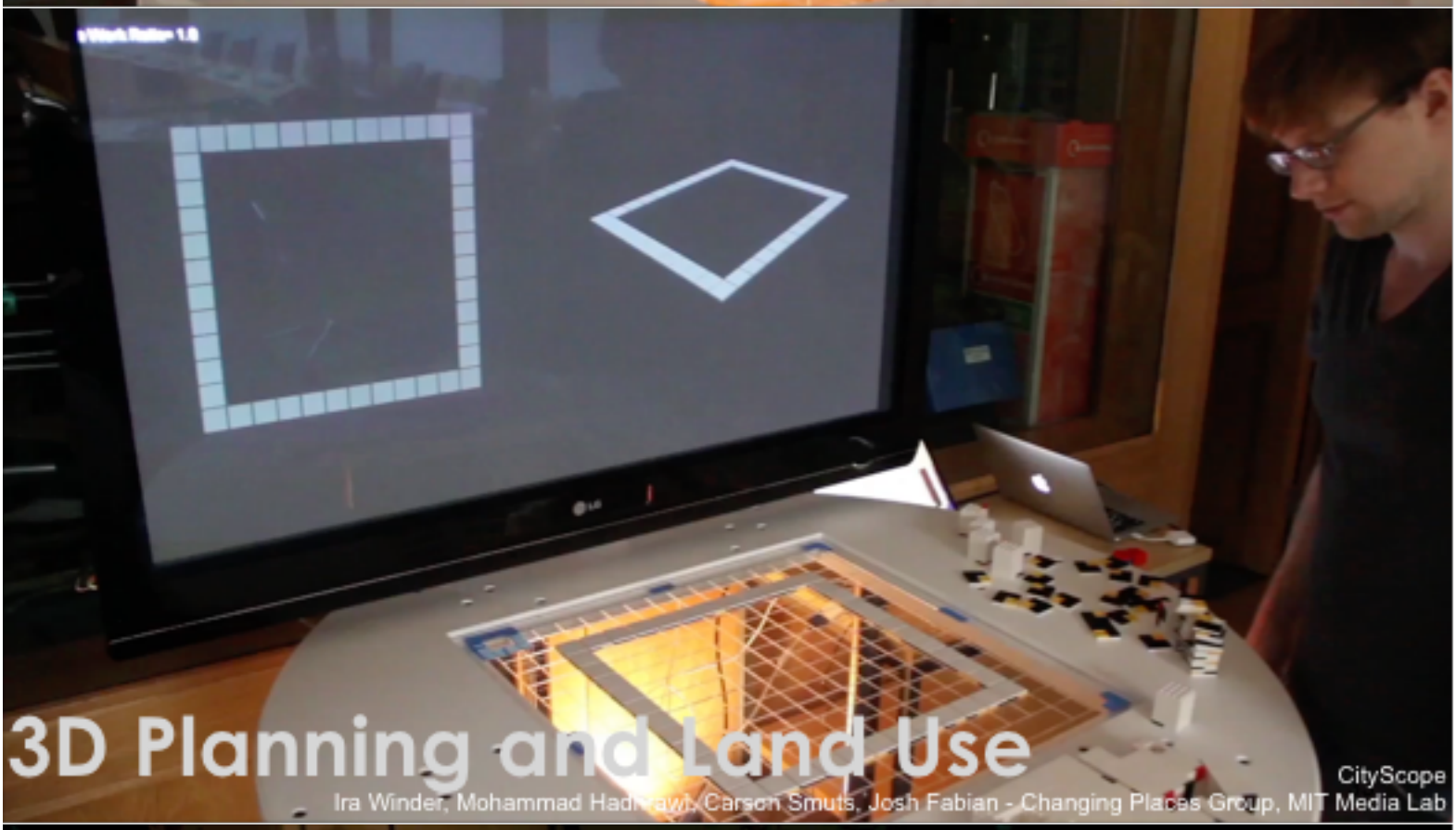
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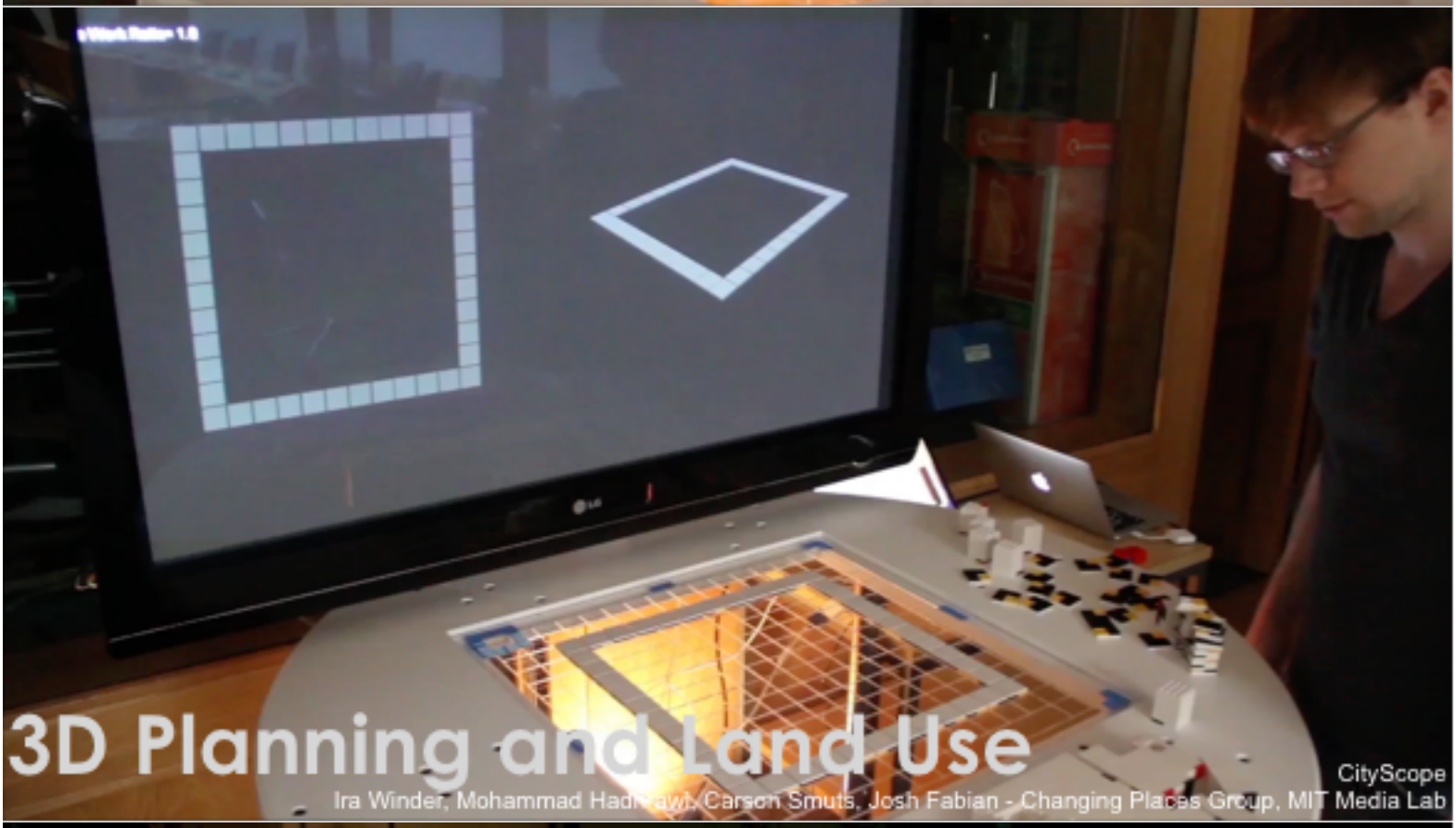

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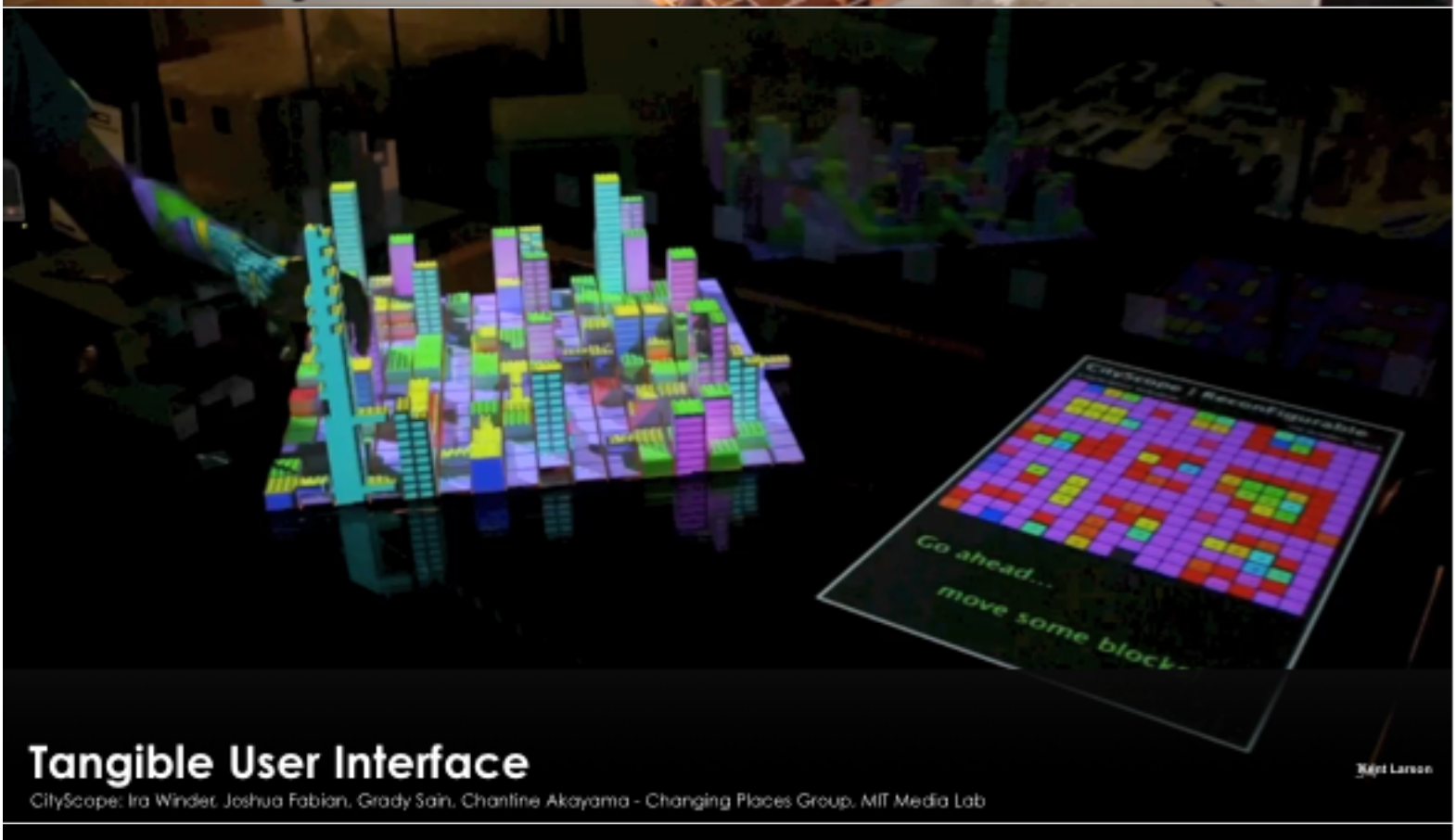


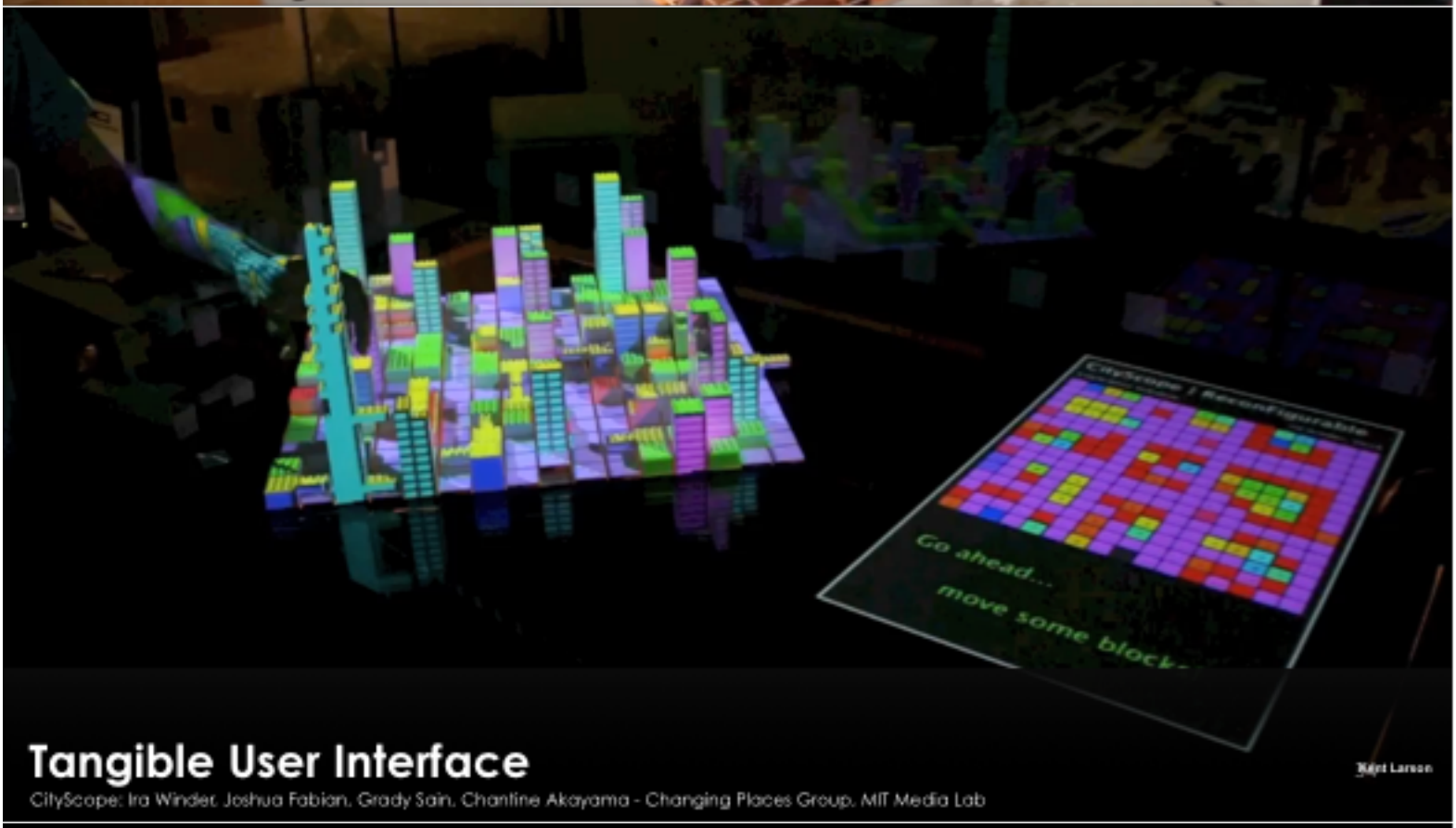
Tangible User Interface

CityScope: Ira Winder, Joshua Fabian, Grady Sain, Chantine Akayama - Changing Places Group, MIT Media Lab

3D Planning and Land Use

CityScope

Ira Winder, Mohammad Hadi Rayis, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab



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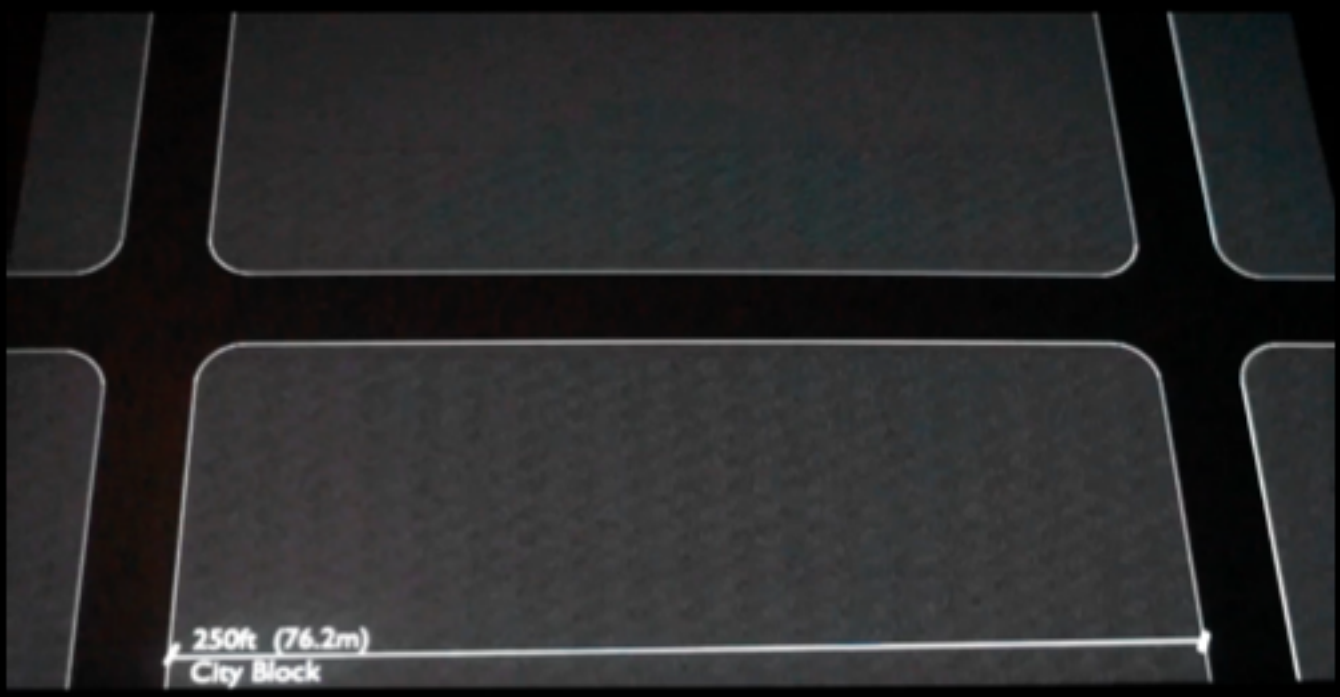
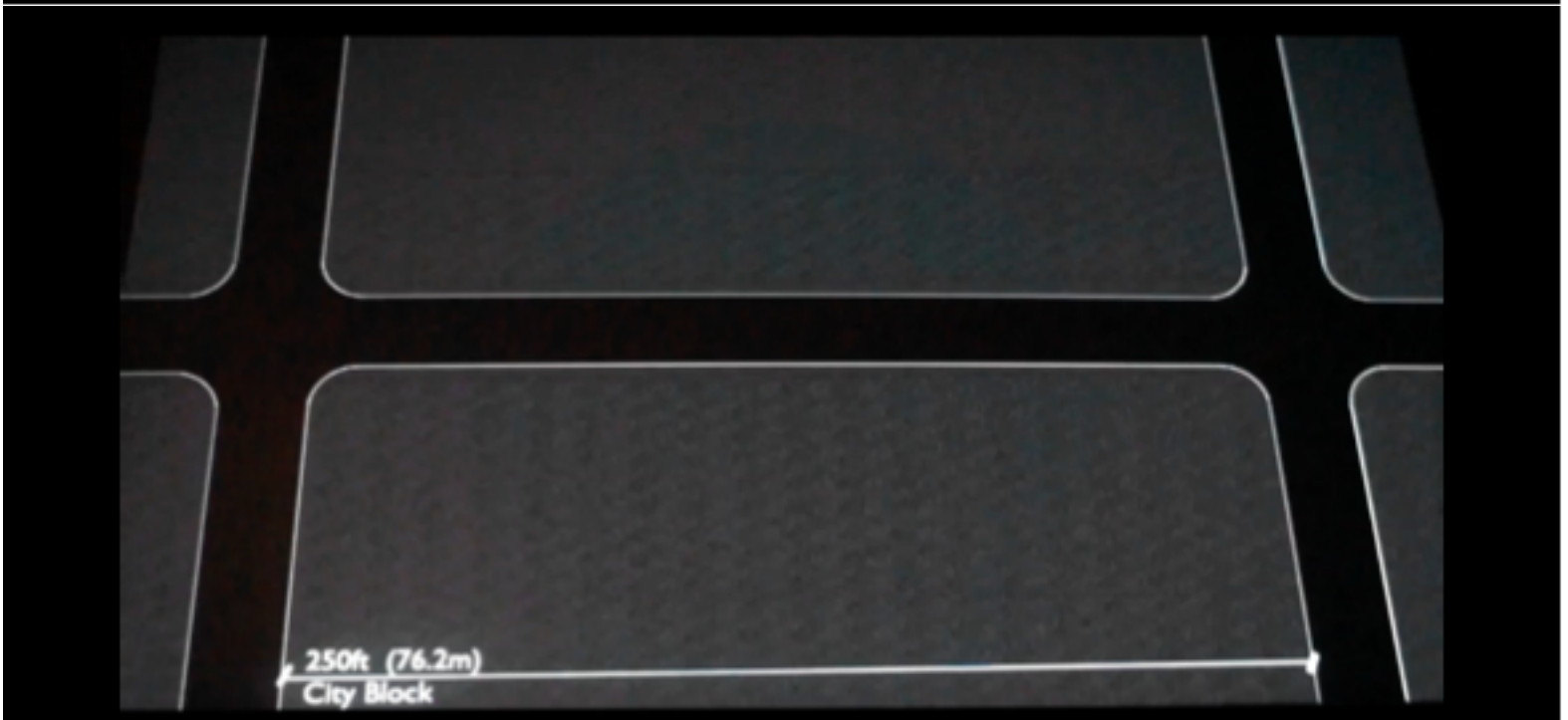


Modeling Human Interactions

CityScope

Carson Smuts - Changing Places Group, MIT Media Lab



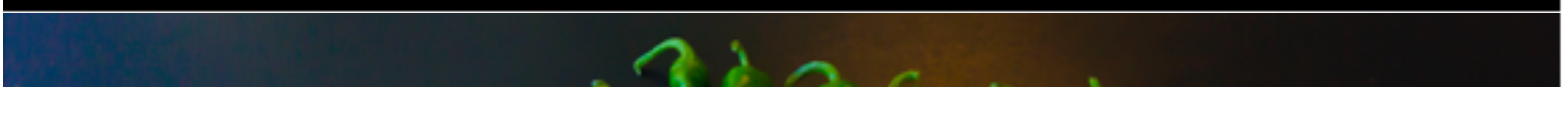
Modeling Human Interactions

CityScope
Carson Smuts - Changing Places Group, MIT Media Lab

2

Food for Cities

(addressing nutrition and the challenges of water and energy scarcity with facade-integrated aeroponics)



Modeling Human Interactions

CityScope
Carson Smuts - Changing Places Group, MIT Media Lab

2

Food for Cities

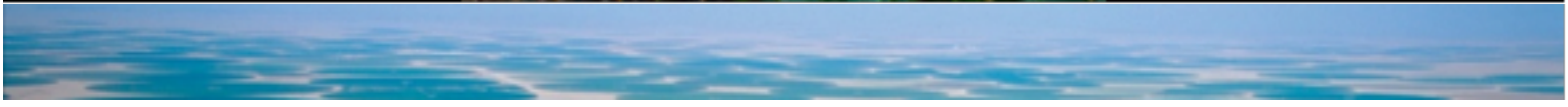
(addressing nutrition and the challenges of water and energy scarcity with facade-integrated aeroponics)

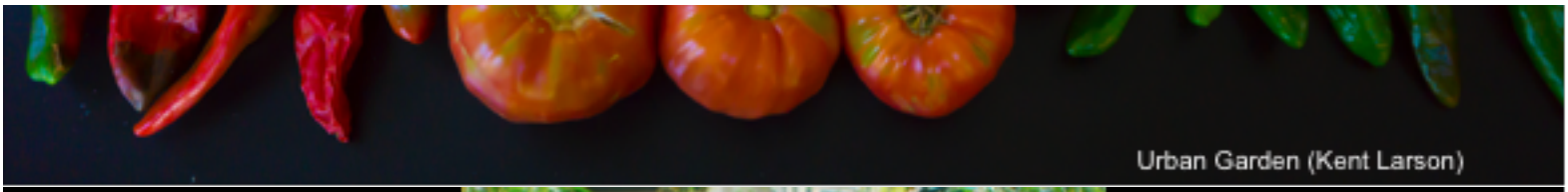
Urban Garden (Kent Larson)

integrated aeroponics)

Urban Garden (Kent Larson)

Urban Garden (Kent Larson)

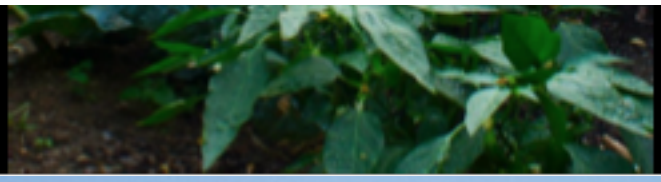




Urban Garden (Kent Larson)

Urban Garden (Kent Larson)

The countries of origin for the food



Urban Garden (Kent Larson)

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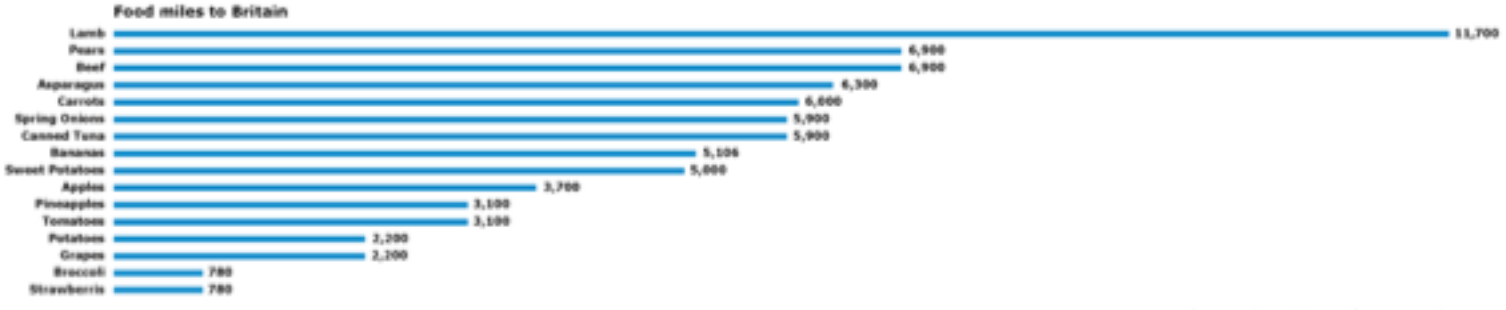
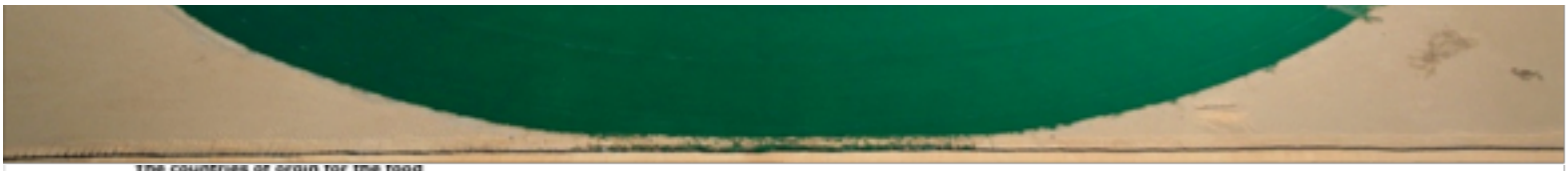
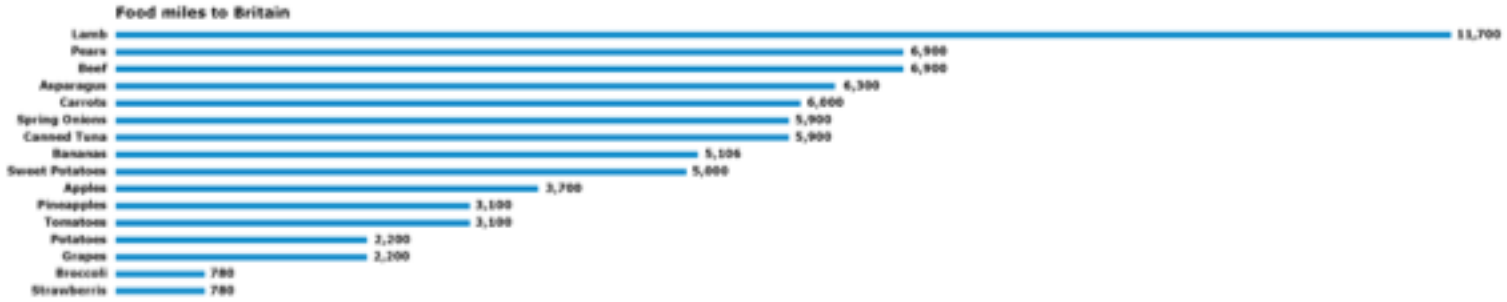


Source: http://surreyfarmersmarket.com





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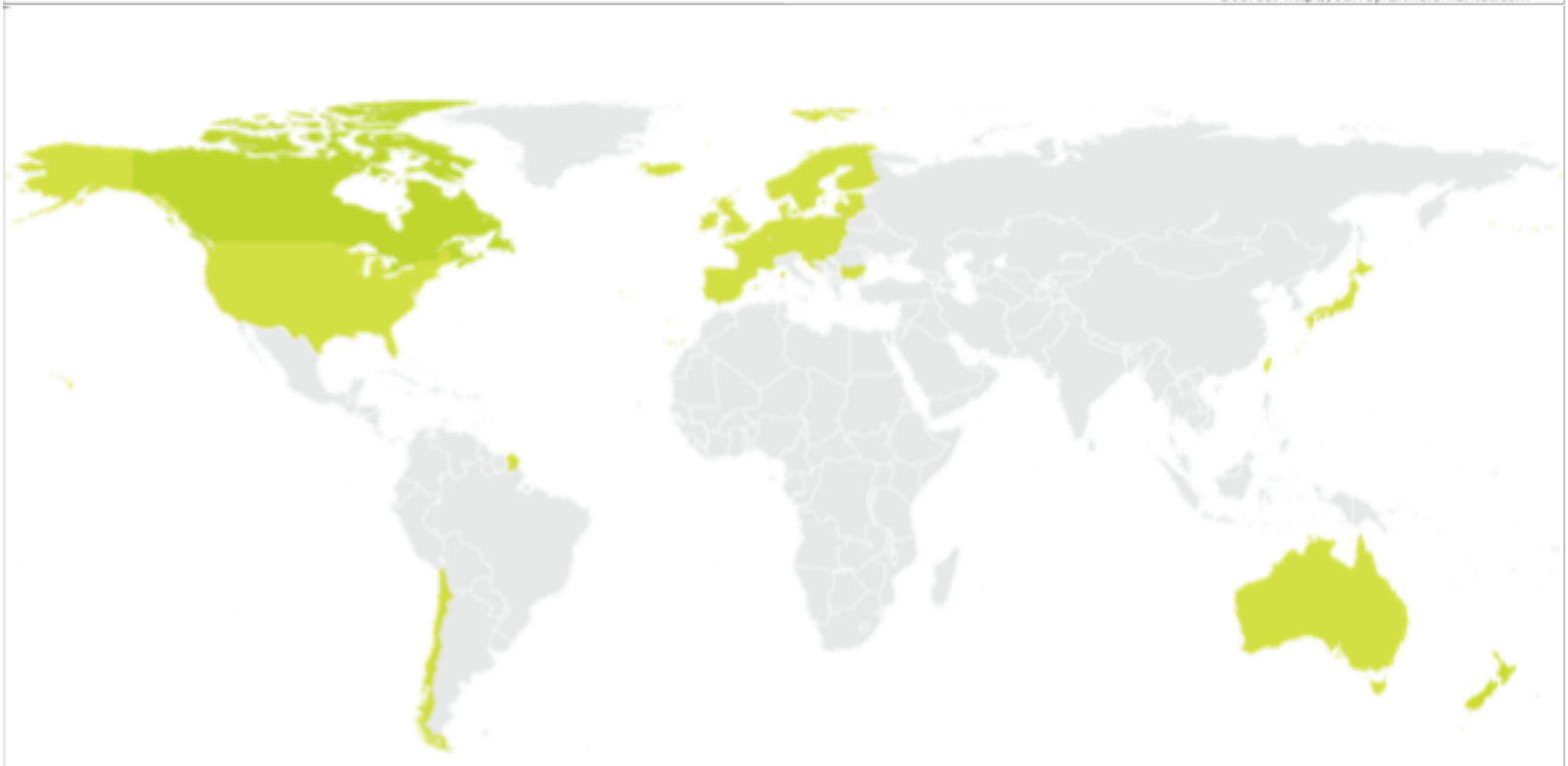

Food Secure Countries (2013)

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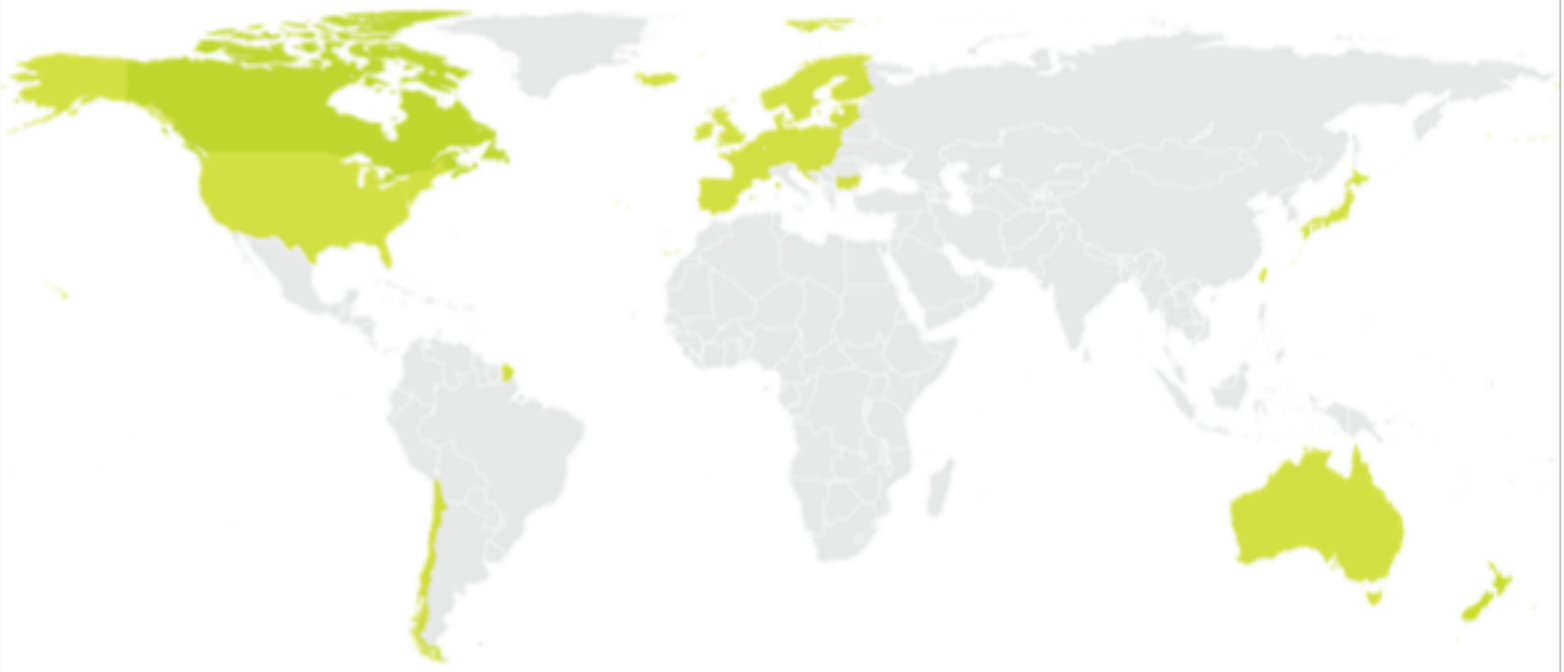
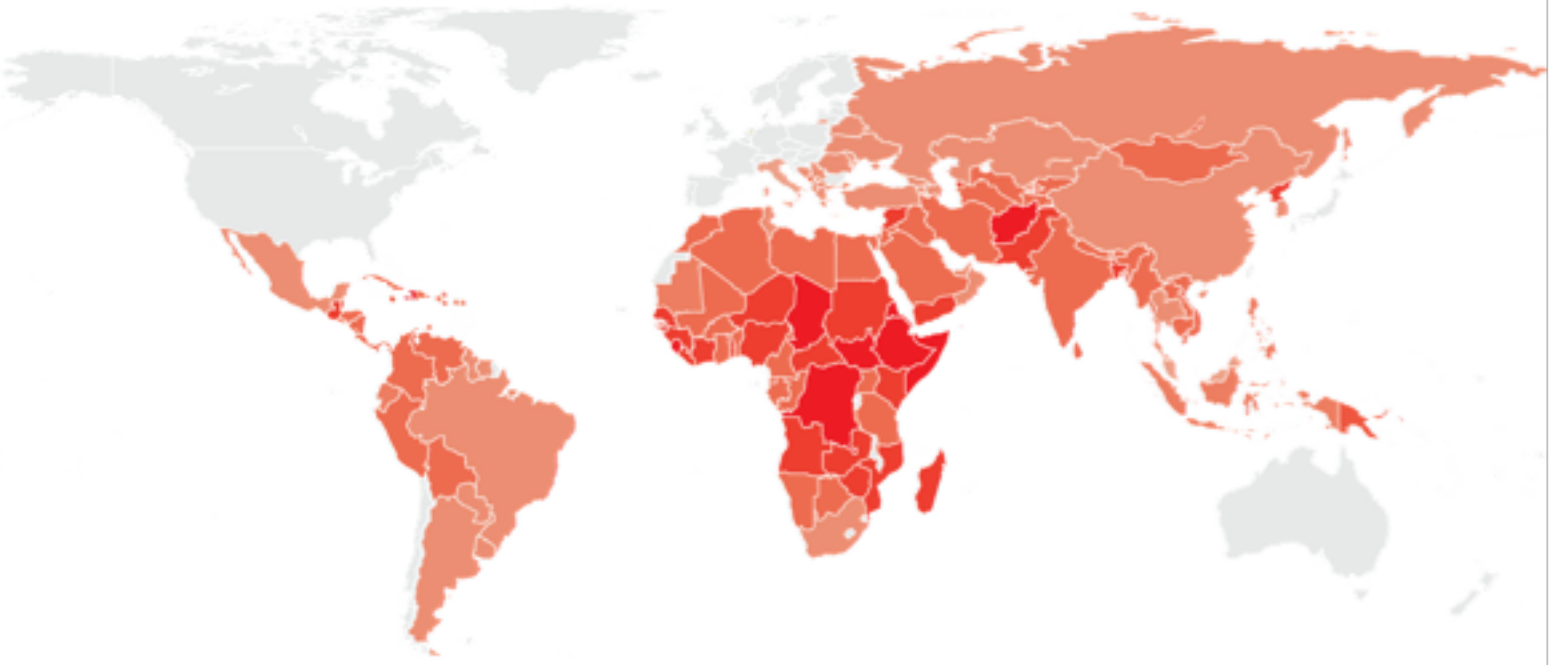
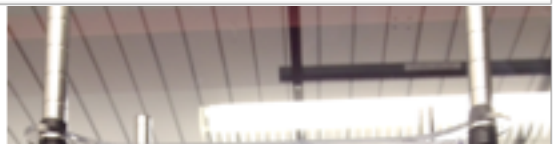


Food Secure Countries (2013)



Food Insecure Countries (2013)



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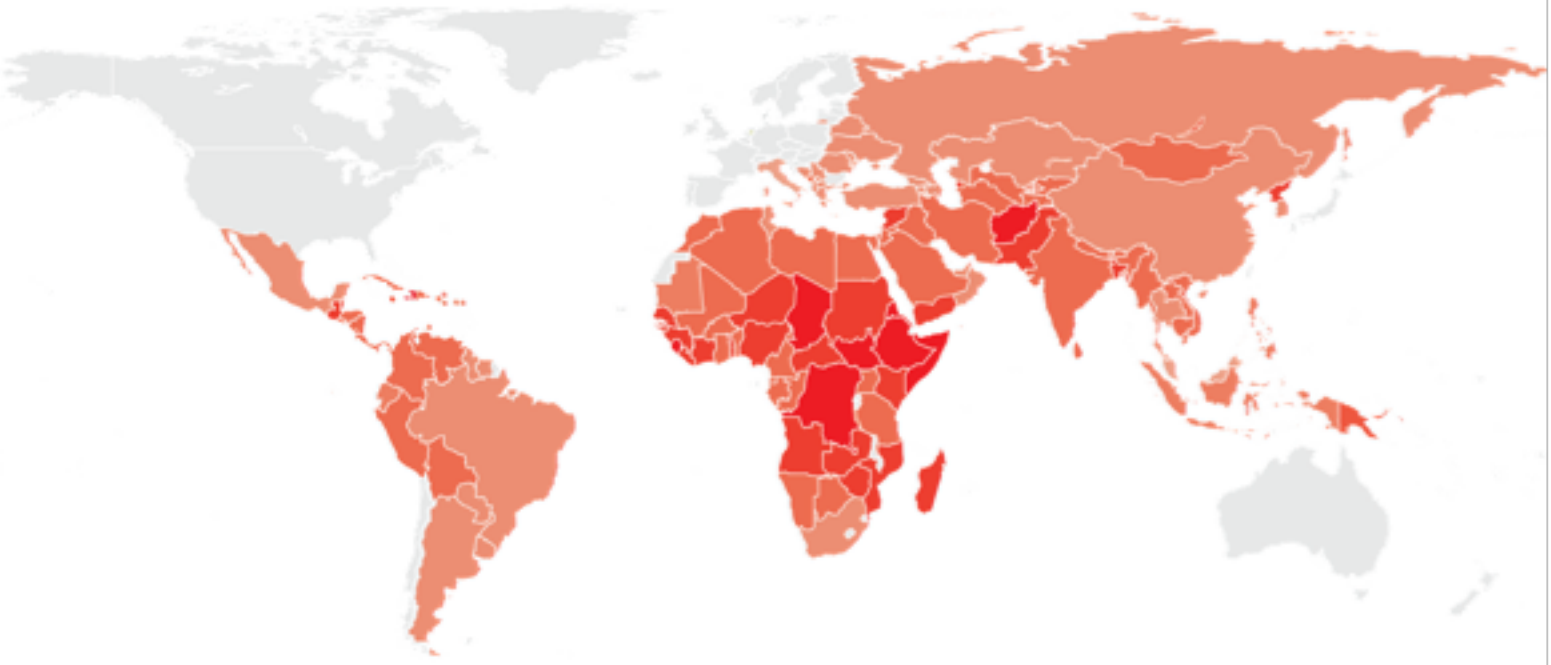

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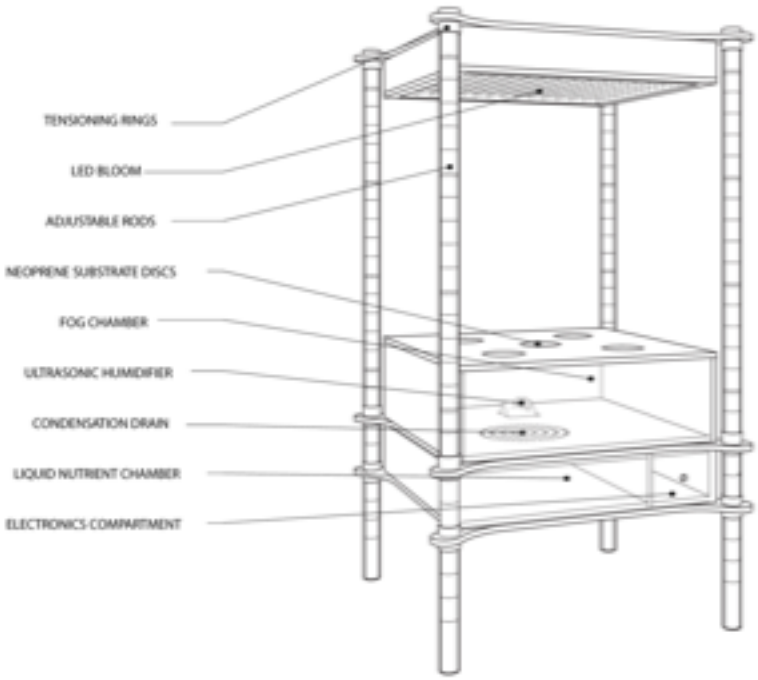
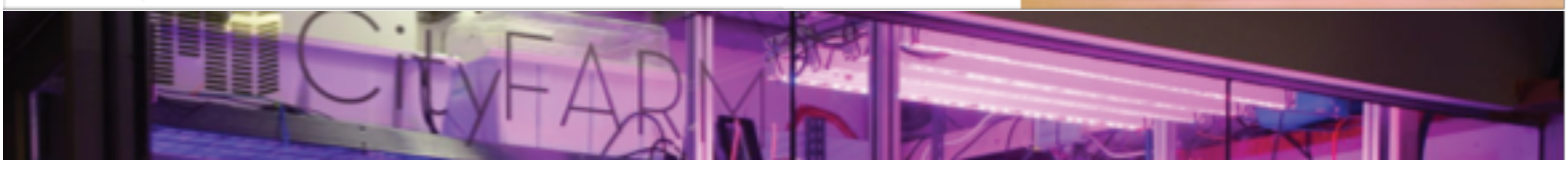


CityFarm 1.0

Caleb Harper



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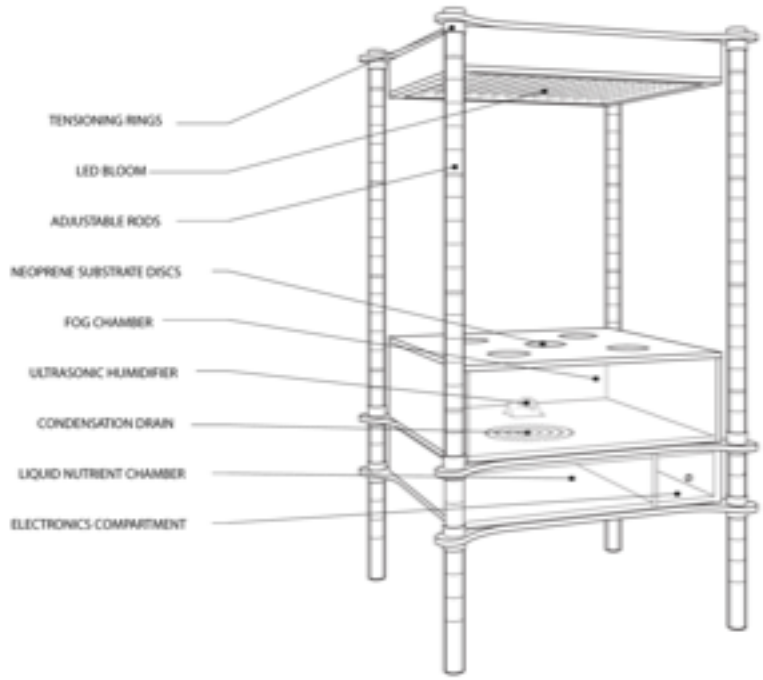


CityFarm 1.0

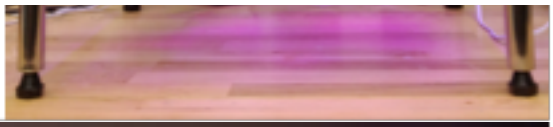
Caleb Harper

CityFARM 2.0

Caleb Harper, Jason Nawyn, Rich Fletcher, Emma Feshbech, Preethi Vaidyanathan, Camille Richman, Li Haung, Sophia Jaffee Elaine Kung

CityFarm 1.0

Caleb Harper



CityFARM 2.0

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CityFARM

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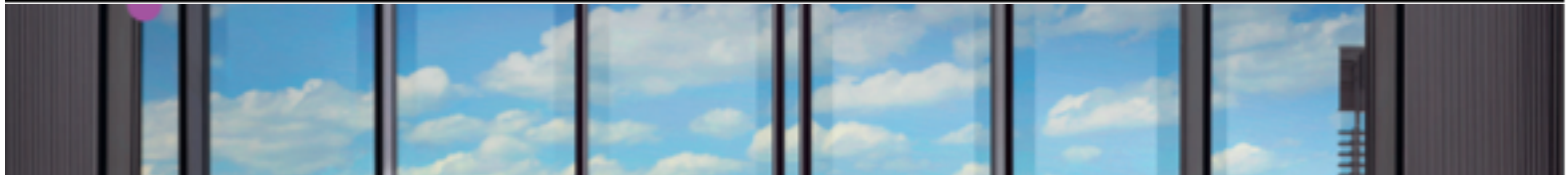

CityFARM 2.0
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CityFARM

CityFARM 2.0

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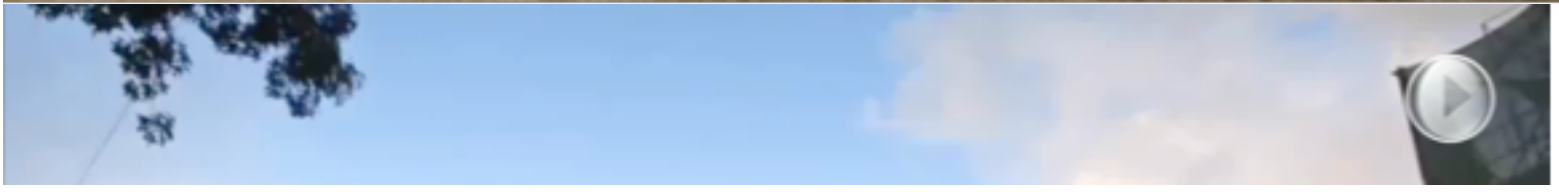
CityFARM 3.0

Caleb Harper, Jason Nawyn, Rich Fletcher, Emma Feshbech, Preethi Vaidyanathan, Camille Richman, Li Haung, Sophia Jaffee Elaine Kung



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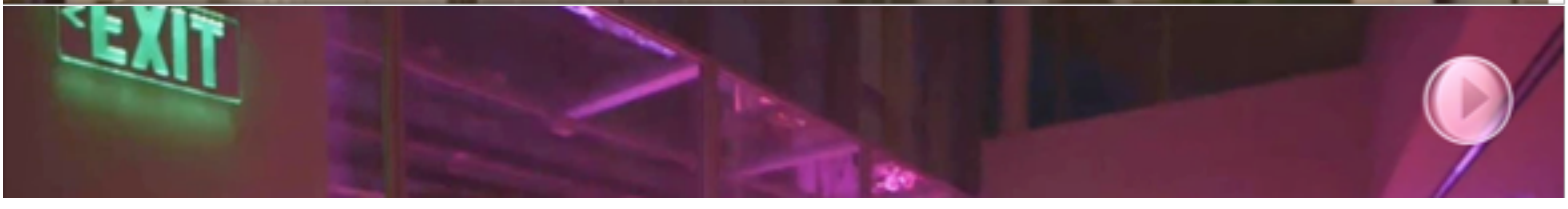

CityFARM 3.0
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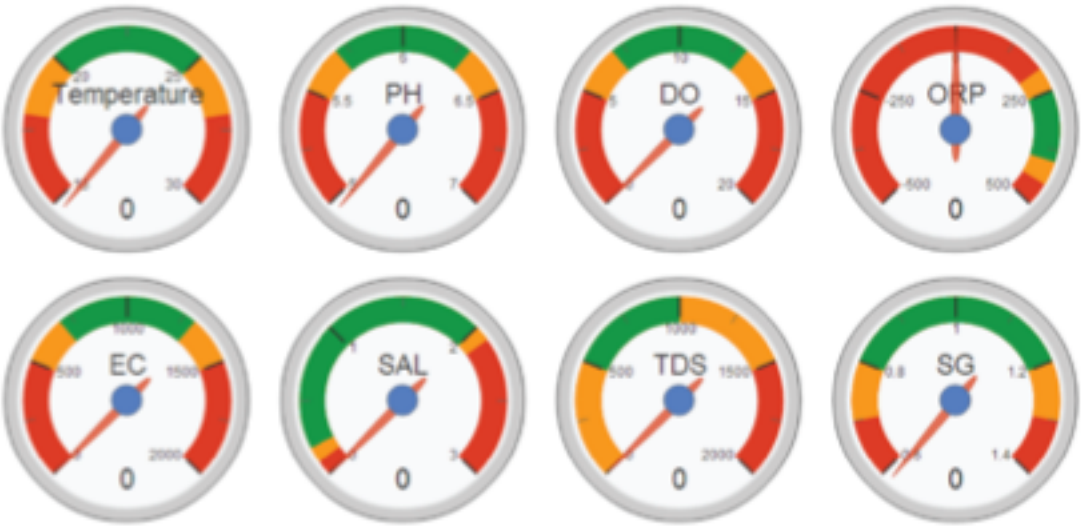
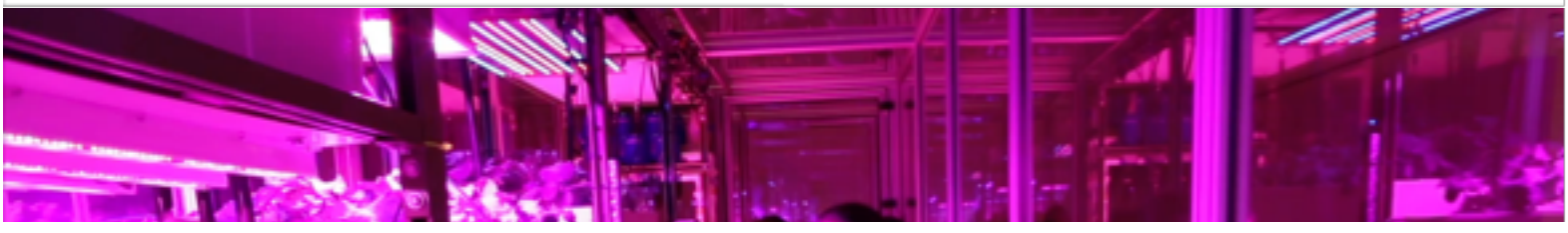
View Sensor History For...

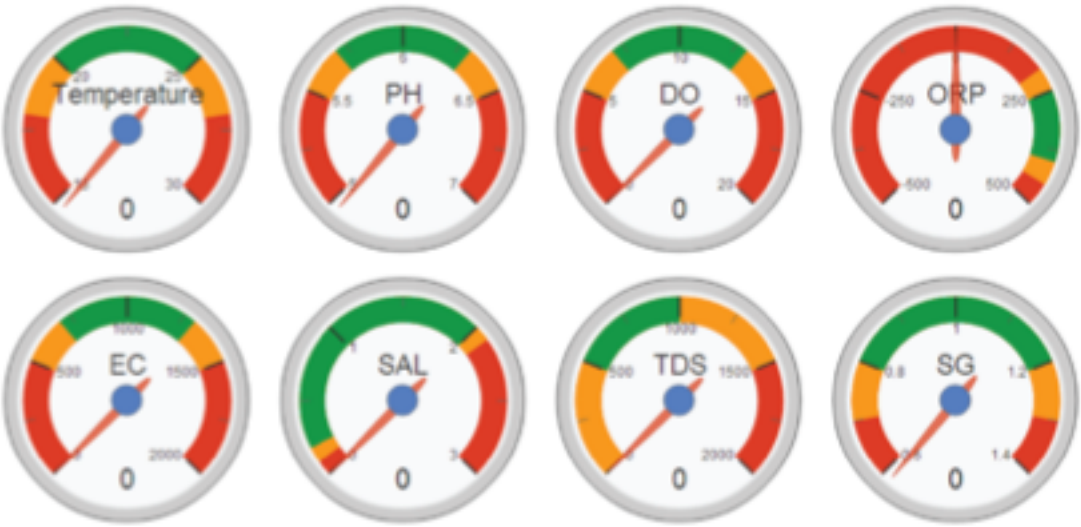
Caleb Harper, Jason Nawyn, Rich Fletcher, Emma Feshbech, Preethi Vaidyanathan, Camille Richman, Li Haung, Sophia Jaffee Elaine Kung



View Sensor History For...

- The Past Hour
- Today
- A Specific Date
- A Range of Dates




Temperature
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PH
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DO
0
ORP
0
EC
0
SAL
0
TDS
0
SG
0
View Sensor History For...
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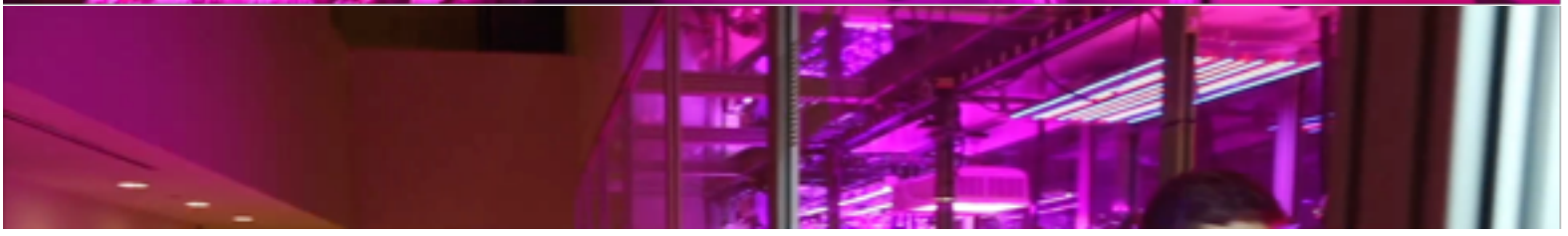


CityFARM 3.0
Caleb Harper, Jason Nawyn, Rich Fletcher, Emma Feshbech, Preethi Vaidyanathan, Camille Richman, Li Haung, Sophia Jaffee Elaine Kung

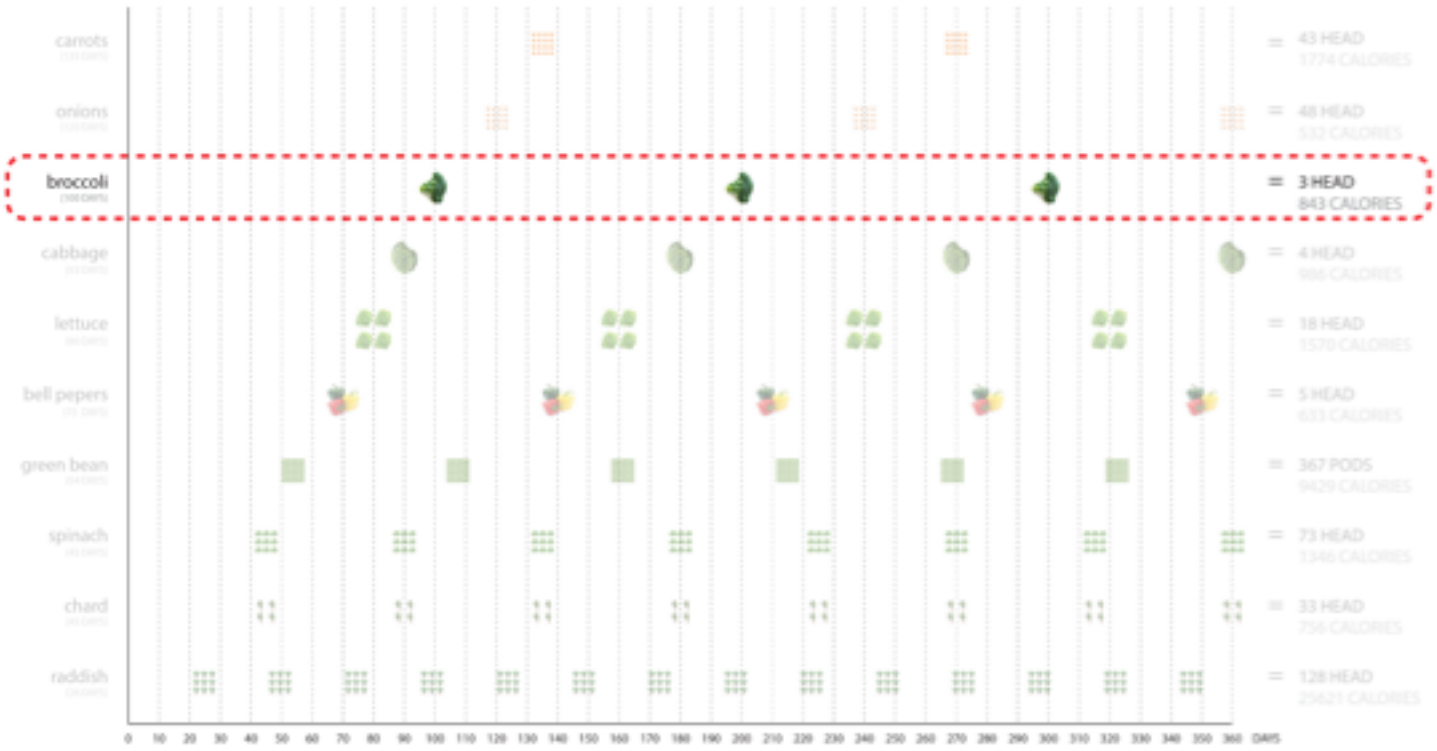
CityFARM 3.0
Caleb Harper, Jason Nawyn, Rich Fletcher, Emma Feshbech, Preethi Vaidyanathan, Camille Richman, Li Haung, Sophia Jaffee Elaine Kung

carrots
= 43 HEAD
1774 CALORIES
onions
= 48 HEAD
532 CALORIES
broccoli
= 3 HEAD
843 CALORIES

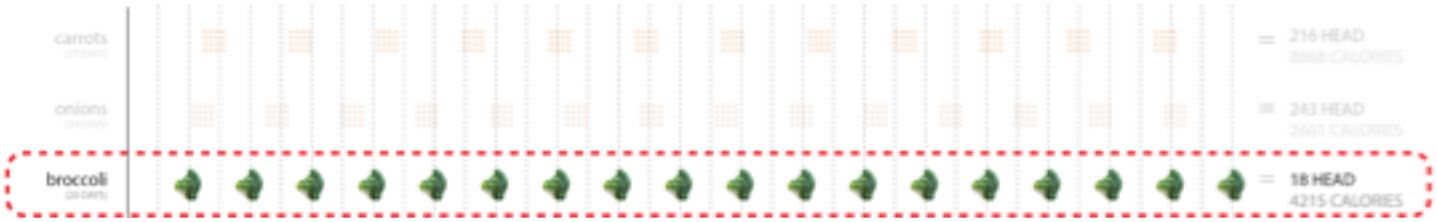
Caleb Harper, Jason Nawyn, Rich Fletcher, Emma Feshbech, Preethi Vaidyanathan, Camille Richman, Li Haung, Sophia Jaffee Elaine Kung

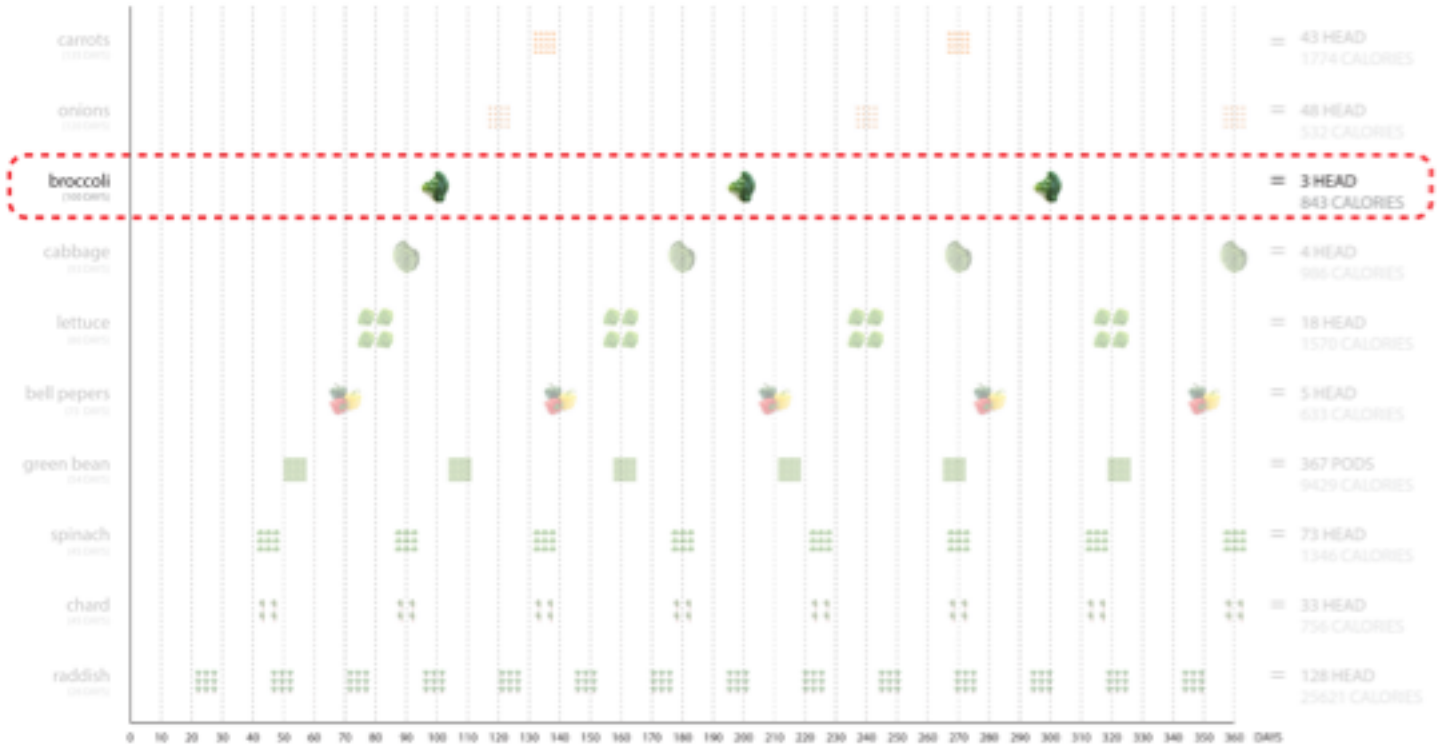
CityFARM 3.0

Caleb Harper, Jason Nawyn, Rich Fletcher, Emma Feshbech, Preethi Vaidyanathan, Camille Richman, Li Haung, Sophia Jaffee Elaine Kung



Soil Metrics = 3 heads/sf





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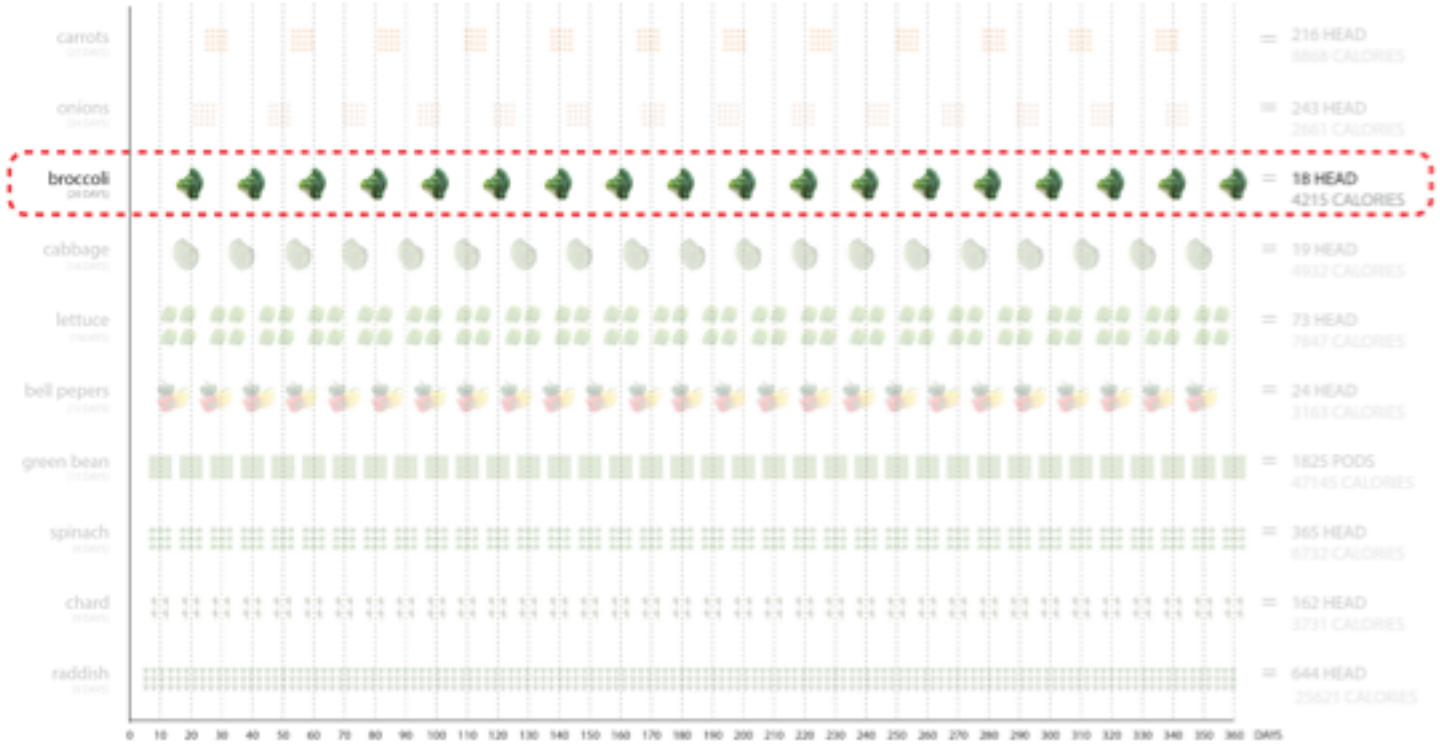
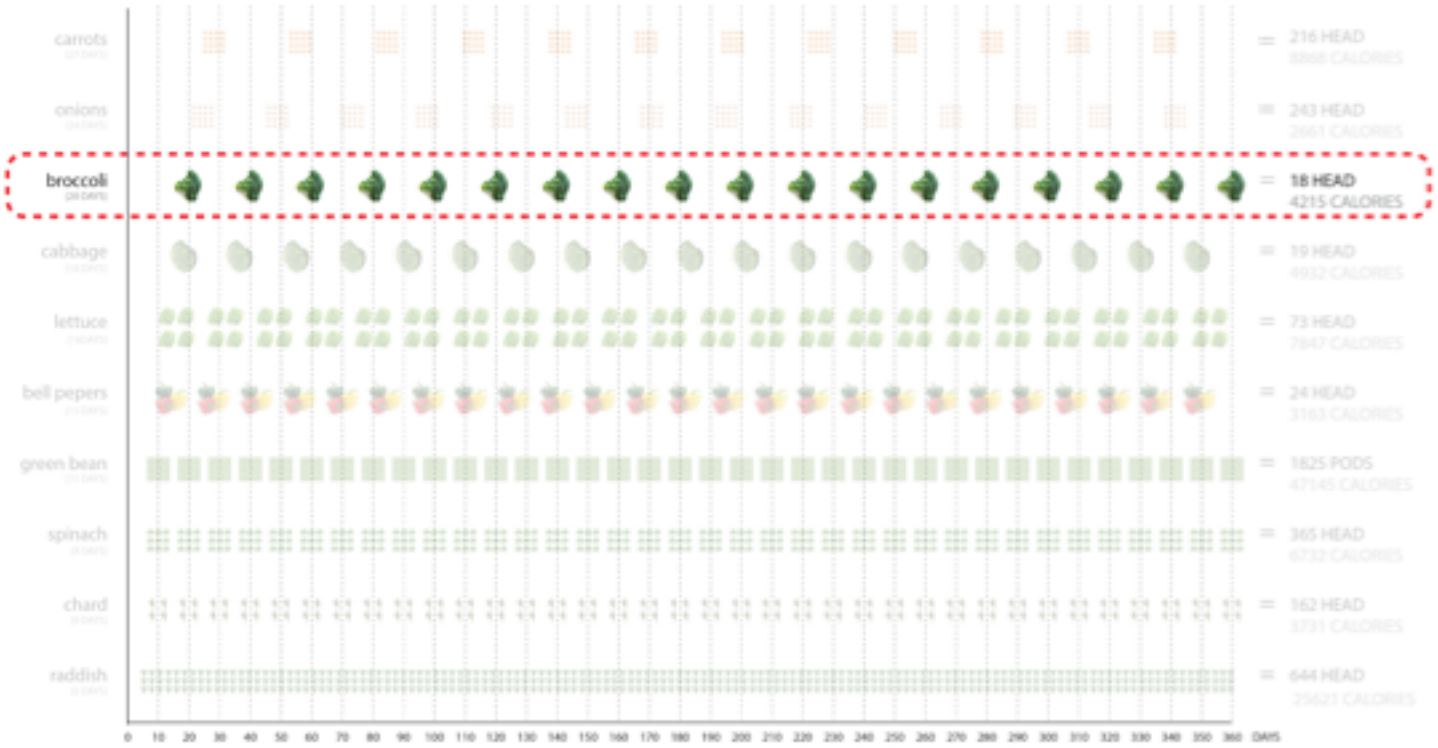


Aeroponic Metrics = 18 heads/sf



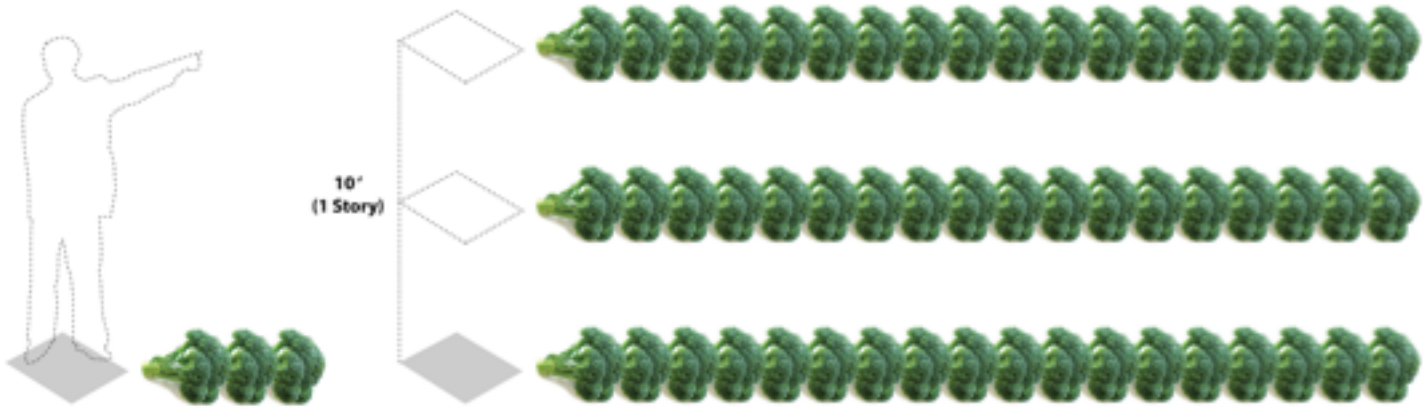
Aeroponic Metrics = 18 heads/sf

Soil = 3/sf

Aeroponics = 18/sf (5X)

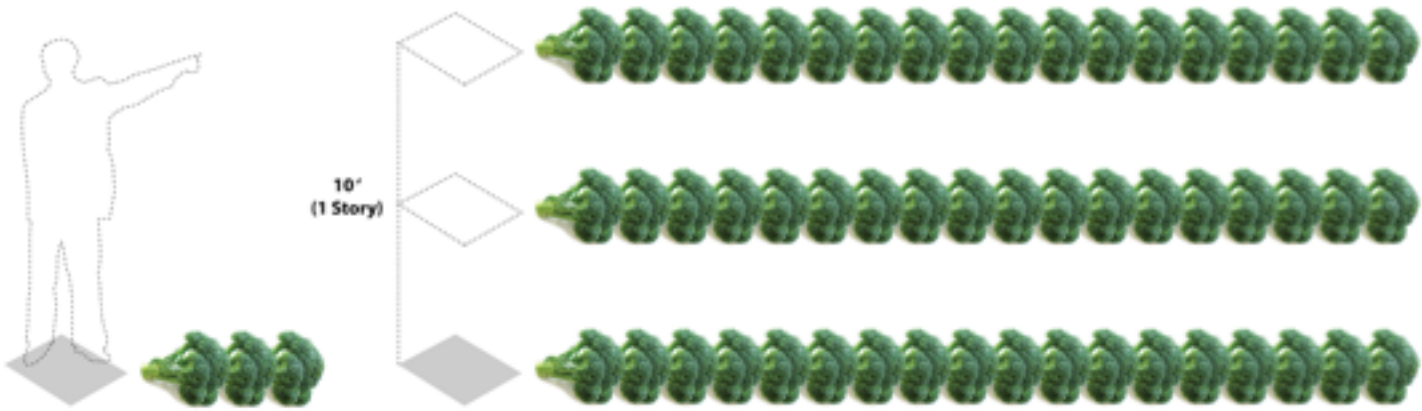
Soil = 3/sf

Aeroponics = 18/sf (5X)



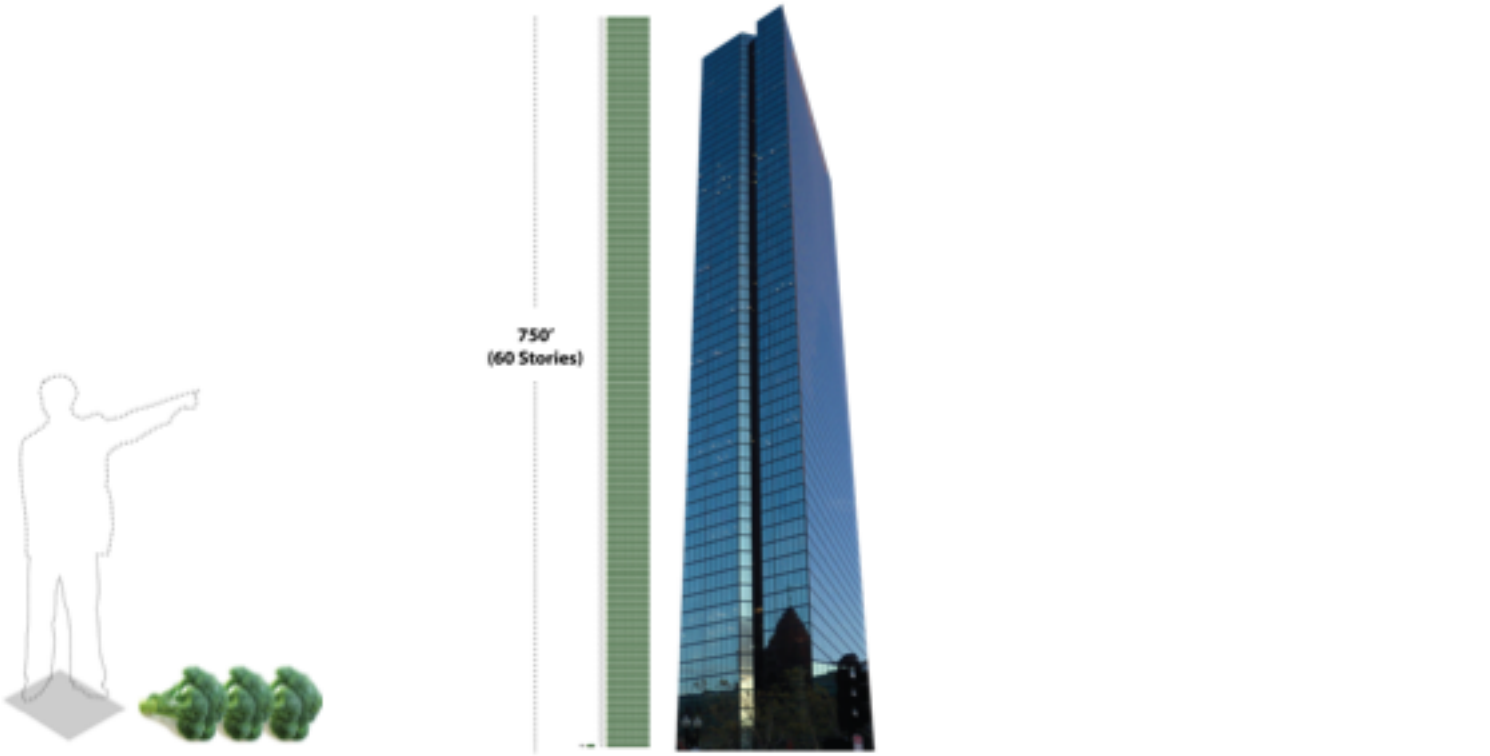
Soil = 3/sf

Aeroponics = 54/sf per floor (18X)



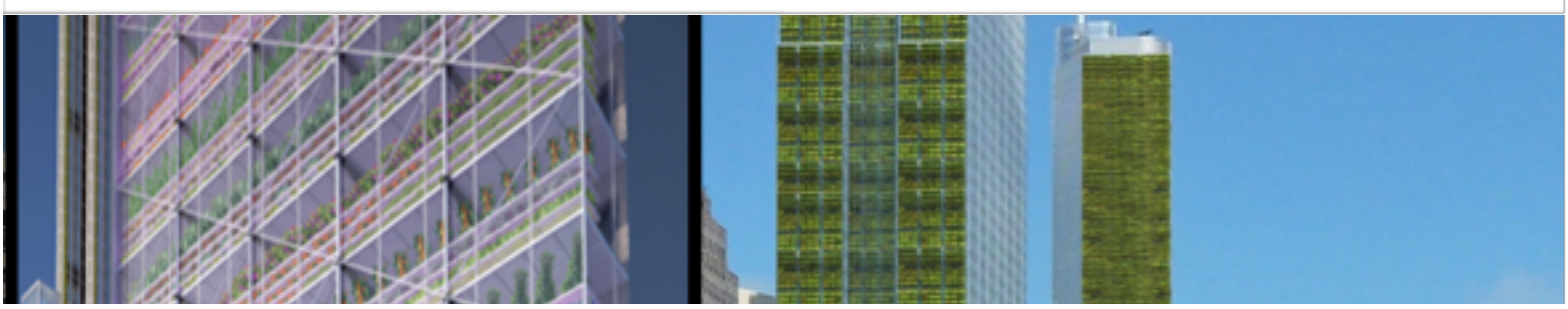
Soil = 3/sf

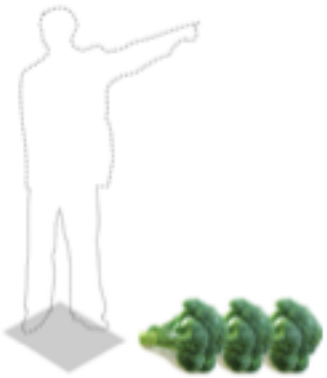
Aeroponics = 54/sf per floor (18X)

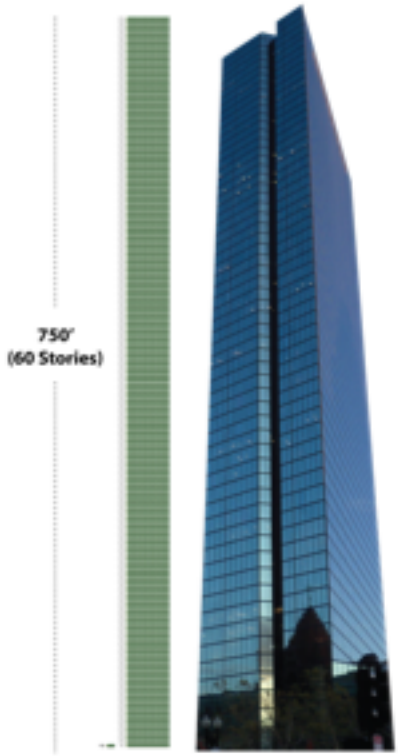


Soil = 3/sf

Aeroponics = 3240/sf @ 60 floors (1080X)







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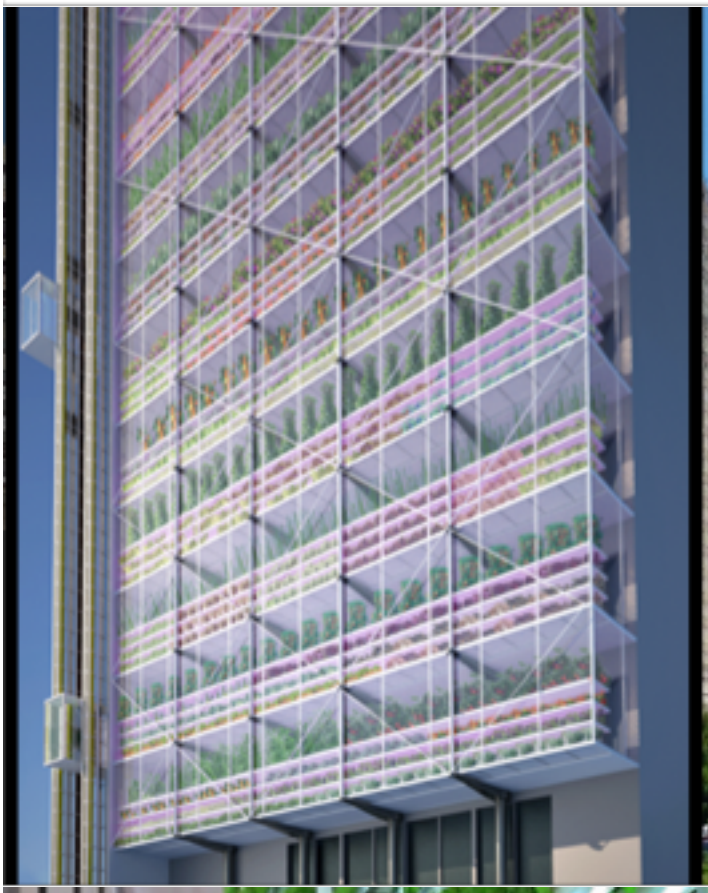
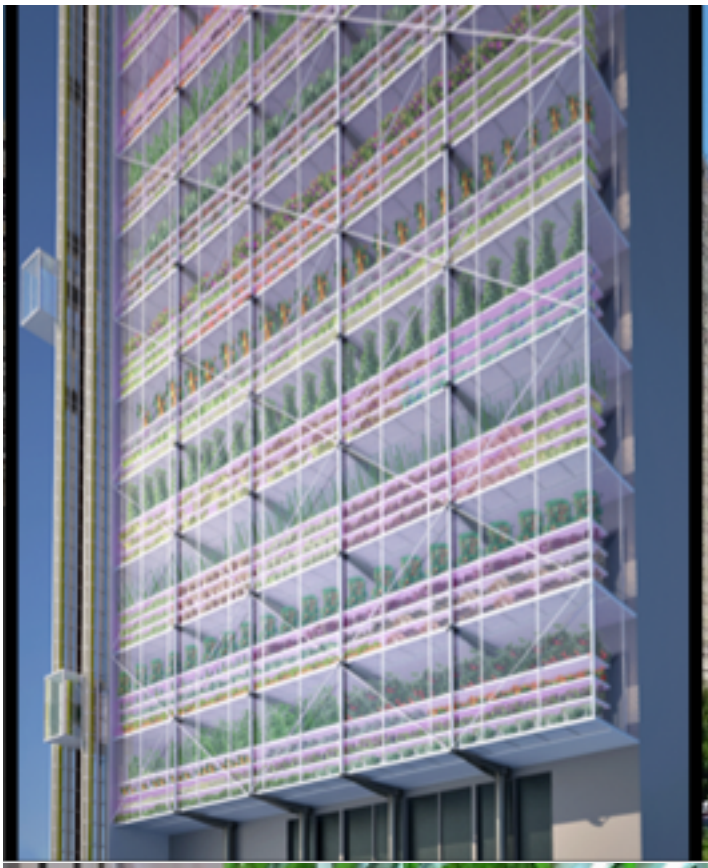


compared to soil-based farming

100x Produce/land area



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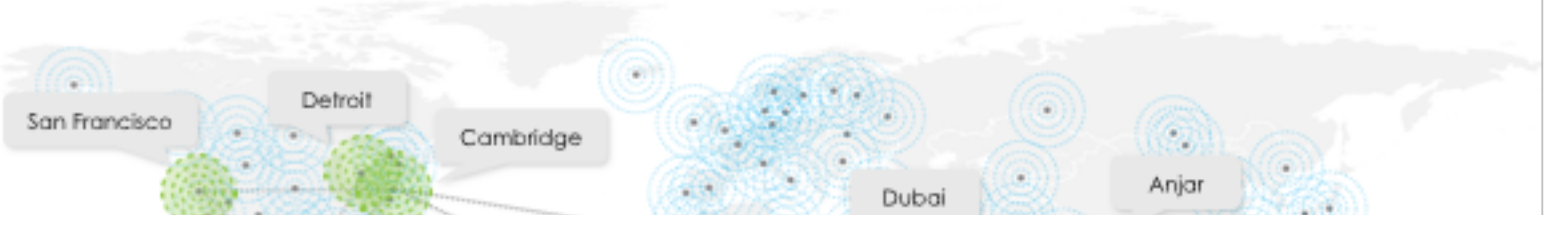

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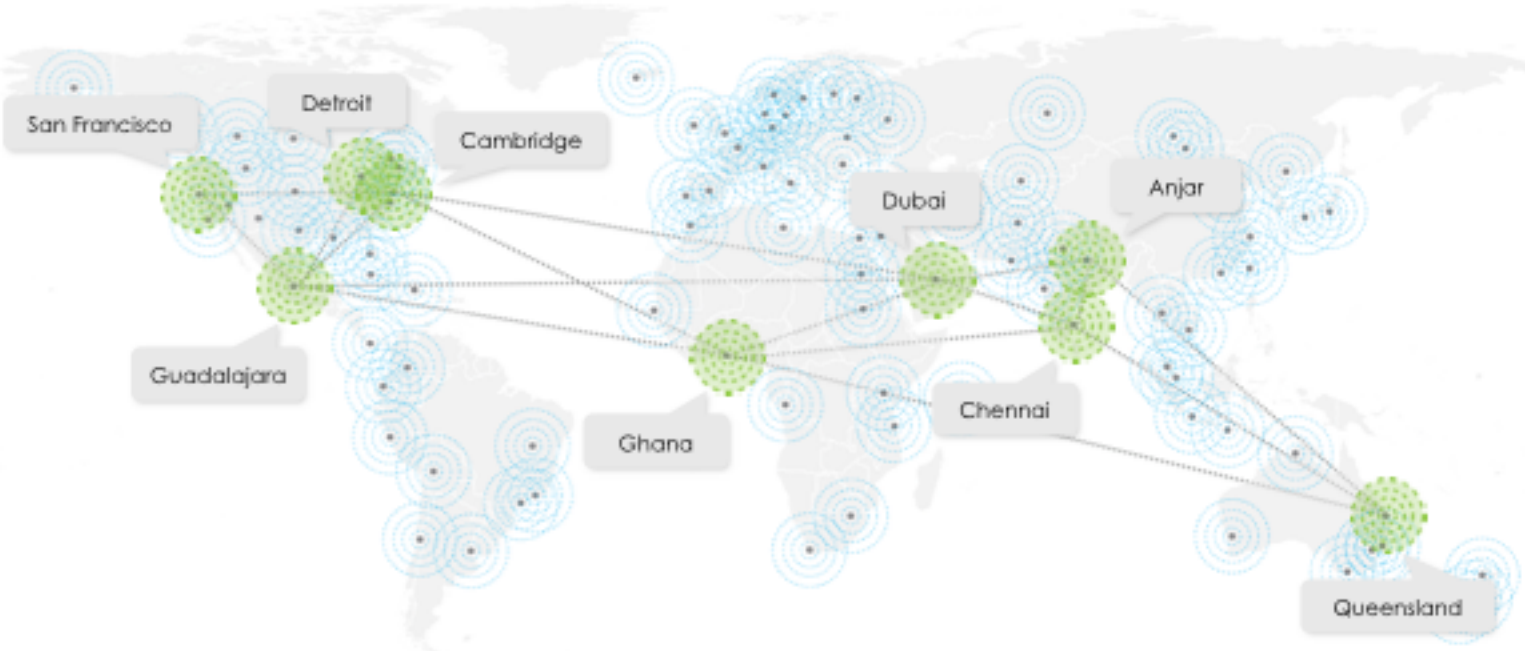
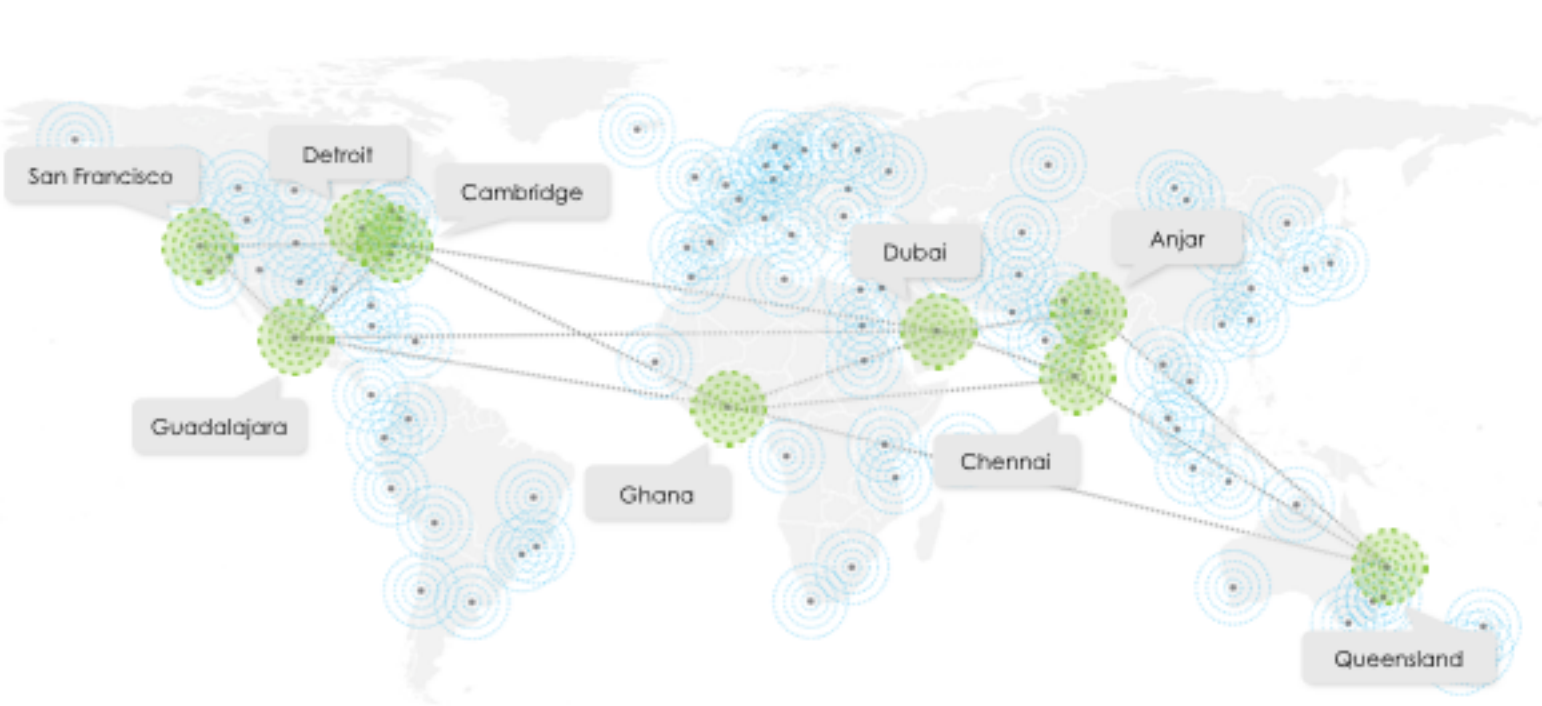


Open Ag Project

@MITCityFARM



Open Ag Project

@MITCityFARM

3

3

Mobility-on-Demand

(creating alternatives to the
private automobile in compact districts)

Walking (Privileged Mode)

Shared Bikes

On Demand Bus / Tram

3

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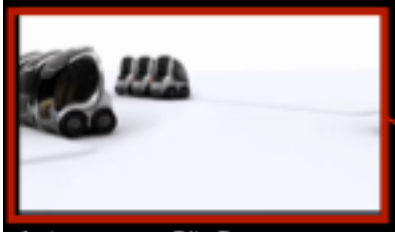
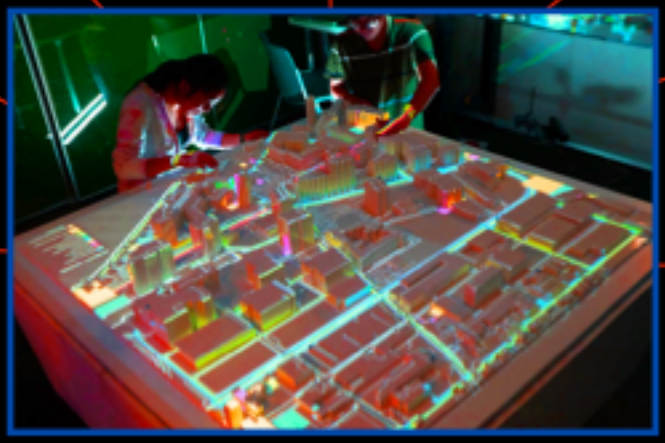
Walking (Privileged Mode)

Shared Bikes

On Demand Bus / Tram



Autonomous CityCars

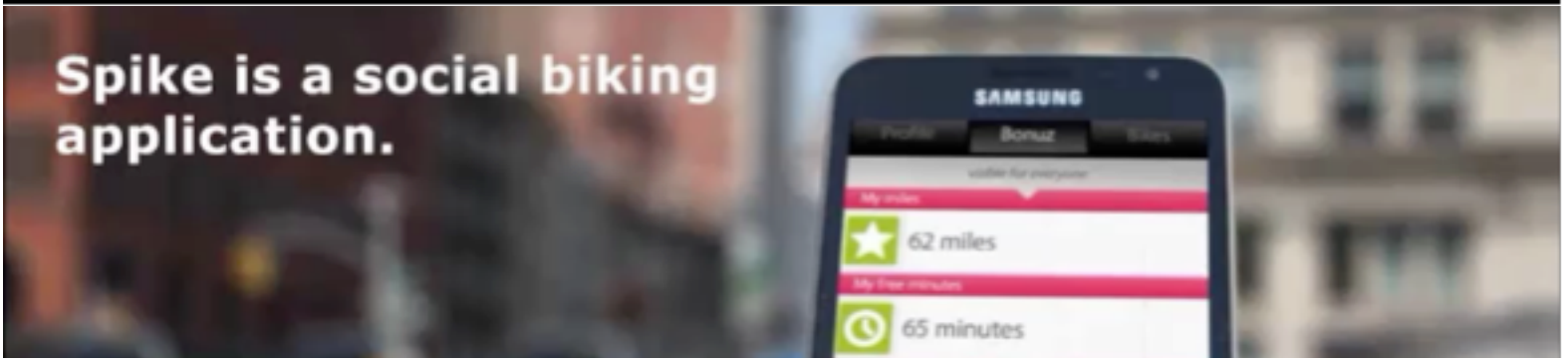


Mobility-on-Demand Modes

Shared eBikes

Shared eScooters

Autonomous Shared PEVs



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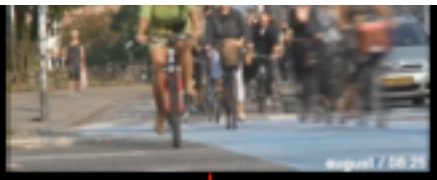
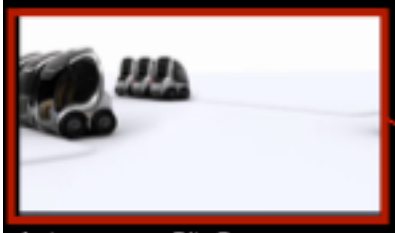


Shared Bikes

On Demand Bus / Tram



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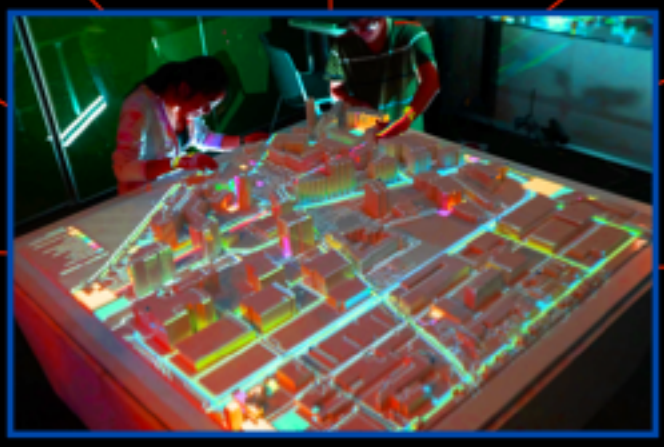

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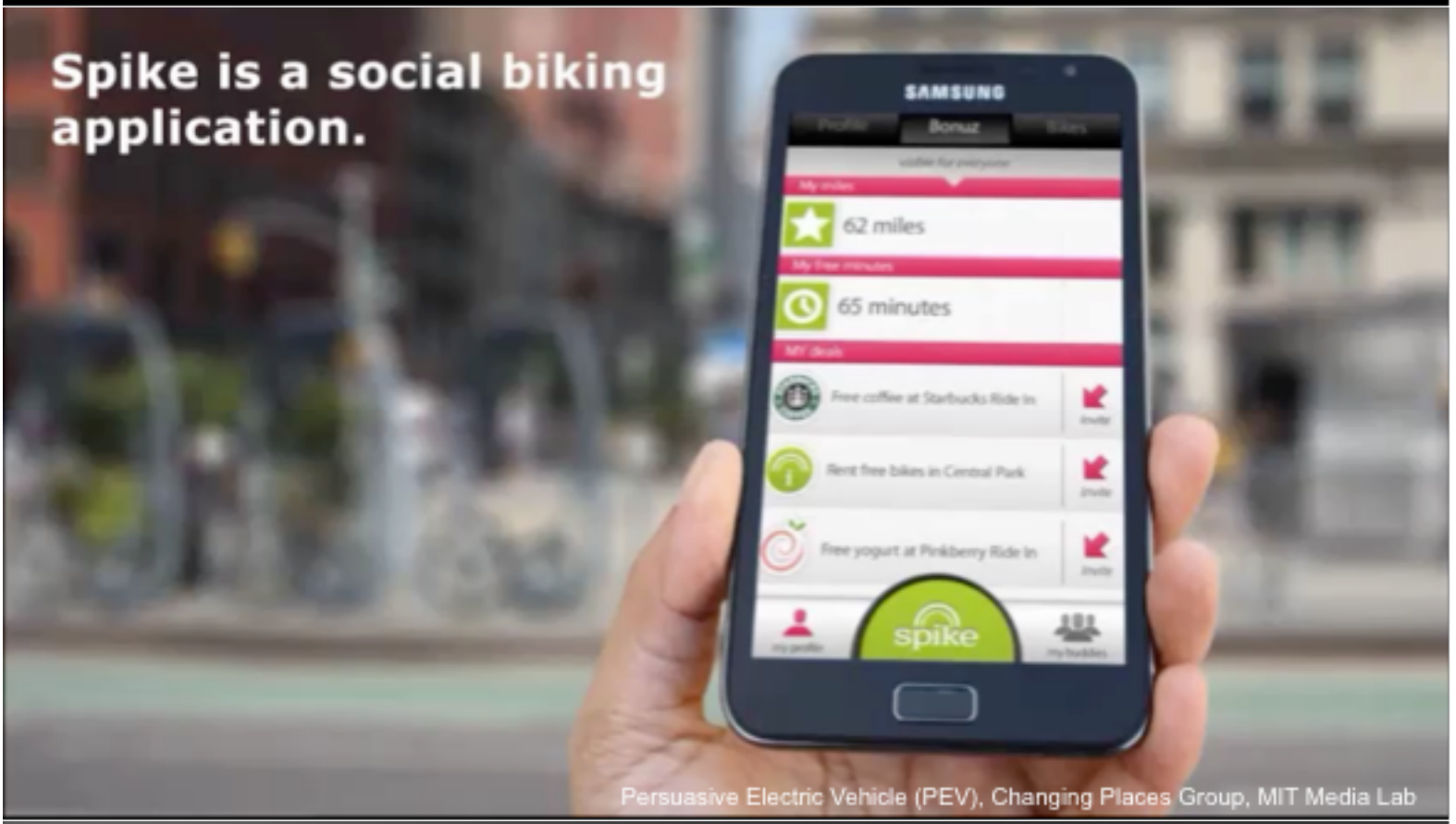
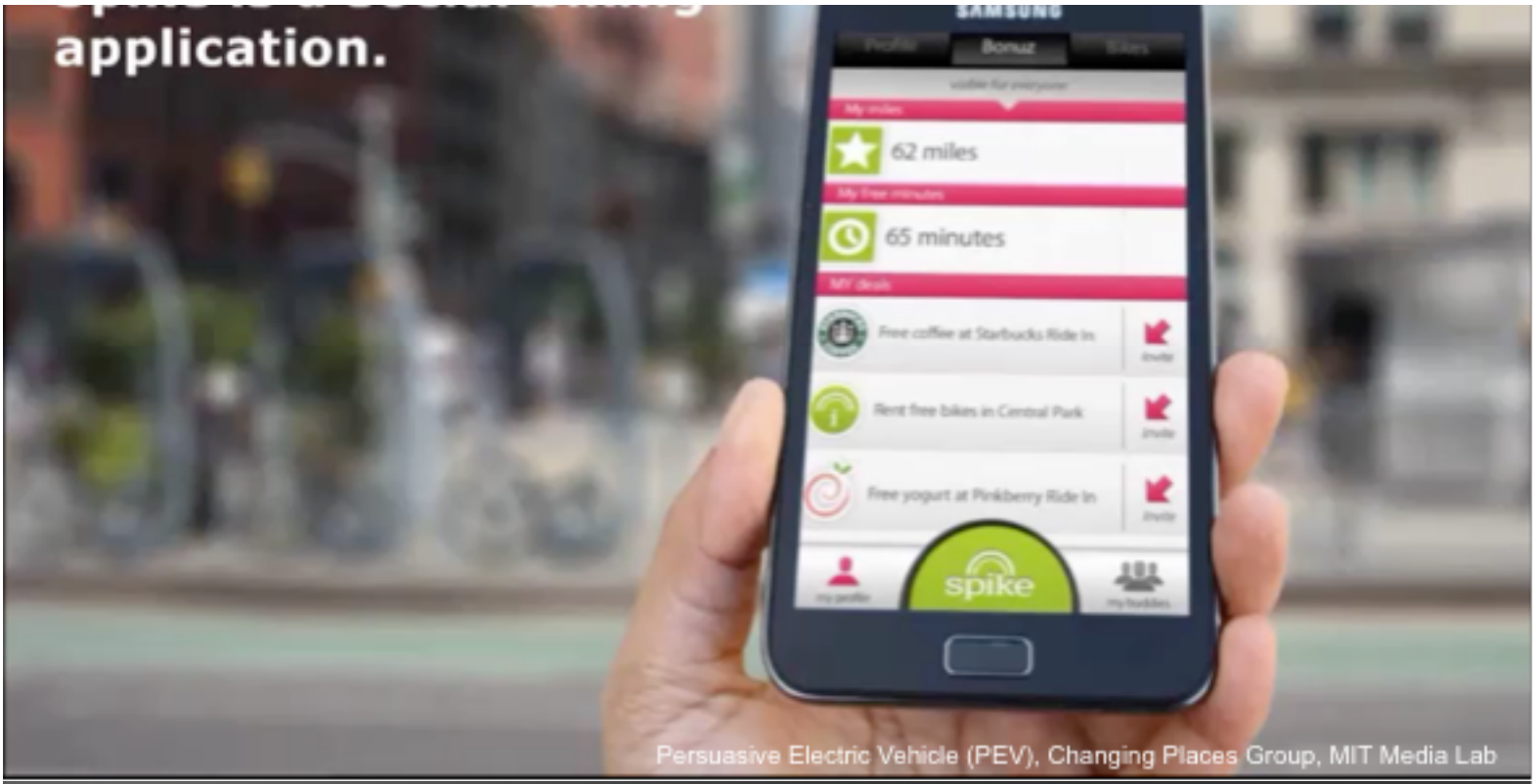


Persuasive Electric Vehicle (PEV), Changing Places Group, MIT Media Lab



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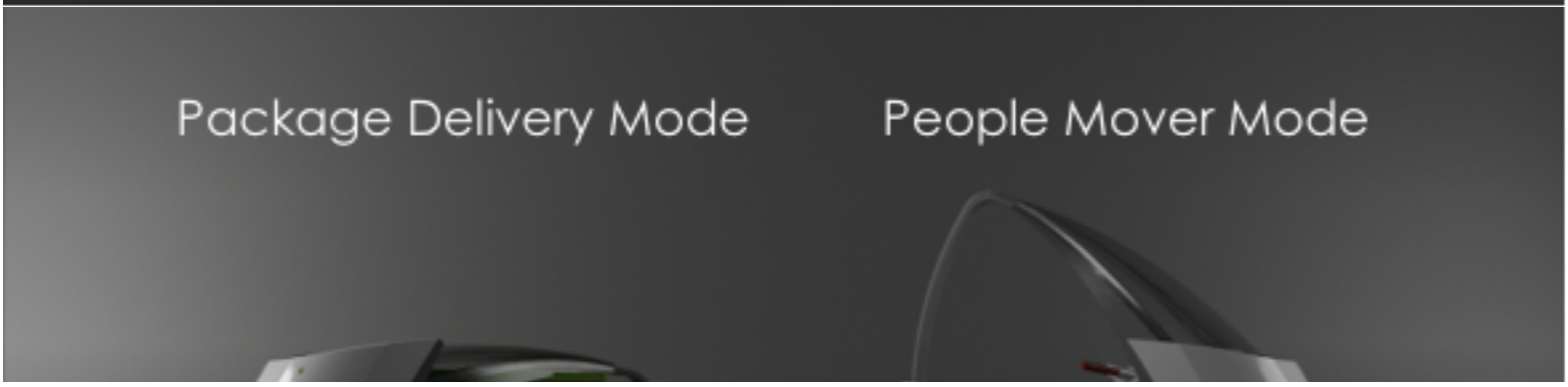
Persuasive Electric Vehicle (PEV)

Ryan Chin, Michael Lin, Sandra Richter



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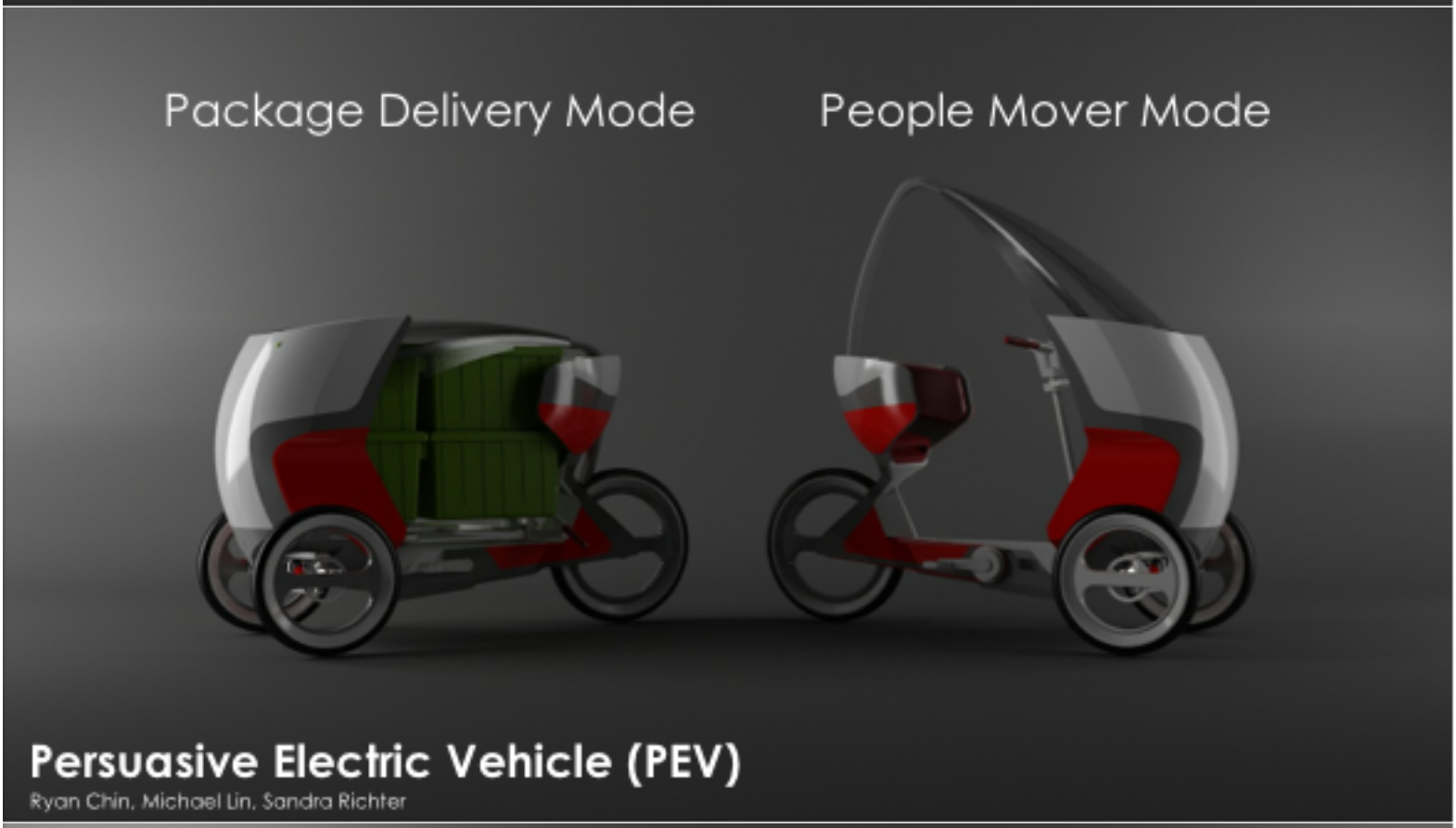

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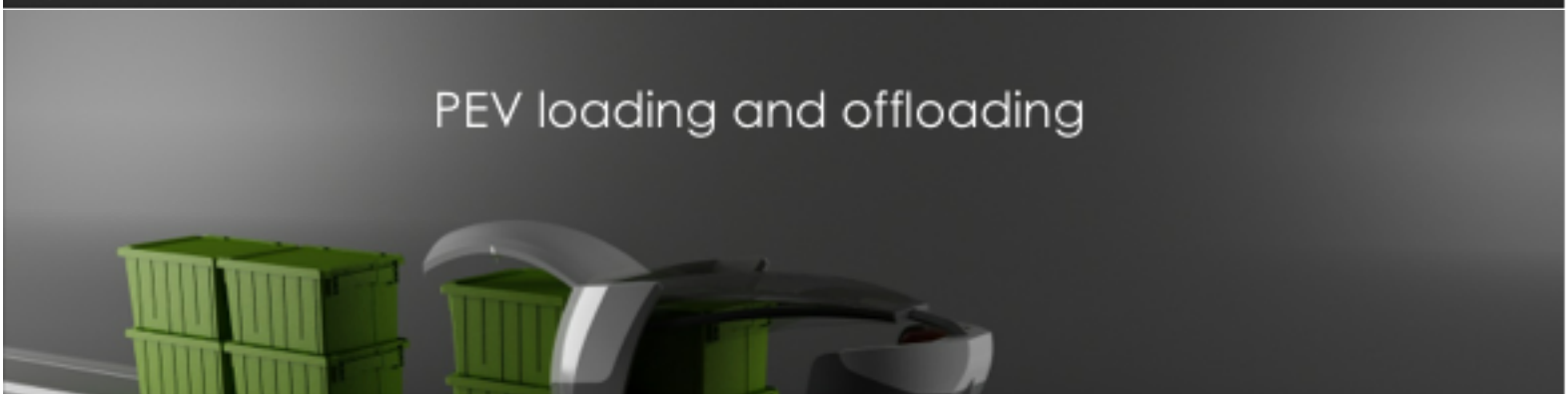


Package Delivery Mode People Mover Mode

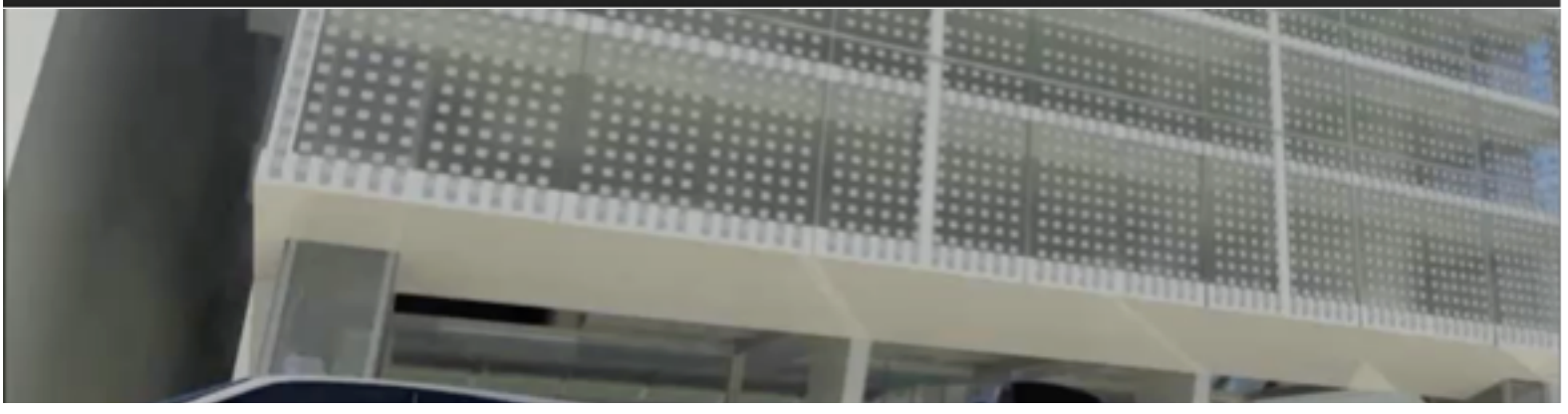
Persuasive Electric Vehicle (PEV)

Ryan Chin, Michael Lin, Sandra Richter

PEV loading and offloading

Persuasive Electric Vehicle (PEV)

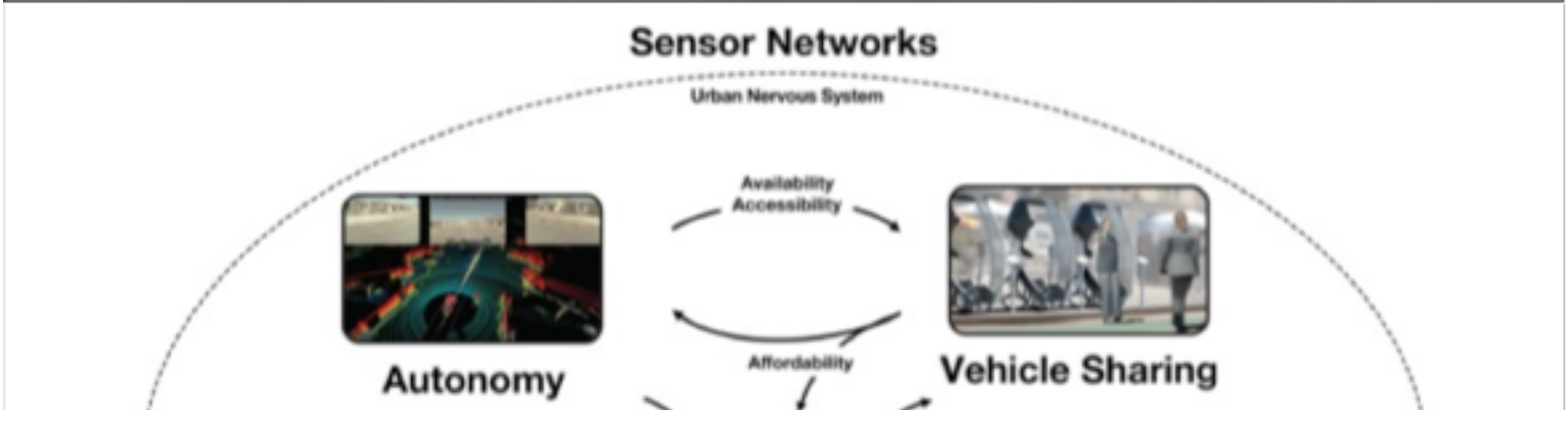
Ryan Chin, Michael Lin, Sandra Richter

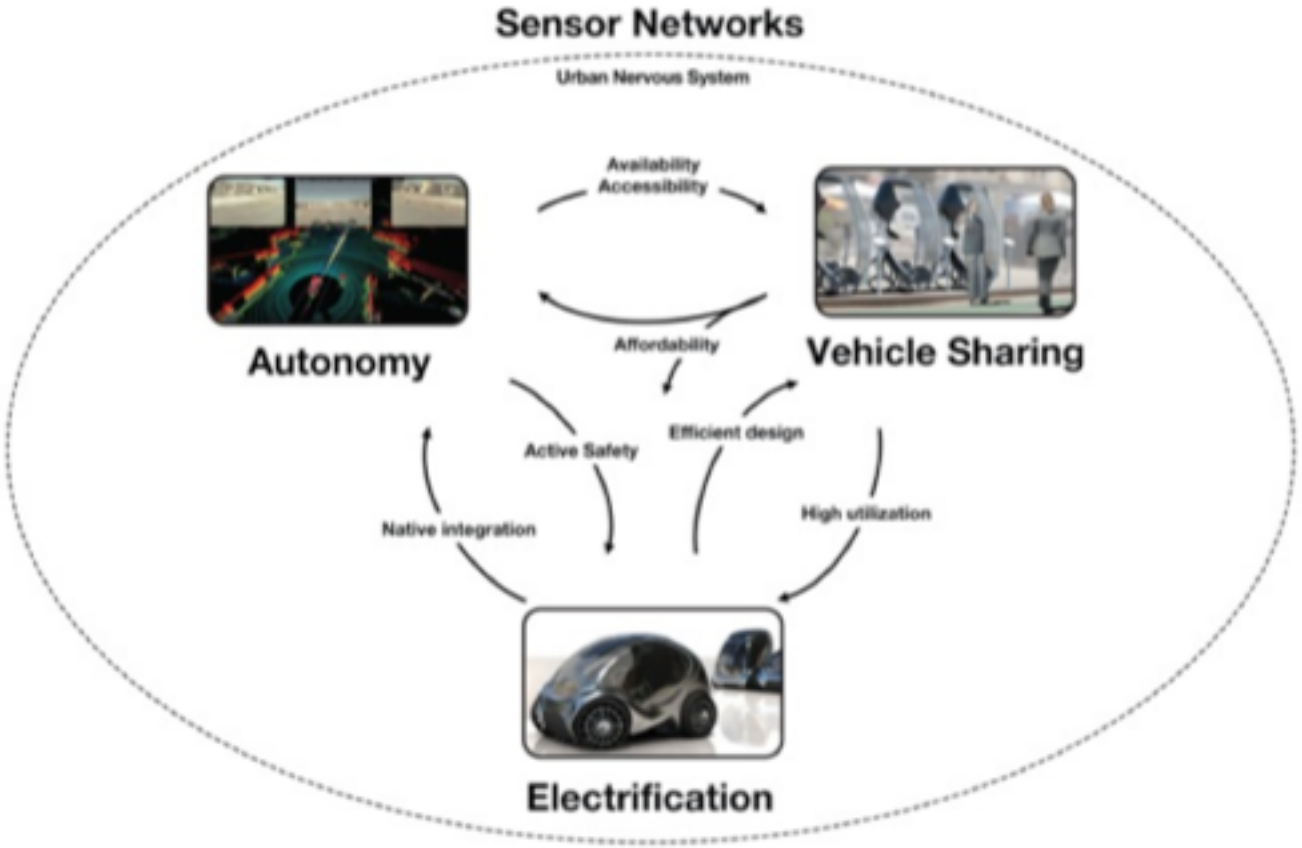


Persuasive Electric Vehicle (PEV)

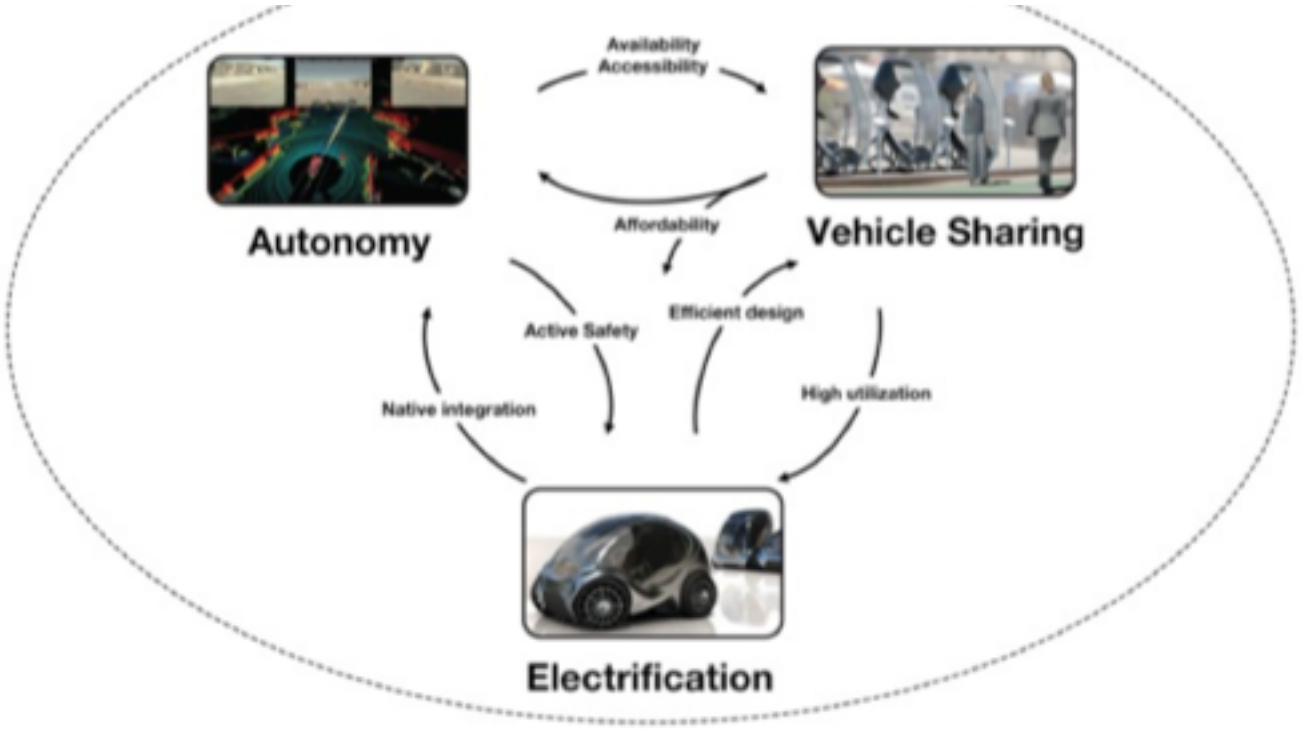
Ryan Chin, Michael Lin, Sandra Richter

CityCar, Changing Places Group, MIT Media Lab





- Mobility on Demand Systems in Singapore (NUS Campus)



- **Mobility on Demand Systems in Singapore (NUS Campus)**

DARPA Urban Challenge

~500,000$ (US)

CityCar prototype

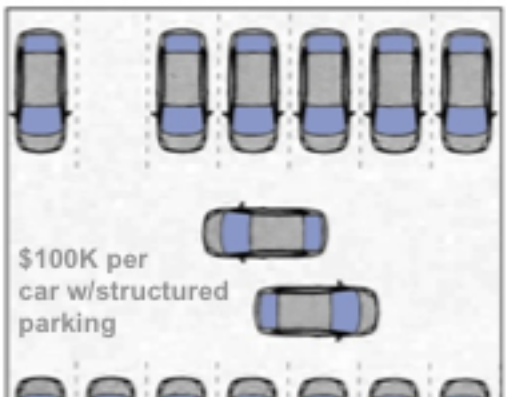
~50,000$ (US)

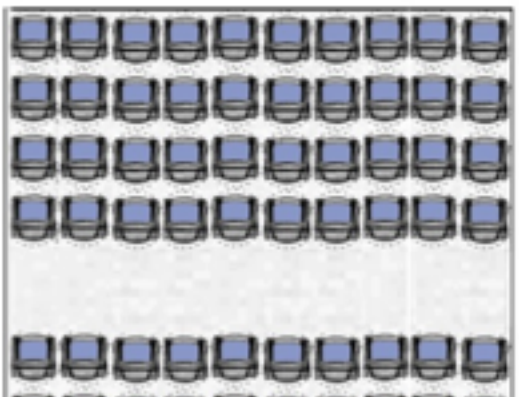
?

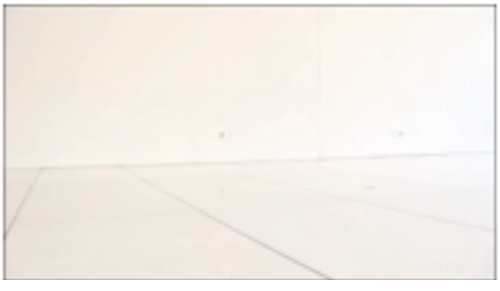
~5,000$ each (US)

Singapore-MIT Alliance for Research and Technology

AEROASTRO







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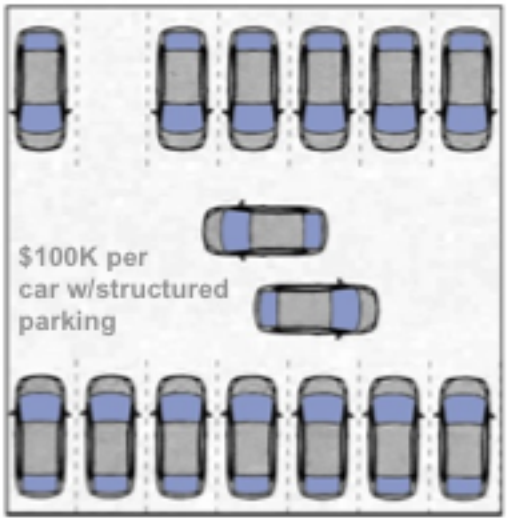
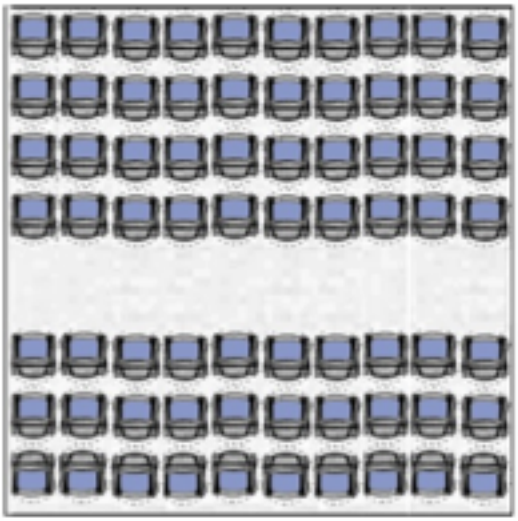


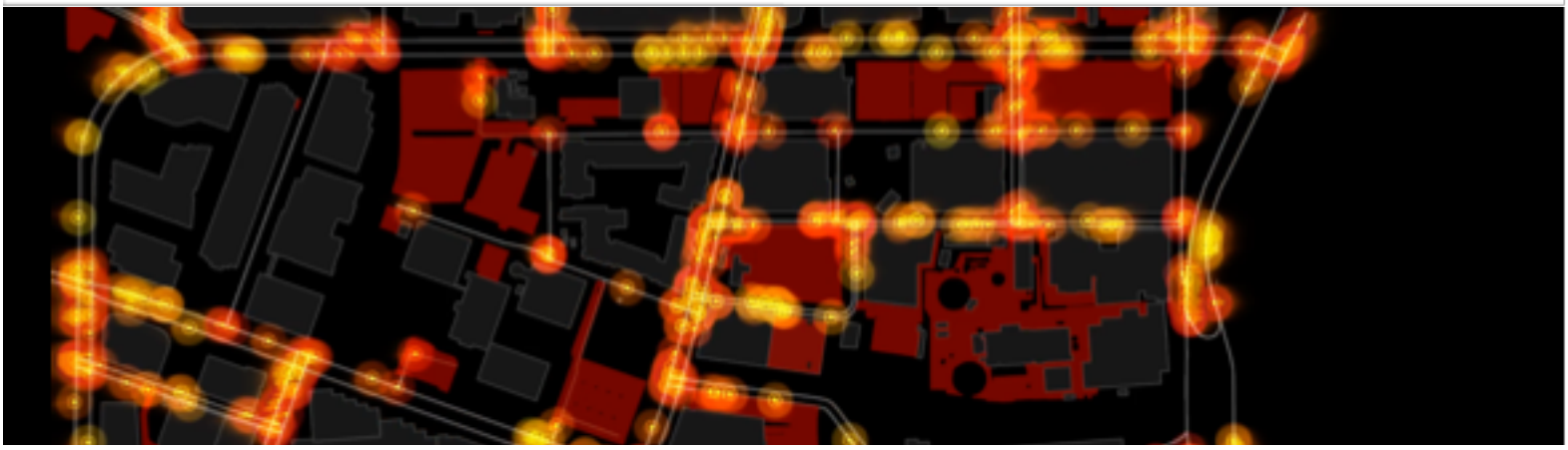


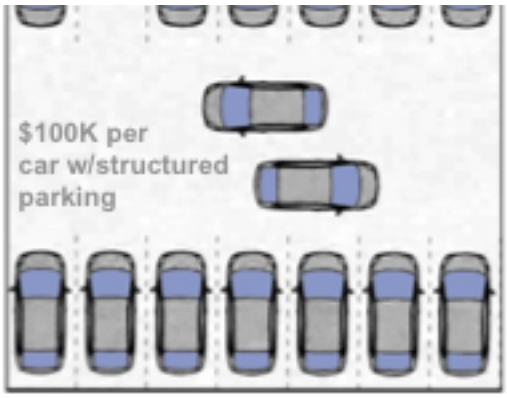
5X + 4X = 20X

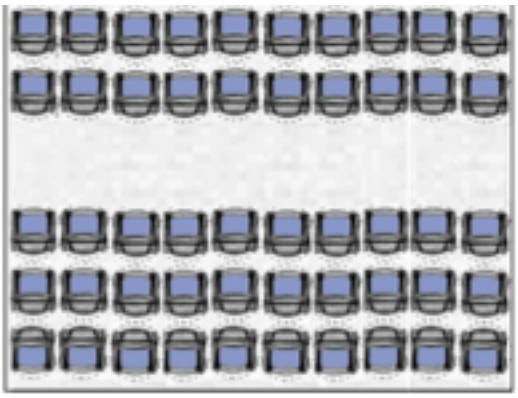
cars/area with folding and autonomous parking

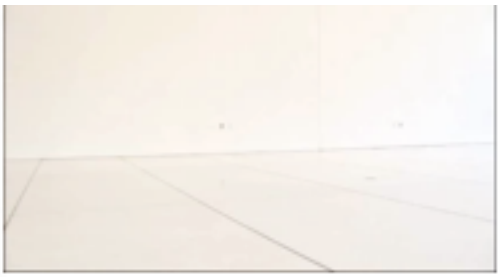
car replacement/ person with shared use

increase in land utilization









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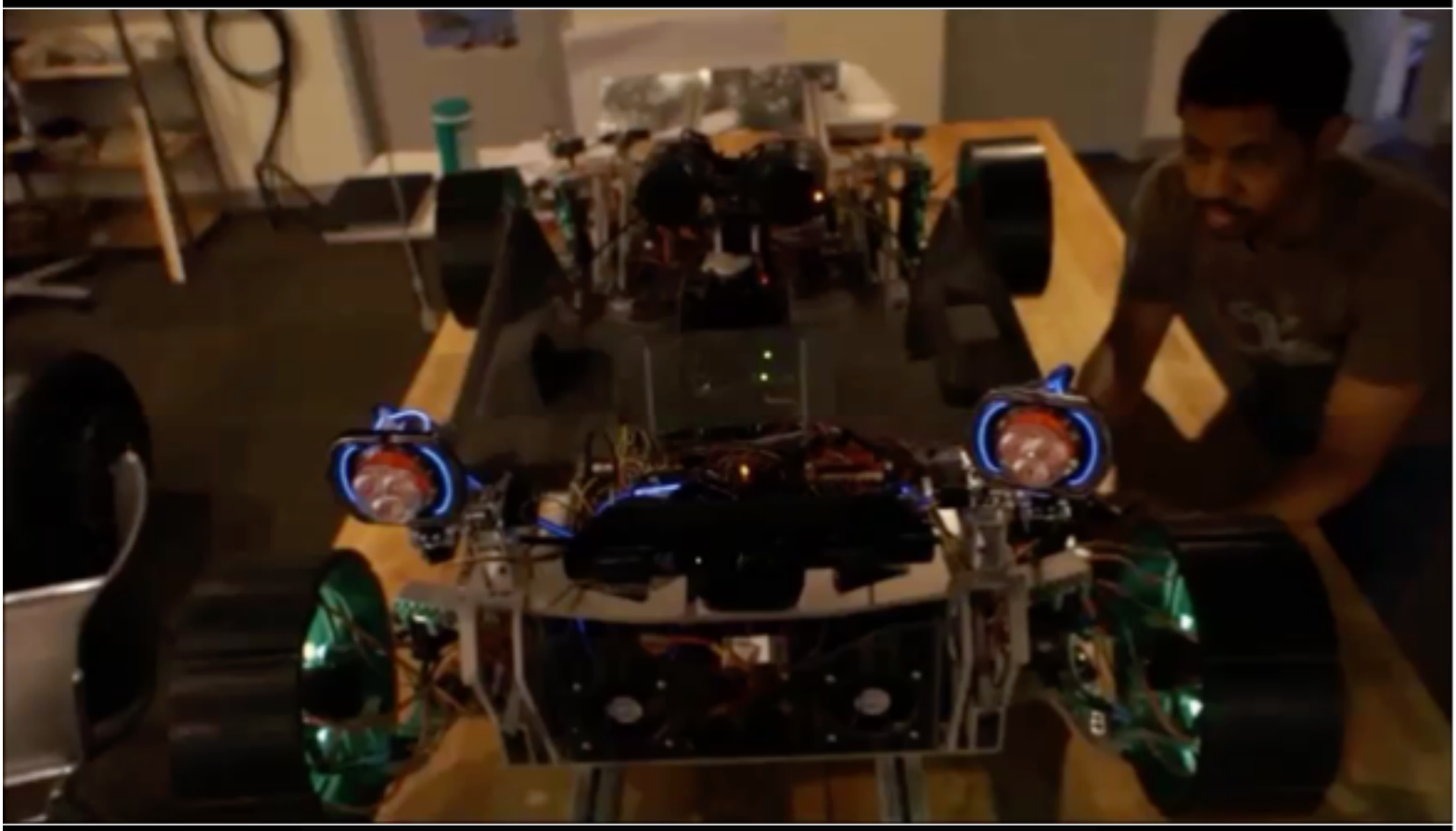
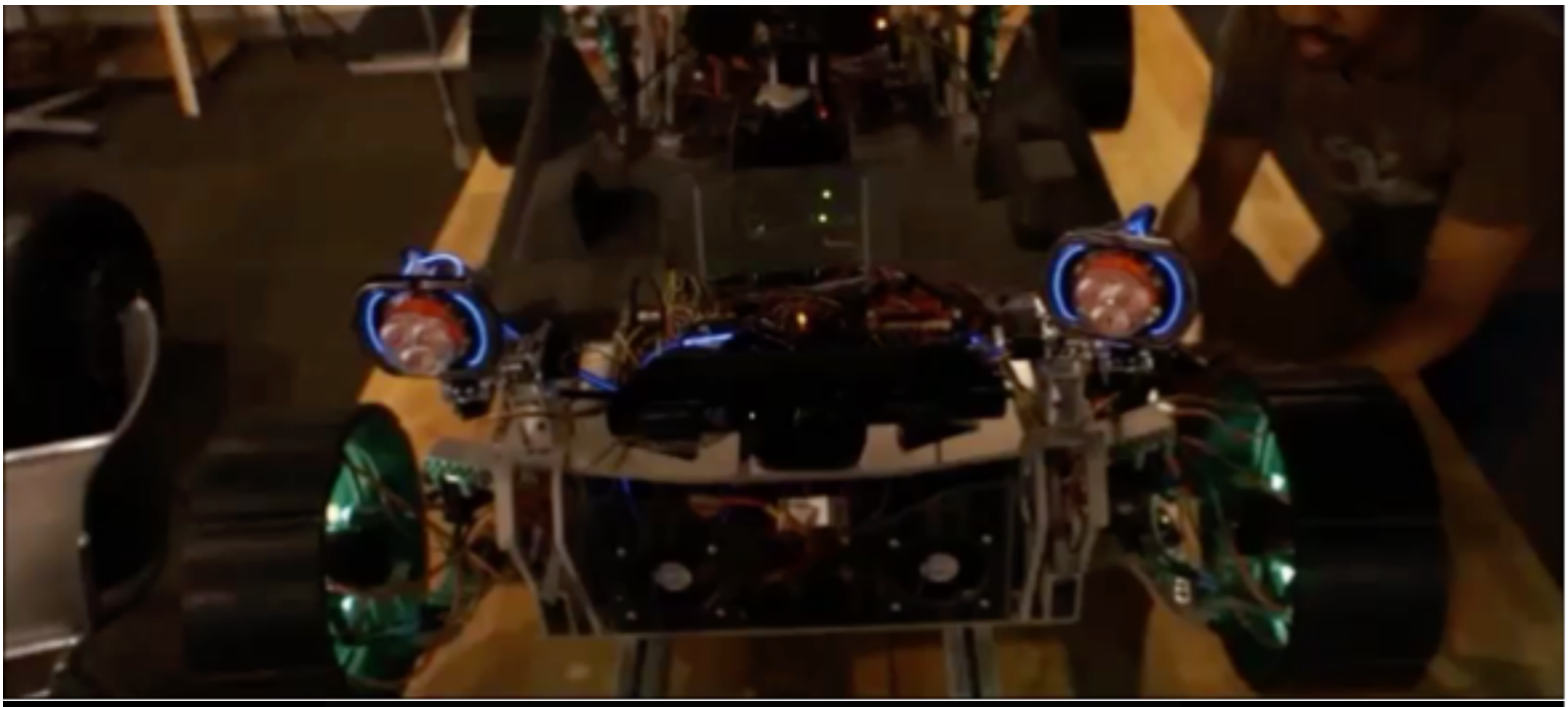


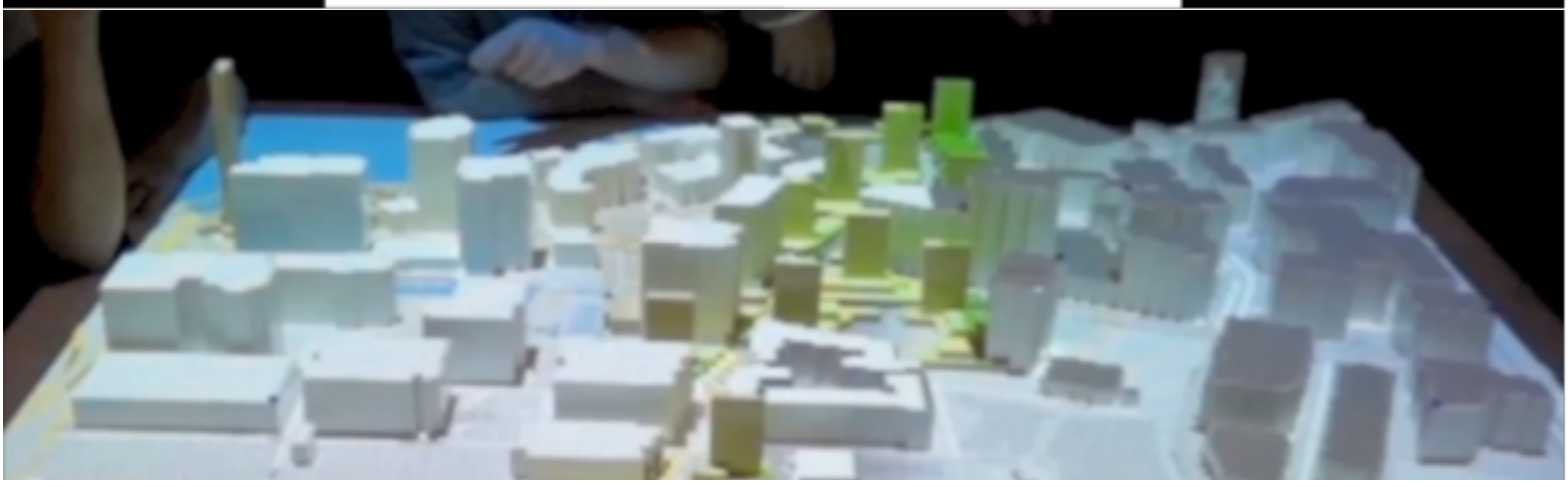
Smithsonian.com



Smithsonian.com

(Photo: Marcia Taylor)

Hamburg Plans to Become Car-Free By 2034



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Hamburg Plans to Become Car-Free By 2034

Persuasive Electric Vehicle (PEV)

Ryan Chin
Carson Smuts
Waleed Gowharji

Wolfgang Gruel
Michael Lin
Luis Alonso

Kent Larson

4

Hyper-efficient Places of

Persuasive Electric Vehicle (PEV)

Ryan Chin
Carson Smuts
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Kent Larson

4

Hyper-efficient Places of Living & Work

(transformable homes and co-working to increase diversity in cities)

4

Hyper-efficient Places of Living & Work

(transformable homes and co-working to increase diversity in cities)

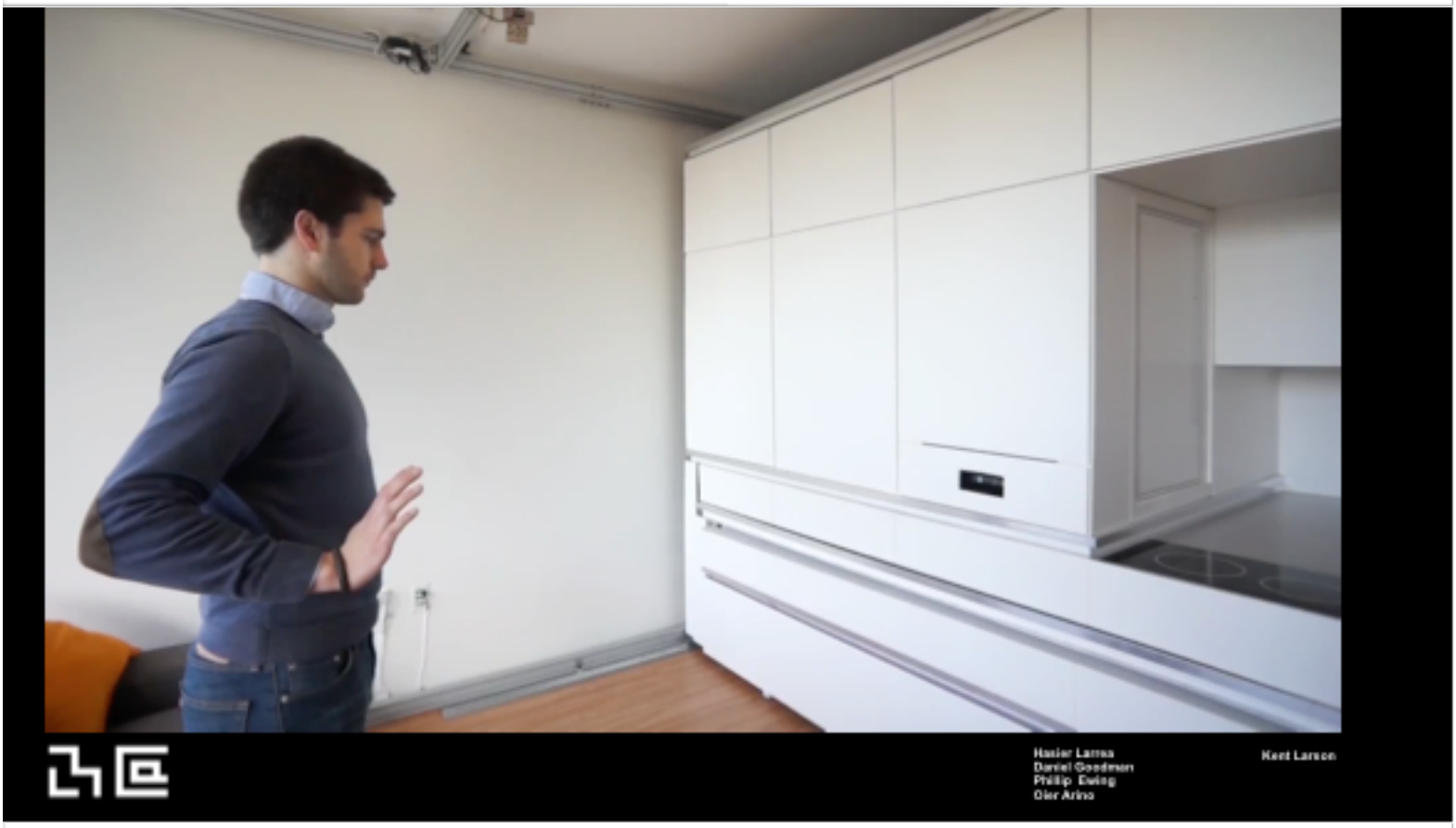
300sf Manhattan Micro-Unit

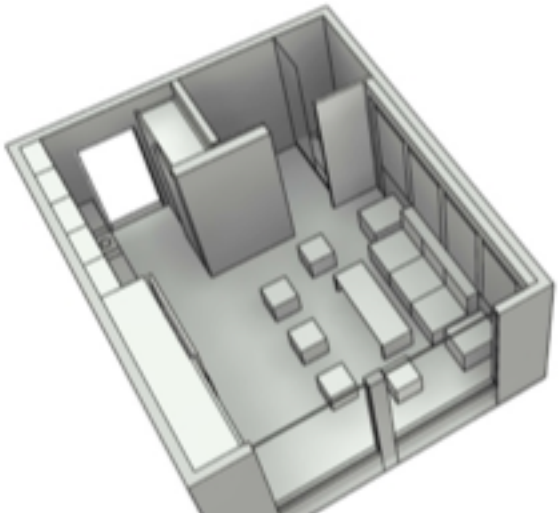
What if 200ft² could be 3x larger?

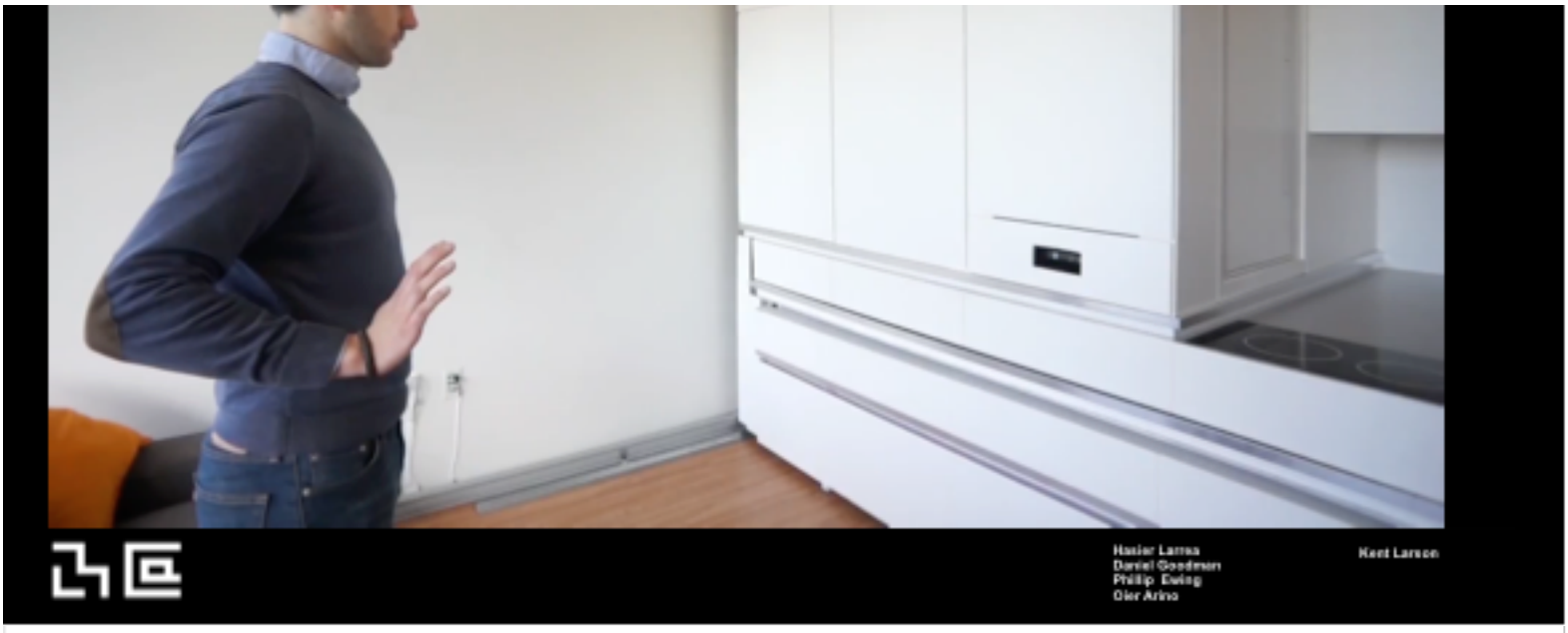
Exercise

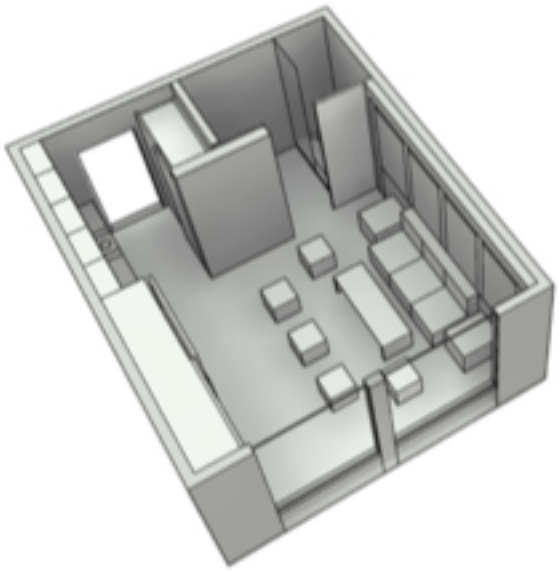
What if 200ft² could be 3x larger?

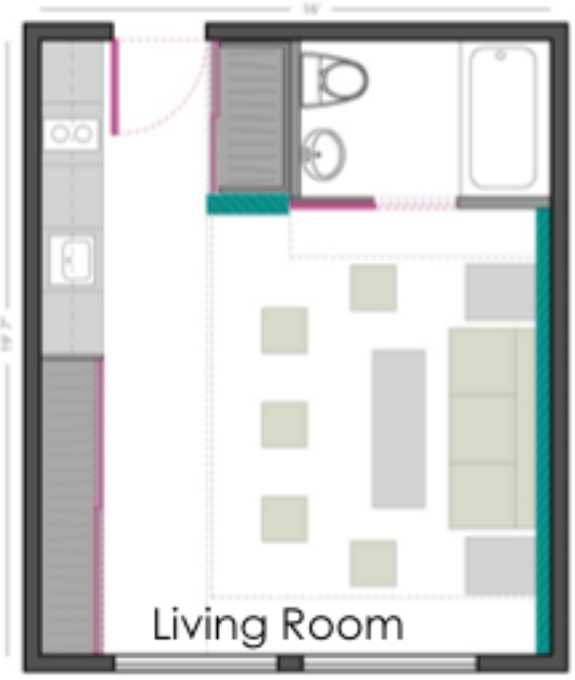
What if 200ft² could be 3x larger?





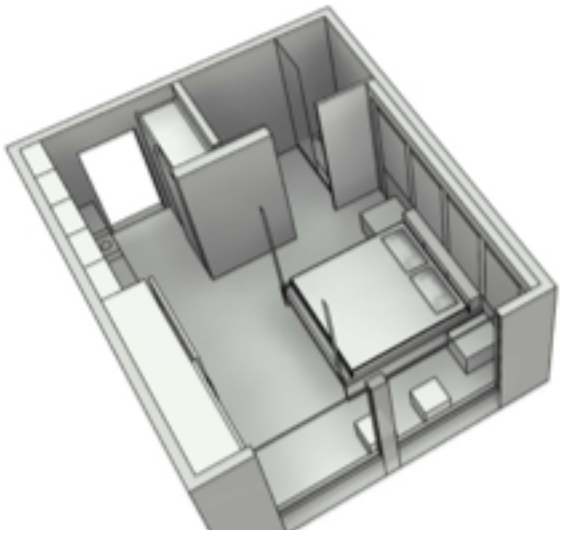


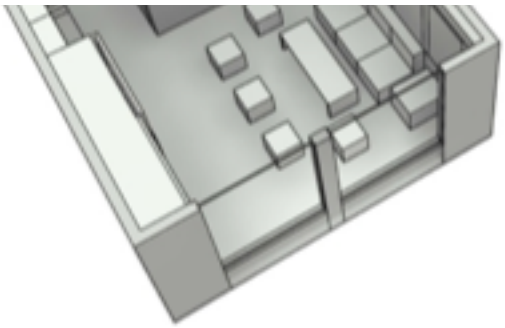




313ft² (29m²) Transformable CityHome

Zbode Systems





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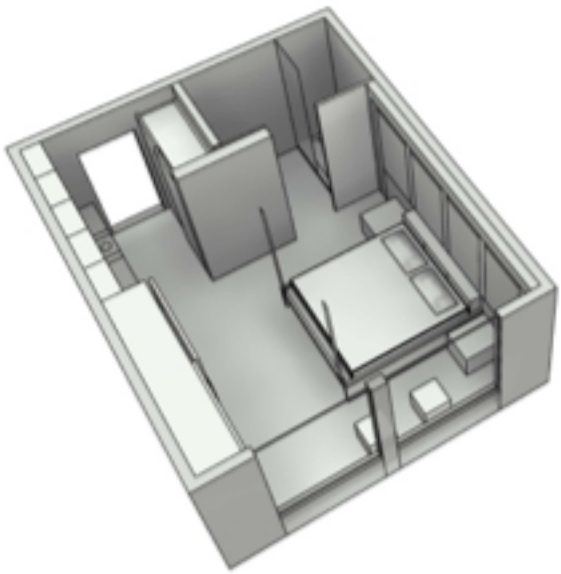

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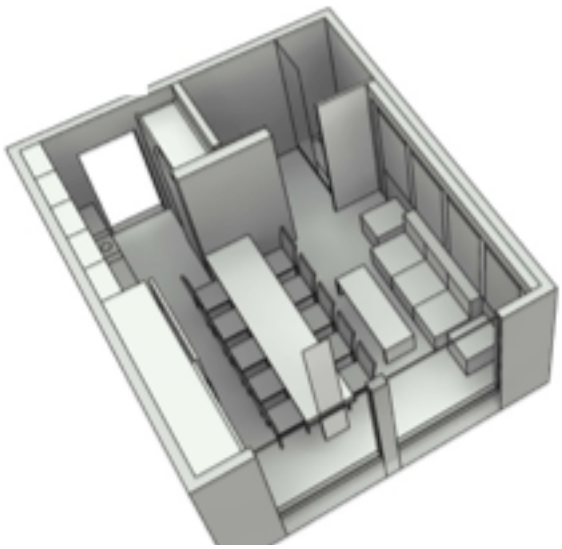
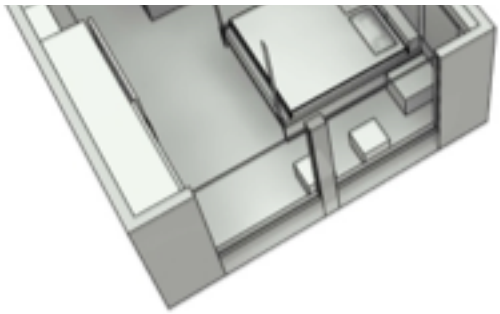
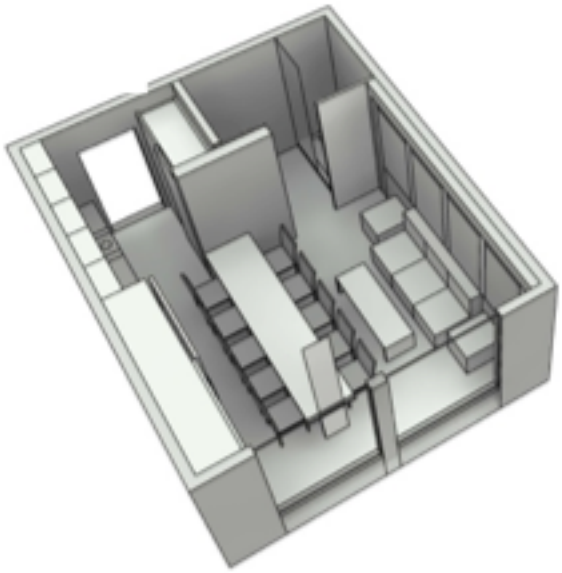
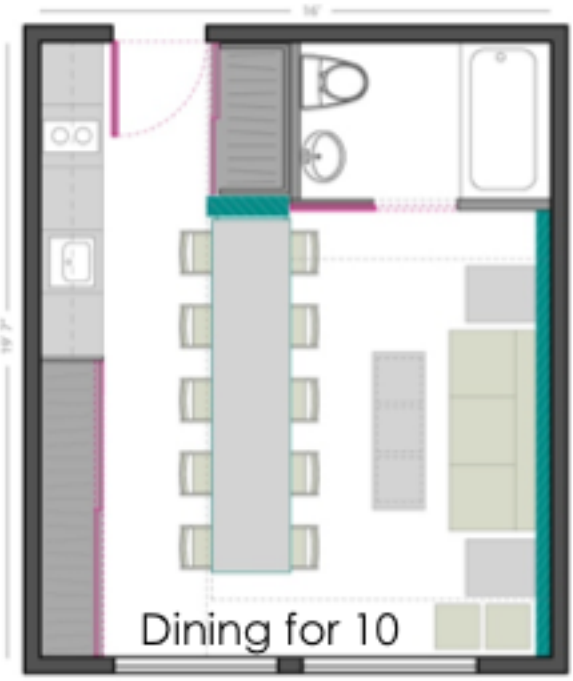




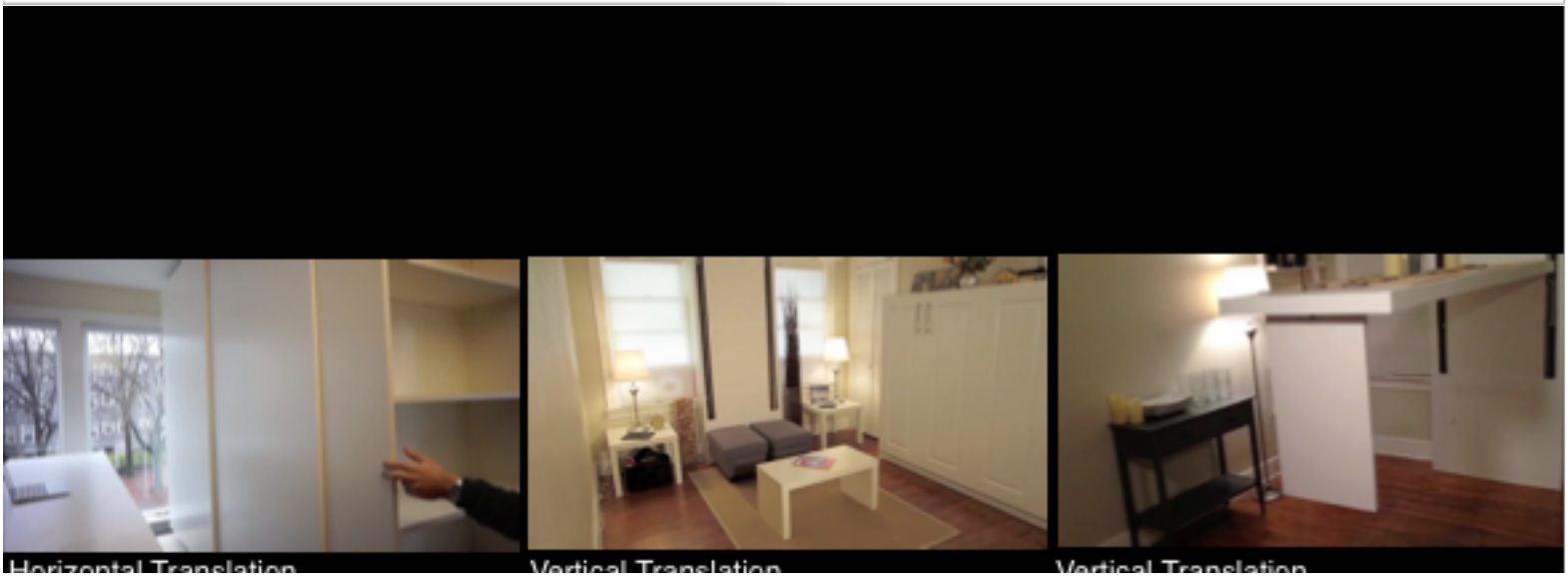
313ft² (29m²) Transformable CityHome

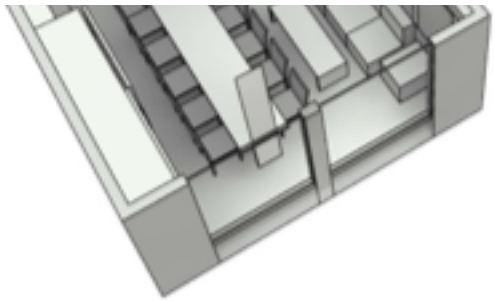
Zbode Systems





313ft² (29m²) Transformable CityHome





313ft^2 (29m^2) Transformable CityHome

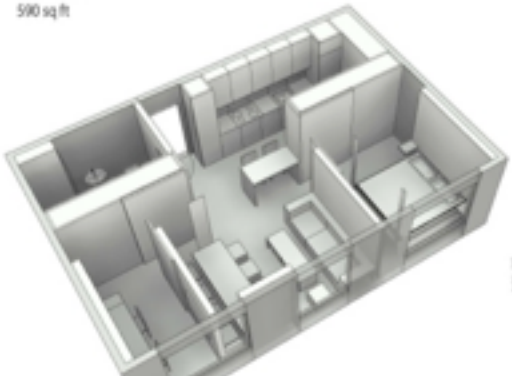
Horizontal Translation

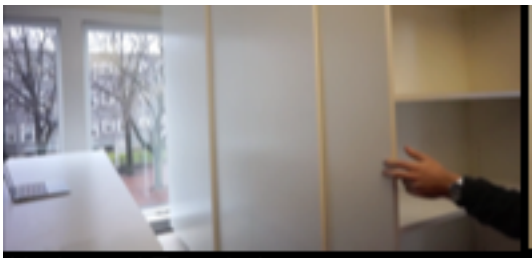
Vertical Translation

Vertical Translation

Zbode Systems

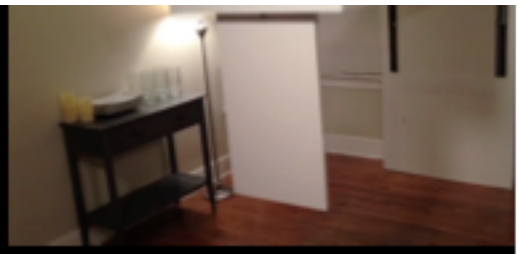
Three Bay Apartment
2 Bedroom
1 Bathroom
590 sq ft





Horizontal Translation

Vertical Translation



Vertical Translation

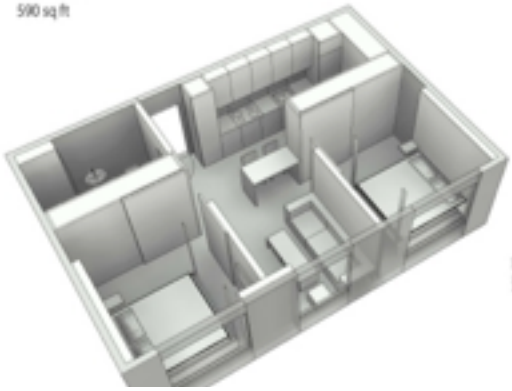
Zbode Systems

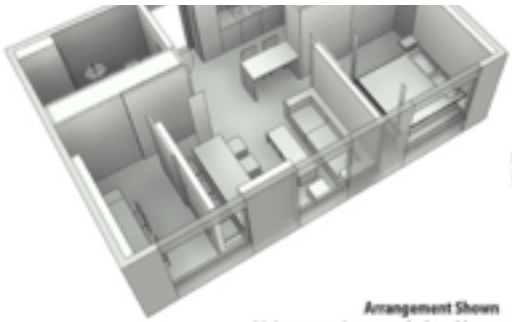
Three Bay Apartment
2 Bedroom
1 Bathroom
590 sq ft

Arrangement Shown
Living room is expanded and large dining table is deployed to accommodate dinner for 8.
A private offices is maintained behind transforming wall.

Zbode Technologies:
2 RoboWalls
1 Ceiling-Deployed Table
2 Ceiling-Deployed Bed w/ Desk

Three Bay Apartment
2 Bedroom
1 Bathroom
590 sq ft





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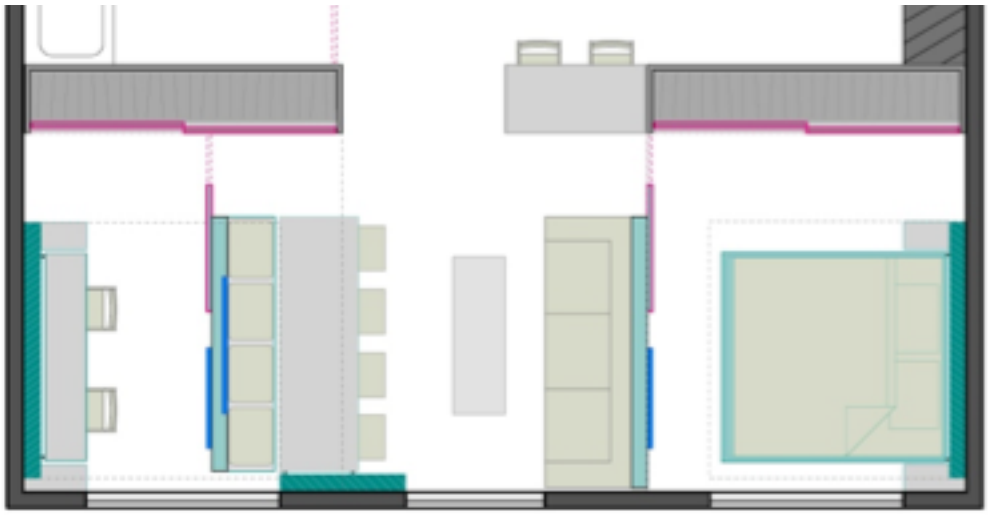

Three Bay Apartment
2 Bedroom
1 Bathroom
590 sq ft

Arrangement Shown
King size beds are deployed to the ground within each private bedroom.
The living room is arranged for typical lounge and entertainment.

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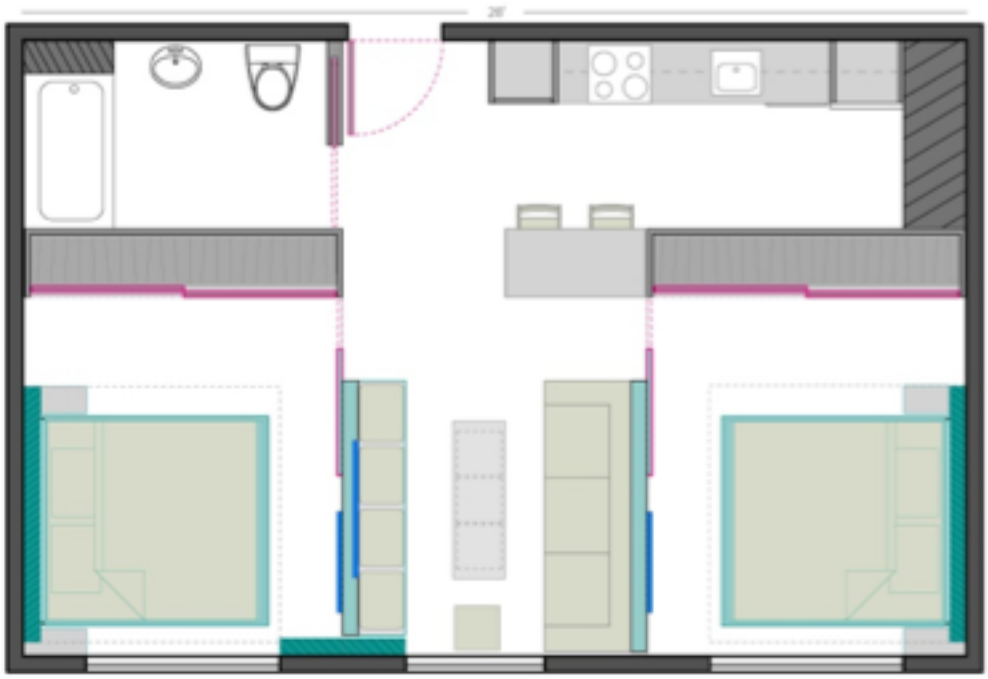
2 RoboWalls
1 Ceiling-Deployed Table
2 Ceiling-Deployed Bed w/ Desk



Three Bay Apartment
2 Bedroom
1 Bathroom
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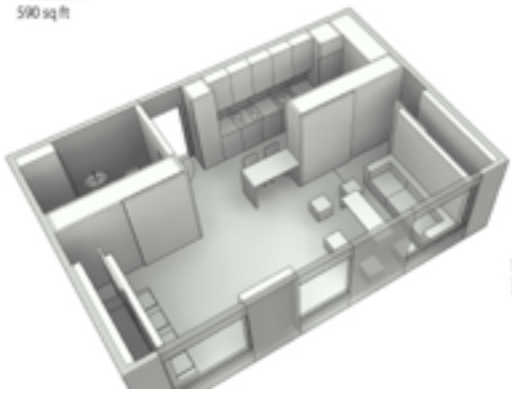

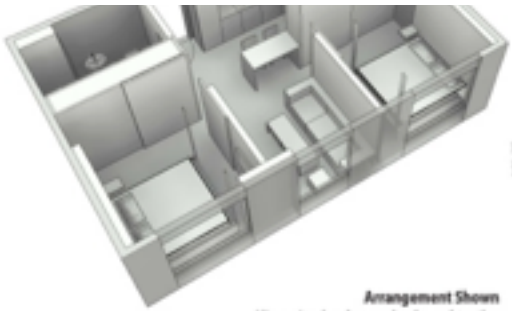

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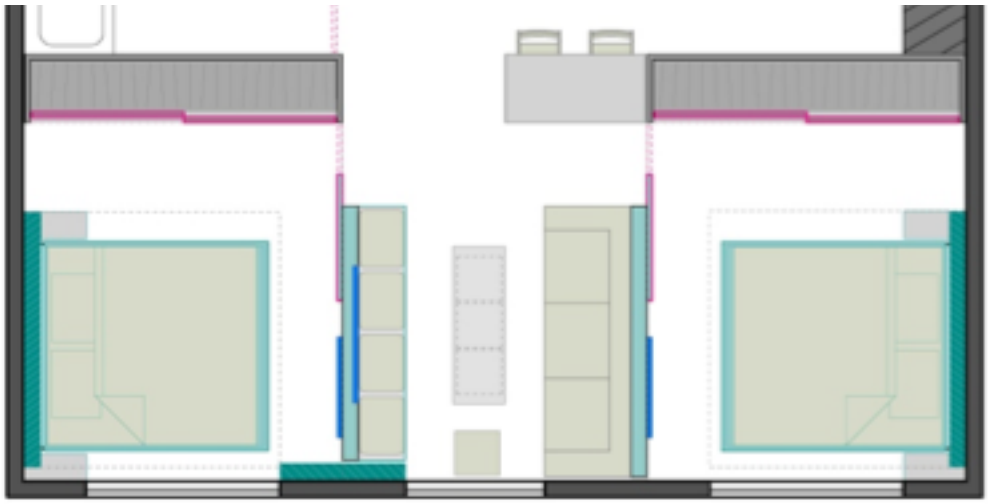
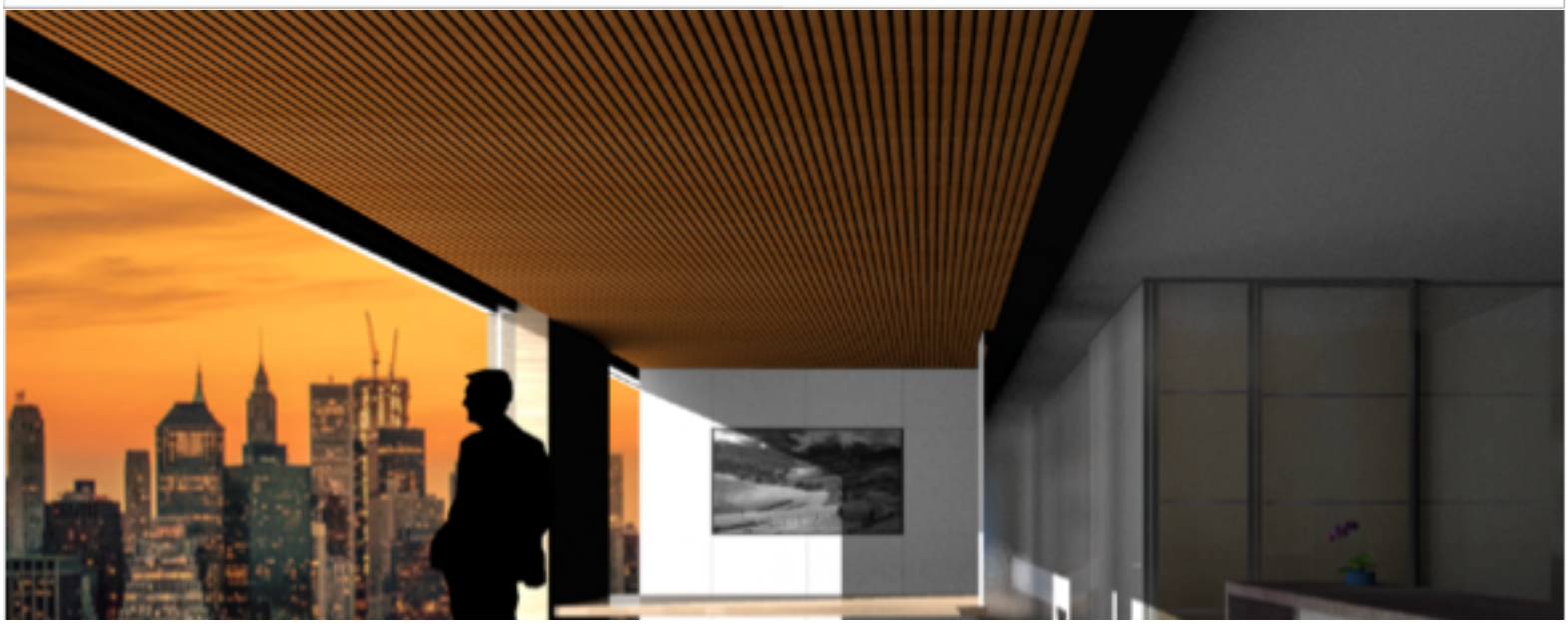


Three Bay Apartment
2 Bedroom
1 Bathroom
590 sq ft

Arrangement Shown
Apartment space is fully opened to accommodate larger groups and activities.

Zbode Technologies:
2 RoboWalls
1 Ceiling-Deployed Table
2 Ceiling-Deployed Bed w/ Desk



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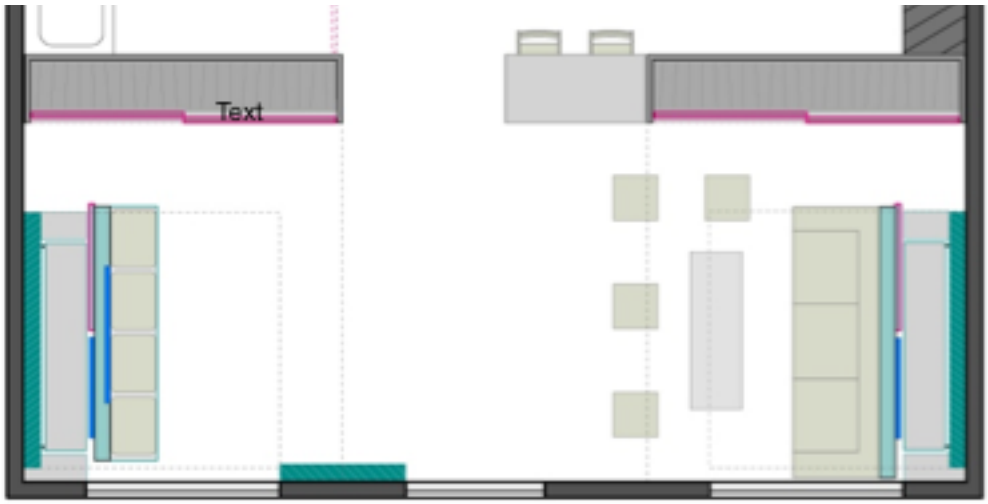
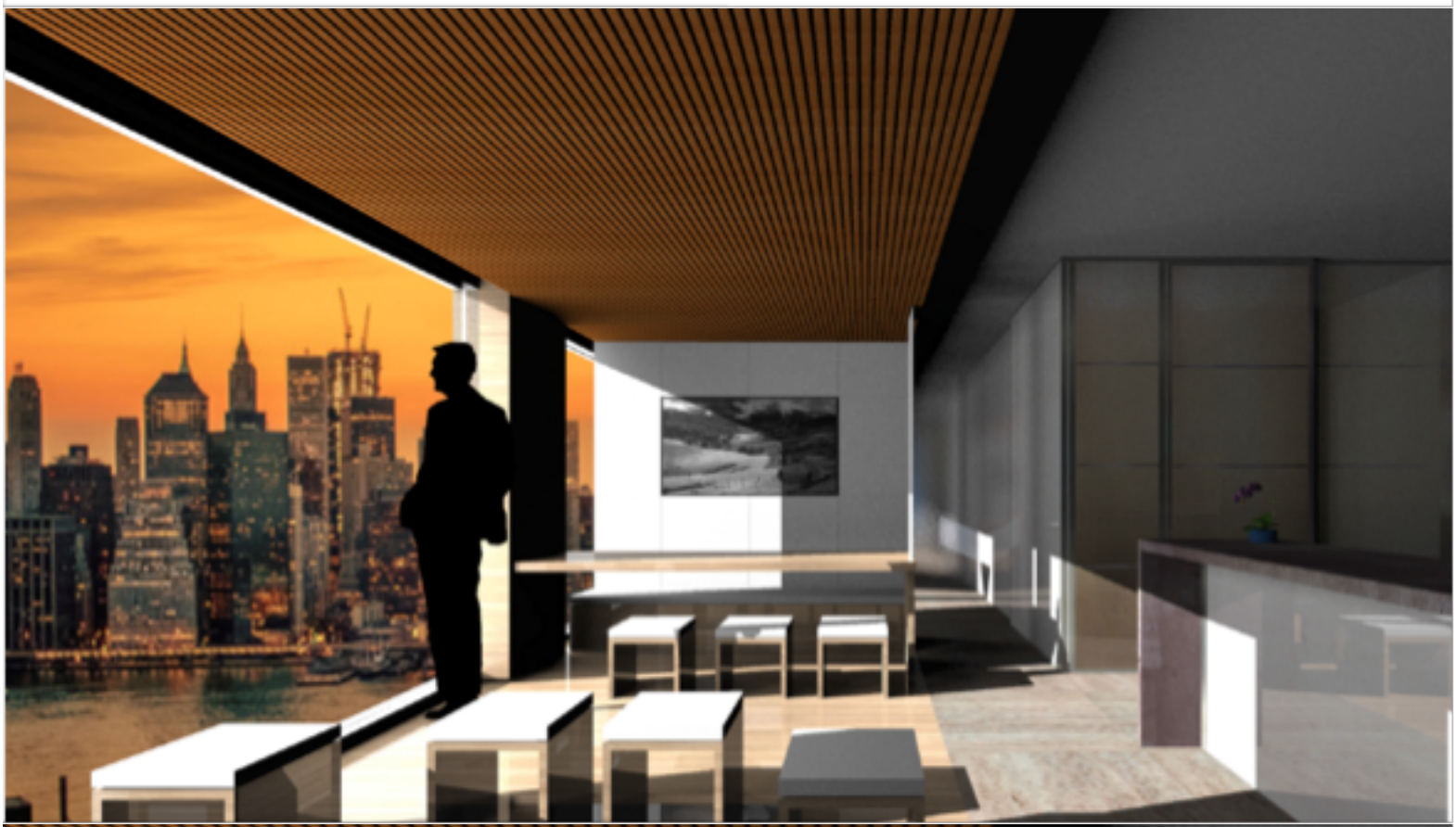
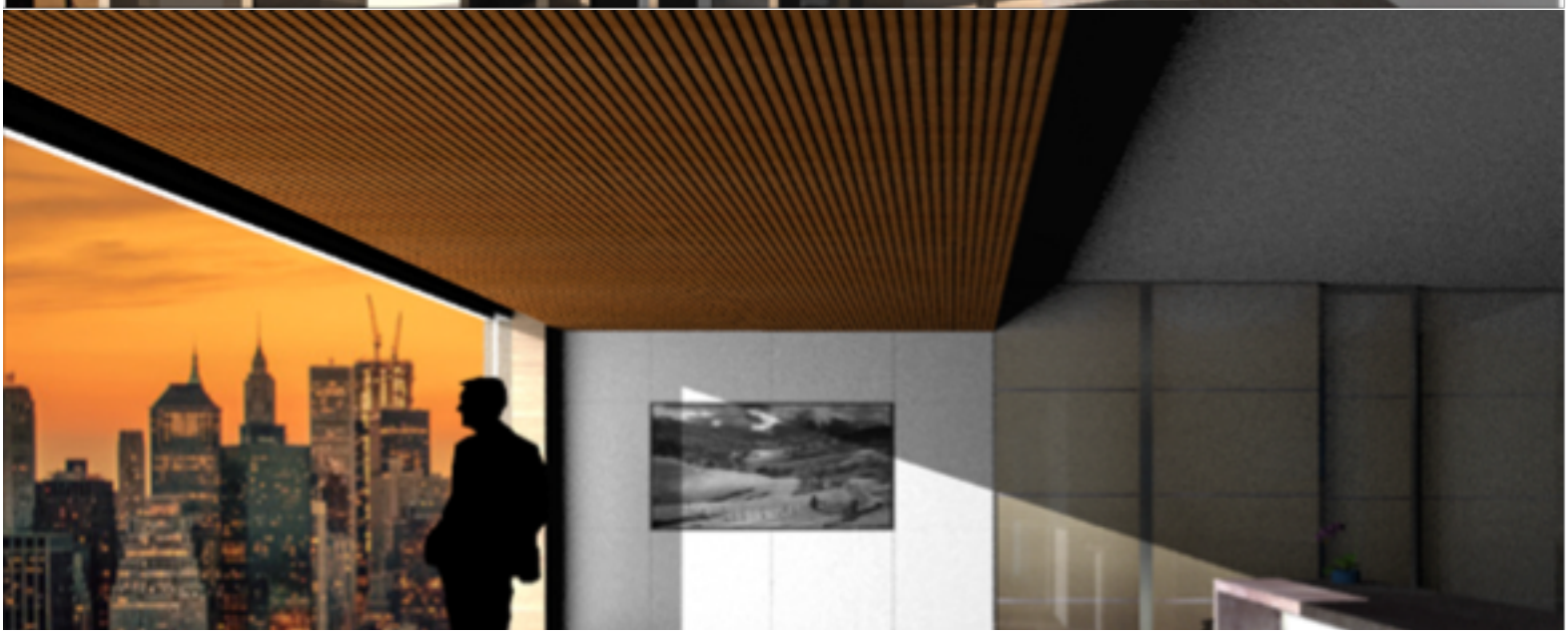
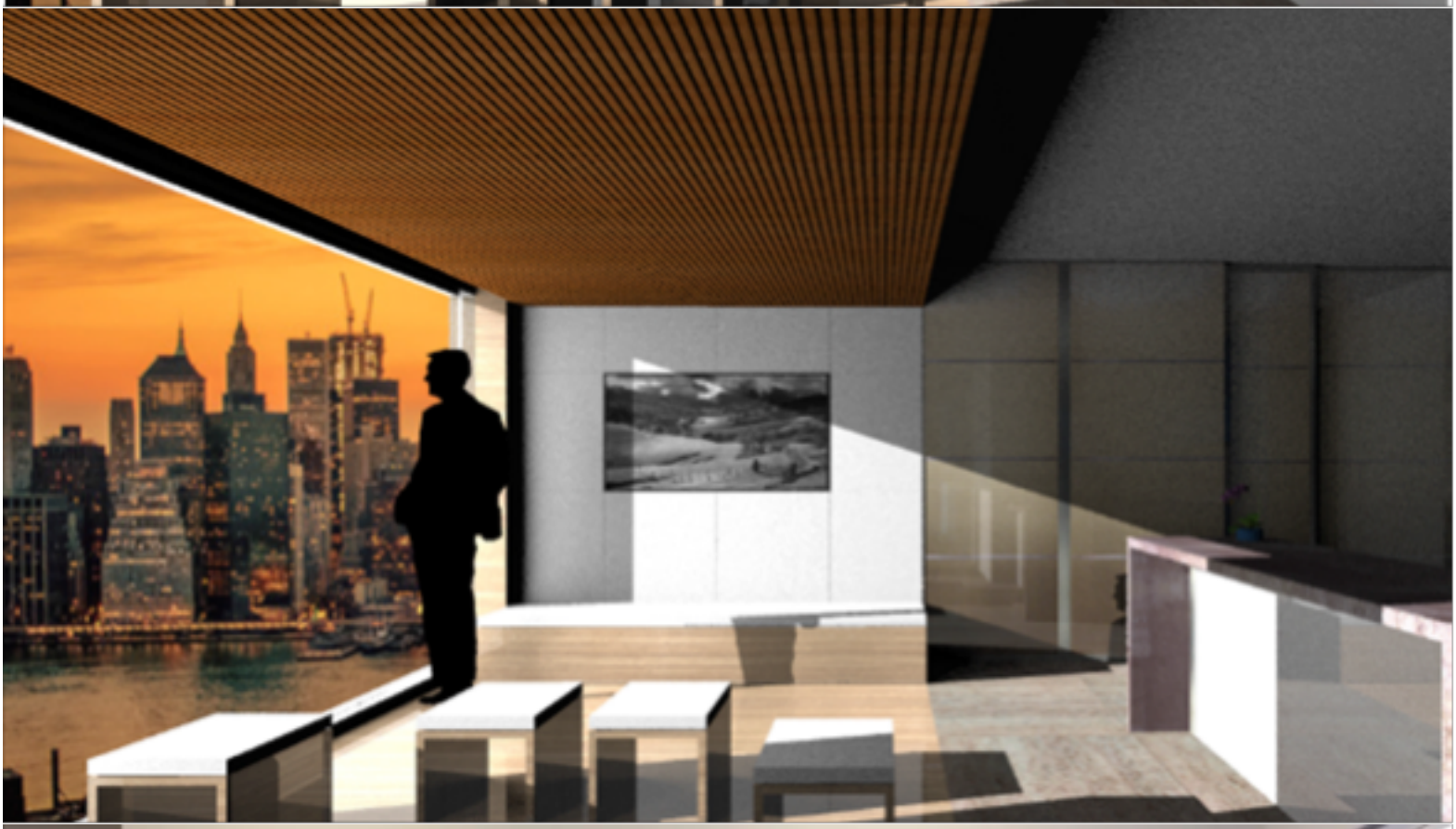




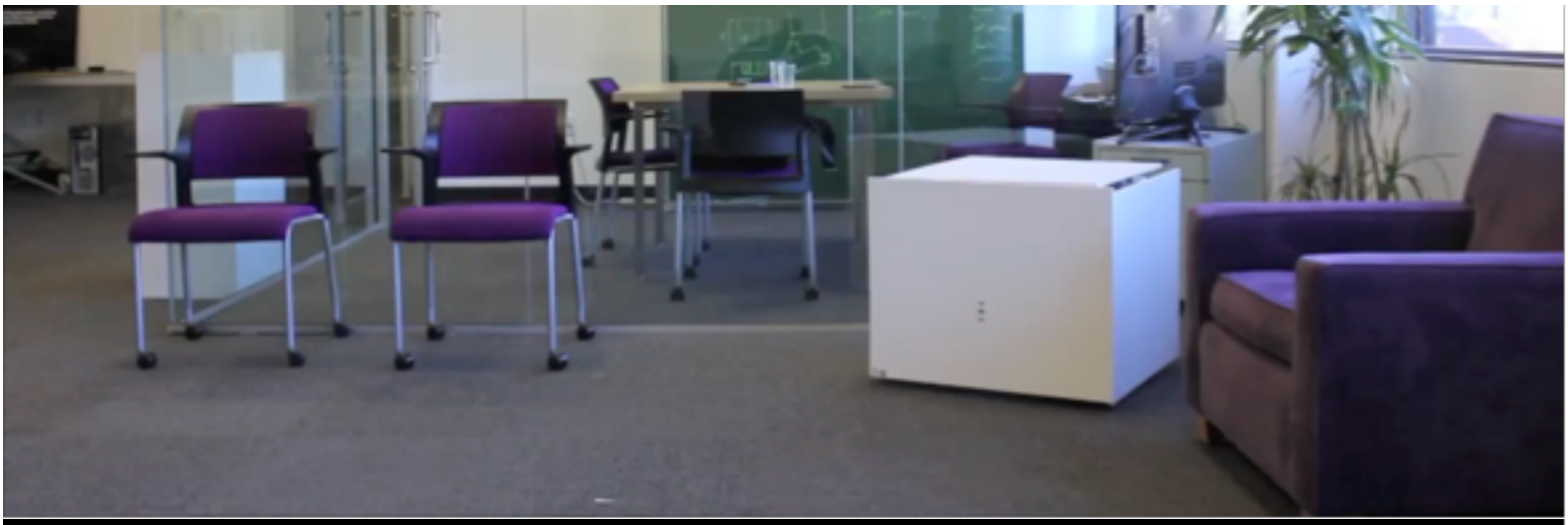




5

Responsive Technology

(responding in real-time to human activity)



5

Responsive Technology

(responding in real-time to human activity)

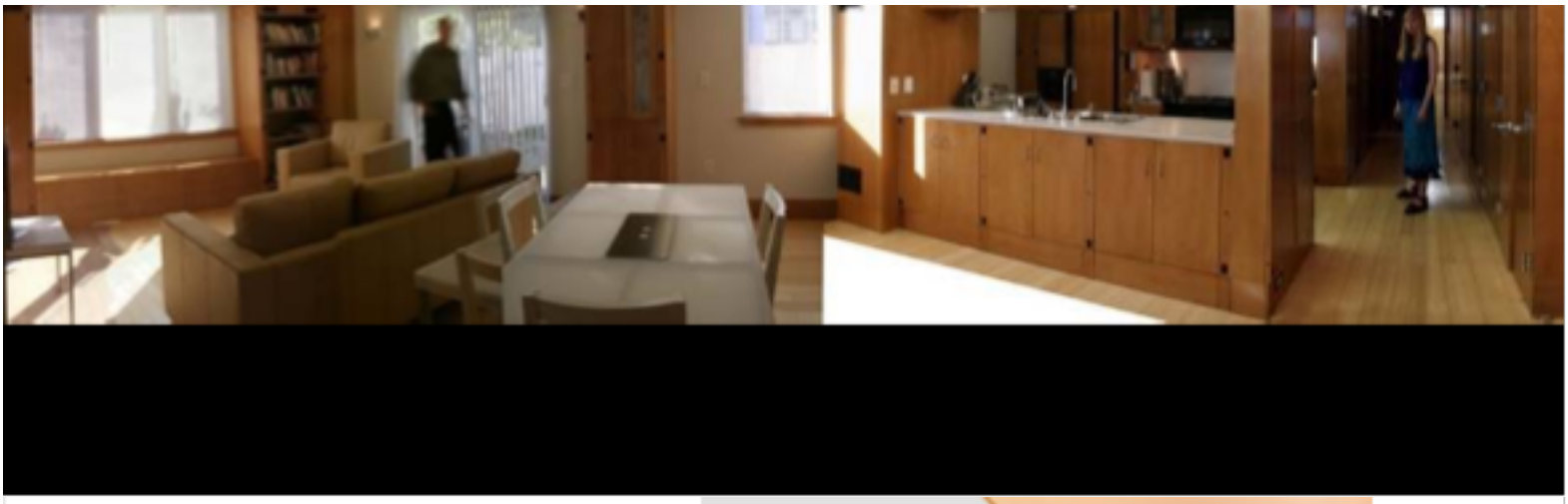
Place Lab

Responsive Technology

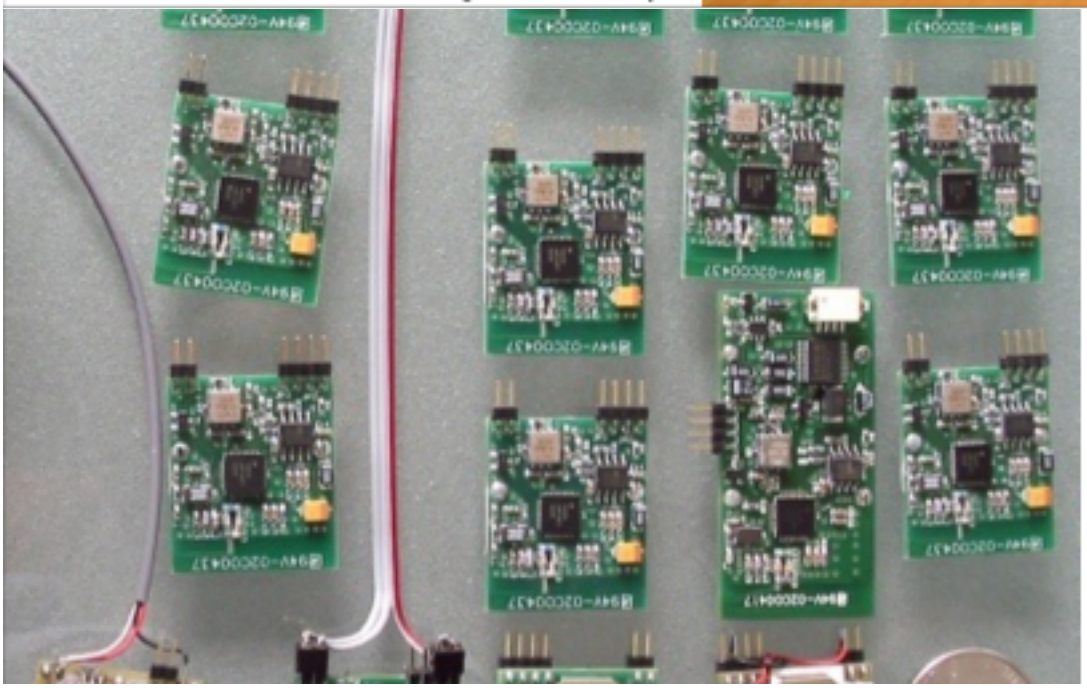
(responding in real-time to human activity)

Place Lab

Place Lab

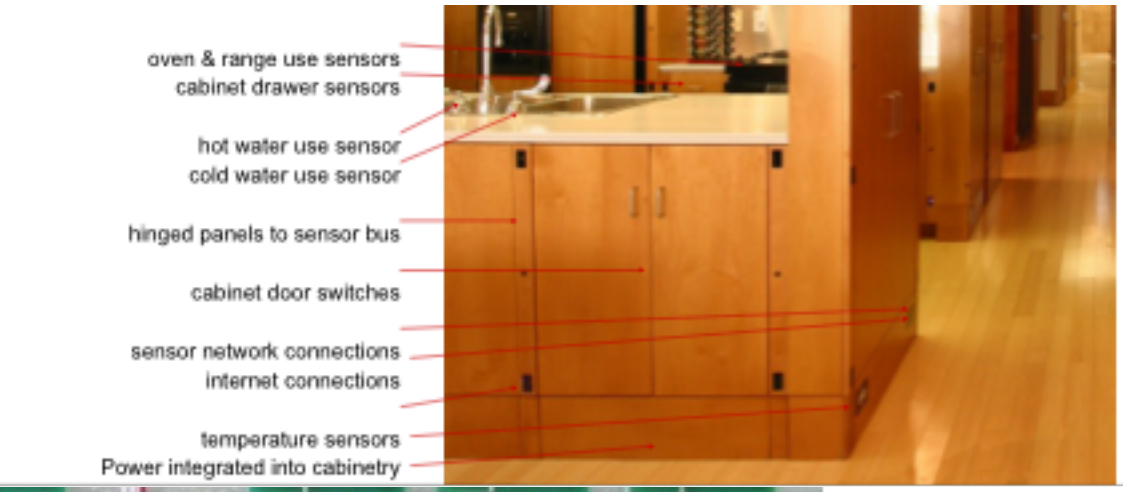


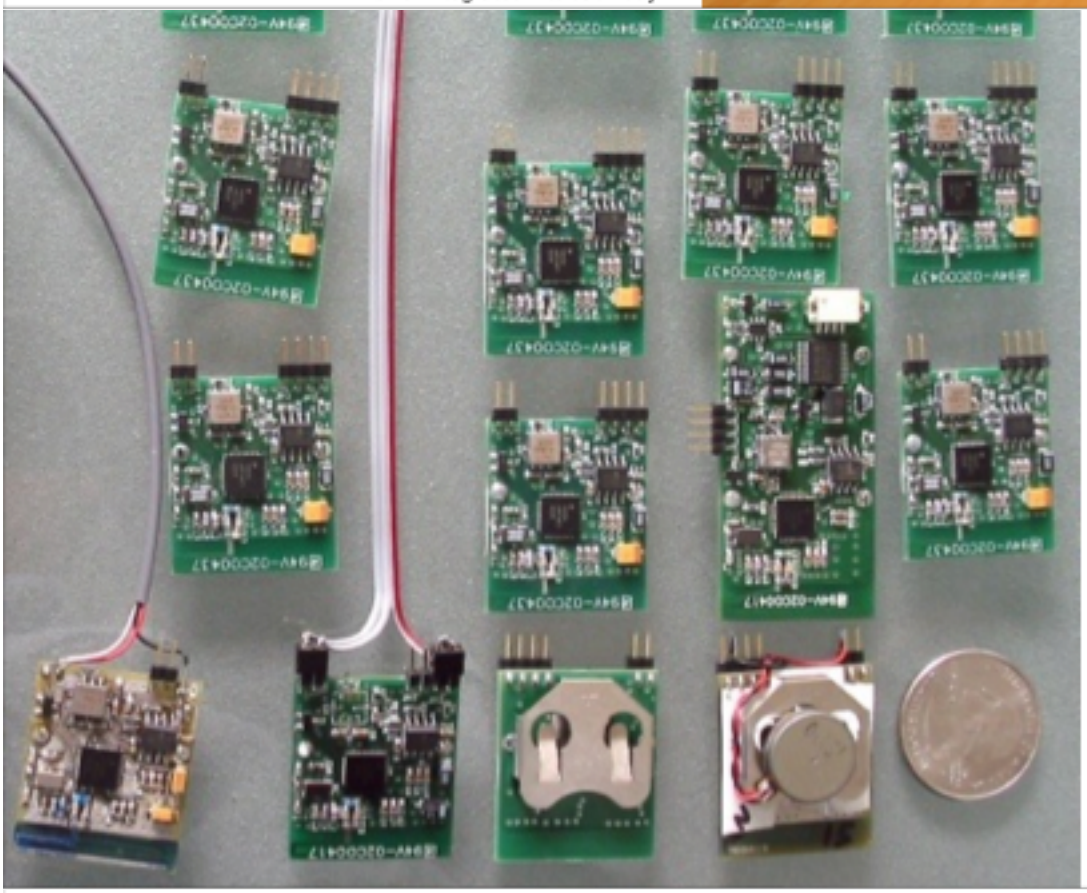
Place Lab



MITes
(MIT Environmental Sensors)

1) Object motion
2) Body movement
3) Temperature
4) Light level
5) RFID reader
6) Haptic output
7) Location beacons
8) IR distance ranger
9) Electrical current
   (Electrical device use)
10) Ultra violet light
11) Heart rate monitor





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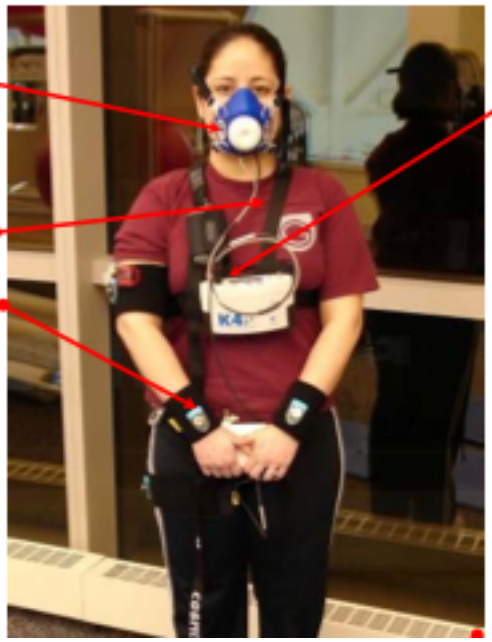
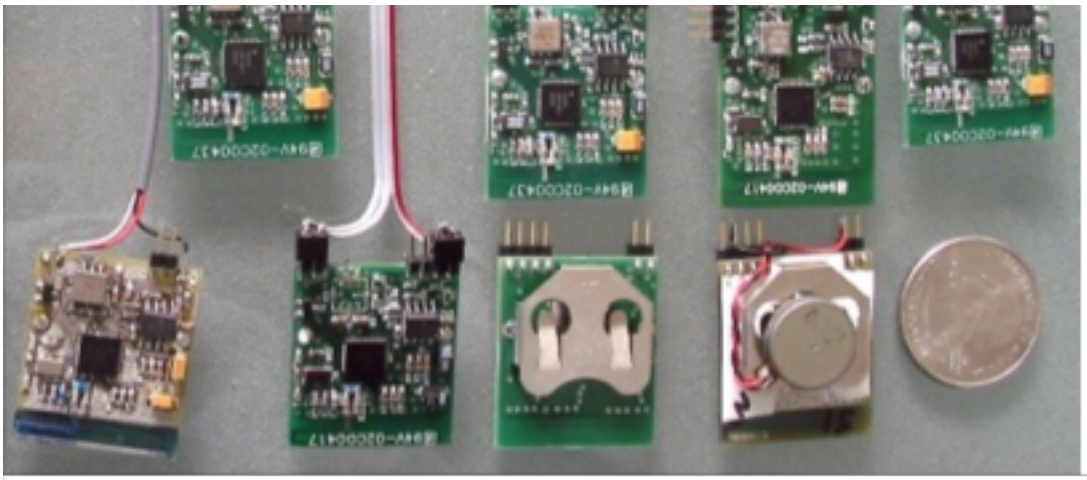
Emmanuel Muguia Tapia, MAS PhD Thesis, energy expenditure recognition





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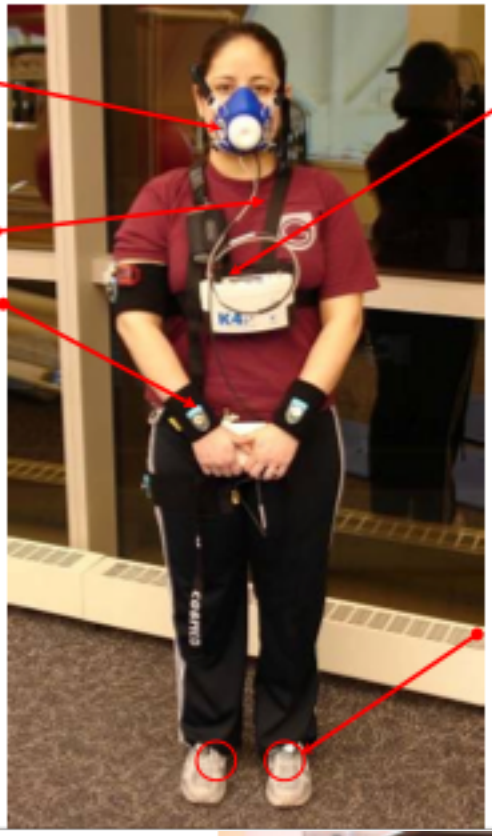


Exercise activities

Motion MITes
3 axis
accelerometers
@ 30Hz

Exercise activities

Domestic activities

Domestic activities

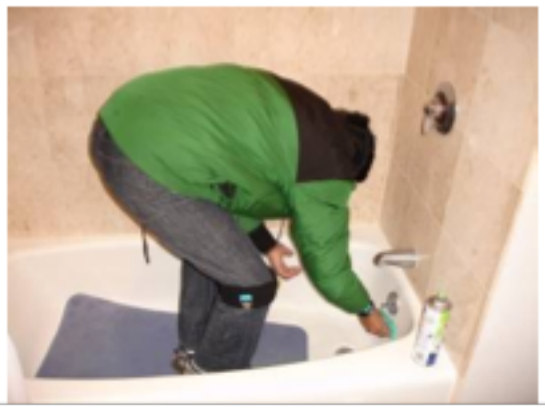
Activity recognition results (52 activities)

Household activities

Type	Type
Carrying groceries	Vacuuming
Doing dishes	Walking around block
Gardening	Washing windows
Ironing	Watching TV
Making the bed	Weeding
Mopping	Wiping/Dusting
Playing videogames	Writing
Scrubbing a surface	Taking out trash
Stacking groceries	

Gym activities

Type	Intensity
Running	Treadmill 5mph at 0% grade
Running	Treadmill 6mph at 0% grade
Stairs Ascend stairs	Not applicable
Stairs Descend stairs	Not applicable
Cycling	80 rpm, light, moderate, hard
Cycling	60 rpm, light
Cycling	100 rpm, light
Rowing	30 spm, light, moderate, hard
Bicep curls	Light, moderate, hard



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Typing	

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Rowing	30 spm, light, moderate, hard
Bicep curls	Light, moderate, hard
Bench weight lifting	Light, moderate, hard
Sit-ups	Not applicable
Crunches	Not applicable

52 activities: Sensor subsets and activity recognition

Sensor Combination	Subject Dependent Accuracy
All sensors	87.9 ± 2.0
Hip + DWrist + DFoot	-1.8 %
Hip + DFoot	-3.5 %
Hip + DWrist	-4.9 %
DWrist + DThigh	-7.2 %
DWrist + DFoot	-7.7 %
Hip	-8.4 %
DFoot	-14.9 %
DThigh	

Sensor Combination	Subject Independent Accuracy
All sensors	50.6 ± 5.2
Hip + DWrist + DFoot	-7.9 %
DWrist + DThigh	-8.1 %
DWrist + DFoot	-13.0 %
Hip + DWrist	-15.6 %
Hip + DFoot	-18.9 %
DUpperArm	26.5 %
DWrist	-27.7 %
Hip	-28.5 %

Mopping	Wiping/Dusting
Playing videogames	Writing
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DUpperArm	-15.4 %
DWrist	-19.6 %

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DUpperArm	26.5 %
DWrist	-27.7 %
Hip	-28.5 %
DFoot	-34.8 %
DThigh	-42.7 %

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DFoot	-14.9 %
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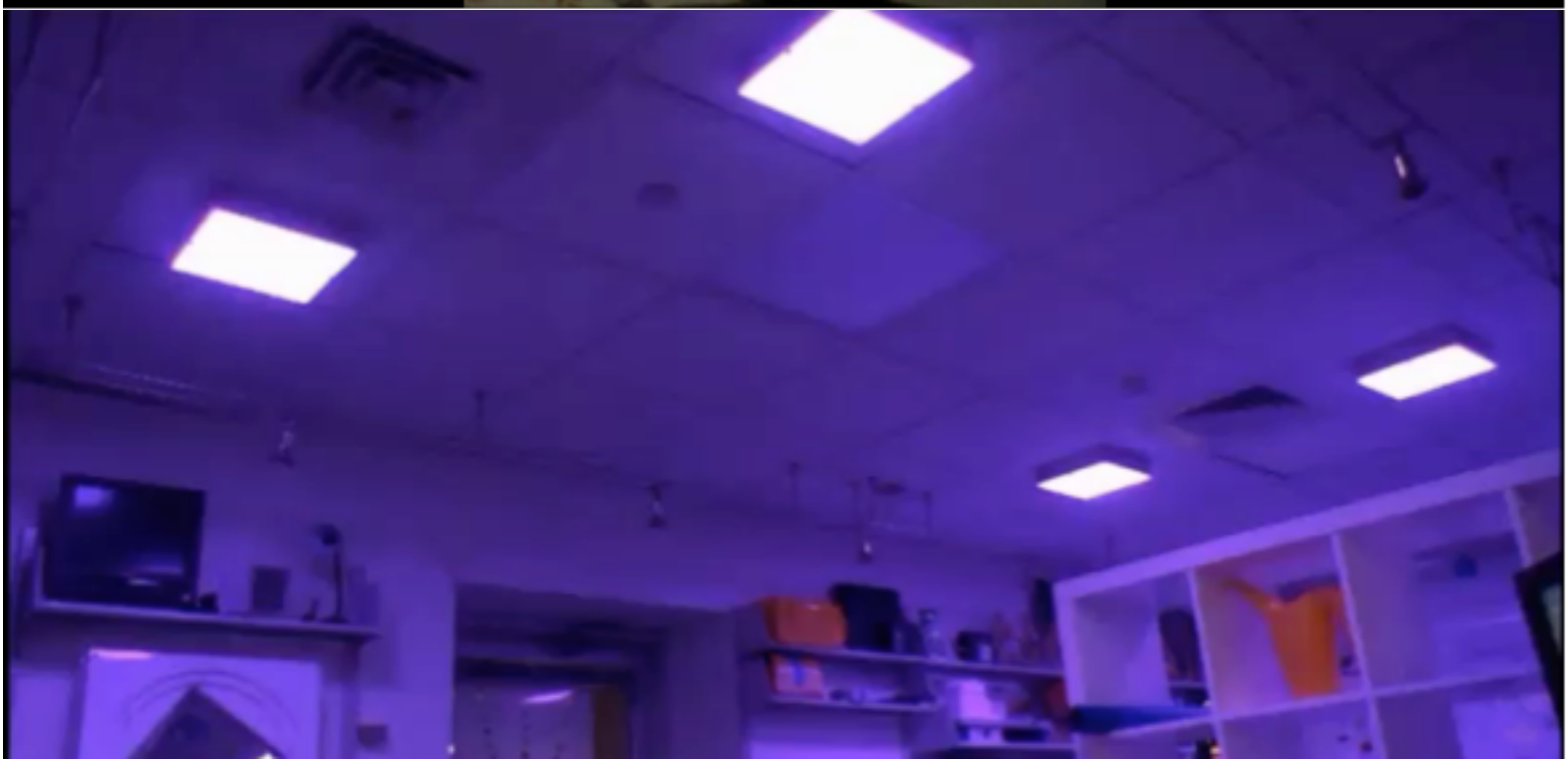
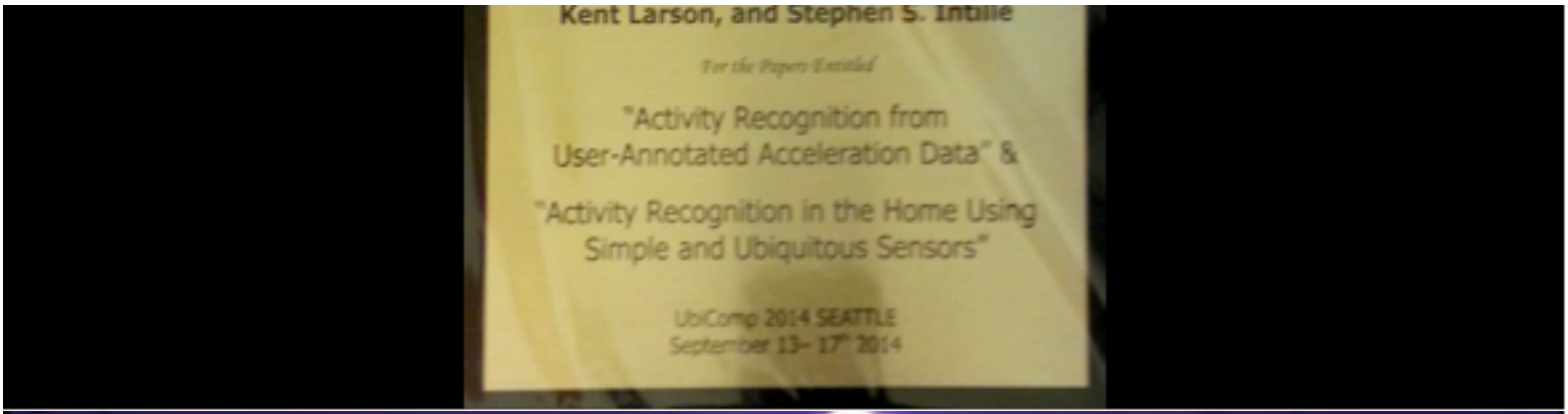
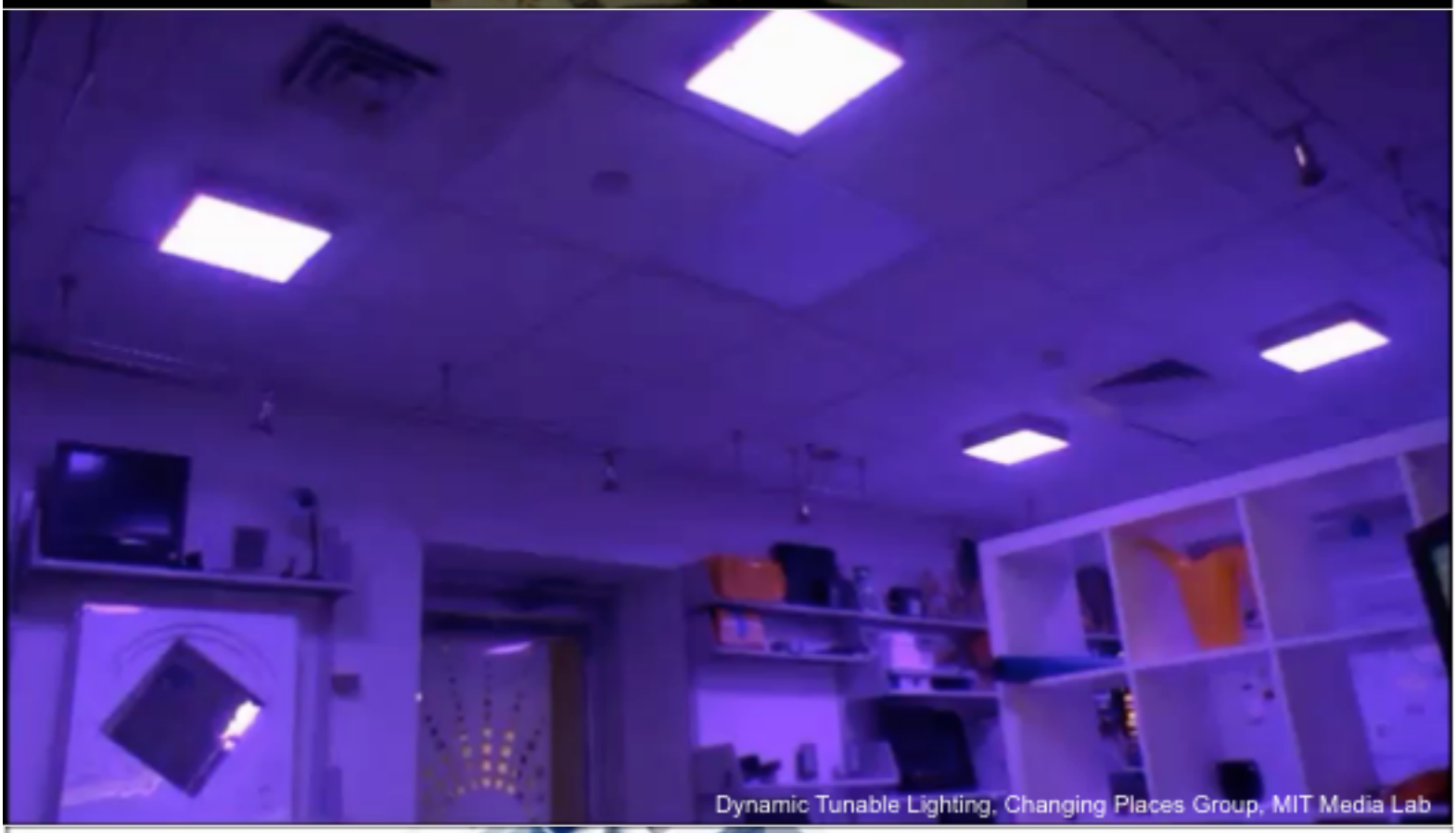
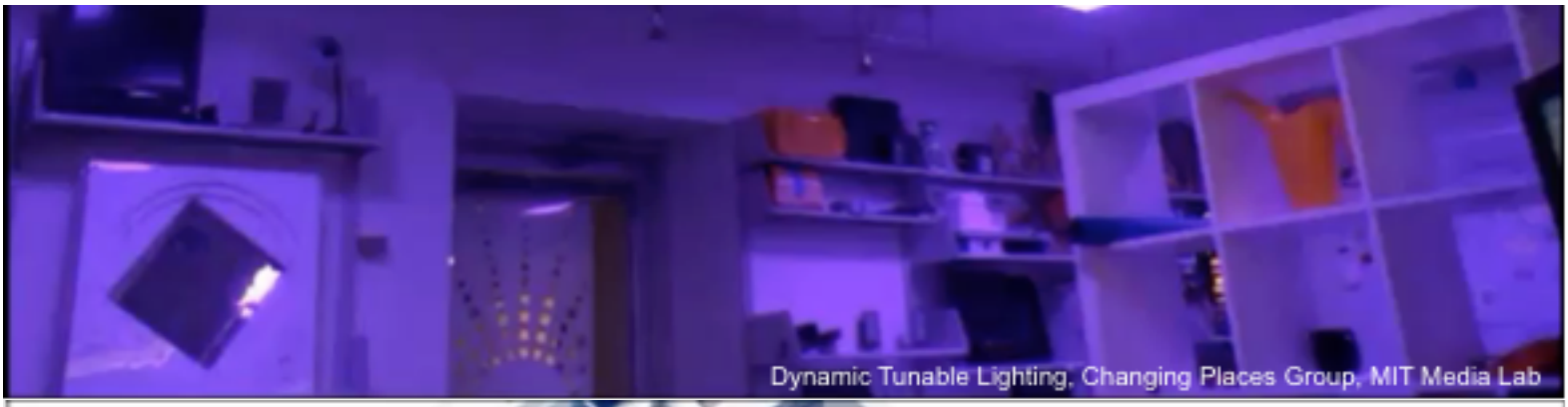



Kent Larson, and Stephen S. Intille
For the Papers Entitled
"Activity Recognition from
User-Annotated Acceleration Data" &
"Activity Recognition in the Home Using
Simple and Ubiquitous Sensors"
UbiComp 2014 SEATTLE
September 13– 17th 2014


Dynamic Tunable Lighting, Changing Places Group, MIT Media Lab



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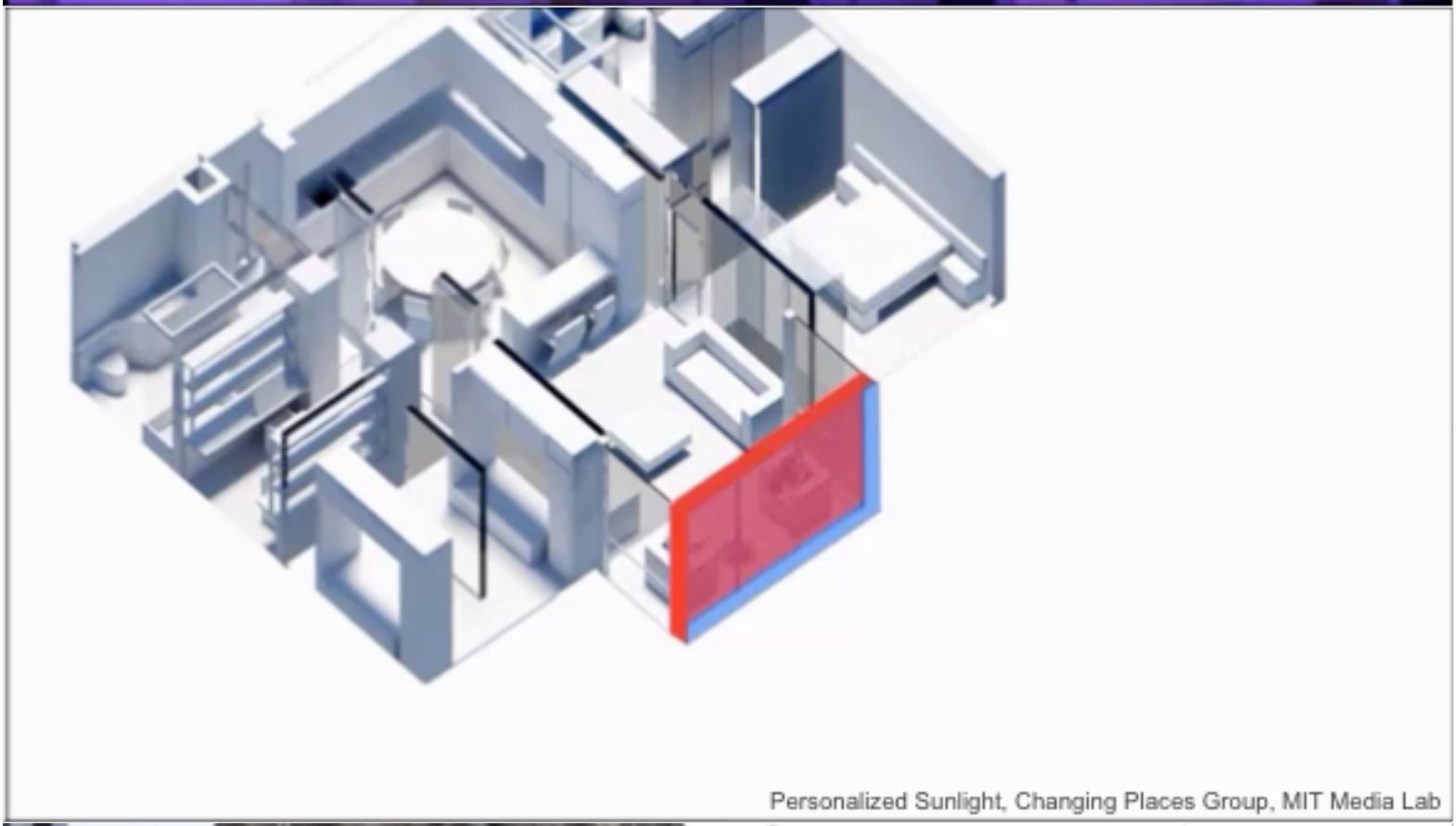
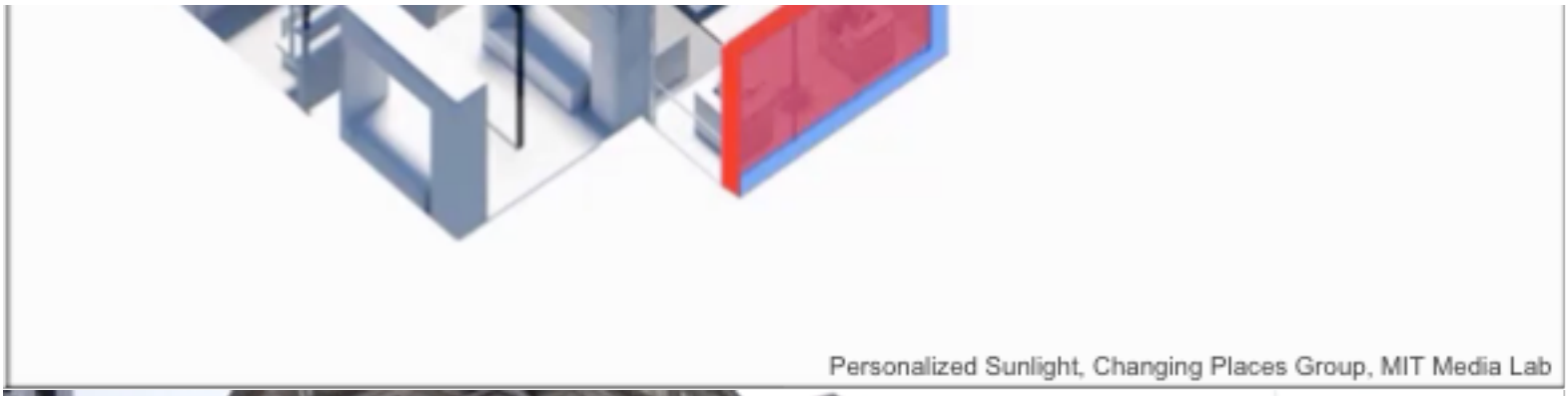


Personalized Sunlight, Changing Places Group, MIT Media Lab



Personalized Sunlight, Changing Places Group, MIT Media Lab

Design for people, not machines (add technology as needed)