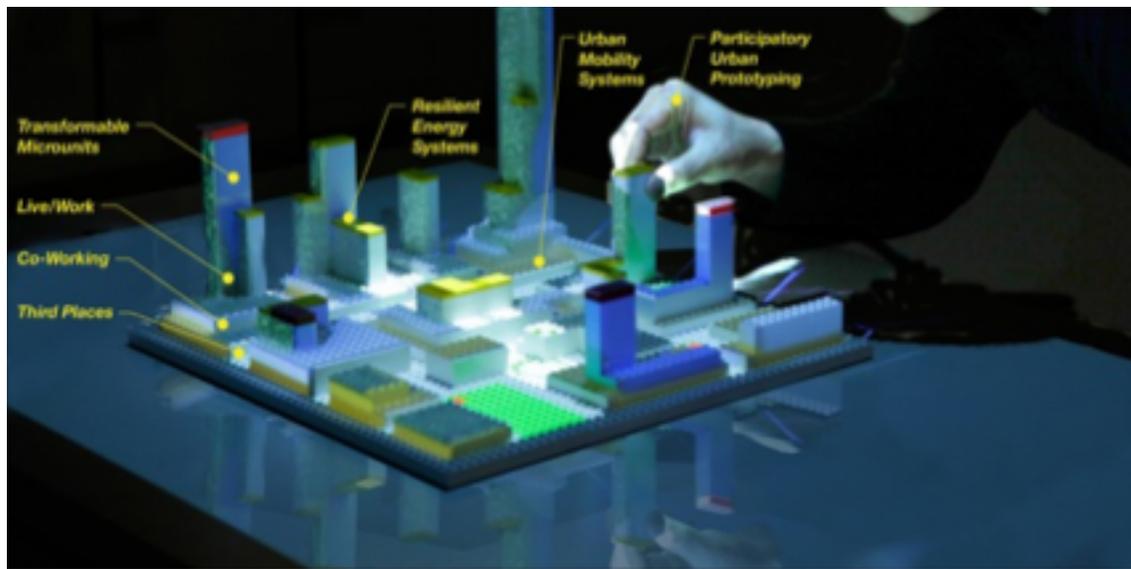


Responsive Cities

2014 NSF Cyber-Physical Systems  
Principal  
Investigators'  
Meeting

Kent Larson  
MIT Media Lab  
@Larson\_MIT  
kll@mit.edu

What enables  
innovative  
entrepreneurial,



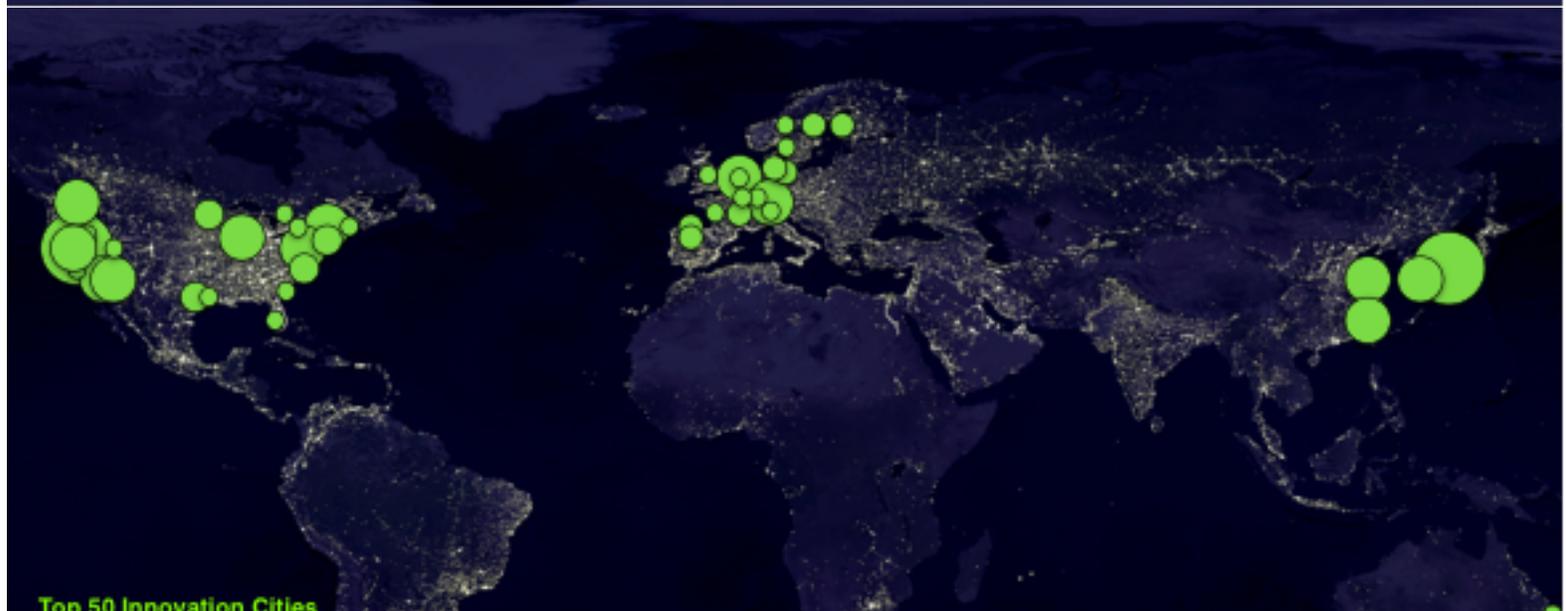
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What enables  
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entrepreneurial,  
high-performance cities?



# innovative entrepreneurial, high-performance cities?



# Cities: 90% of Population Growth

3

## 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  
... to shopping, eating  
... to schools, healthcare ...

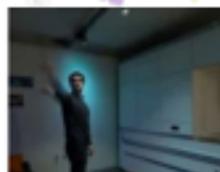
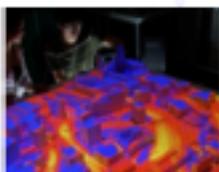
+

## 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  
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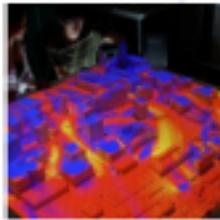
+

## Diversity

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Enterprise  
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Activity ...

+

## New Urban Systems



Simulation/Integration



Responsive Technology



New Model: Mobility



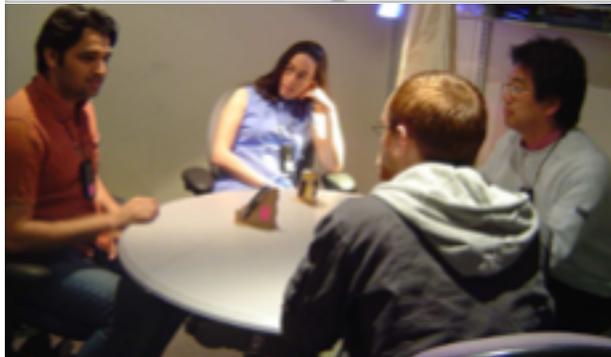
New Model: Food



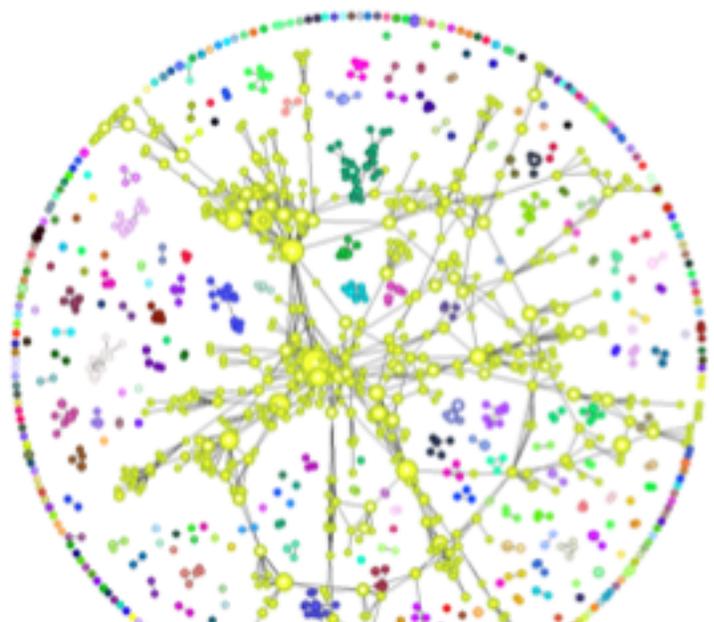
New Model: Housing

=

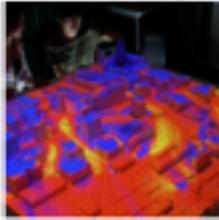
## Quality of Life + Jobs + Resource Reduction



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



# New Urban Systems



Simulation/Integration



Responsive Technology



New Model: Mobility



New Model: Food



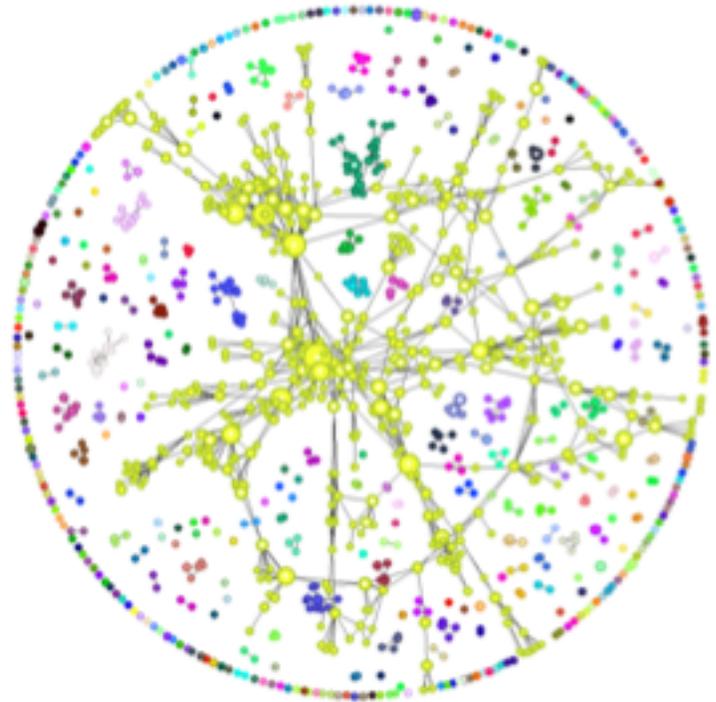
New Model: Housing



Quality of Life + Jobs + Resource Reduction

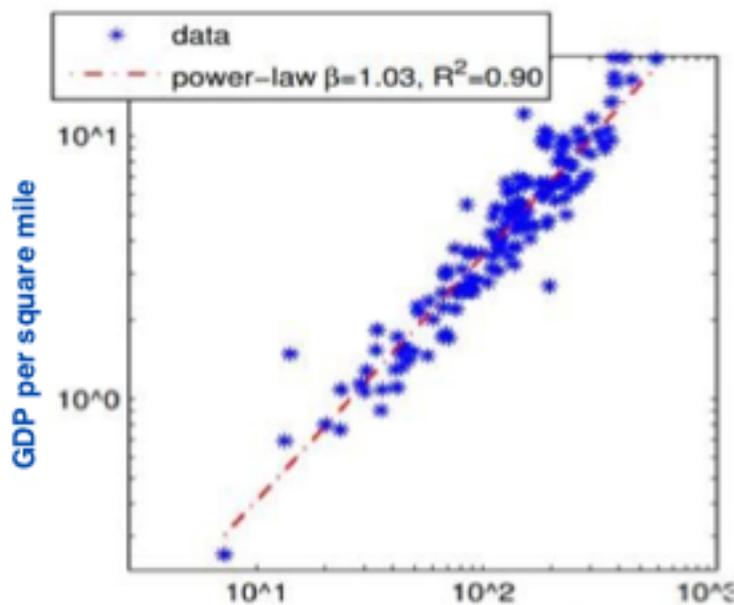


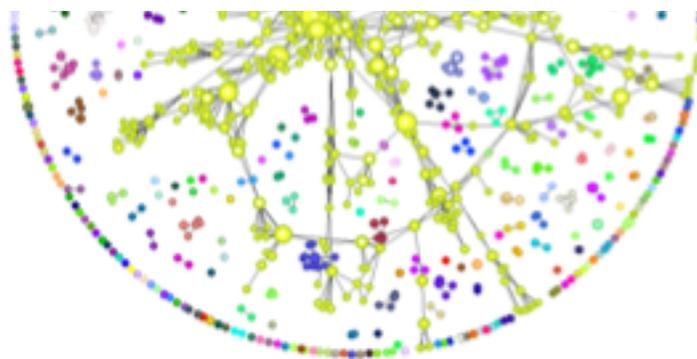
Waber, et al. 2010; Pan et al. 2011; Cebrian et al. 2011. Ductor, 2010.



## Social Ties Increase Productivity

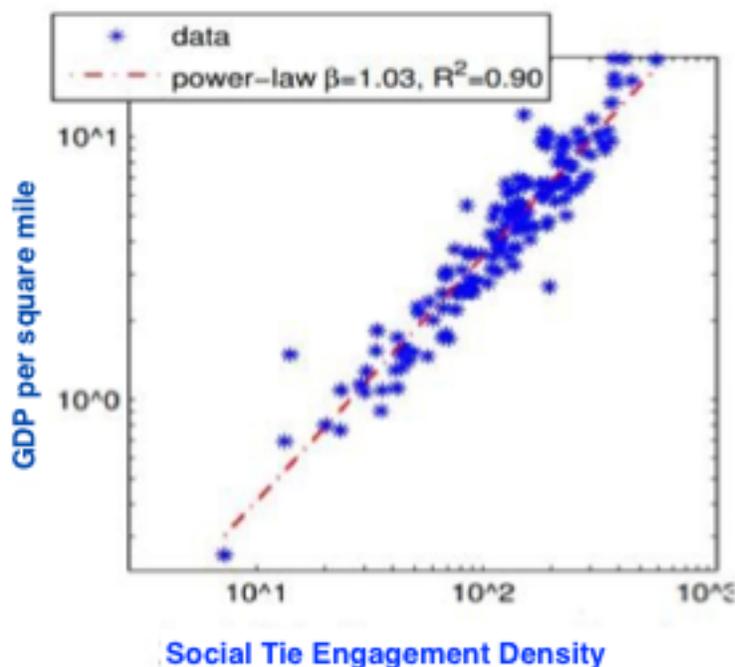
Human Dynamics Group, MIT Media Lab





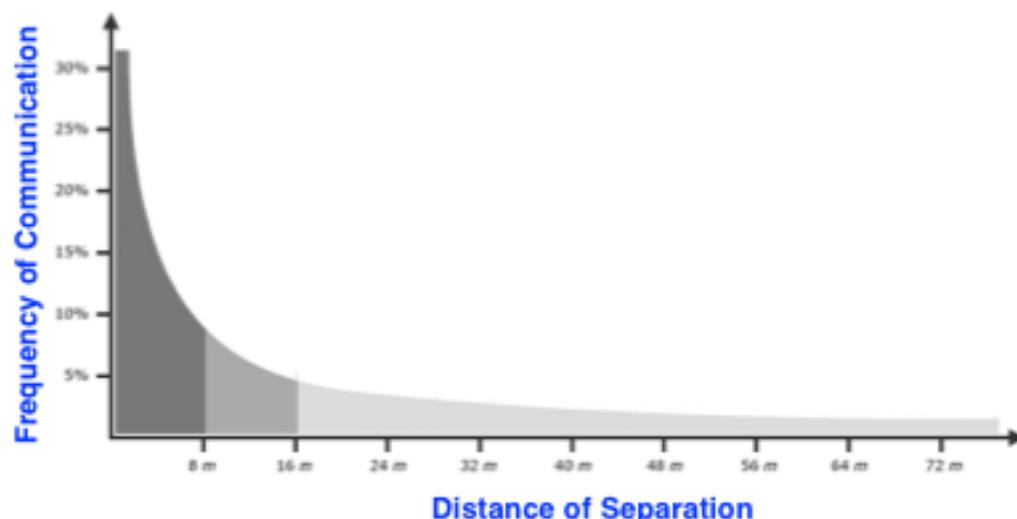
# Social Ties Increase Productivity

Human Dynamics Group, MIT Media Lab

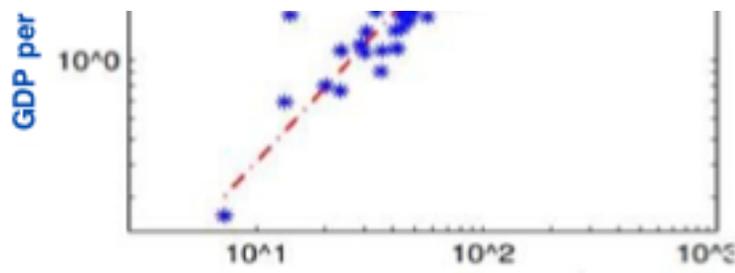


# Social Tie Density Increases GDP

Human Dynamics Group, MIT Media Lab



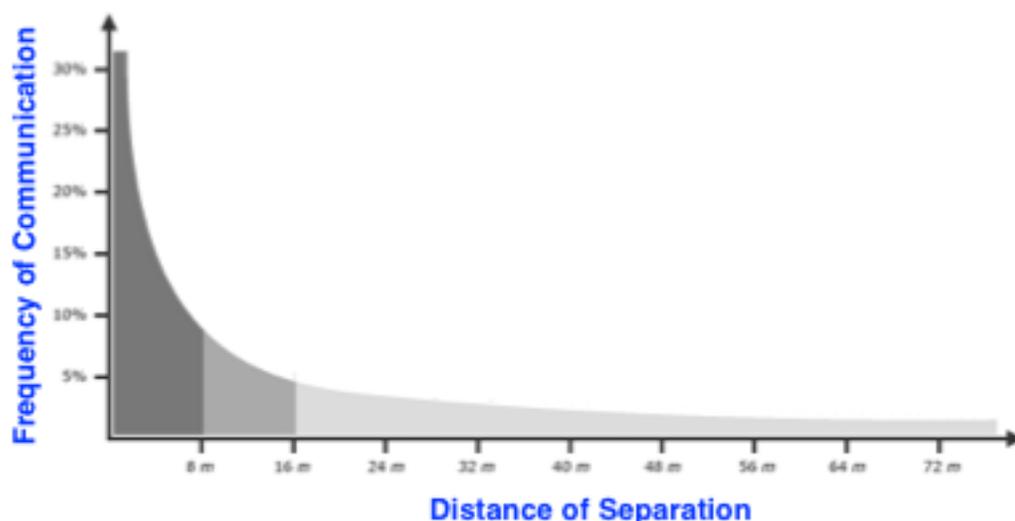
Thomas J. Allen  
(MIT Professor of  
Management Emeritus)  
Allen Curve: Proximity  
brings greater frequency  
of Communication



Social Tie Engagement Density

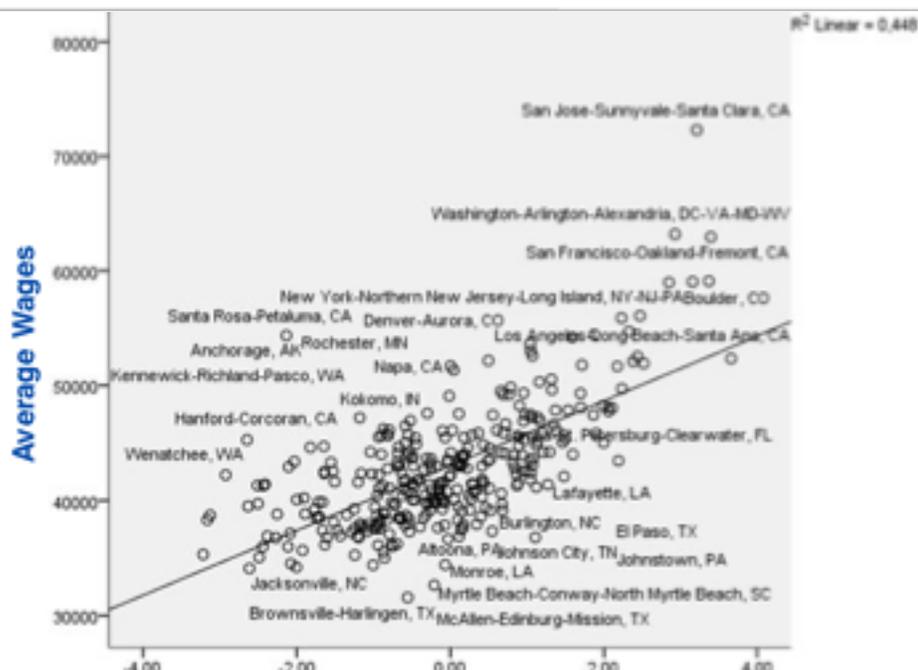
# Social Tie Density Increases GDP

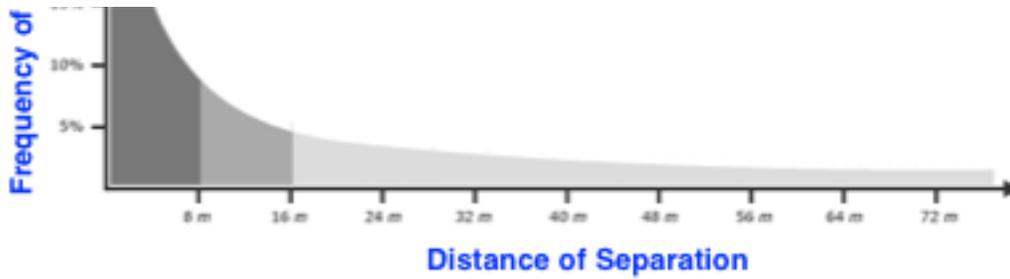
Human Dynamics Group, MIT Media Lab



Thomas J. Allen  
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Allen Curve: Proximity brings greater frequency of Communication

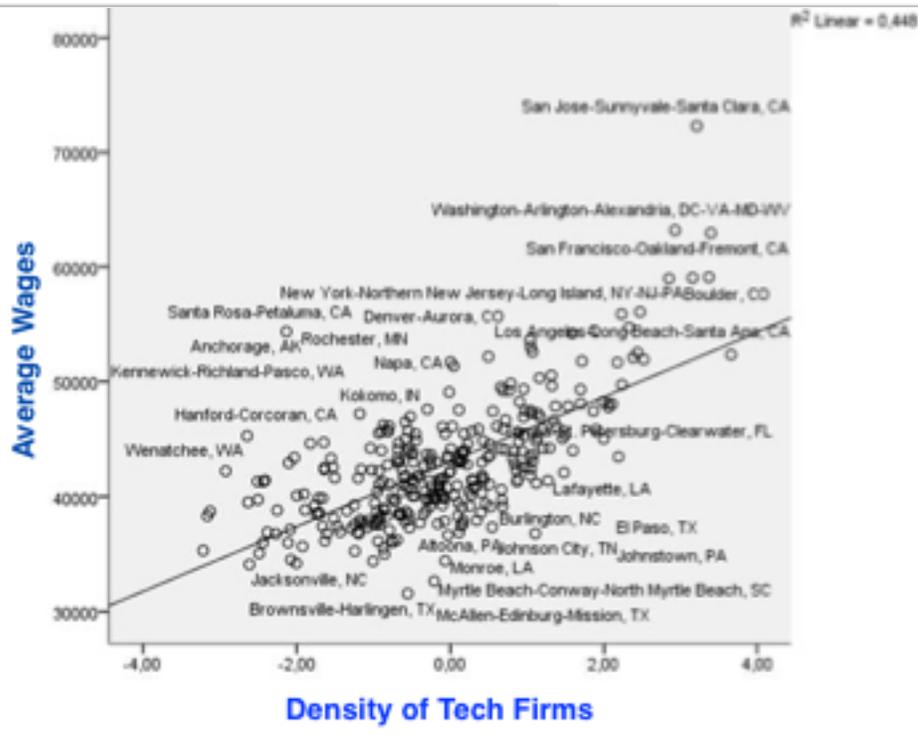
# Proximity Increases Communication



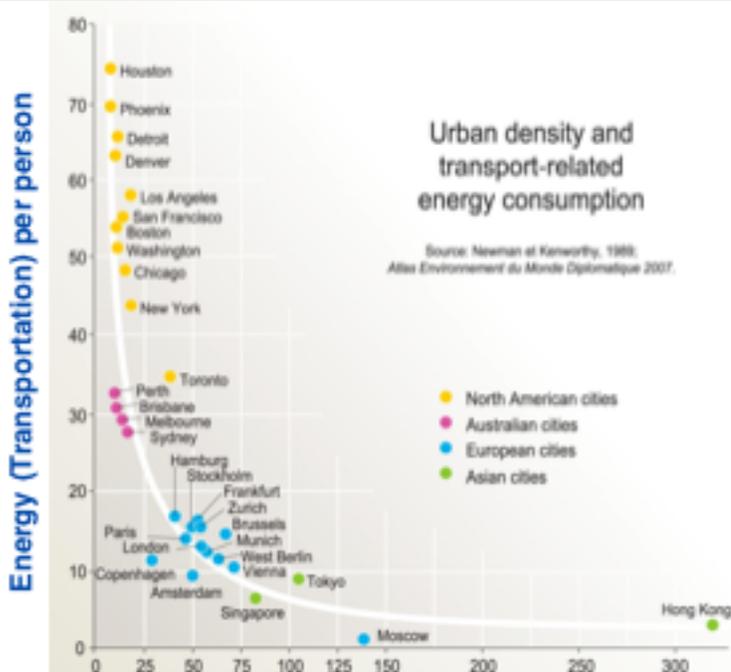


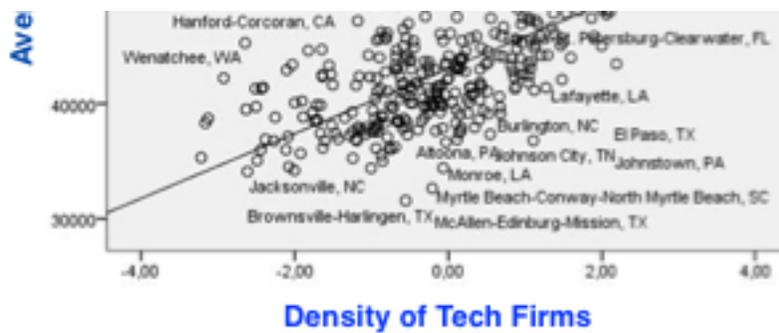
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# Proximity Increases Communication

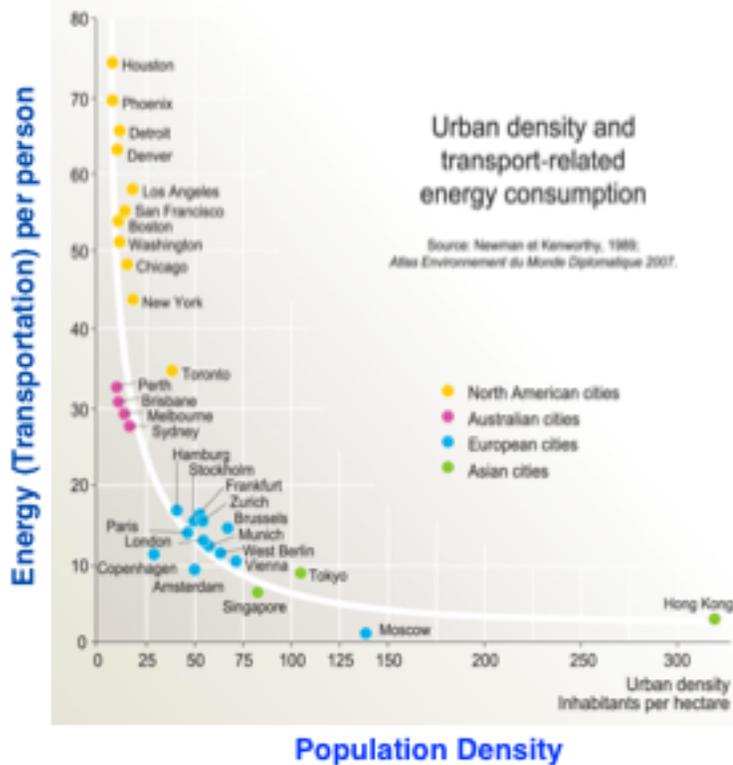


# Firm Density Increases Wages

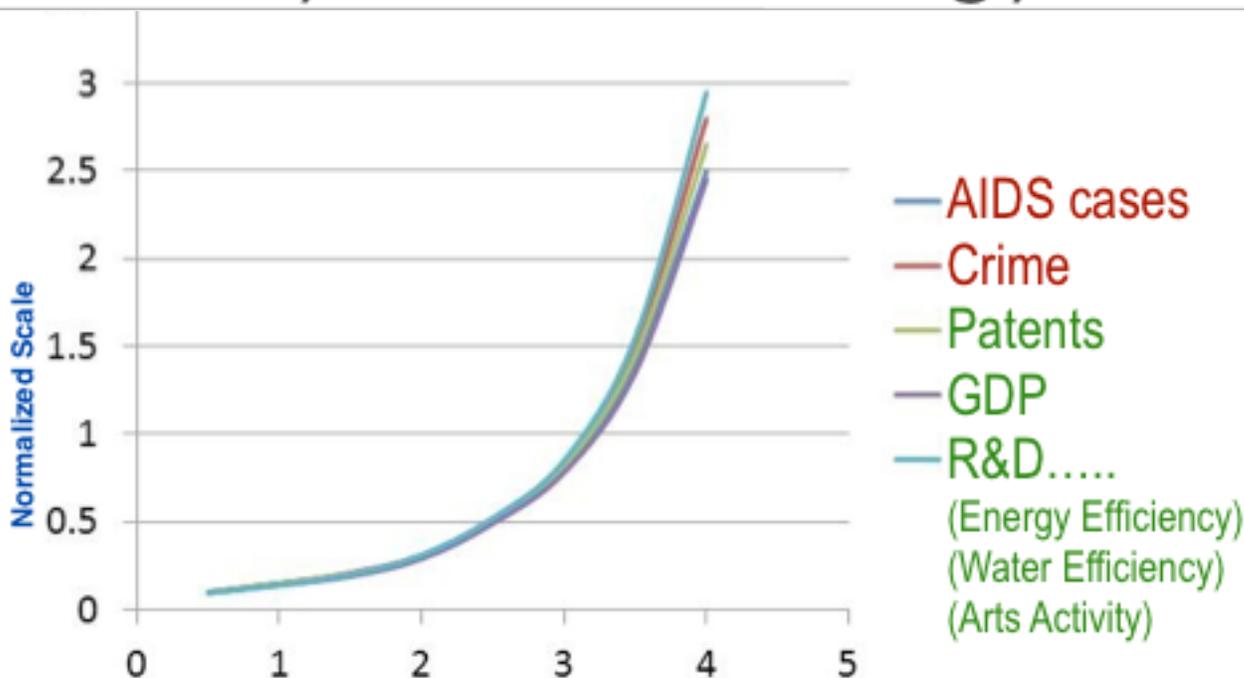


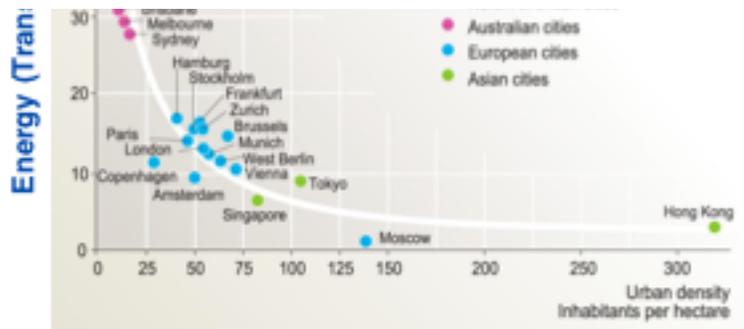


## Firm Density Increases Wages



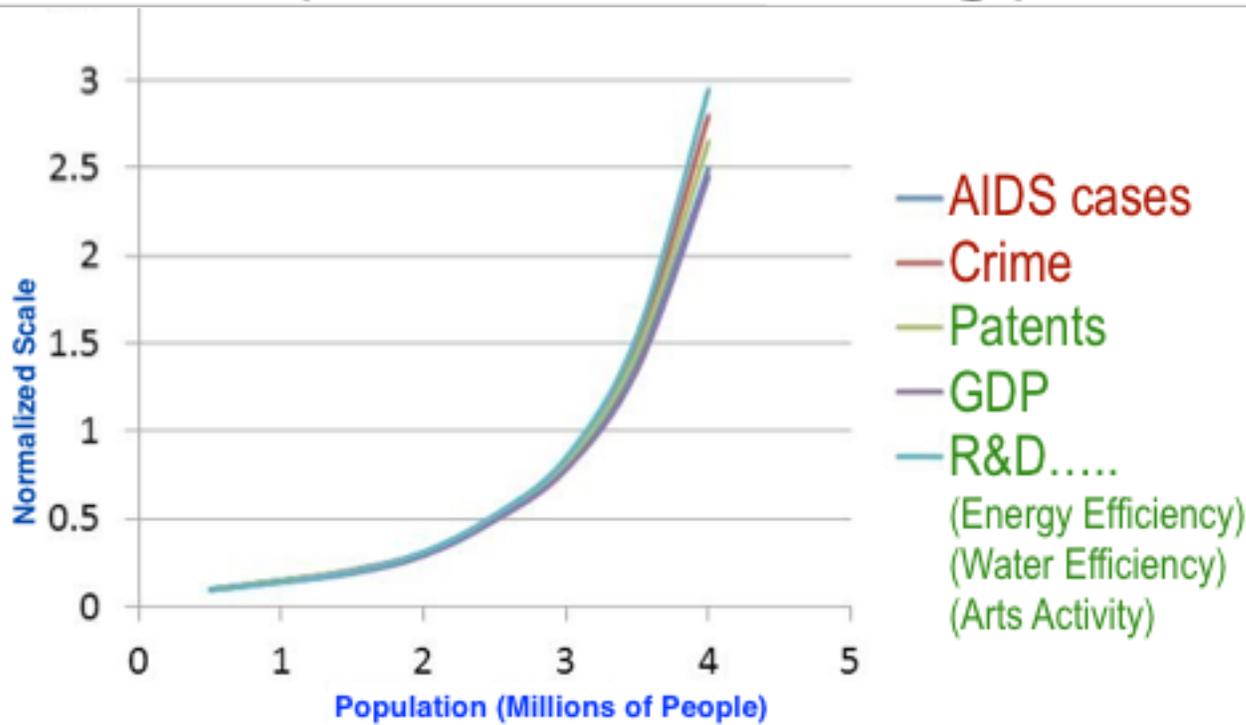
## Density Reduces Energy/Person





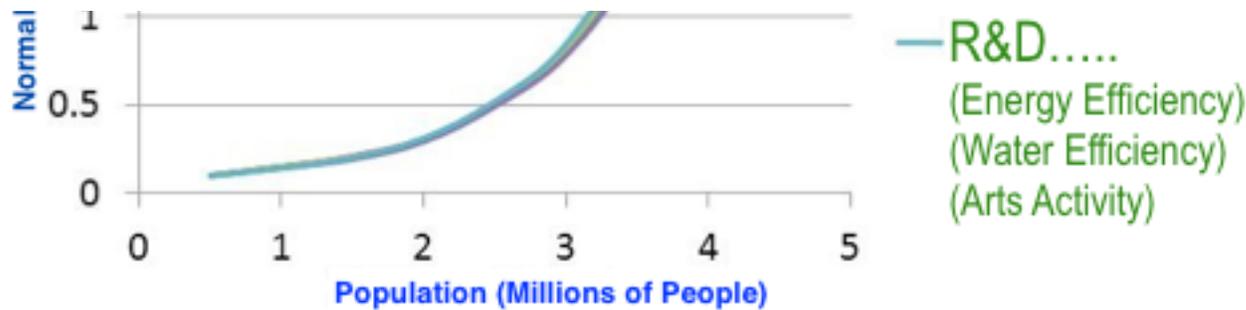
**Population Density**

# Density Reduces Energy/Person

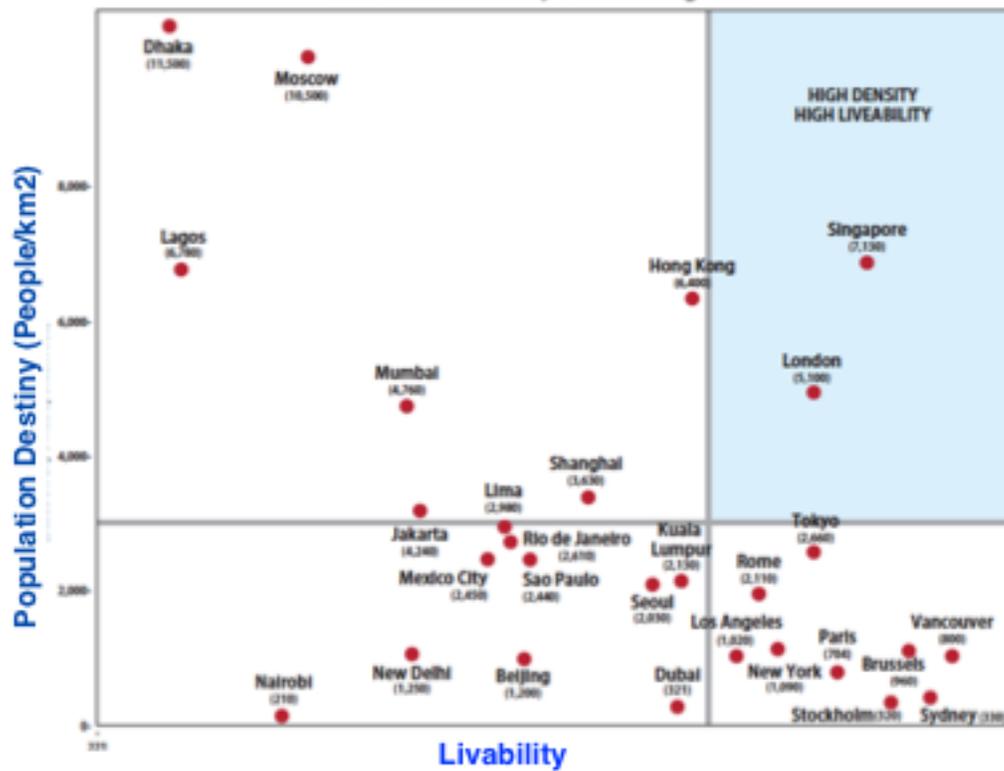


# Population Density: Good & Bad





# 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

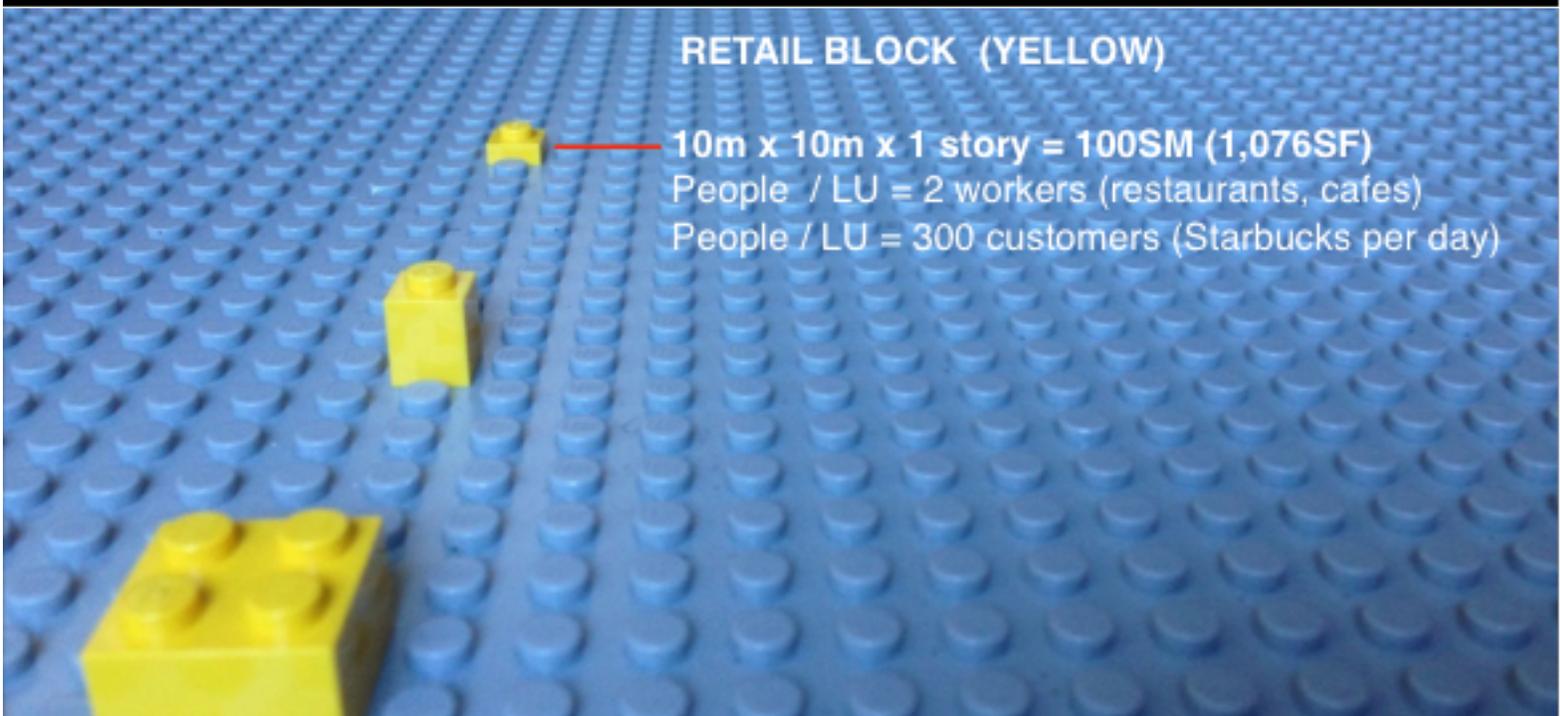
(Compact, Dense, Diverse, Walkable Districts to promote creative interactions and exchange of ideas)

### RETAIL BLOCK (YELLOW)

10m x 10m x 1 story = 100SM (1,076SF)

People / LU = 2 workers (restaurants, cafes)

People / LU = 300 customers (Starbucks per day)



# Decision Support

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Modeling with Data (LEGO) Units



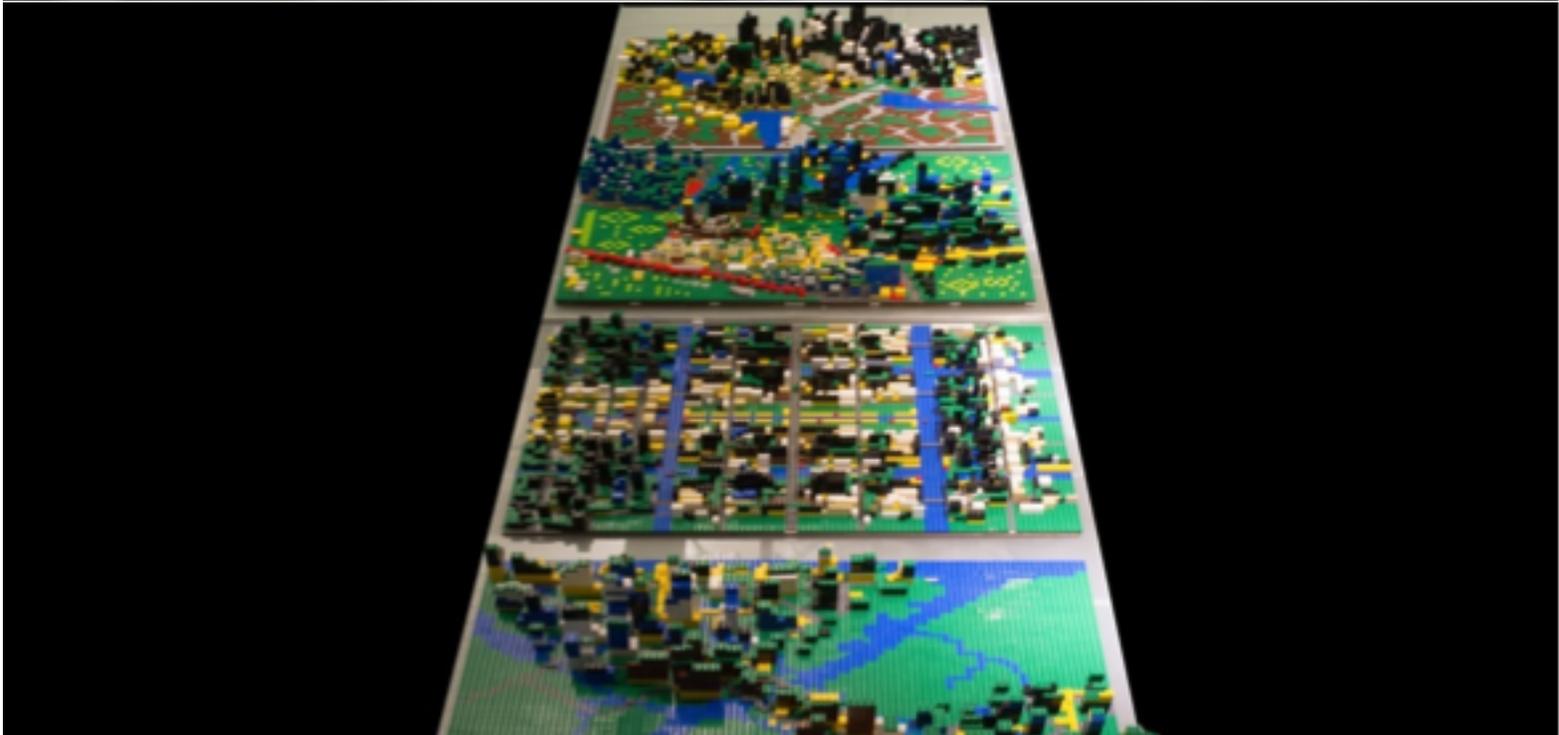


# Modeling with Data (LEGO) Units



# Modeling form/function

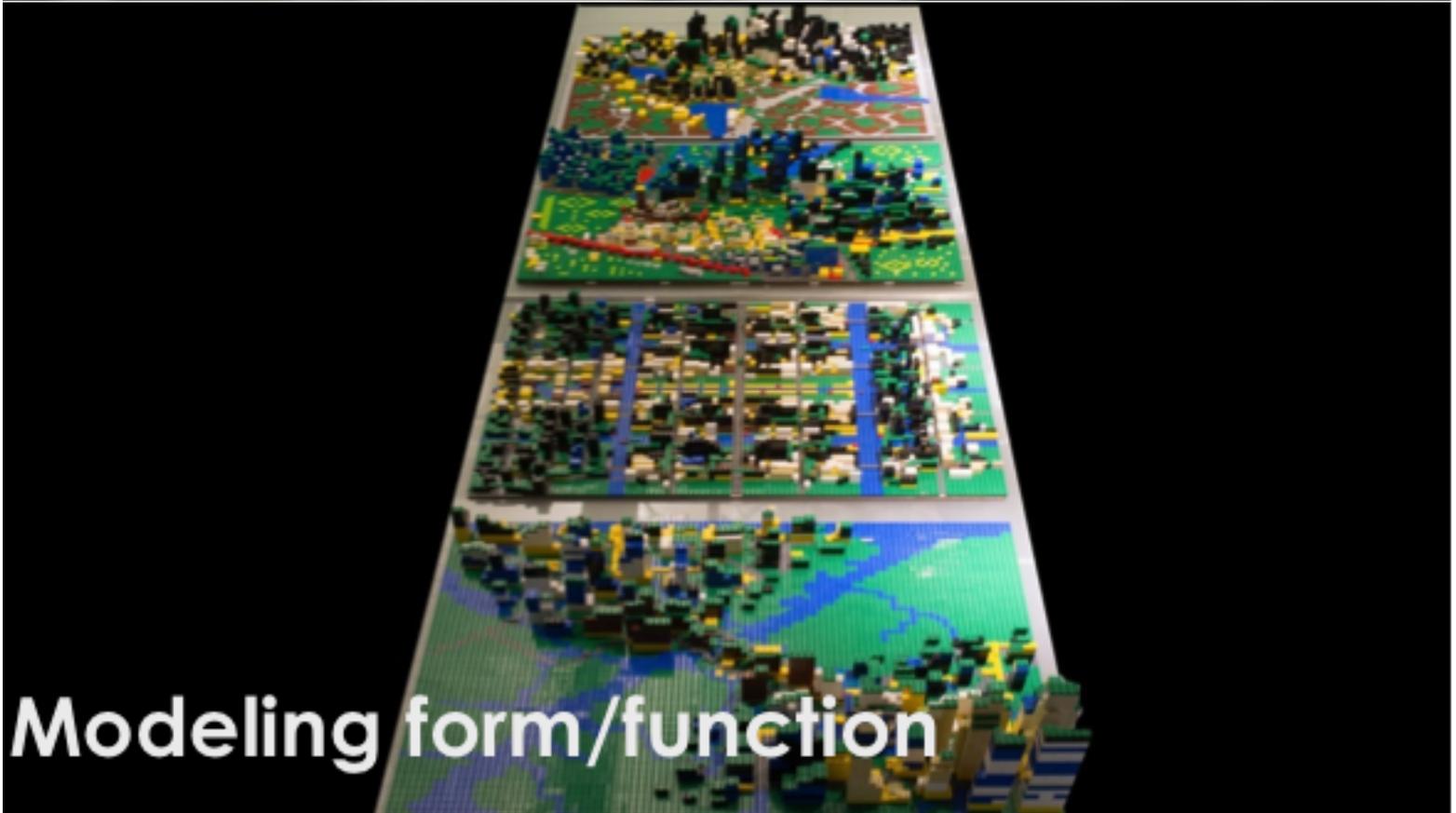
Changing Places Group, MIT Media Lab





# Modeling form/function

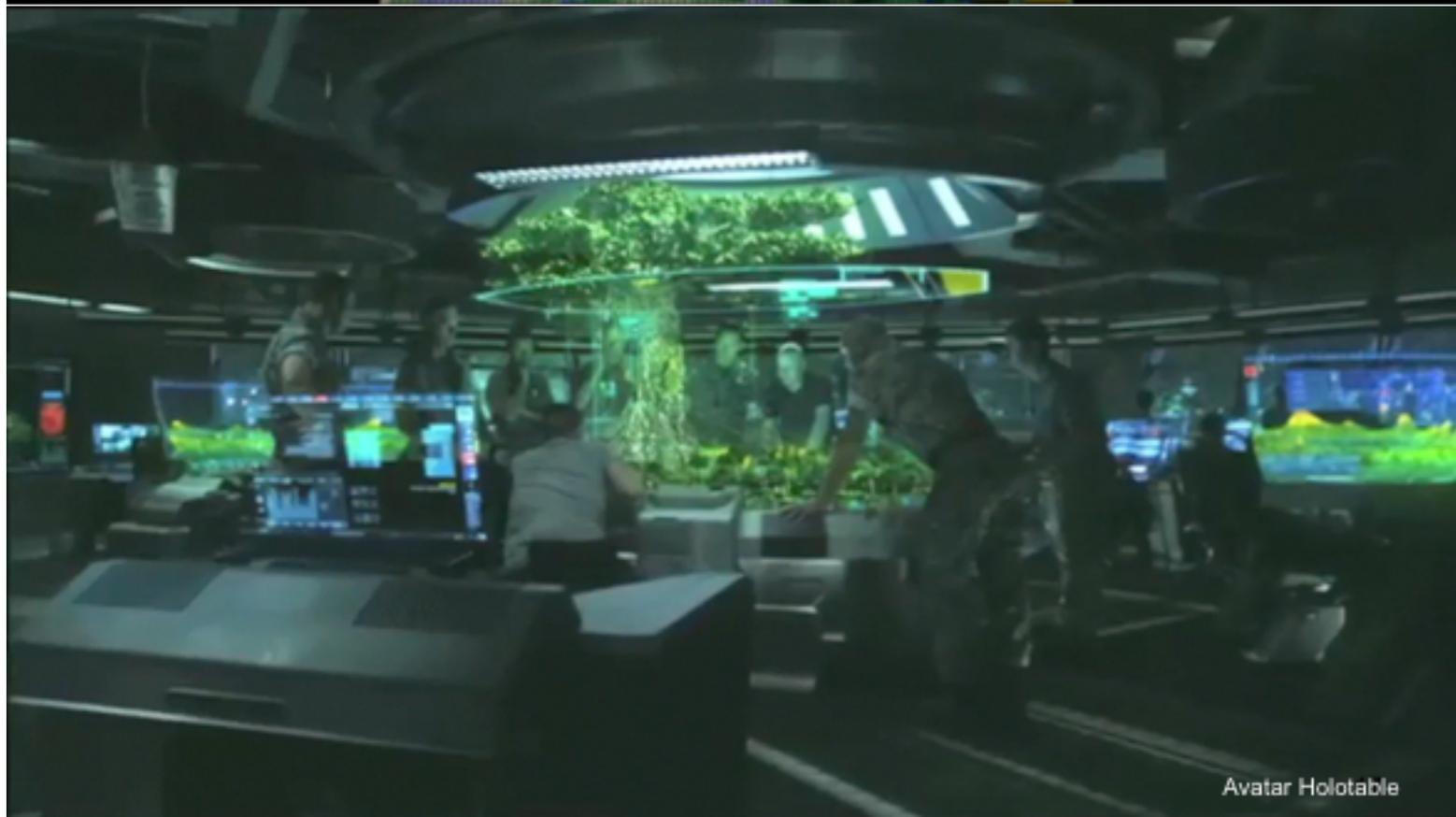
Changing Places Group, MIT Media Lab



# Modeling form/function

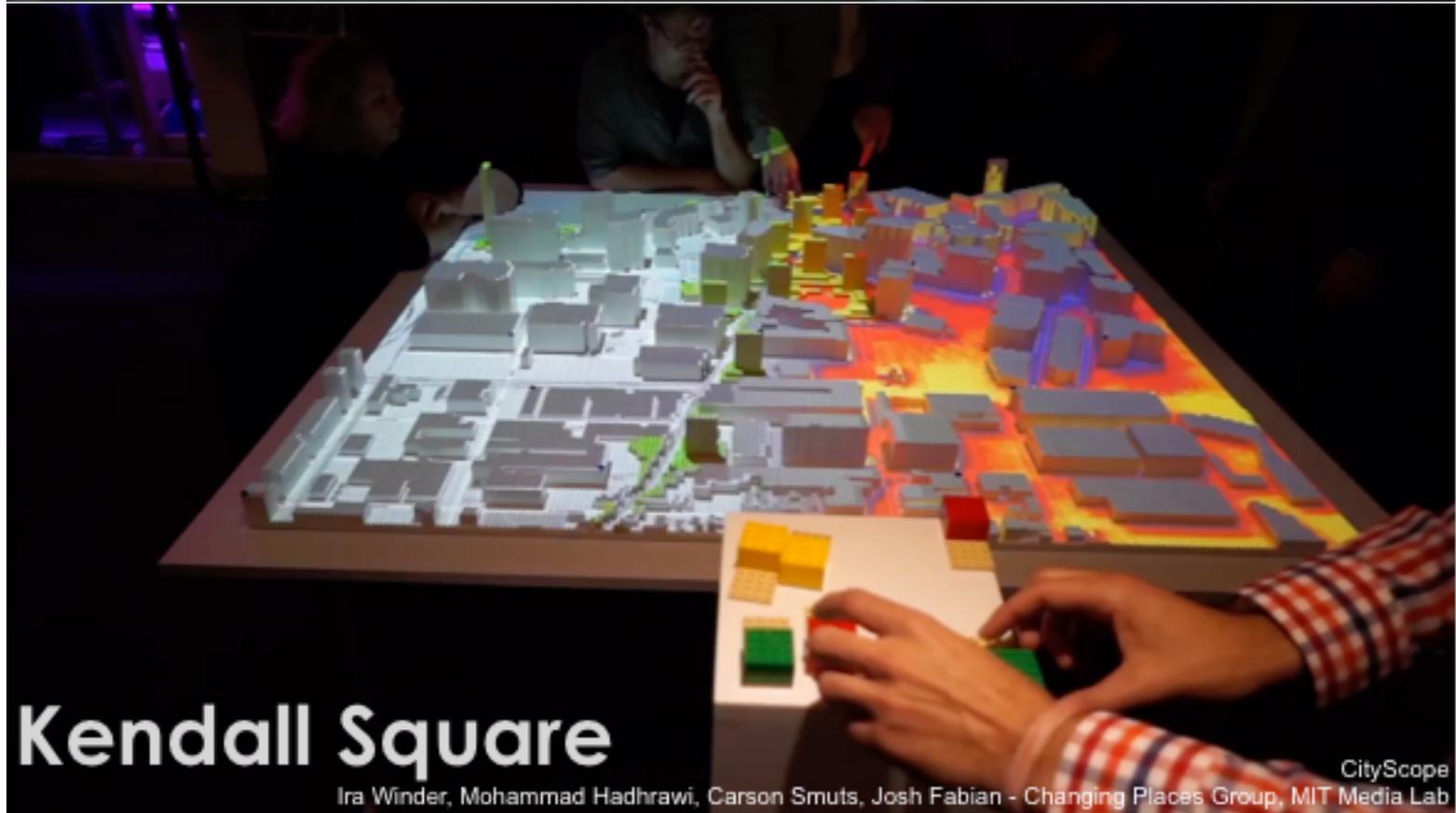


# Modeling form/function





Avatar Holotable



# Kendall Square

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



# Kendall Square

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

CityScope

# Satellite View

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

CityScope

# Satellite View

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

CityScope

A top-down view of a city model with a grid of streets and various building footprints. The model is illuminated from above, casting soft shadows.

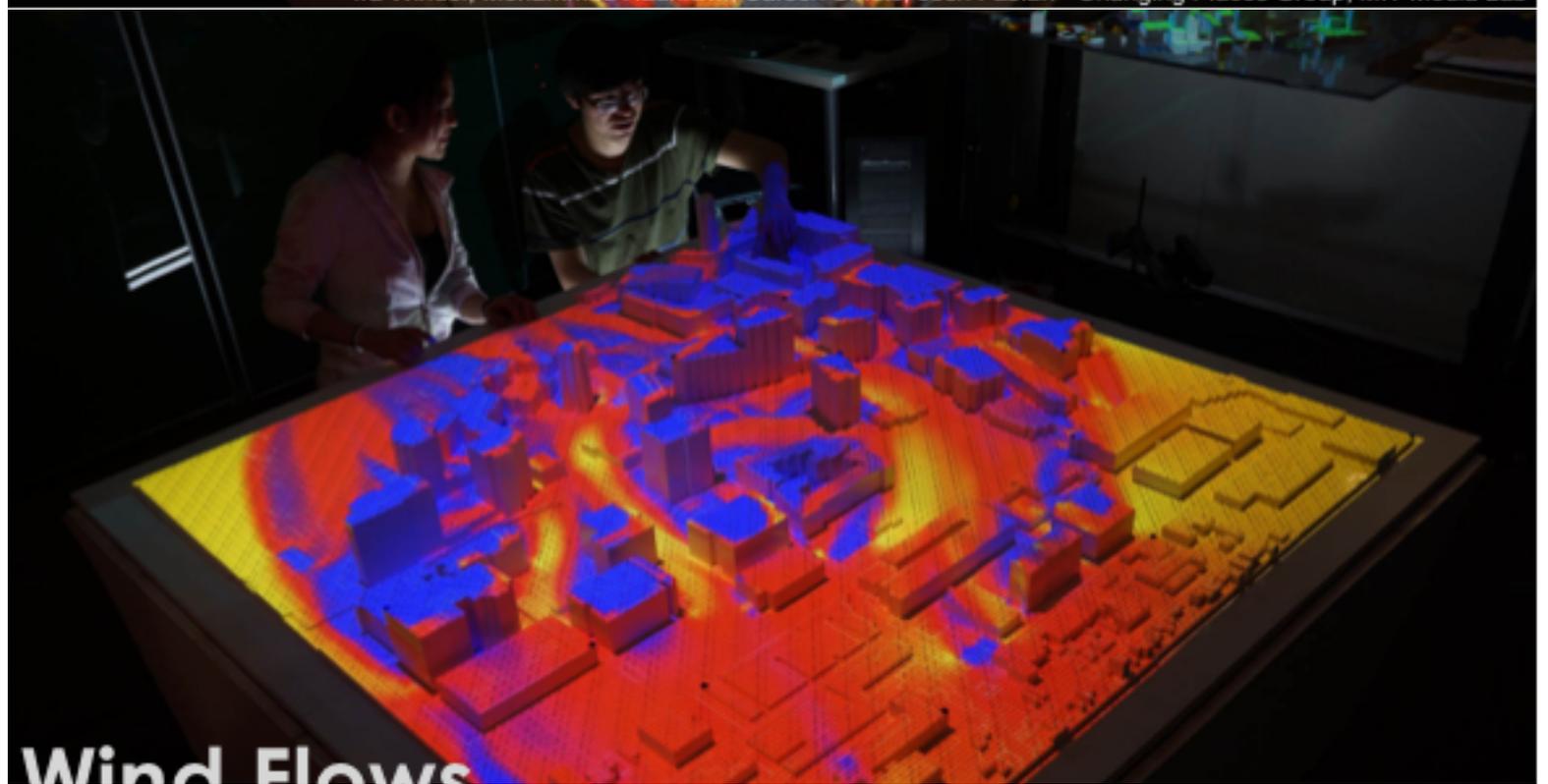
# Satellite View

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

A city model on a large table. The ground surface is color-coded to show solar radiation levels, with a gradient from blue (low) to yellow and red (high). Buildings are shown in grey. Two people are looking at the model.

# Solar Radiation

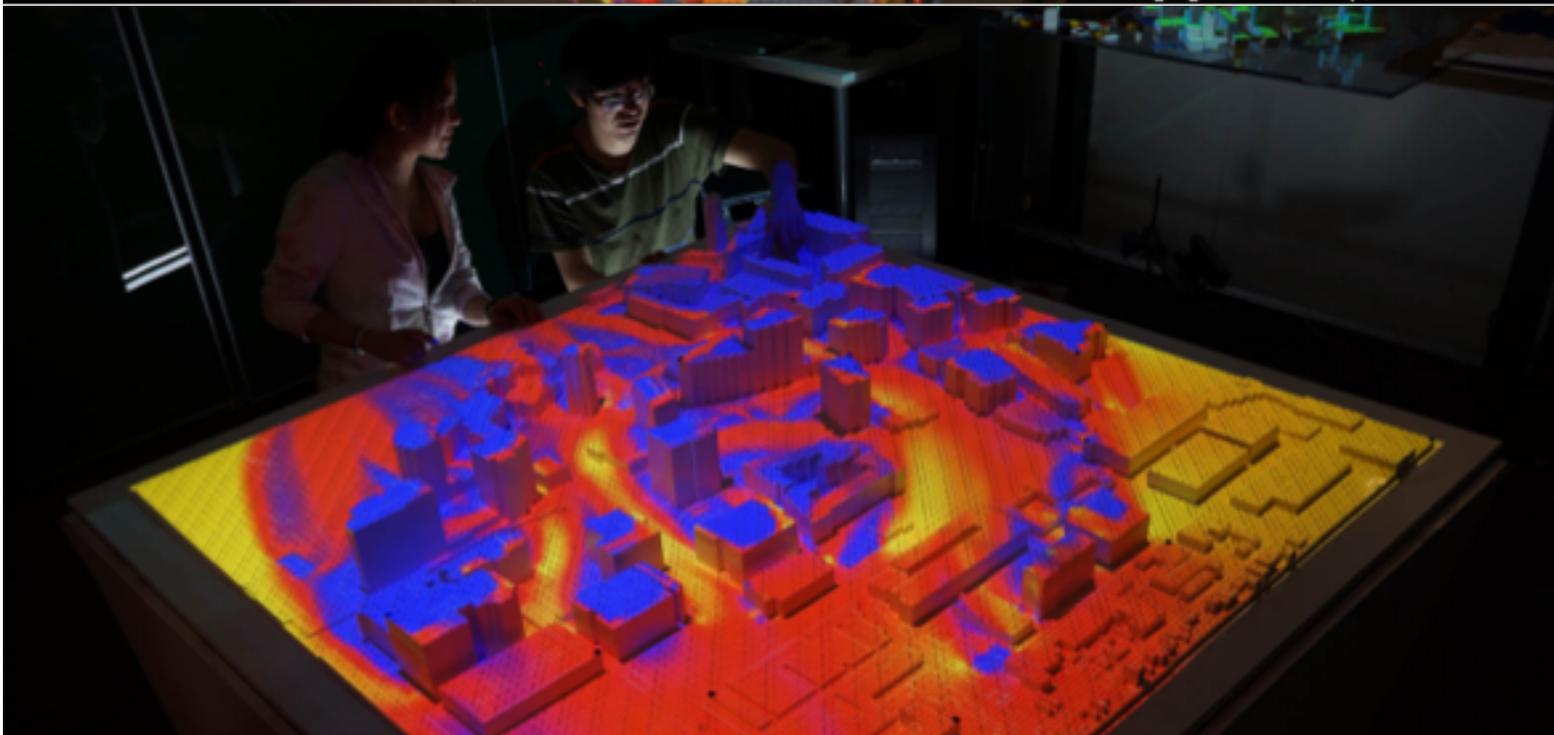
CityScope  
Ira Winder, Mohammad Hadhrawi, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab

A city model on a large table. The ground surface is color-coded to show wind flow patterns, with a gradient from blue (low) to yellow and red (high). Buildings are shown in grey. Two people are looking at the model.

# Wind Flows

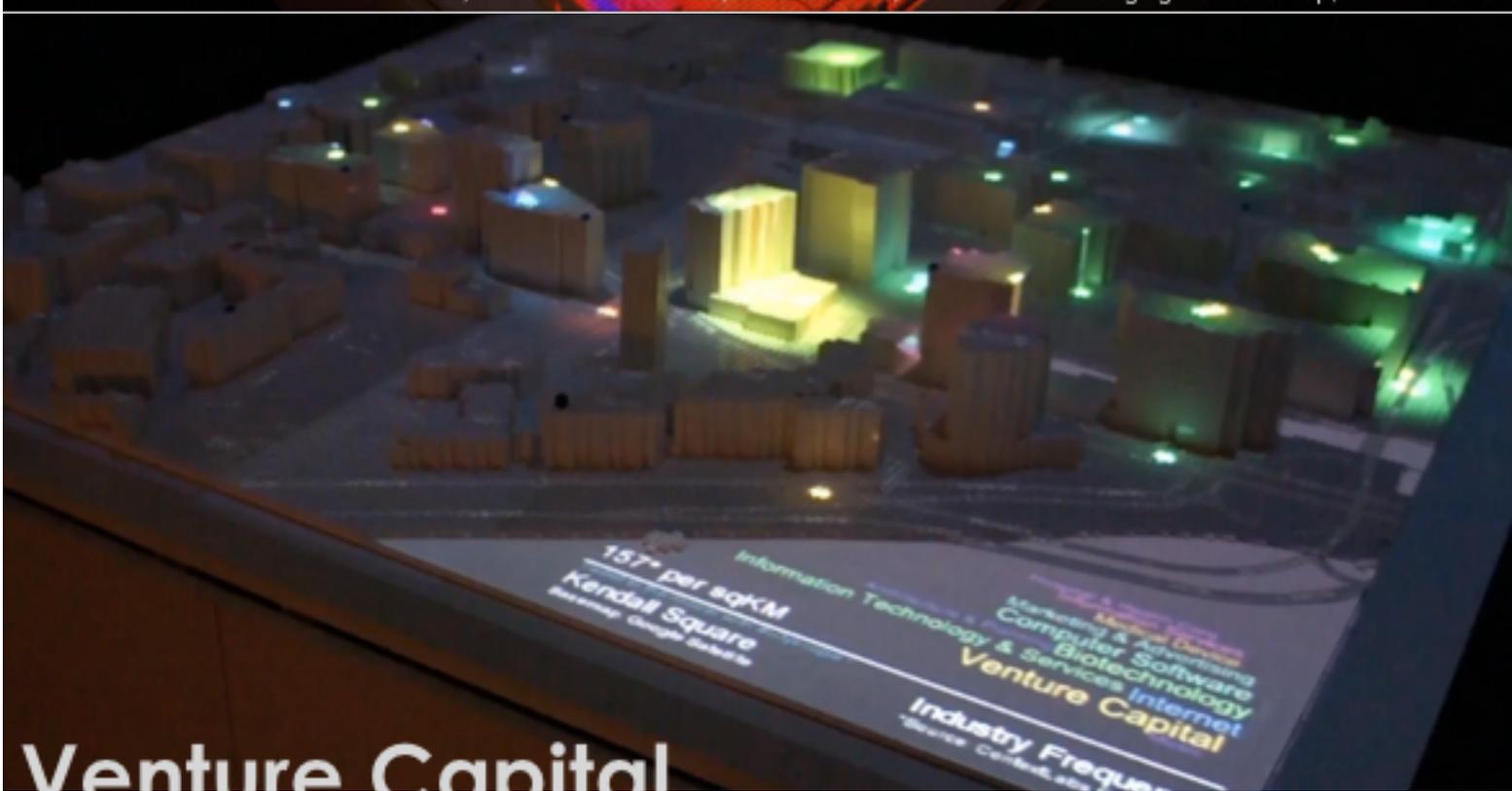
# Solar Radiation

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



# Wind Flows

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



# Venture Capital

157\* per sqKM  
Kendall Square  
Information Technology & Services  
Venture Capital  
Industry Frequency  
\*Source: Crunchbase.com

# Wind Flows

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

CityScope



# Venture Capital

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# Mobility Modes

# Venture Capital

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CityScope



# Mobility Modes

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CityScope



# Tweets

CityScope

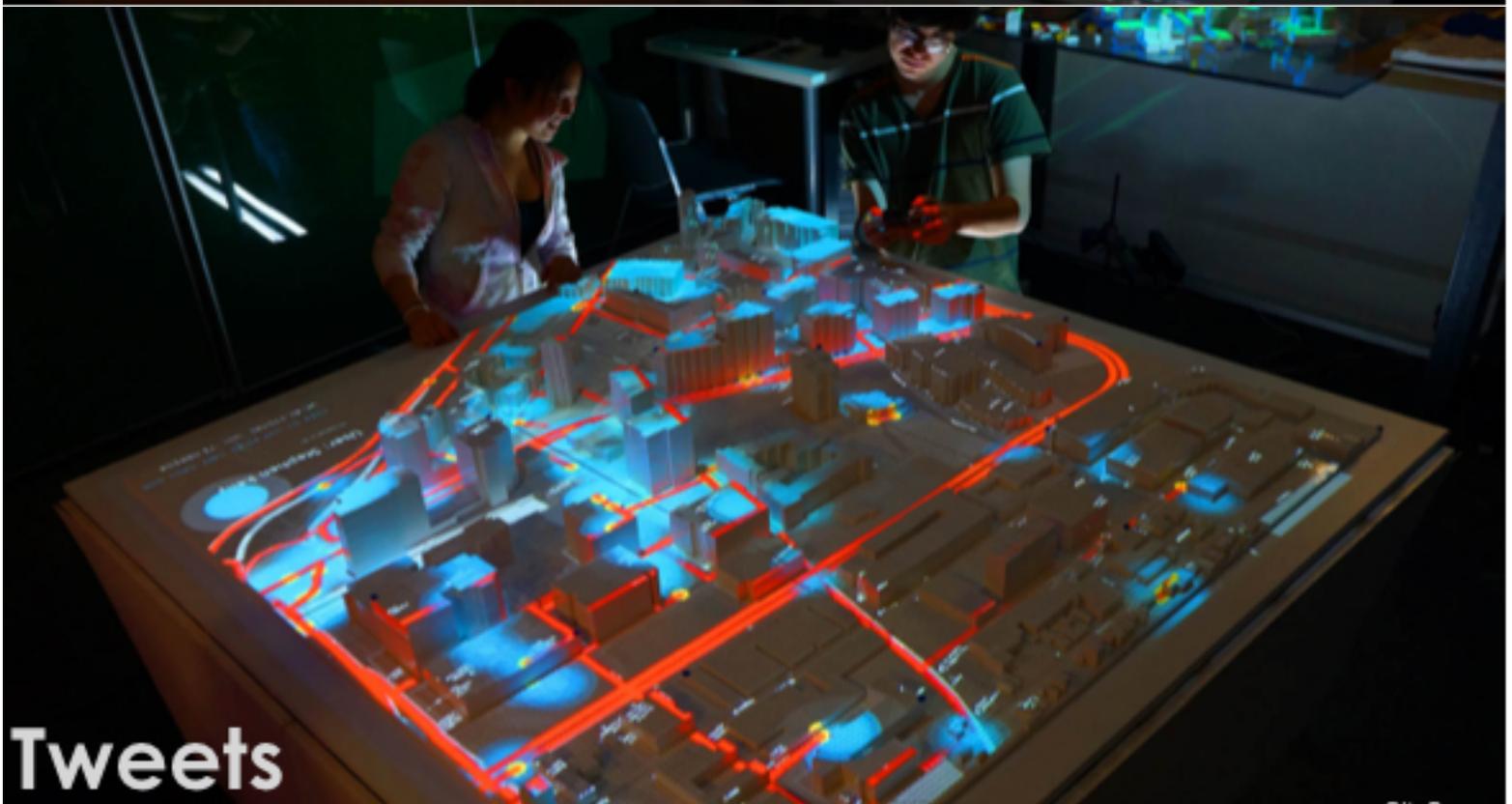
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CityScope  
Ira Winder, Mohammad Hadhrawi, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab



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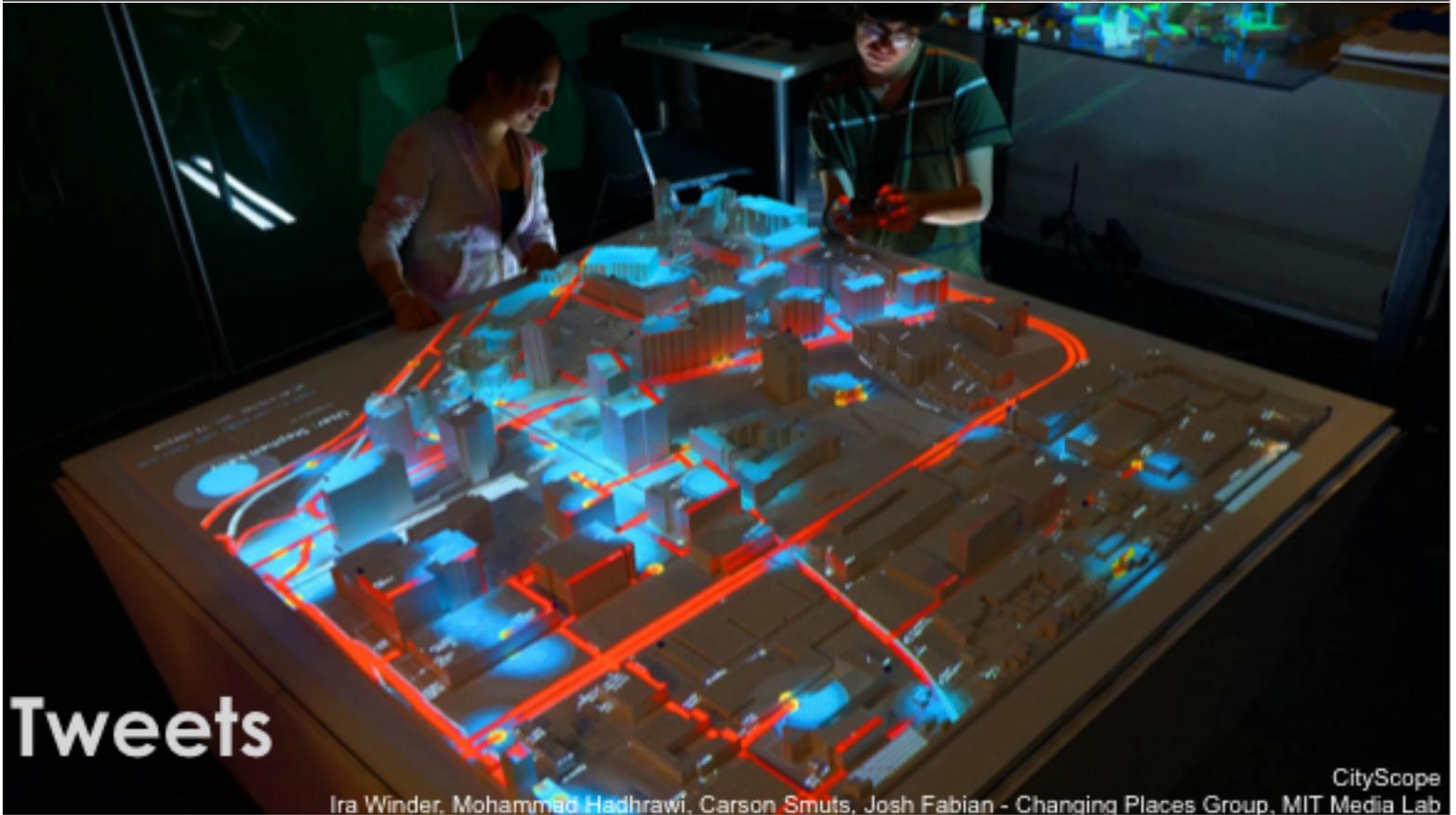


# Tweets

CityScope

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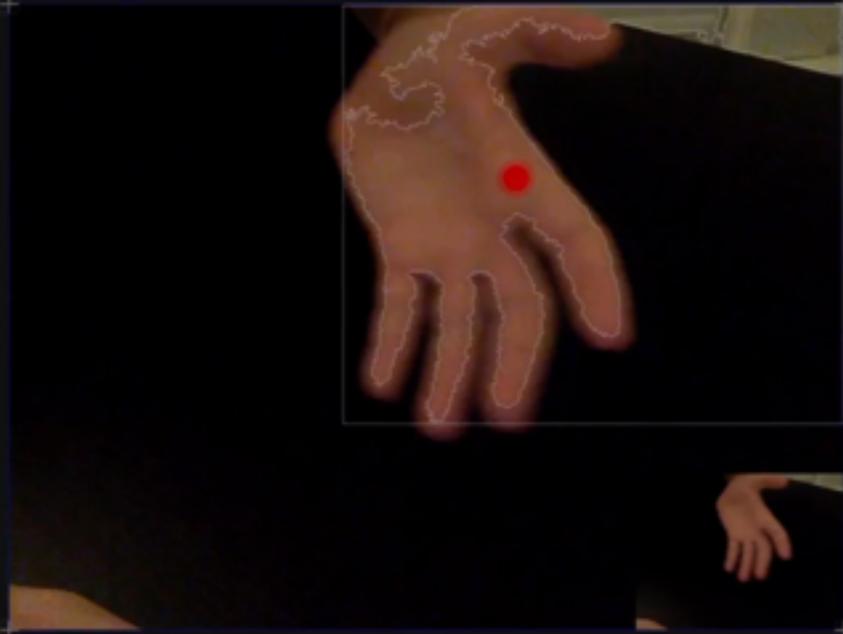
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CityScope  
Ira Winder, Mohammad Hadhrawi, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab

## Scope IR

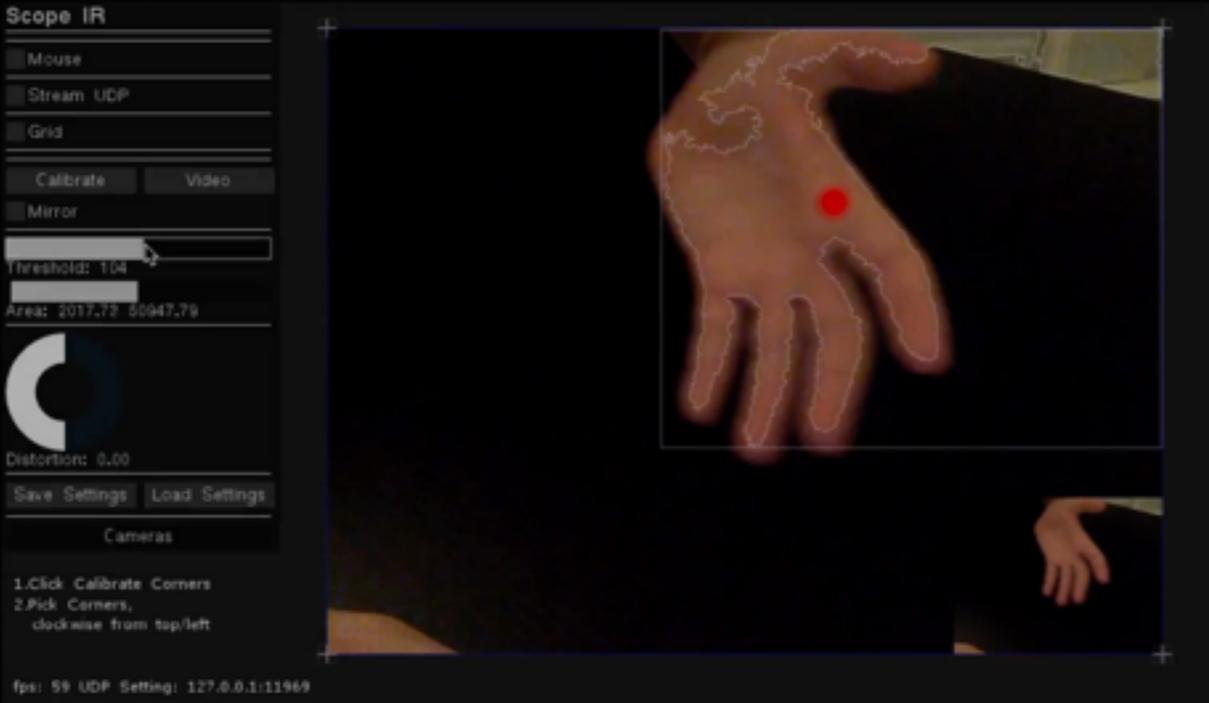
Scope IR interface showing various settings and controls:

- Mouse
- Stream UDP
- Grid
- Calibrate Video
- Mirror
- Threshold: 104
- Area: 2017.73 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



# Tweets

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

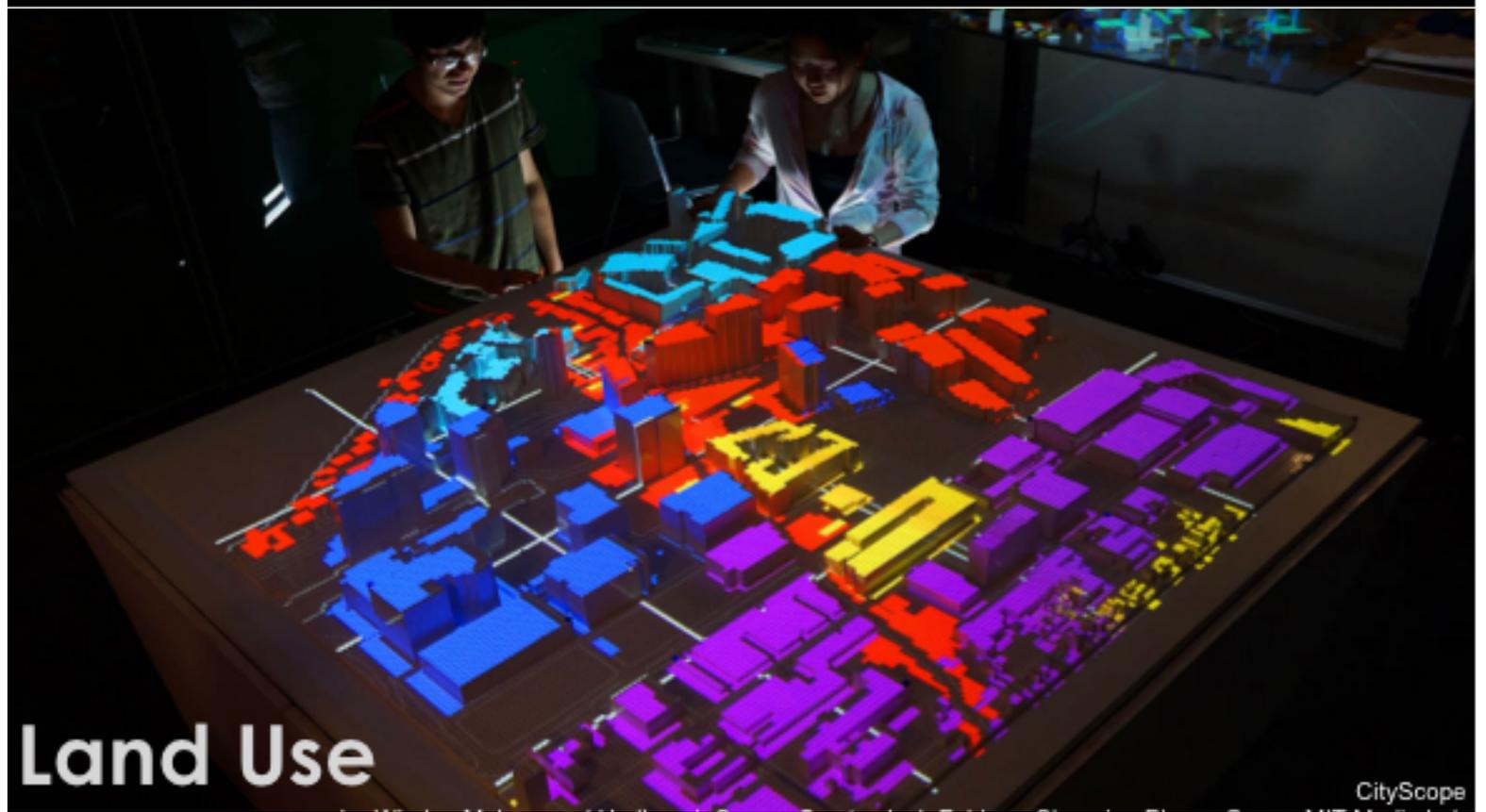


The screenshot displays the 'Scope IR' control panel on the left and a video stream on the right. The video stream shows a hand with a red dot on the palm, indicating a tracked point. The control panel includes the following elements:

- Buttons: Mouse, Stream UDP, Grid, Calibrate, Video, Mirror.
- Slider: Threshold: 104.
- Text: Area: 2017.73 50947.79.
- Distortion: 0.00.
- Buttons: Save Settings, Load Settings.
- Section: Cameras.
- Instructions:
  1. Click Calibrate Corners
  2. Pick Corners, clockwise from top/left
- Status: fps: 59 UDP Setting: 127.0.0.1:11969.

# Land Use

CityScope

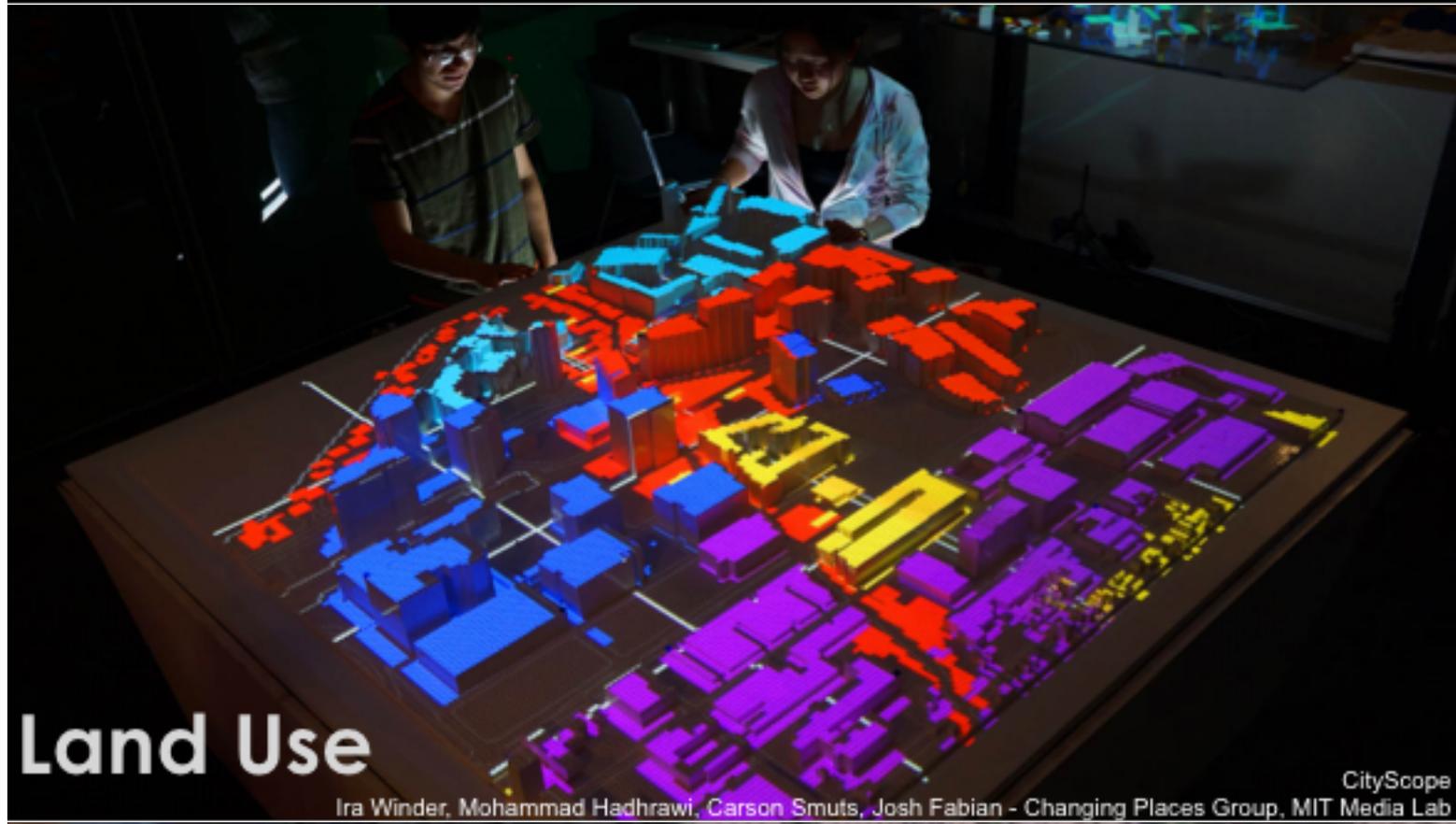
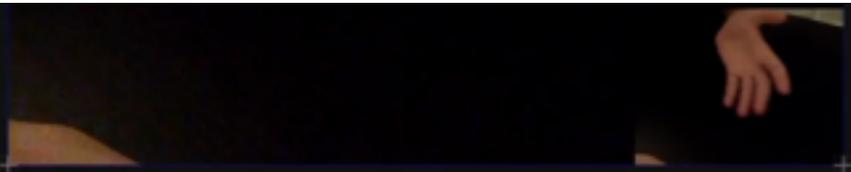


Save Settings | Load Settings

Cameras

- 1. Click Calibrate Corners
- 2. Pick Corners, clockwise from top/left

fps: 59 UDP Setting: 127.0.0.1:11969



# Land Use

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



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

# Land Use

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



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



CityScope, New City, Brisbane Urban Design, Land Use



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



CityScope, New City, Brisbane Urban Design Use Case



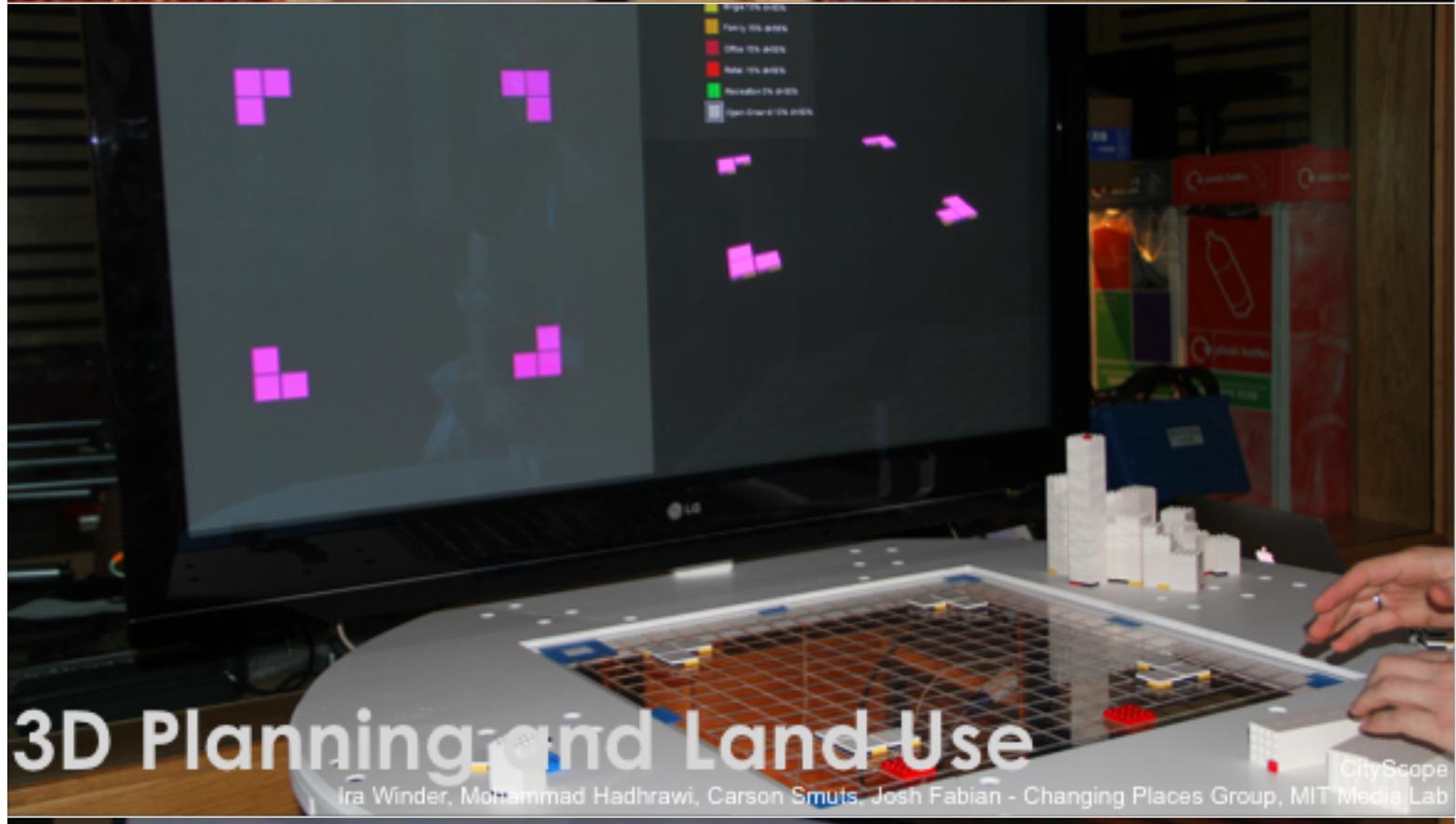
CityScope, Riyadh Urban Design Use Case



CityScope, New City, Brisbane Urban Design Use Case



CityScope, Riyadh Urban Design Use Case



# 3D Planning and Land Use

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

CityScope



# 3D Planning and Land Use

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

CityScope



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CityScope

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

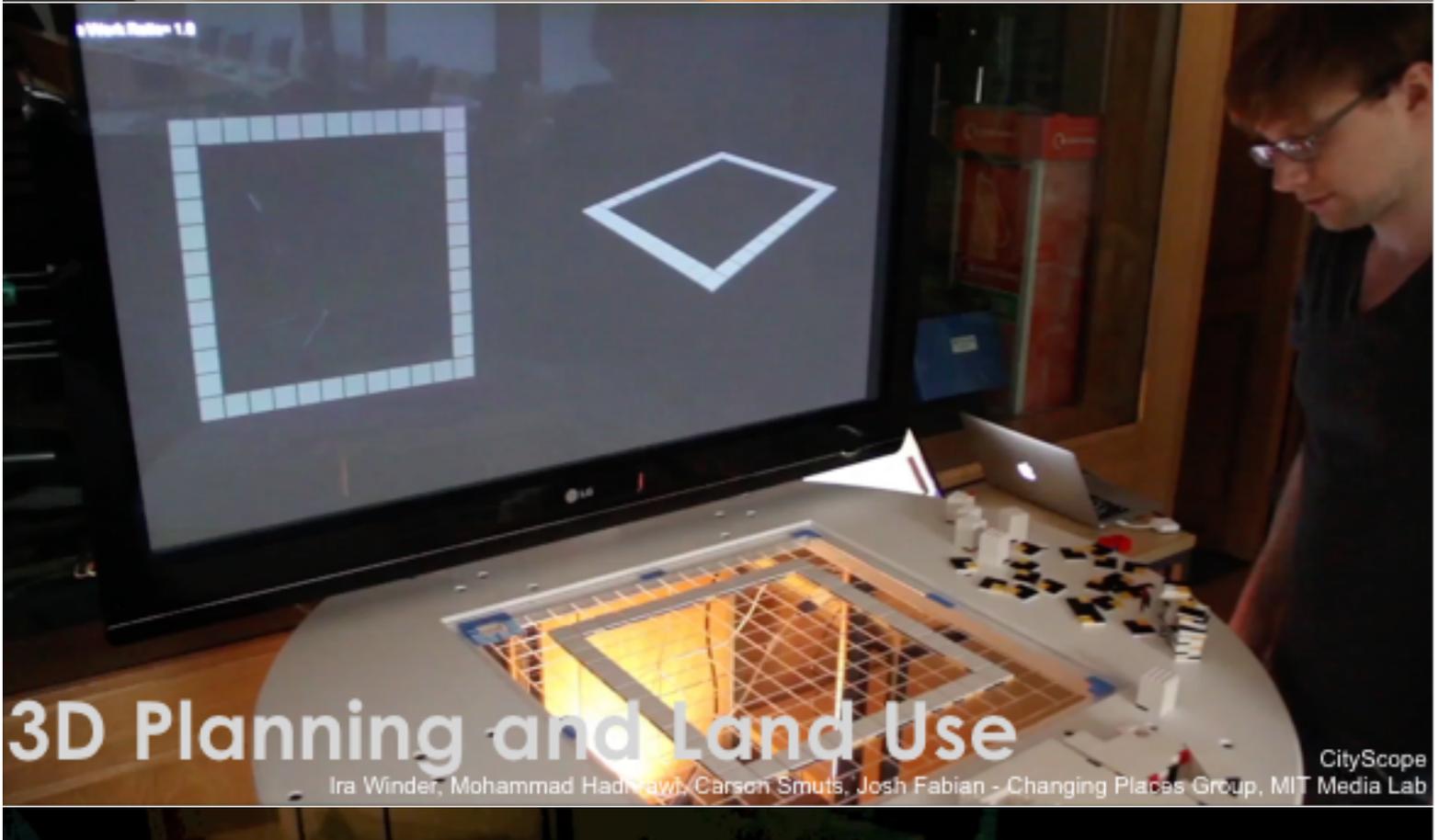
CityScope



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CityScope



# 3D Planning and Land Use

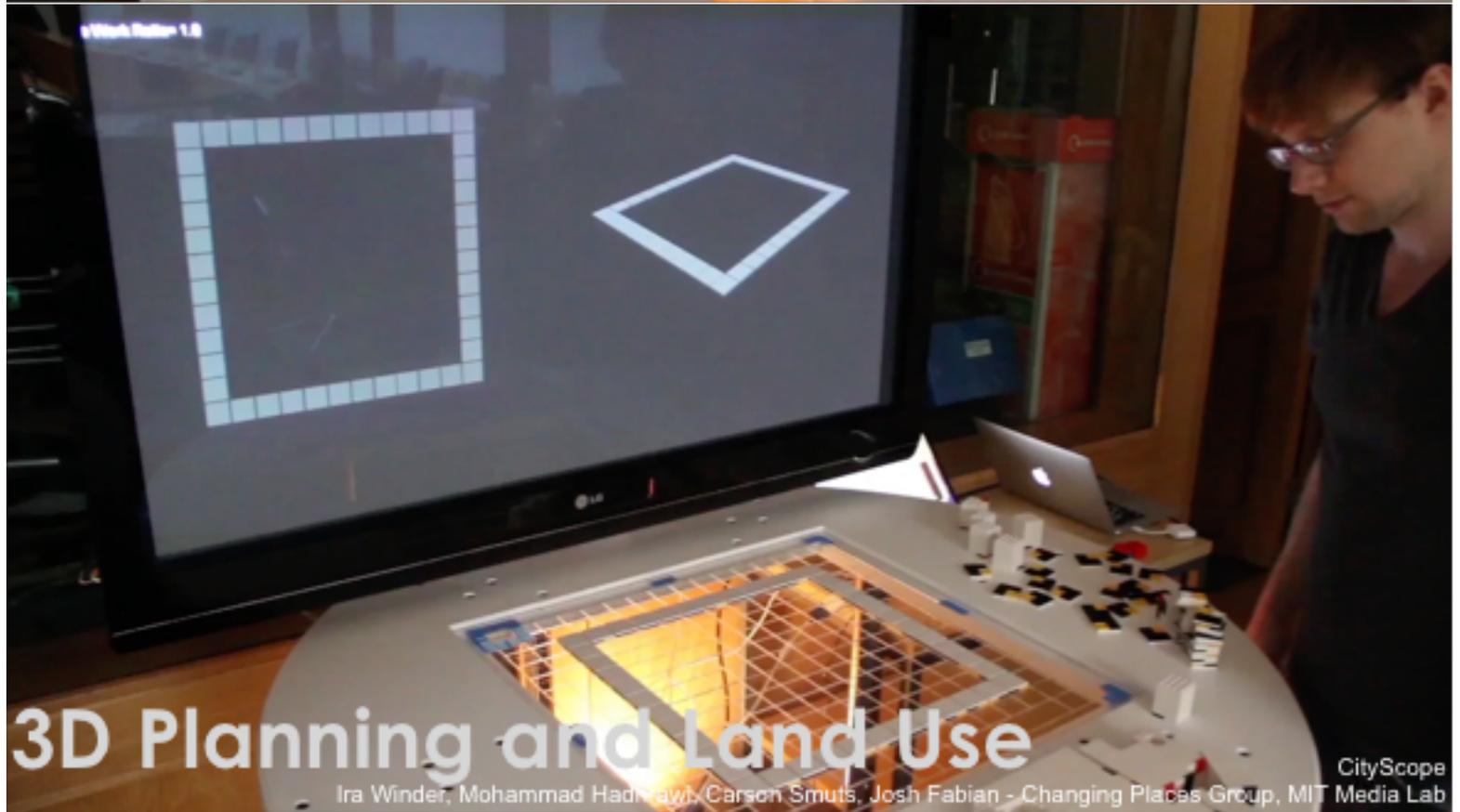
Ira Winder, Mohammad Hadhrawi, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab

CityScope

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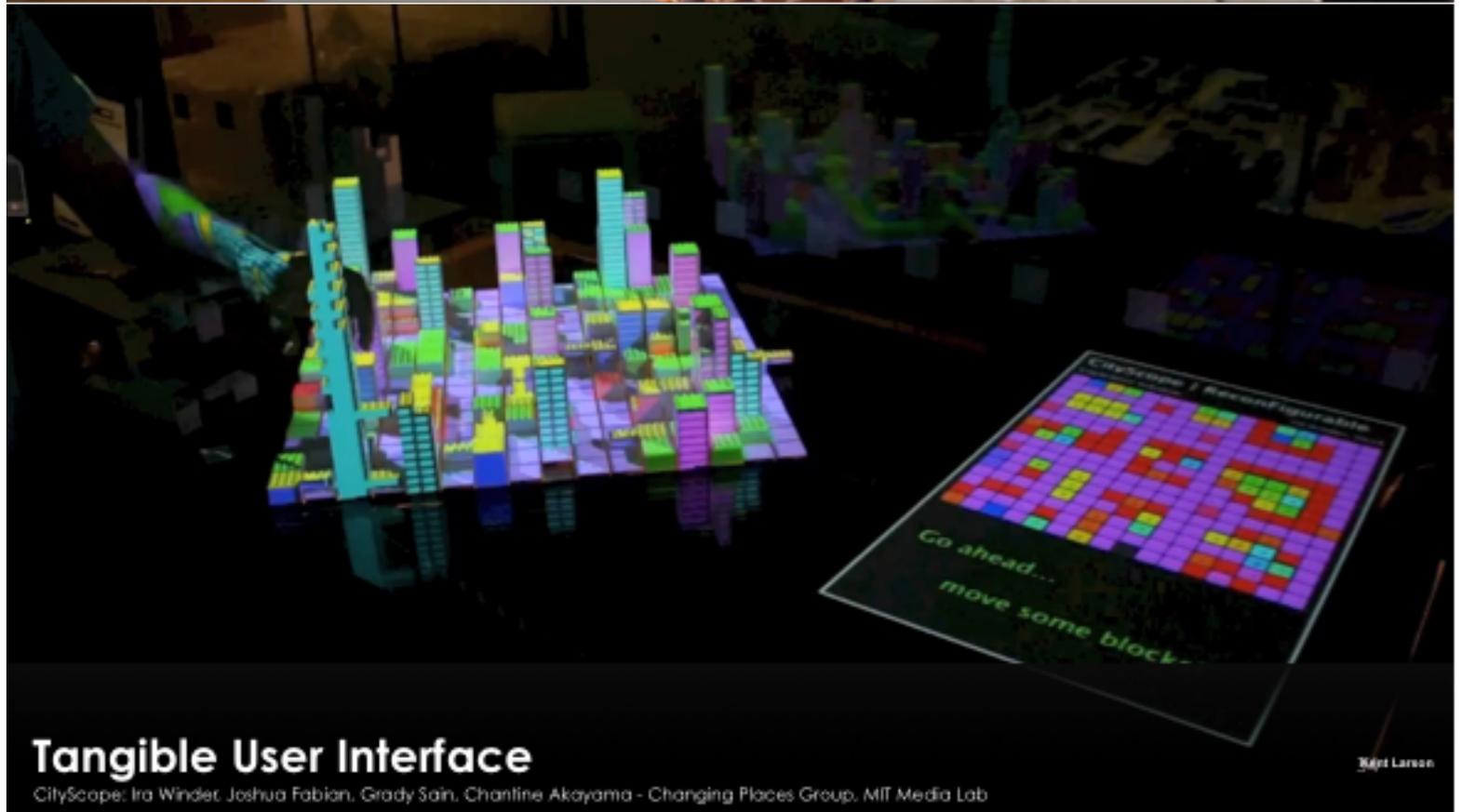
CityScope



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CityScope



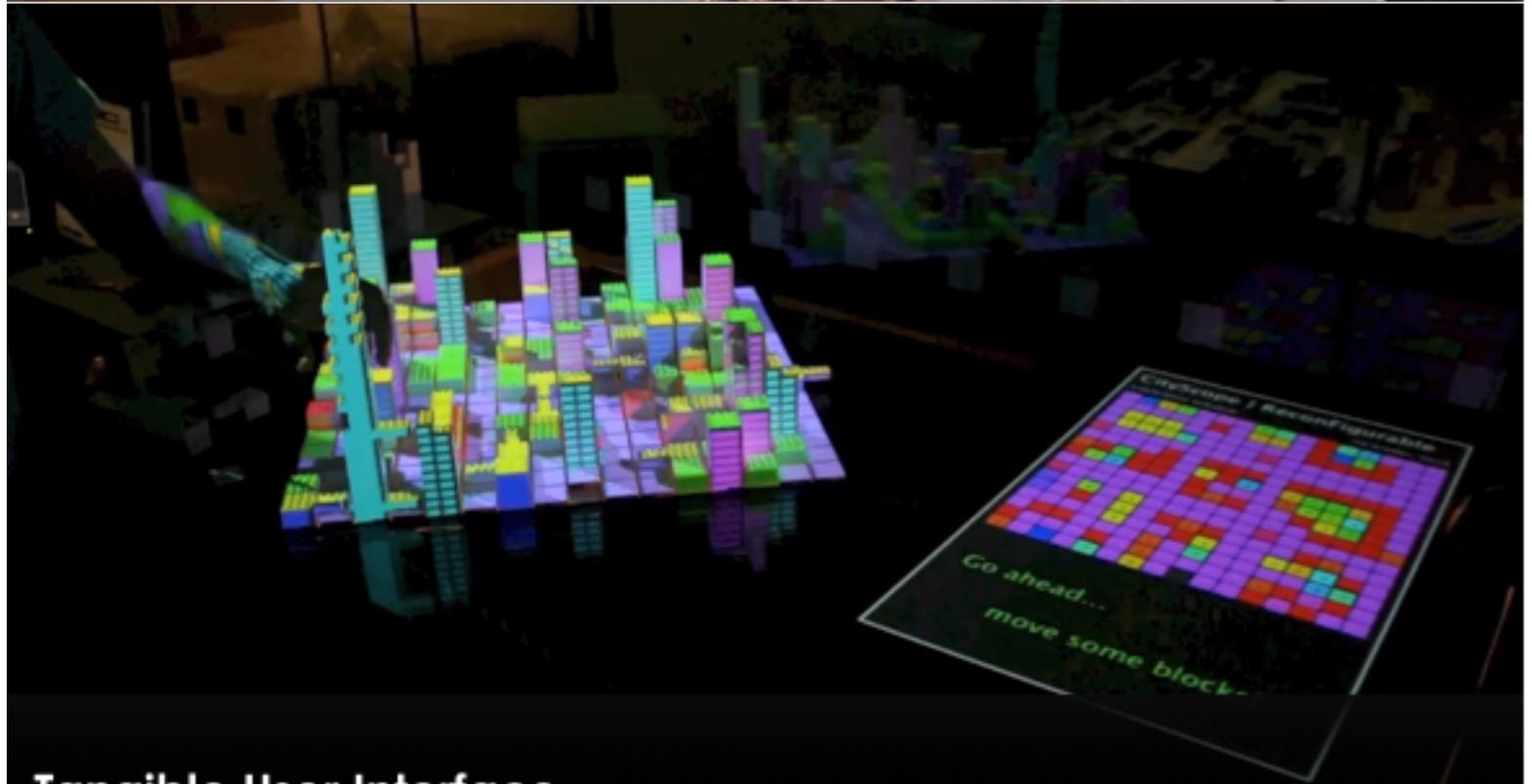
## Tangible User Interface

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

MIT Larson

# 3D Planning and Land Use

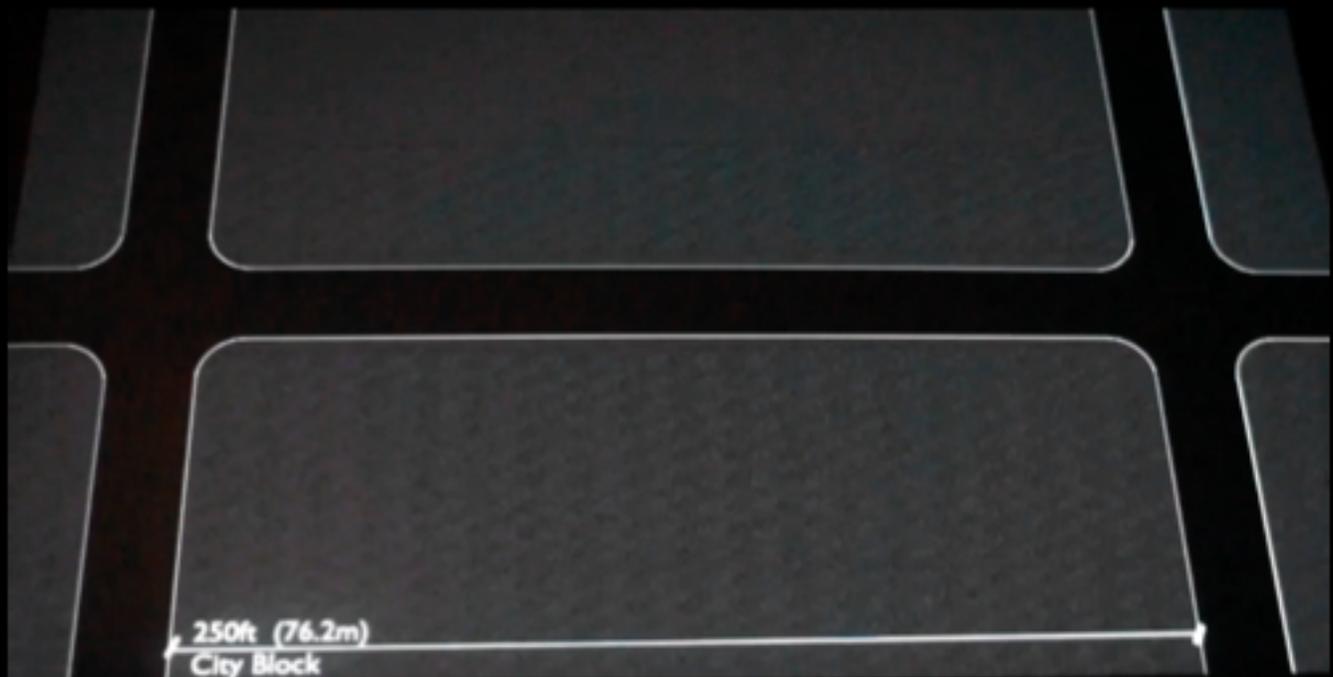
CityScope  
Ira Winder, Mohammad Hadi Nayl, Carson Smuts, Josh Fabian - Changing Places Group, MIT Media Lab



## Tangible User Interface

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

Kyle Larson



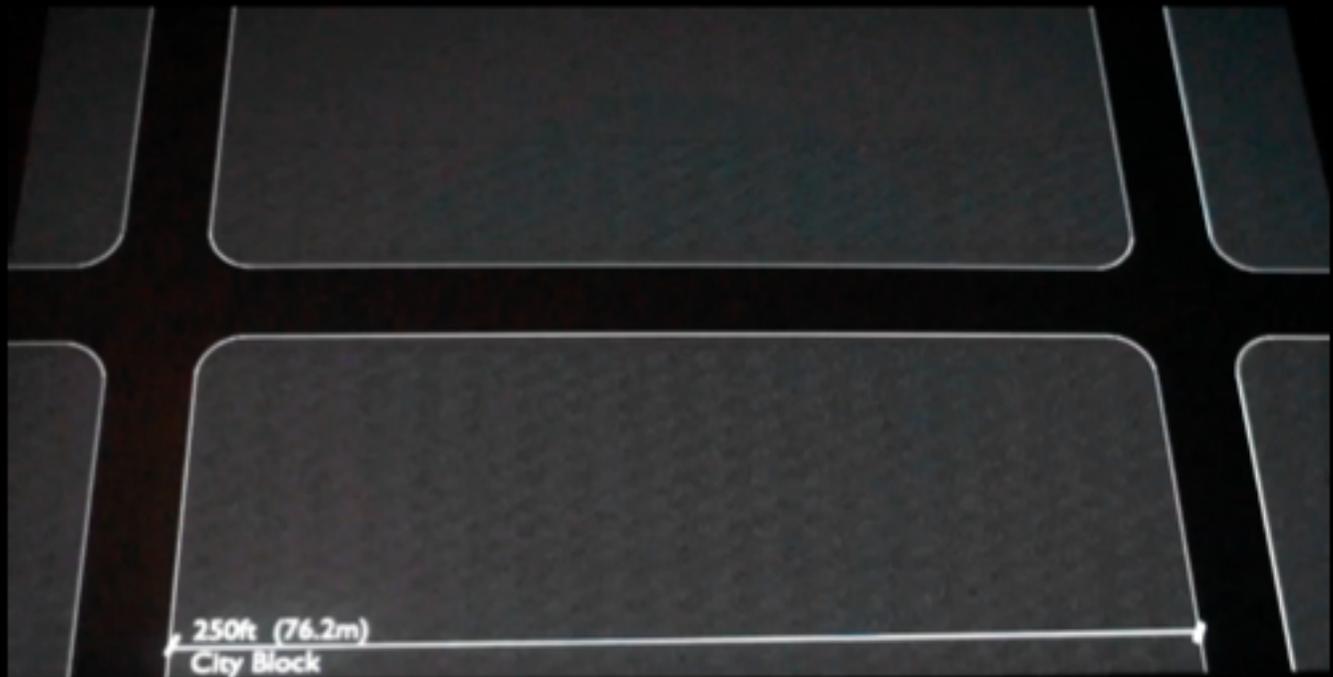
## Modeling Human Interactions

CityScope  
Carson Smuts - Changing Places Group, MIT Media Lab

# Tangible User Interface

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

Kjetil Larsen



# 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

## 2

### Food for Cities

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



Urban Garden (Kent Larson)



# integrated aerponics)



Urban Garden (Kent Larson)



Urban Garden (Kent Larson)





Urban Garden (Kent Larson)



Urban Garden (Kent Larson)



the countries of origin for the food





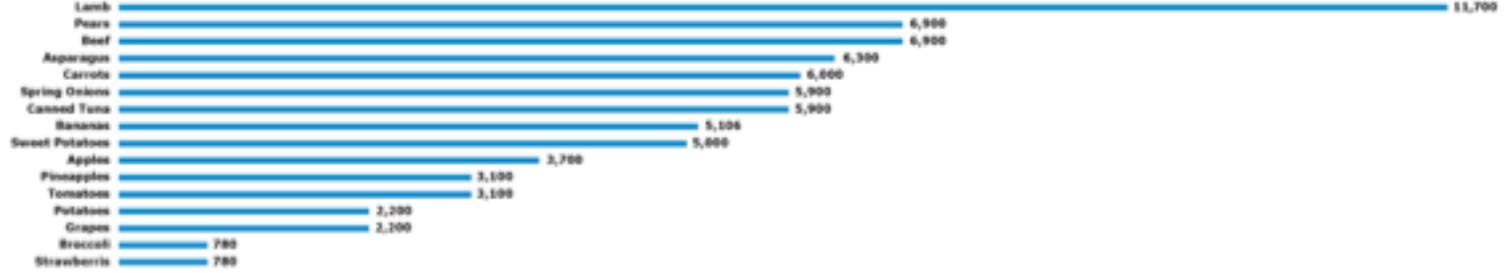
Urban Garden (Kent Larson)



The countries of origin for the food



Food miles to Britain

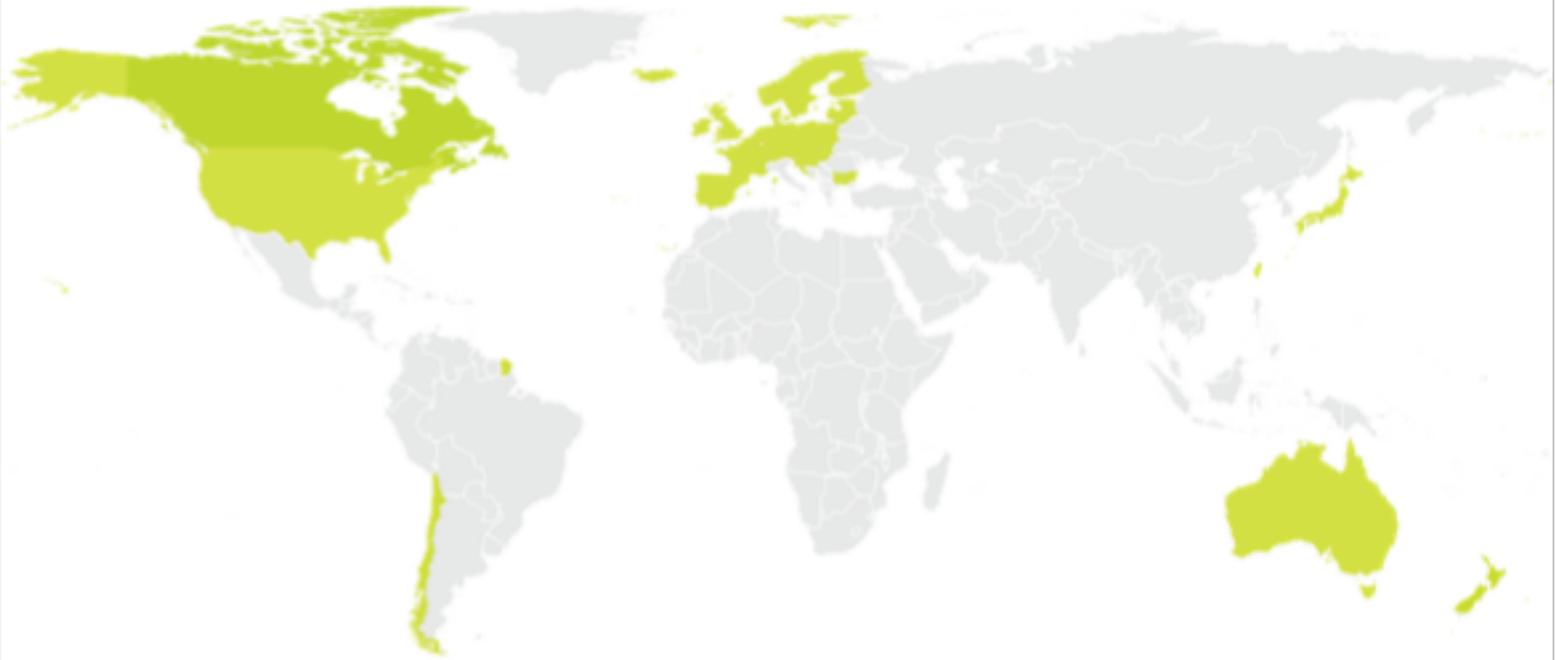


Source: <http://surreyfarmersmarket.com>

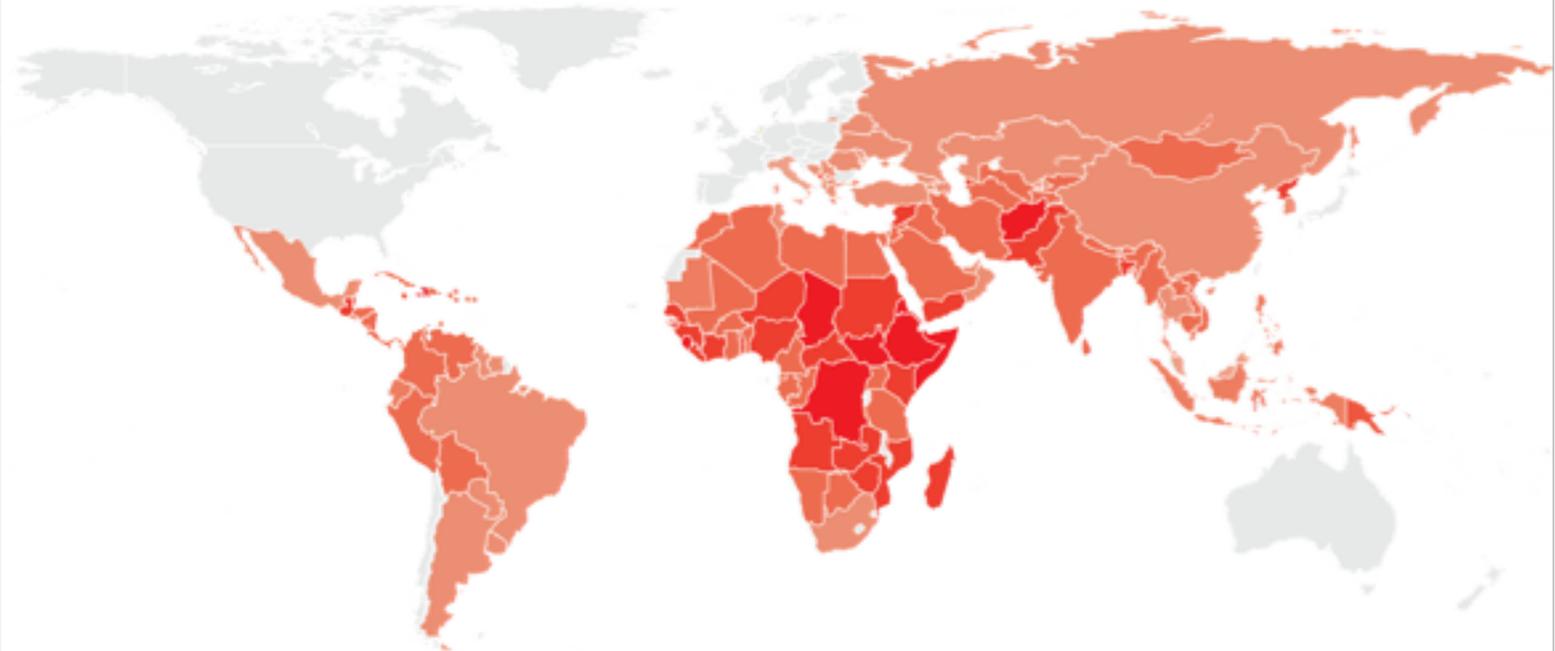


Apples	3,700
Pineapples	3,100
Tomatoes	3,100
Potatoes	2,200
Grapes	2,200
Broccoli	700
Strawberries	700

Source: <http://surreyfarmersmarket.com>



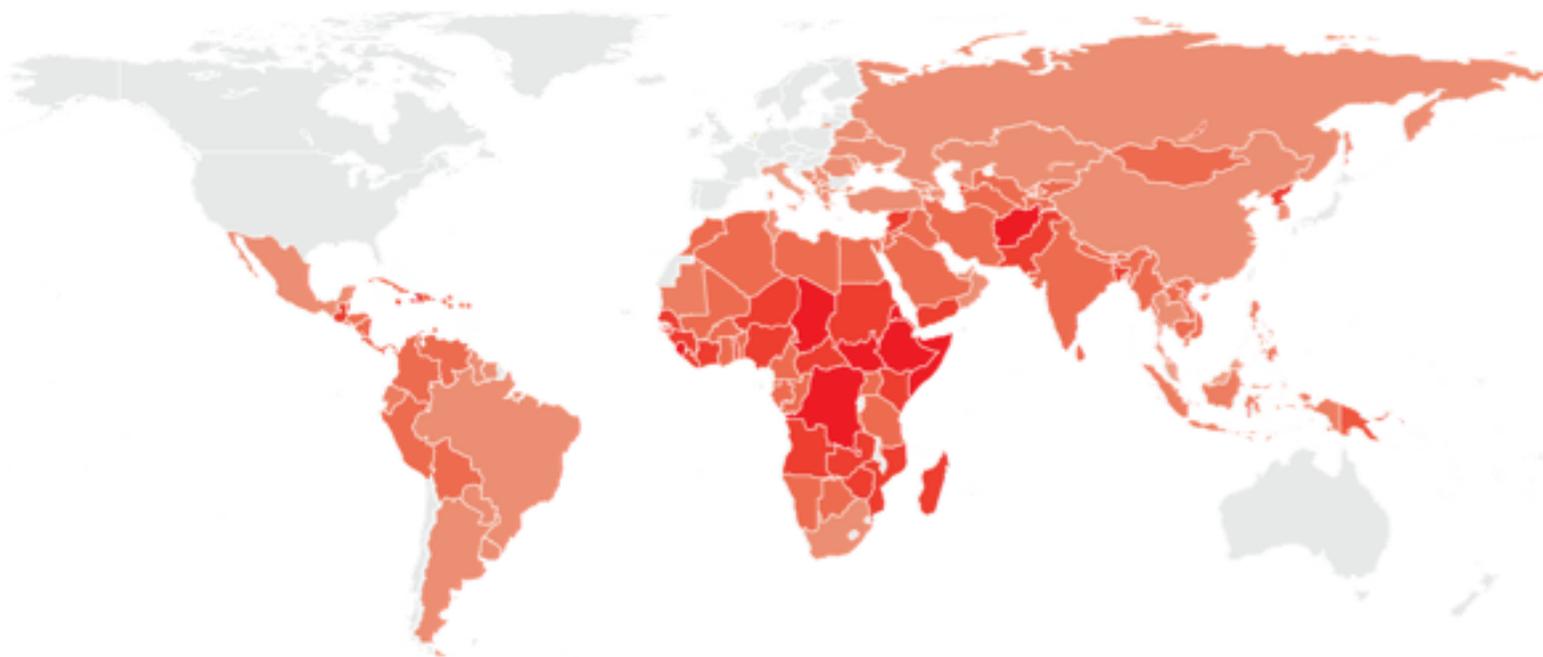
**Food Secure Countries (2013)**



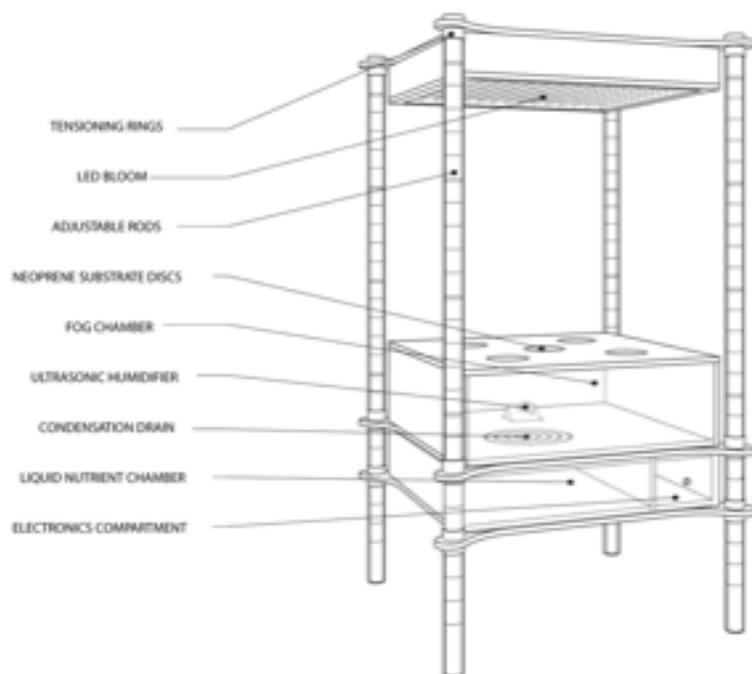
**Food Insecure Countries (2013)**



## Food Secure Countries (2013)



## Food Insecure Countries (2013)

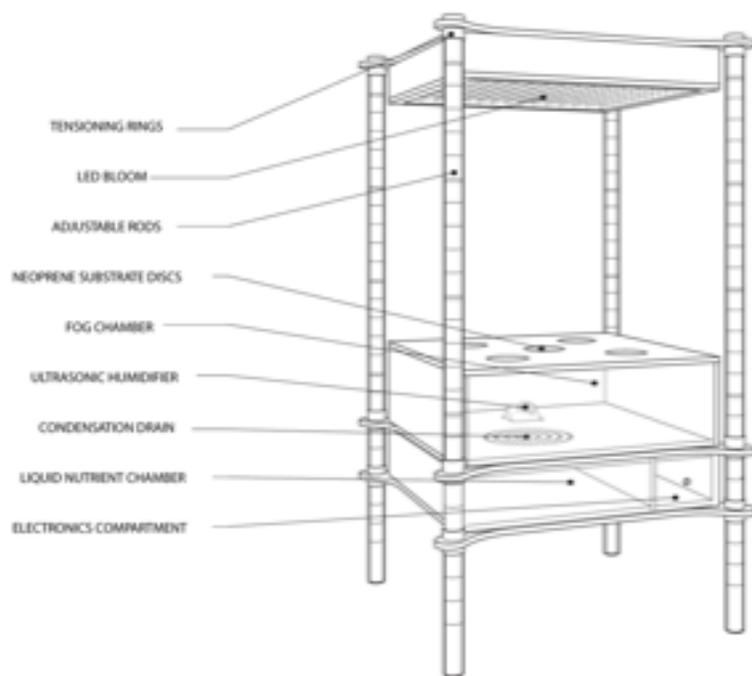


## CityFarm 1.0

Caleb Harper



# Food Insecure Countries (2013)



## 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

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



# CityFARM 2.0

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



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# CITYFARM 2.0

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



# CityFARM 2.0

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



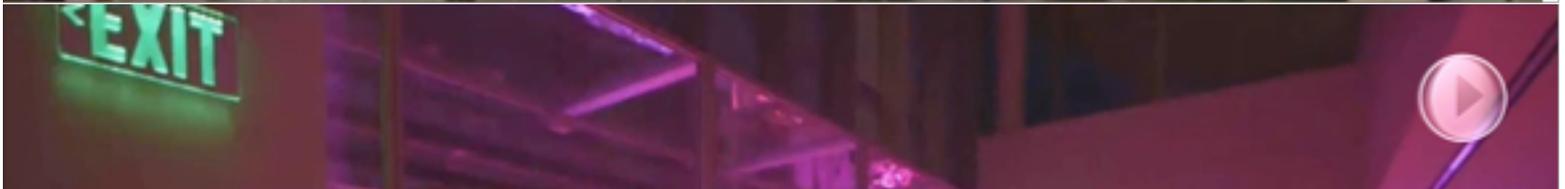
# CityFARM 3.0

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



# 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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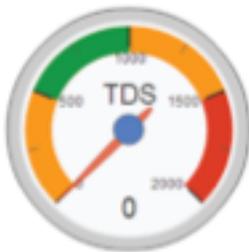
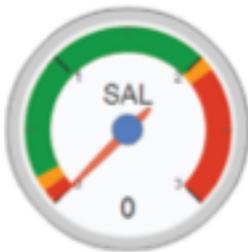
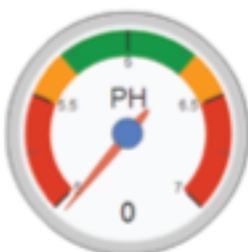
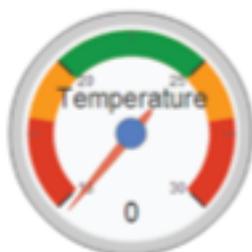
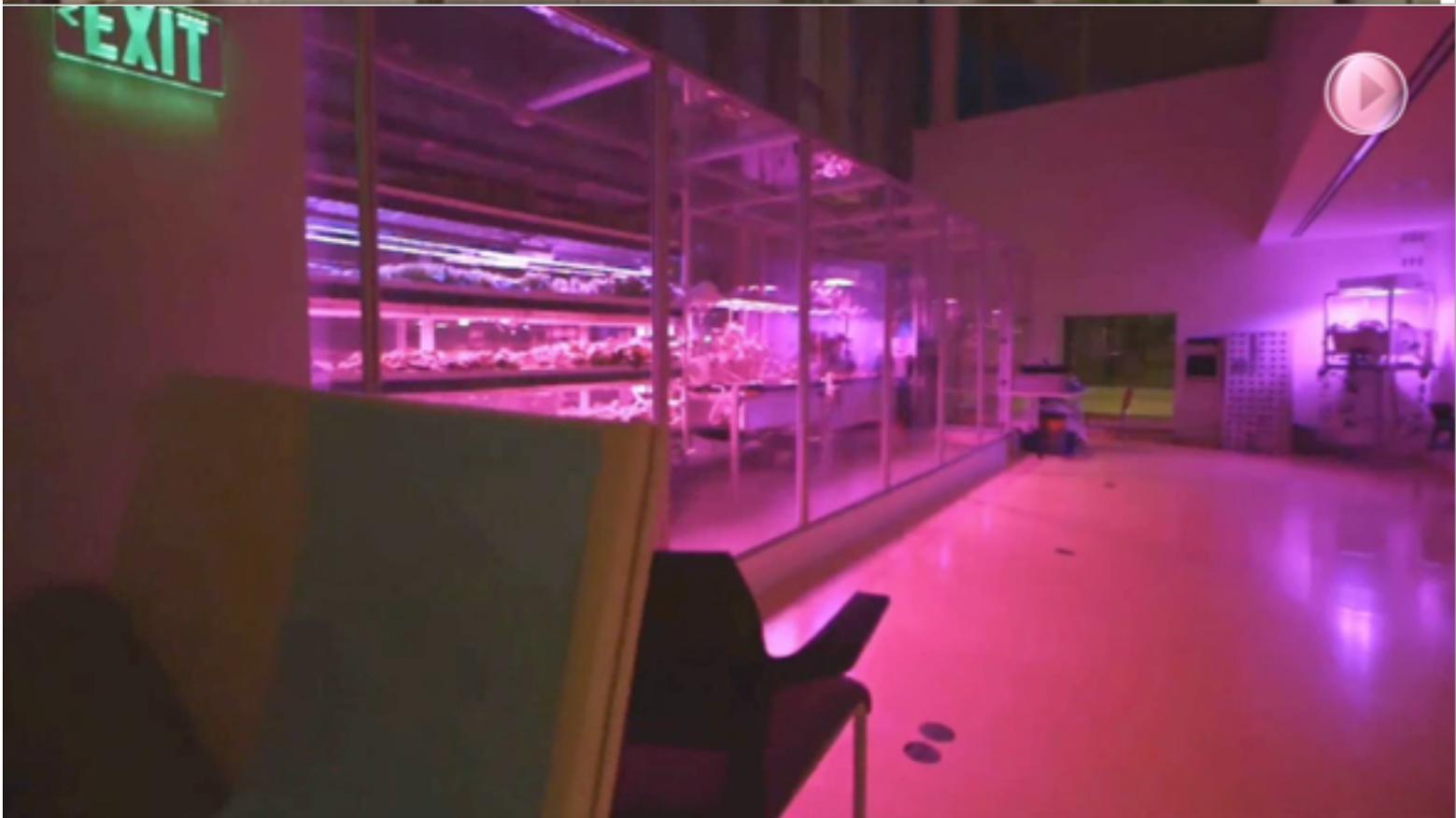


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Caleb Harper, Jason Nawyn, Rich Fletcher, Emma Feshbech, Preethi Vaidyanathan, Camille Richman, Li Haung, Sophia Jaffee Elaine Kung



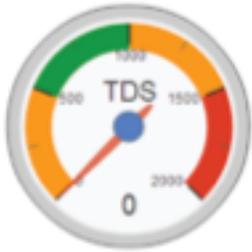
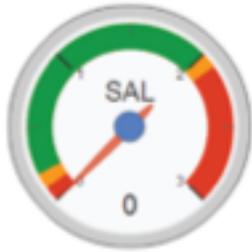
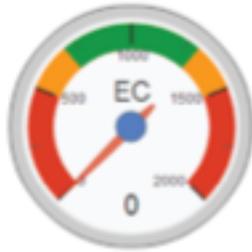
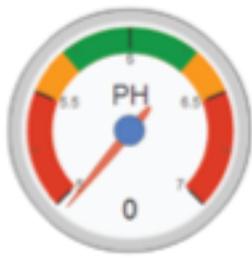
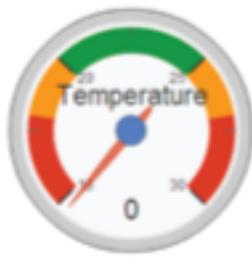
[View Sensor History For...](#)



View Sensor History For...

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





View Sensor History For...

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





# CityFARM 3.0

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



# CityFARM 3.0

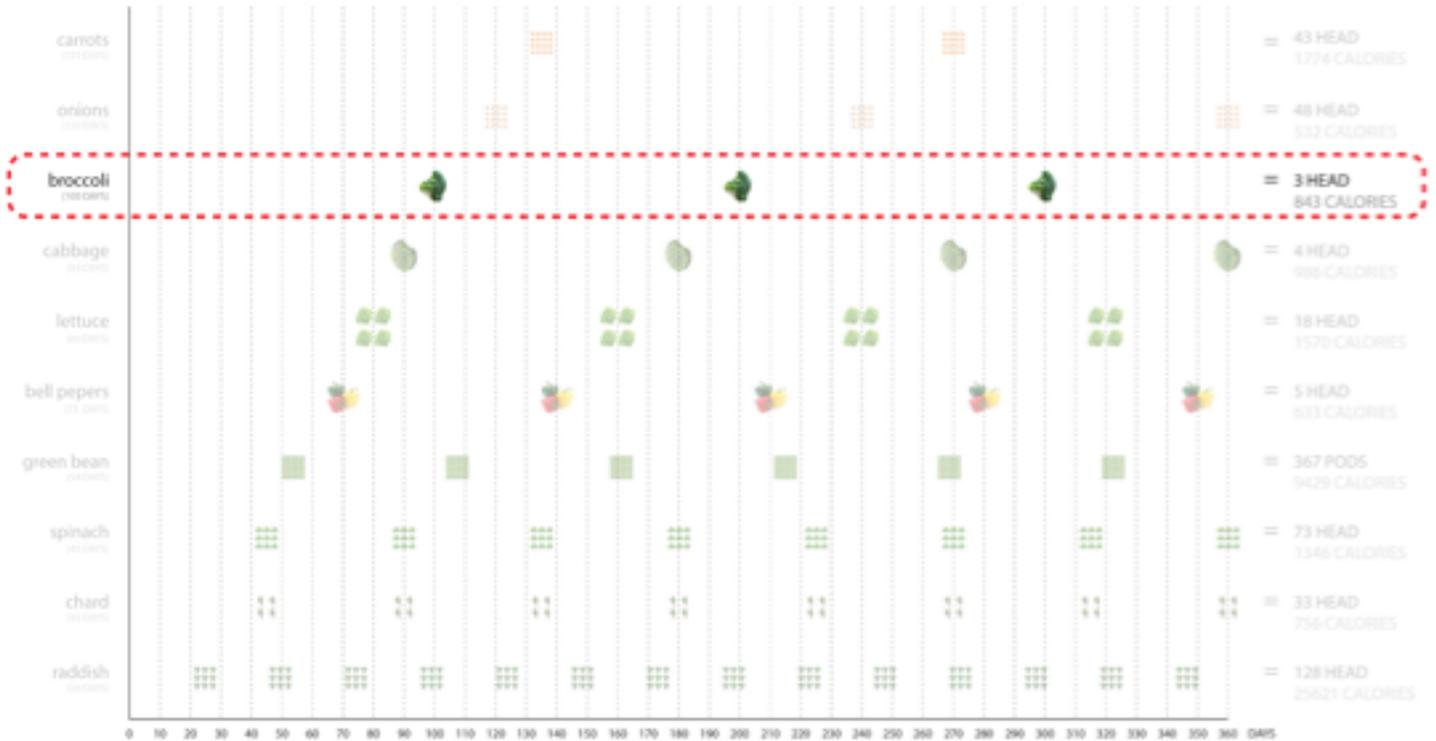
Caleb Harper, Jason Nawyn, Rich Fletcher, Emma Feshbech, Preethi Vaidyanathan, Camille Richman, Li Haung, Sophia Jaffee Elaine Kung



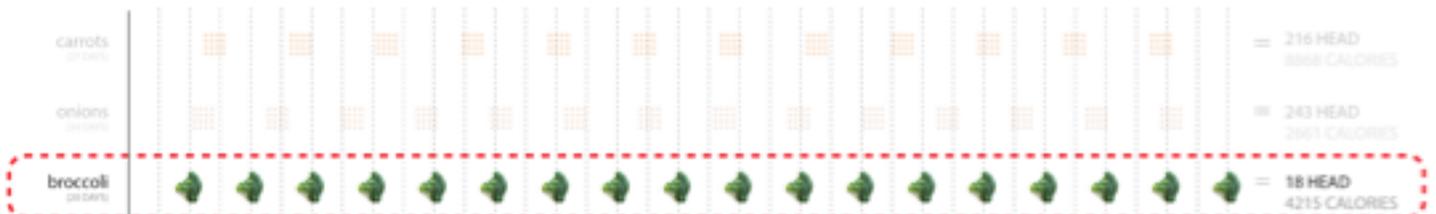


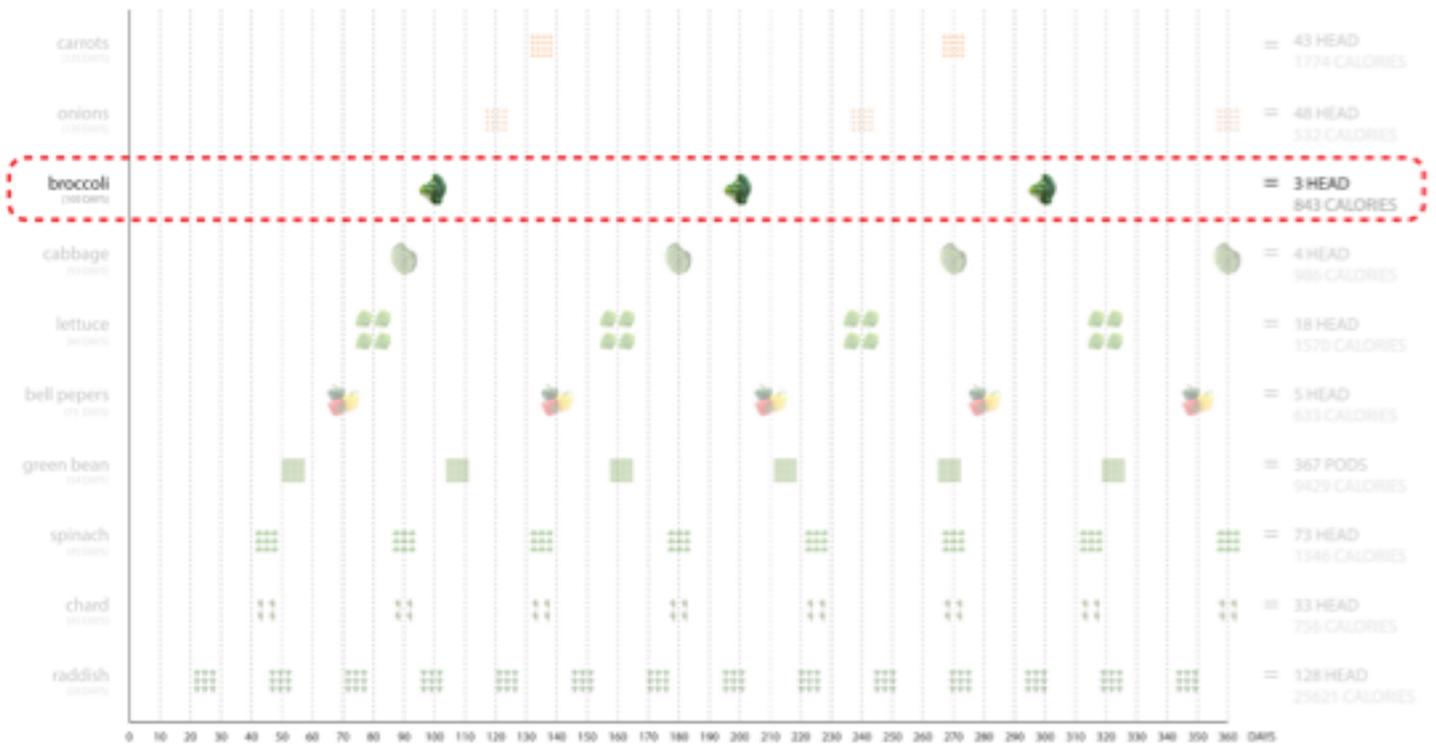
# CityFARM 3.0

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



**Soil Metrics = 3 heads/sf**

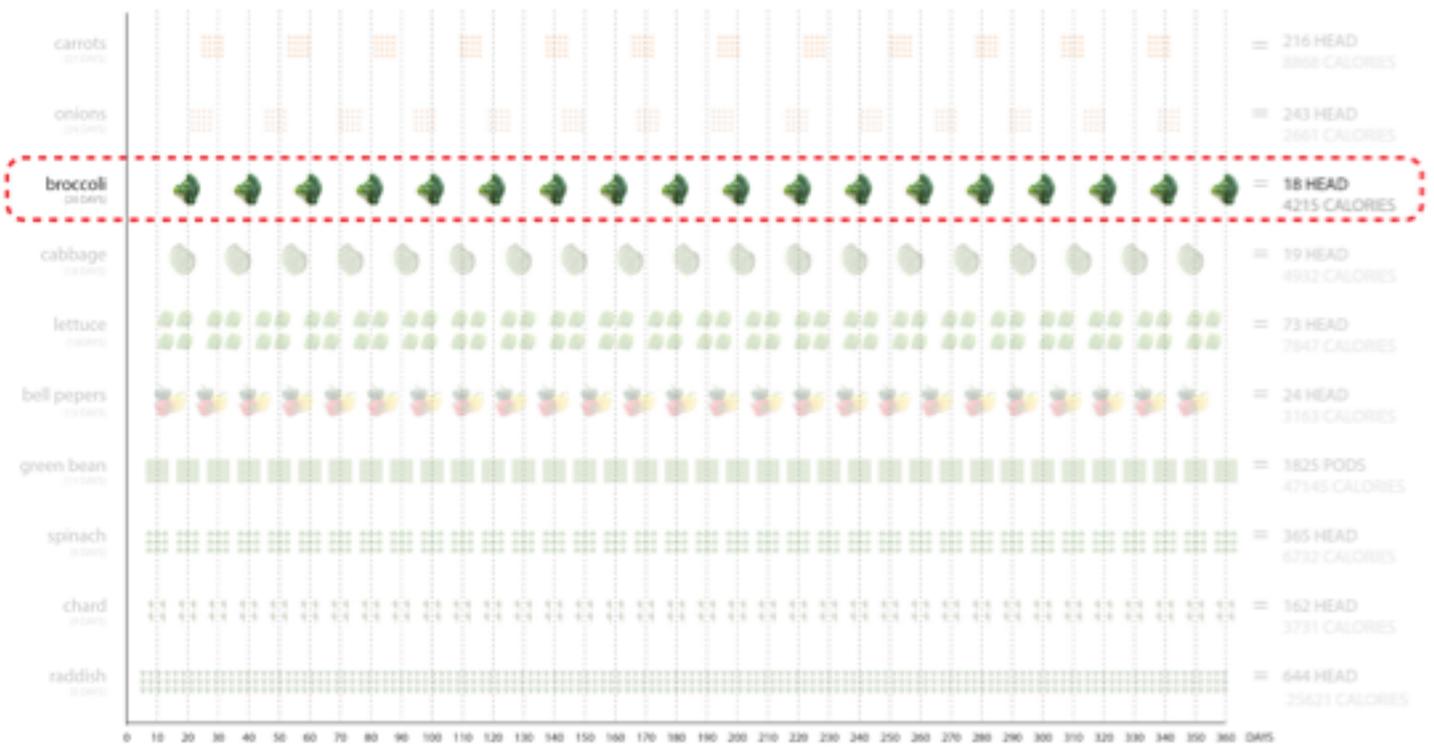




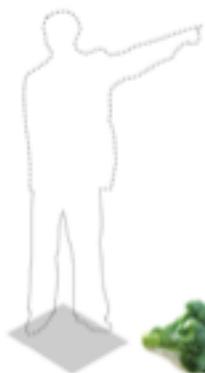
## Soil Metrics = 3 heads/sf



## Aeroponic Metrics = 18 heads/sf



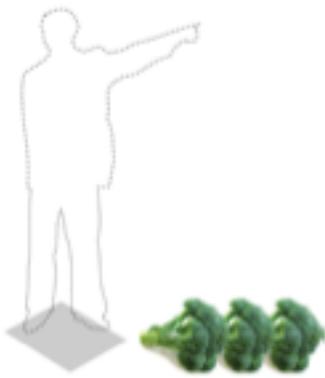
**Aeroponic Metrics = 18 heads/sf**



**Soil = 3/sf**



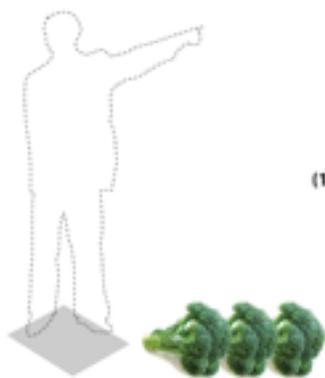
**Aeroponics = 18/sf (5X)**



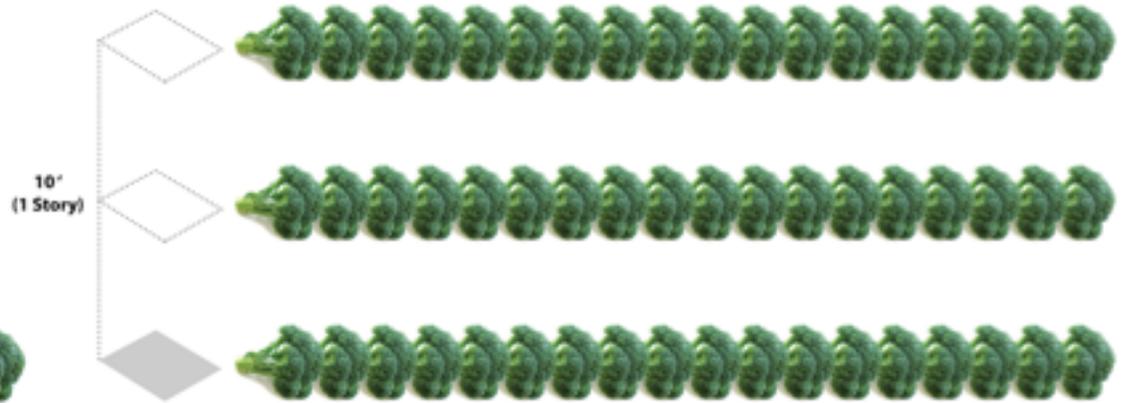
**Soil = 3/sf**



**Aeroponics = 18/sf (5X)**



**Soil = 3/sf**

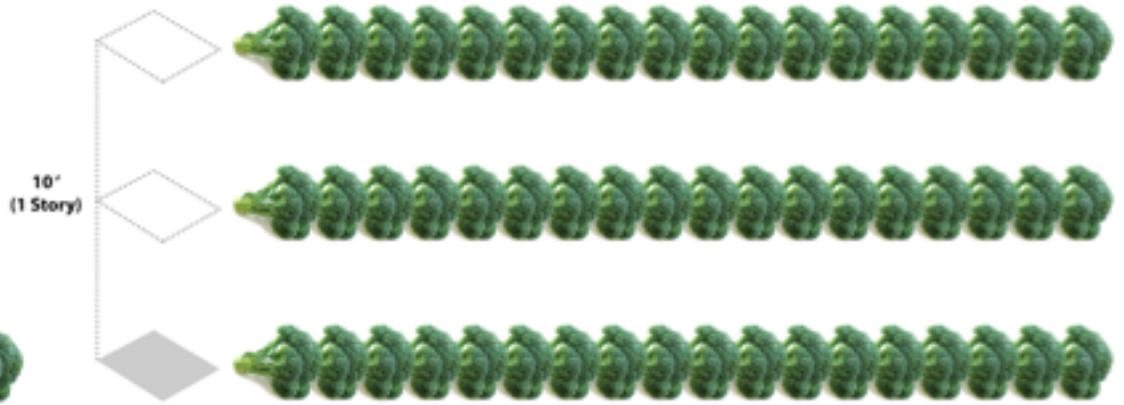


**Aeroponics = 54/sf per floor (18X)**

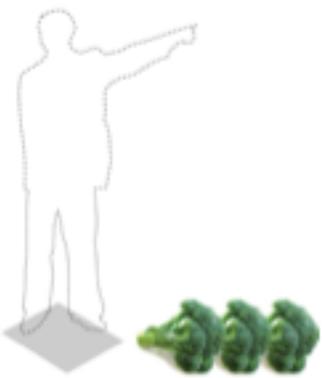




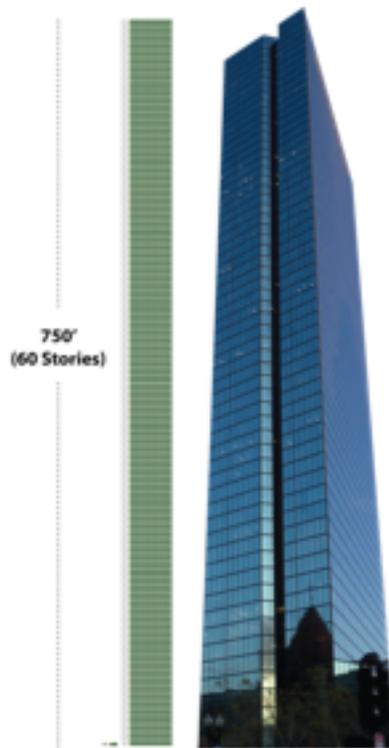
**Soil = 3/sf**



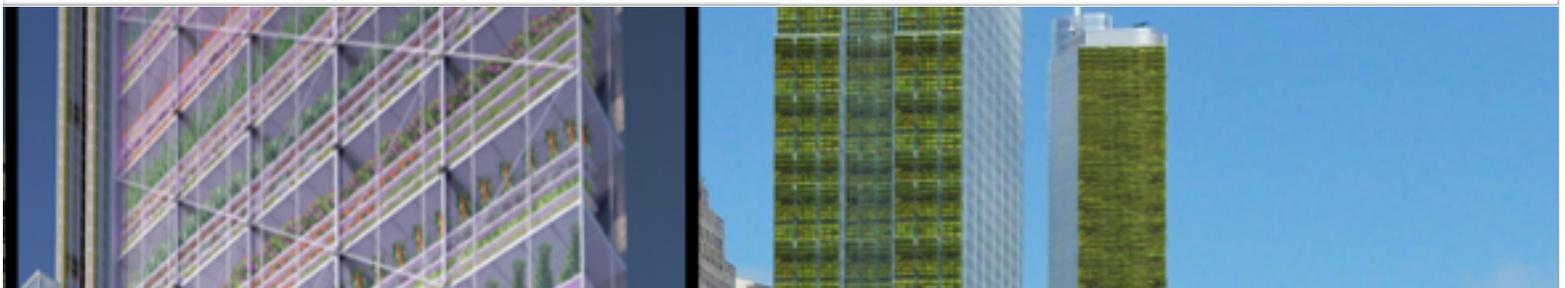
**Aeroponics = 54/sf per floor (18X)**

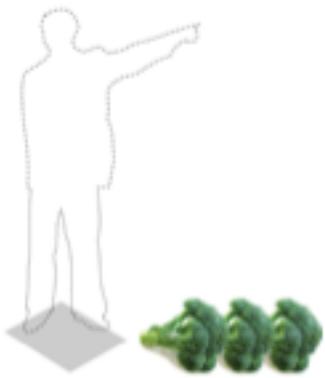


**Soil = 3/sf**

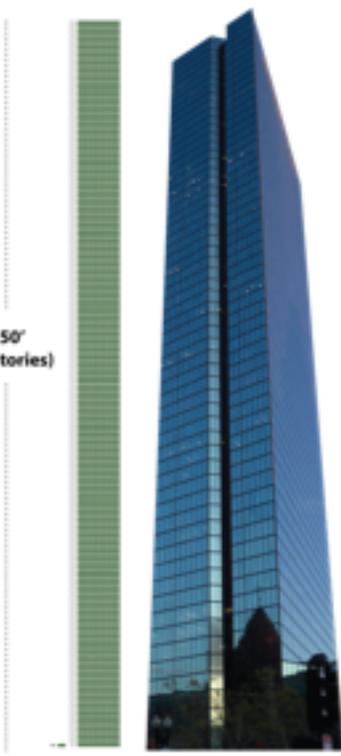


**Aeroponics = 3240/sf @ 60 floors (1080X)**



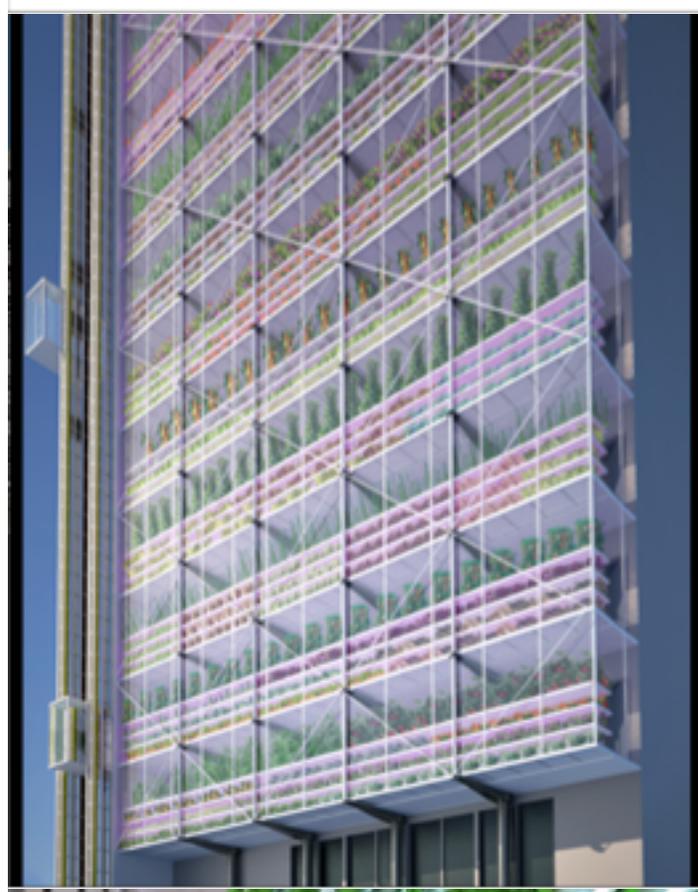


750'  
(60 Stories)

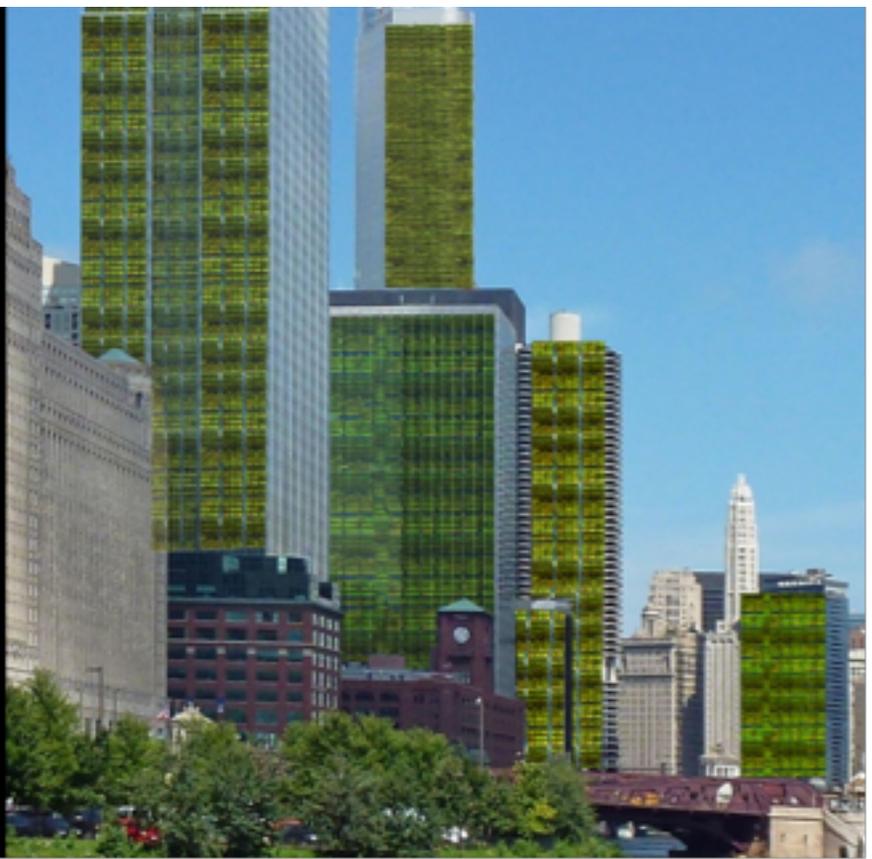


Soil = 3/sf

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



compared to soil-based farming  
**100x** Produce/land area

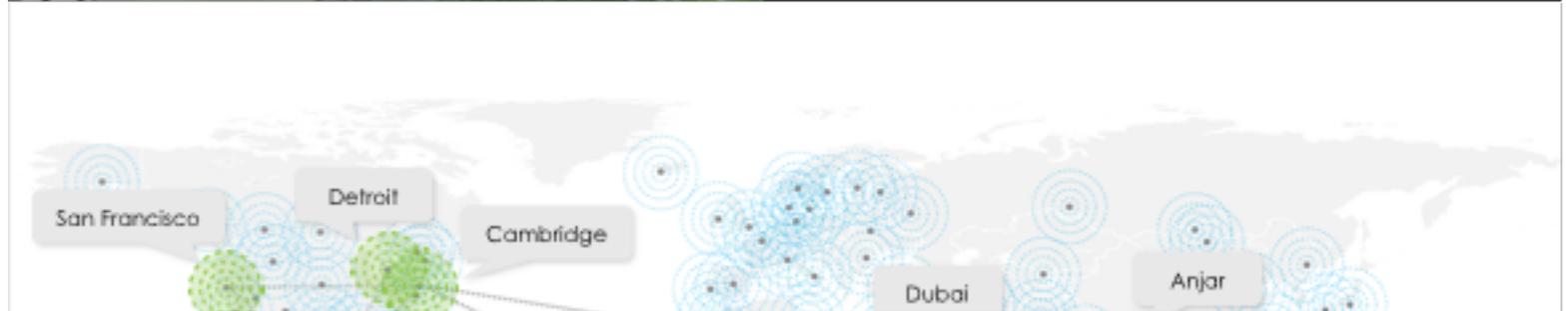


compared to soil-based farming

**100x** Produce/land area

**90%** Less water

**60%** Less fertilizer



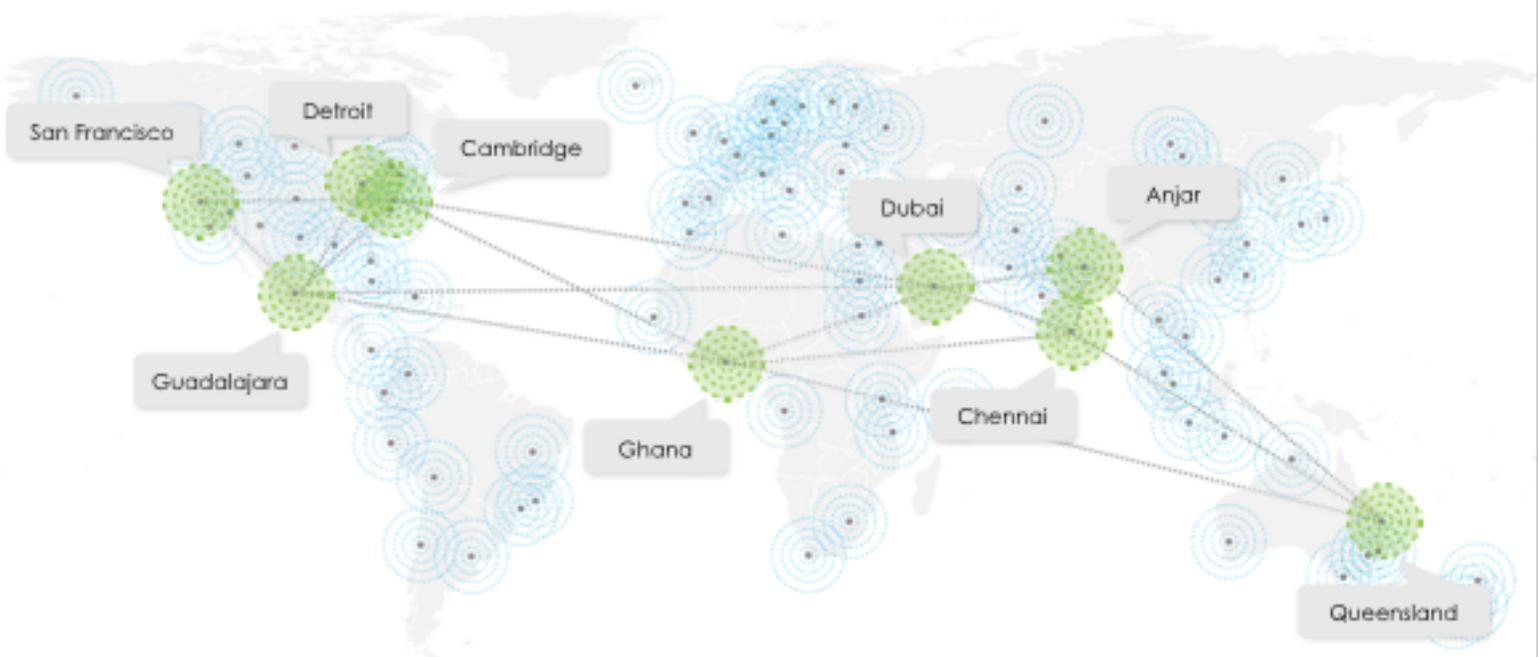


compared to soil-based farming

100x Produce/land area

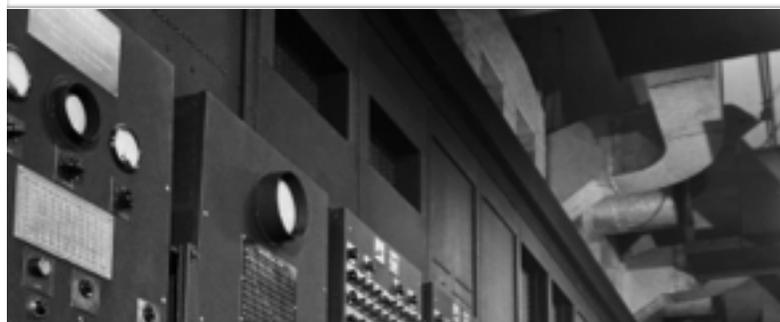
90% Less water

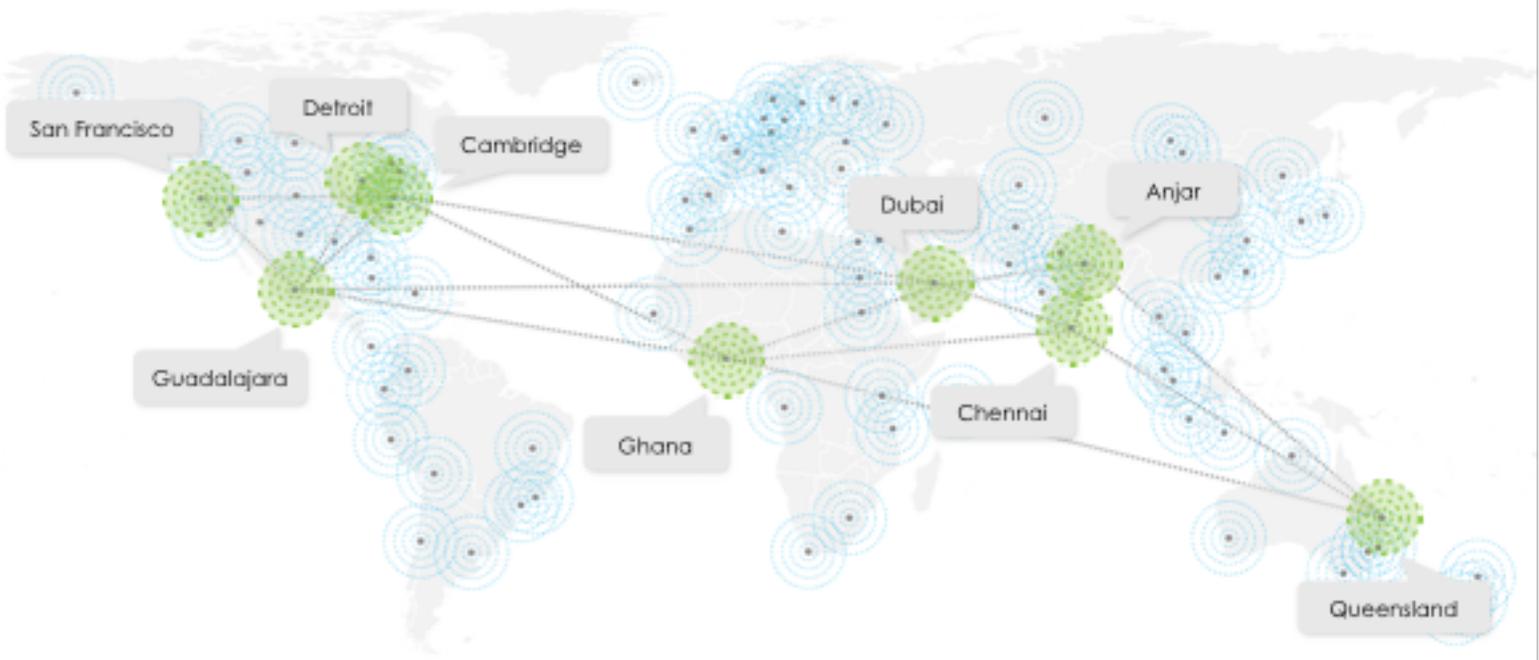
60% Less fertilizer



## Open Ag Project

@MITCityFARM





## Open Ag Project

@MITCityFARM



@MITCityFARM



3



@MITCityFARM



# 3

## Mobility-on-Demand

(creating alternatives to the private automobile in compact districts)



Walking (Privileged Mode)



Shared Bikes



On Demand Bus / Tram

# 3

## Mobility-on-Demand

(creating alternatives to the private automobile in compact districts)



Walking (Privileged Mode)



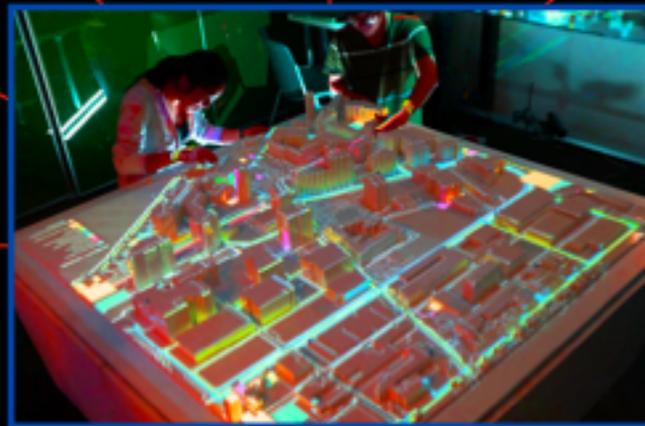
Shared Bikes



On Demand Bus / Tram



Autonomous CityCars



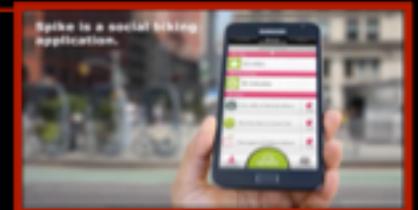
Mobility-on-Demand Modes



Shared eBikes

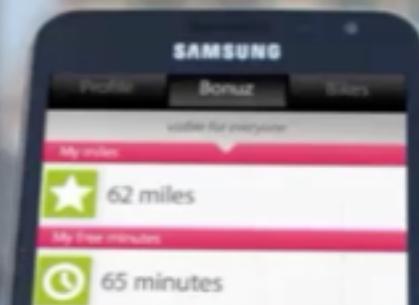


Shared eScooters



Autonomous Shared PEVs

**Spike is a social biking application.**





Walking (Privileged Mode)



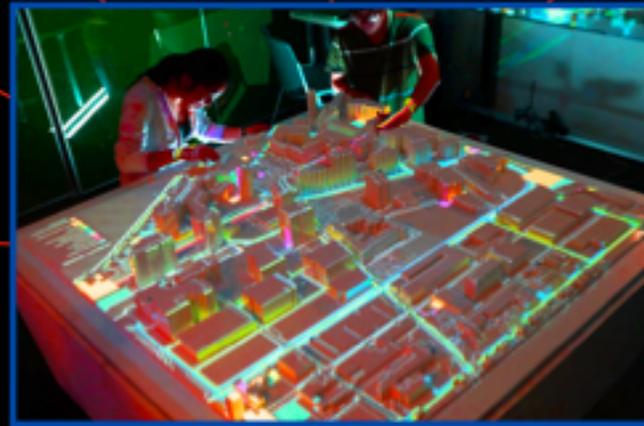
Shared Bikes



On Demand Bus / Tram



Autonomous CityCars



Mobility-on-Demand Modes



Shared eBikes

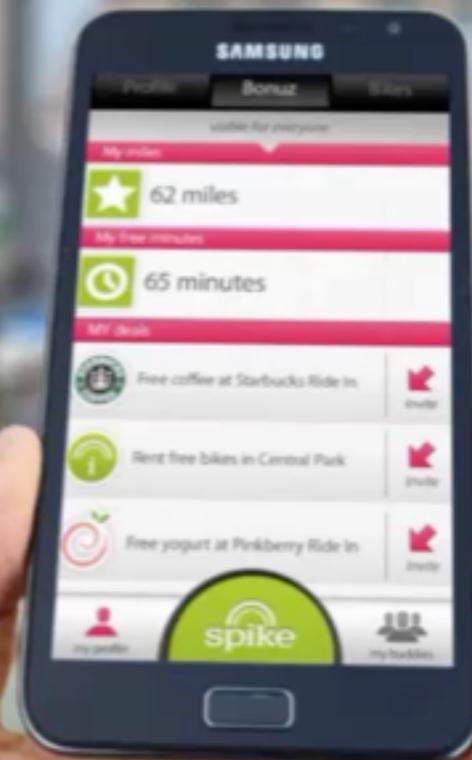


Shared eScooters



Autonomous Shared PEVs

# Spike is a social biking application.



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

Foldable Canopy

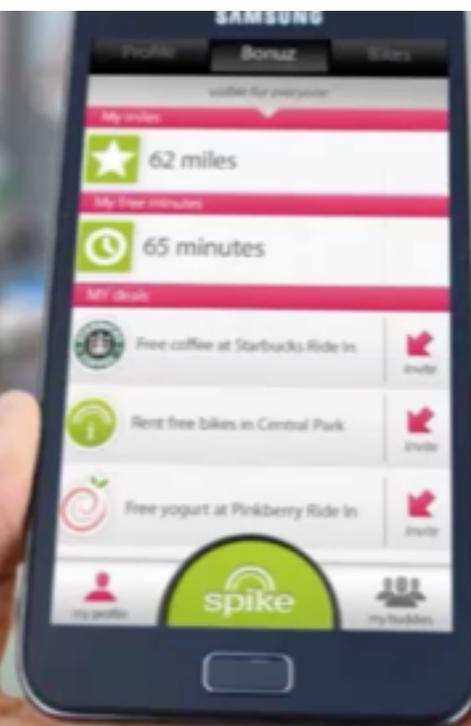
Carbon Fiber Exterior

## EU Bike Lane Regulations

Weight Limitation: 60 KG Weight  
Speed Limitation: 20 KPH

Folding Steering Mechanism

application.



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

Foldable Canopy

Carbon Fiber Exterior

Tilting Mechanism

### EU Bike Lane Regulations

Weight Limitation: 60 KG  
Speed Limitation: 20 KPH

Folding Steering Mechanism

Integrated 250W motor assist drive module

Li-Ion Battery Pack 36V 10Ah

## Persuasive Electric Vehicle (PEV)

Ryan Chin, Michael Lin, Sandra Richter

Package Delivery Mode

People Mover Mode

Foldable Canopy

Weight Limitation: 60 KG Weight  
Speed Limitation: 20 KPH

Carbon Fiber Exterior

Folding Steering Mechanism

Tilting Mechanism

Integrated 250W motor  
assist drive module

## Persuasive Electric Vehicle (PEV)

Ryan Chin, Michael Lin, Sandra Richter

Li-Ion Battery Pack 36V 10Ah

Package Delivery Mode

People Mover Mode



## Persuasive Electric Vehicle (PEV)

Ryan Chin, Michael Lin, Sandra Richter

PEV loading and offloading



Package Delivery Mode

People Mover Mode



## Persuasive Electric Vehicle (PEV)

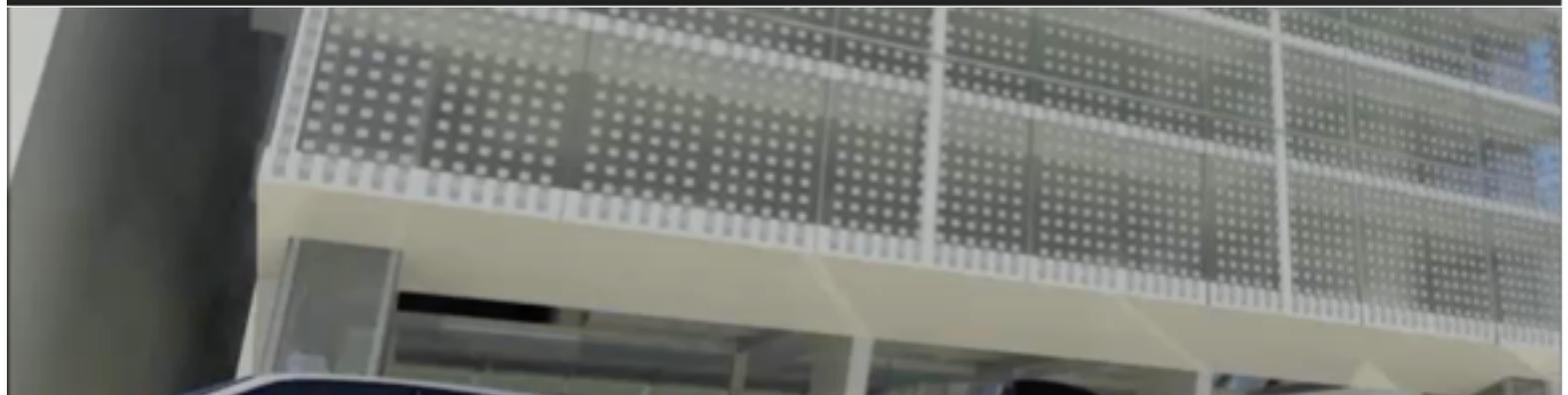
Ryan Chin, Michael Lin, Sandra Richter

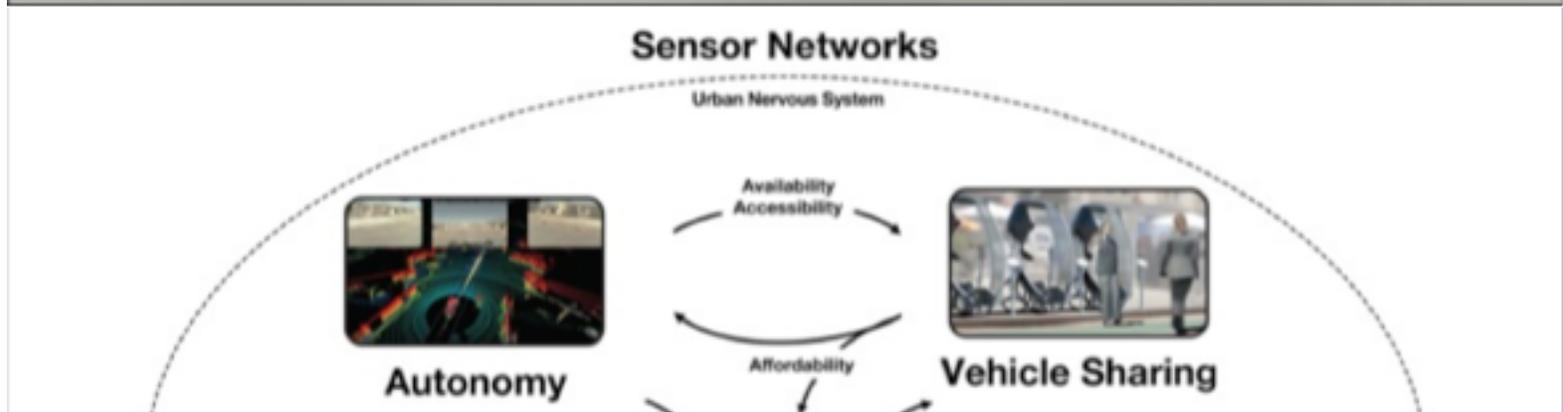
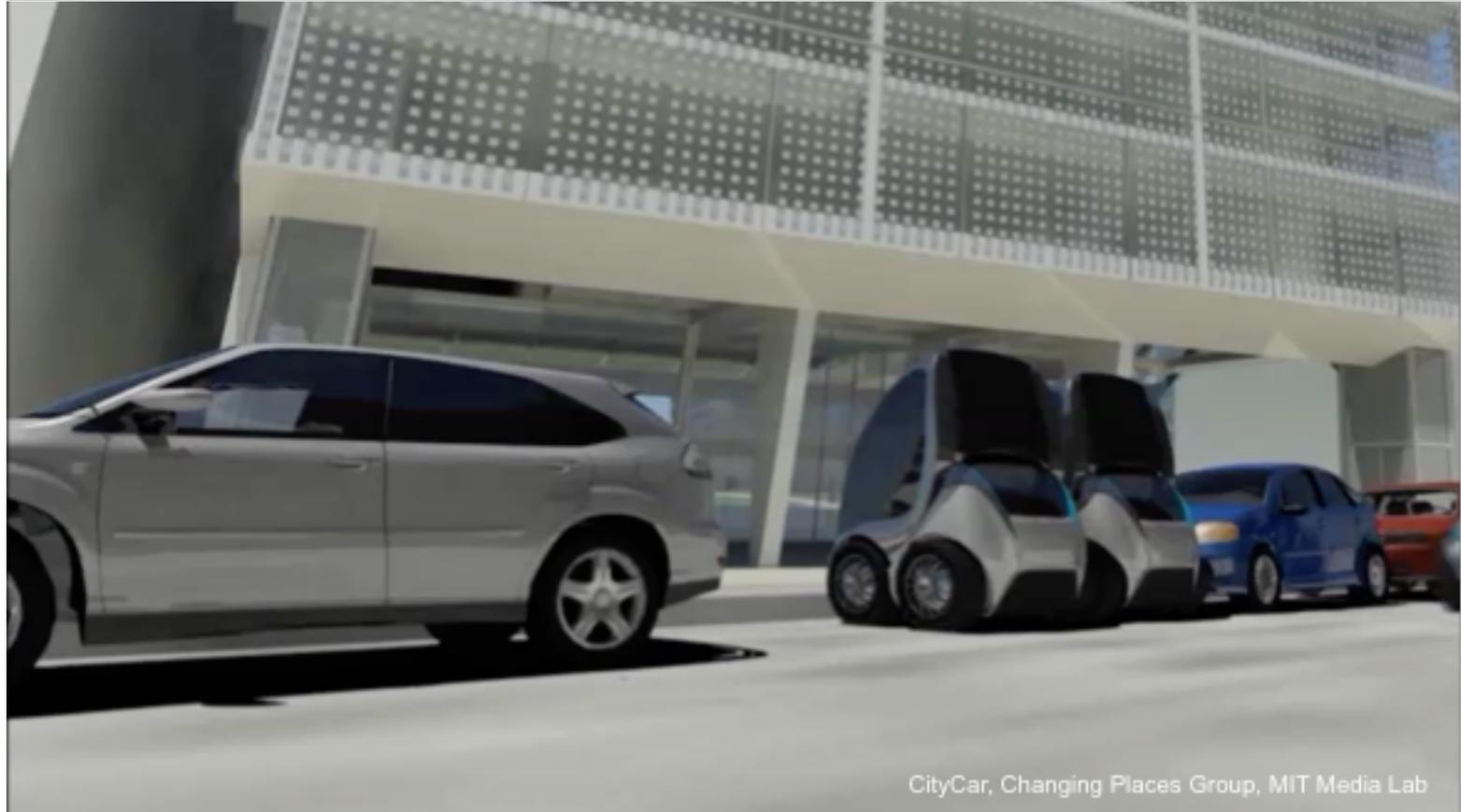
PEV loading and offloading



## Persuasive Electric Vehicle (PEV)

Ryan Chin, Michael Lin, Sandra Richter

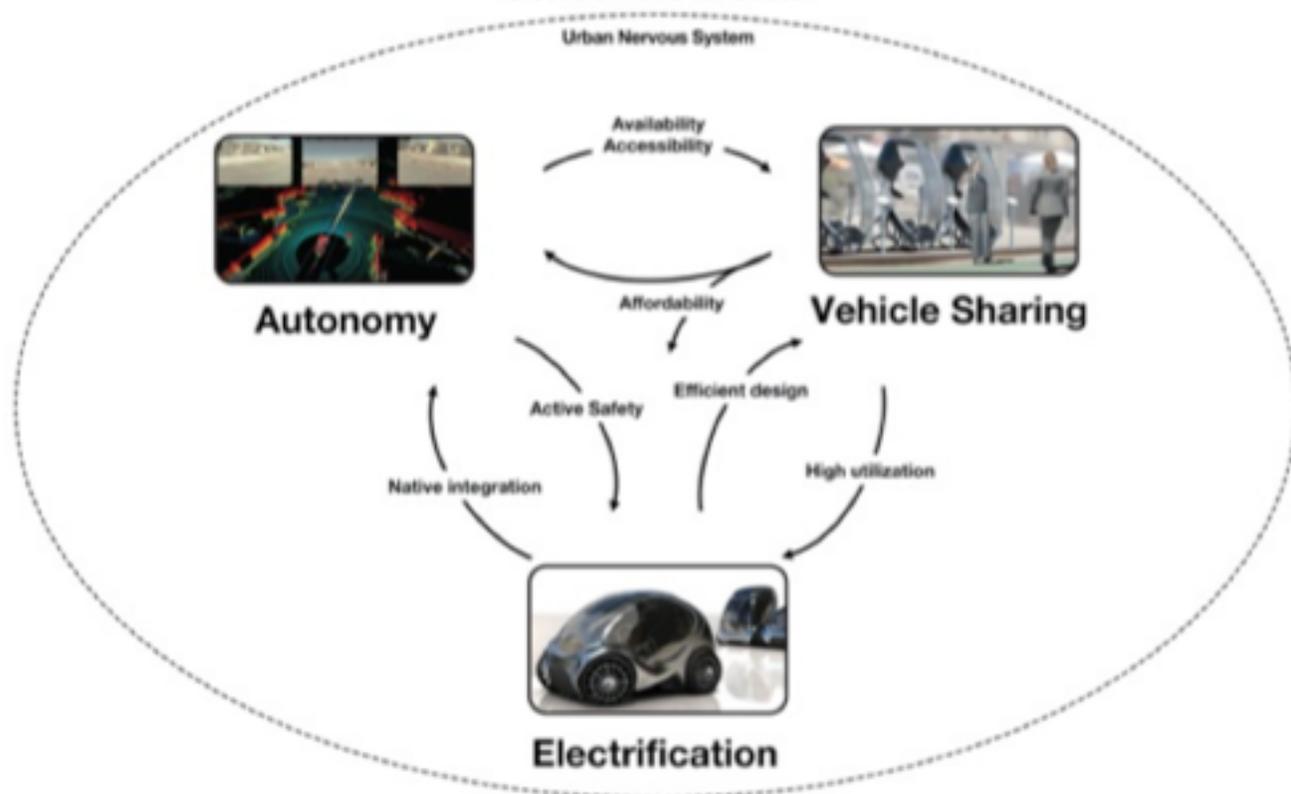






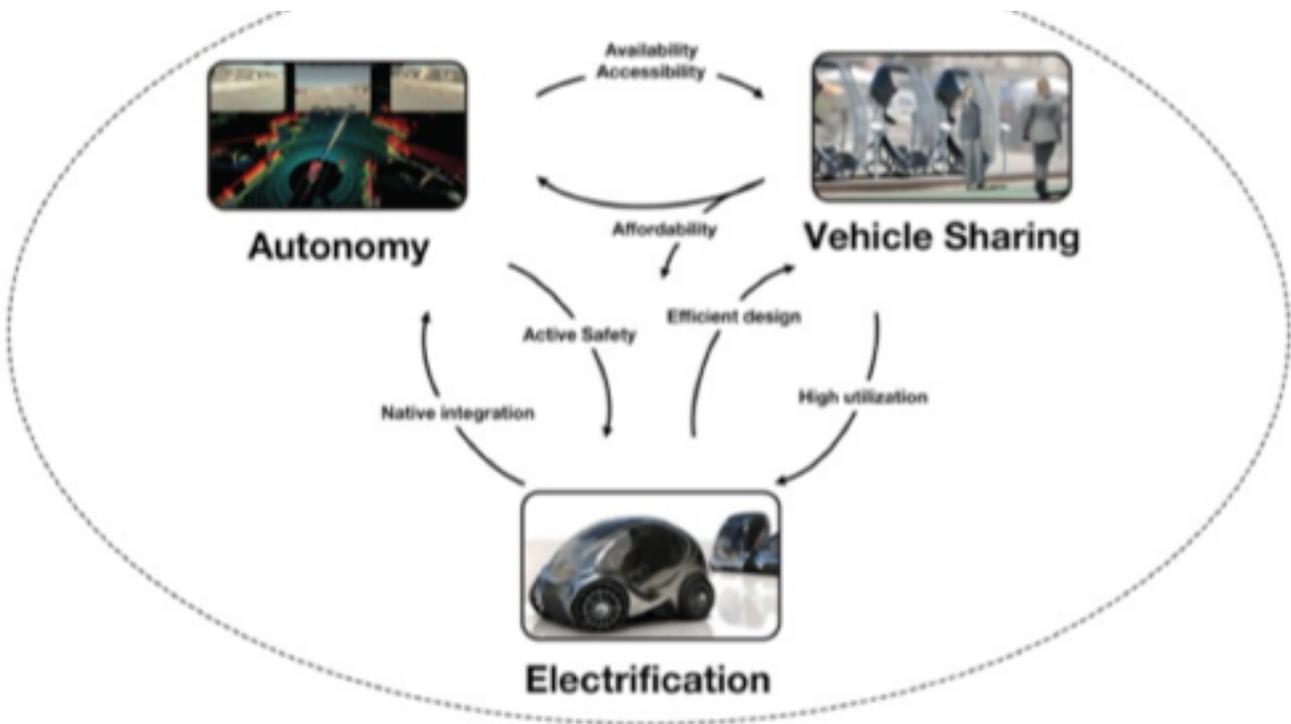
CityCar, Changing Places Group, MIT Media Lab

### Sensor Networks



- Mobility on Demand Systems in Singapore (NUS Campus)





• Mobility on Demand Systems in Singapore (NUS Campus)



DARPA Urban Challenge



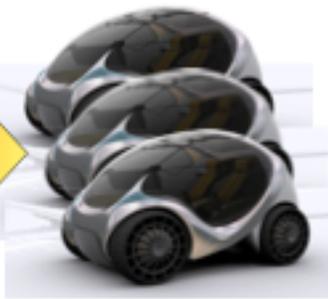
-500,000\$ (US)



CityCar prototype

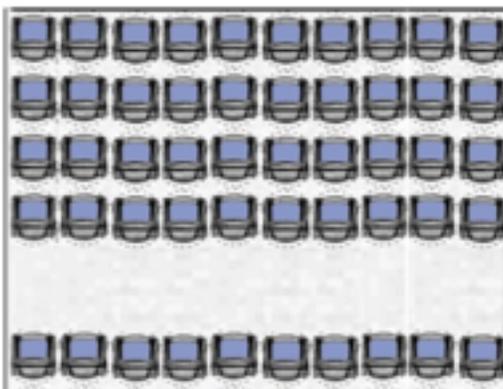
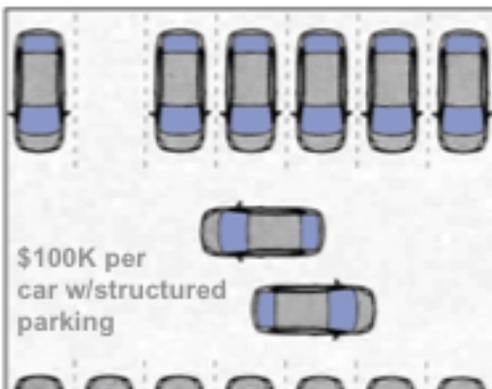


-50,000\$ (US)



-5,000\$ each (US)

Singapore-MIT Alliance for Research and Technology





DARPA Urban Challenge



-500,000\$ (US)



CityCar prototype

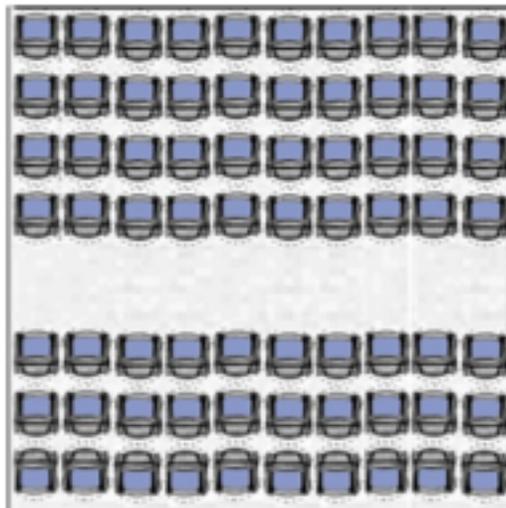
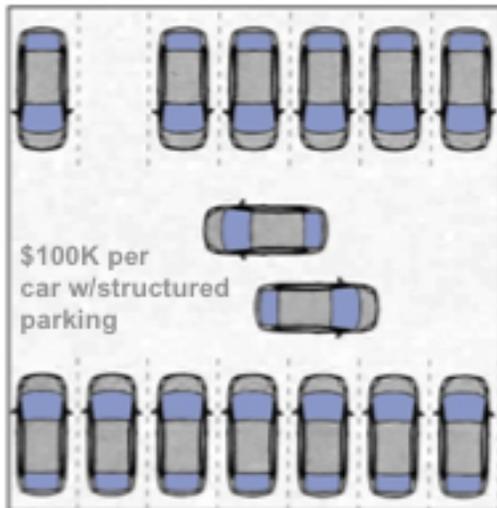


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Singapore-MIT Alliance for Research and Technology

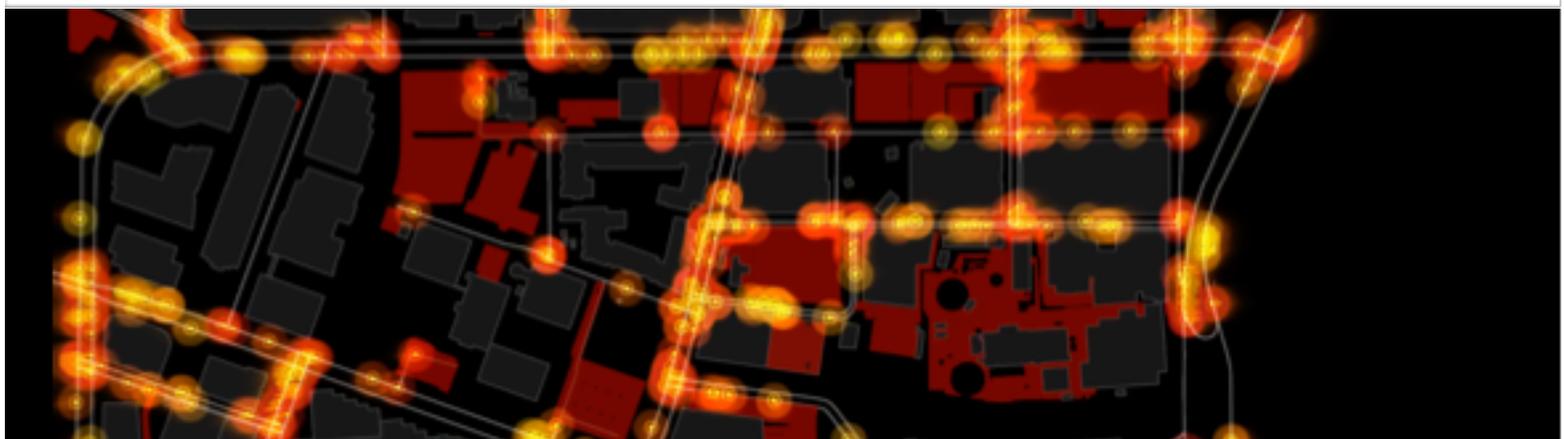


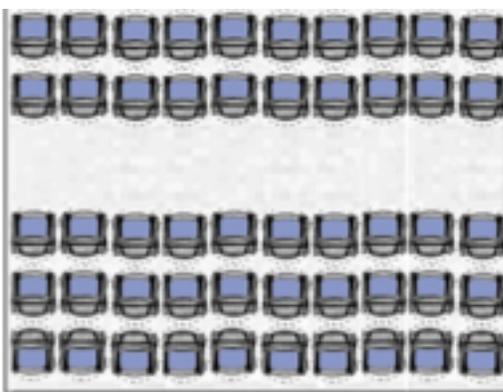
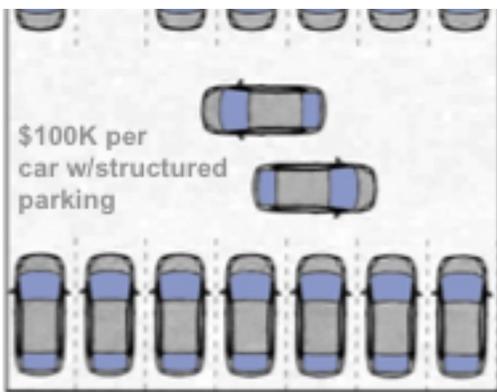
**5X + 4X = 20X**

cars/area with folding and autonomous parking

car replacement/person with shared use

increase in land utilization





$$5X + 4X = 20X$$

cars/area with folding and autonomous parking

car replacement/ person with shared use

increase in land utilization





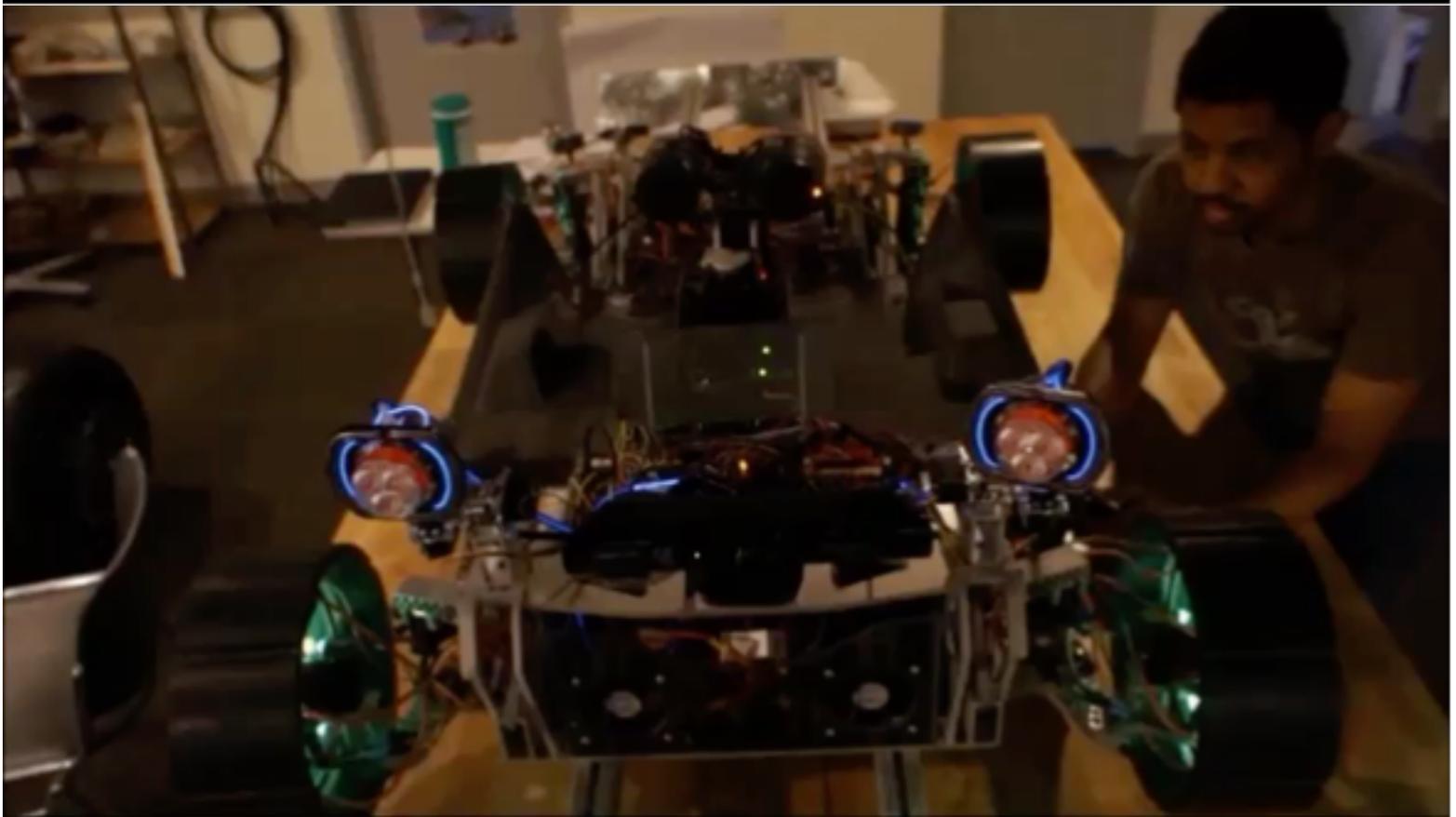
**Private**  
 Vehicles ———  
 Parking ———  
 User Time ———



Private to Shared to Autonomous Vehicle Simulation

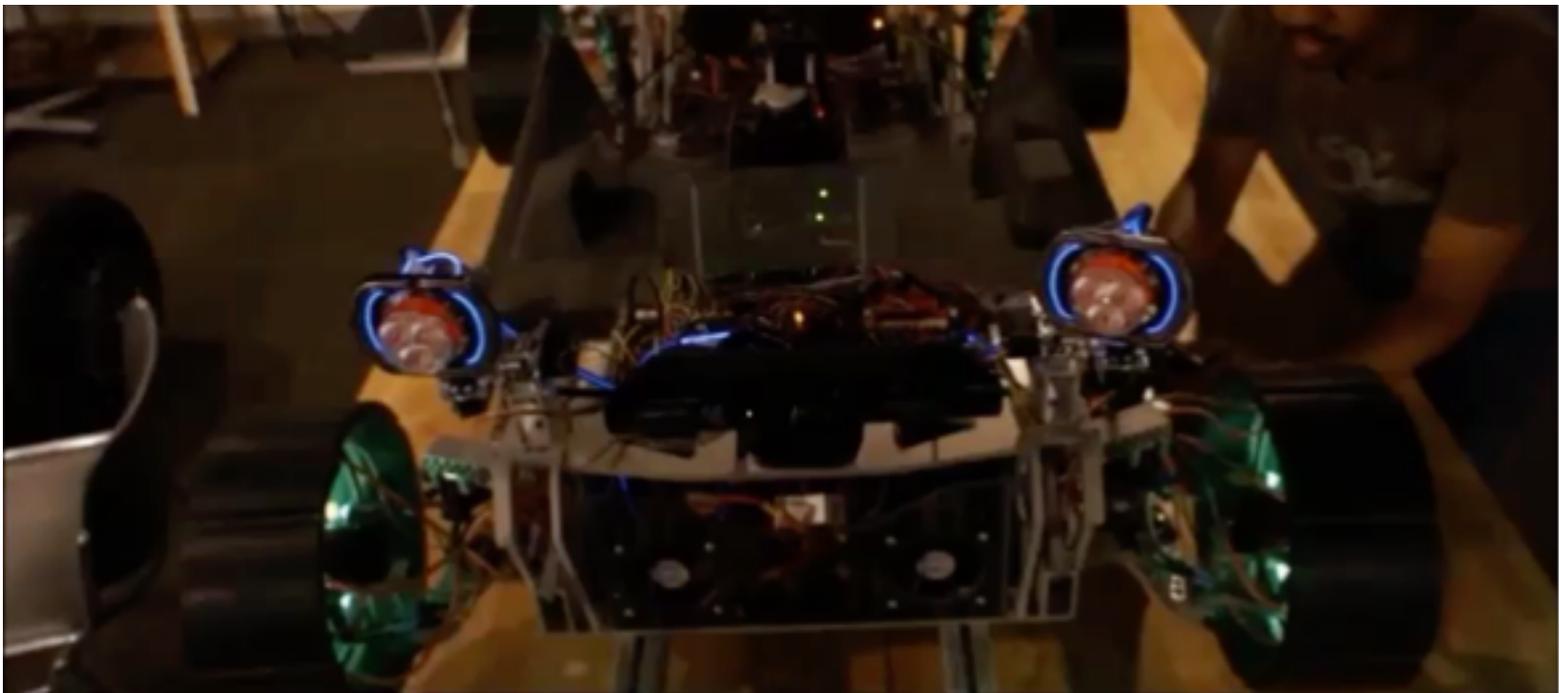
Carsen Smuts

Karl Larson



Smithsonian.com





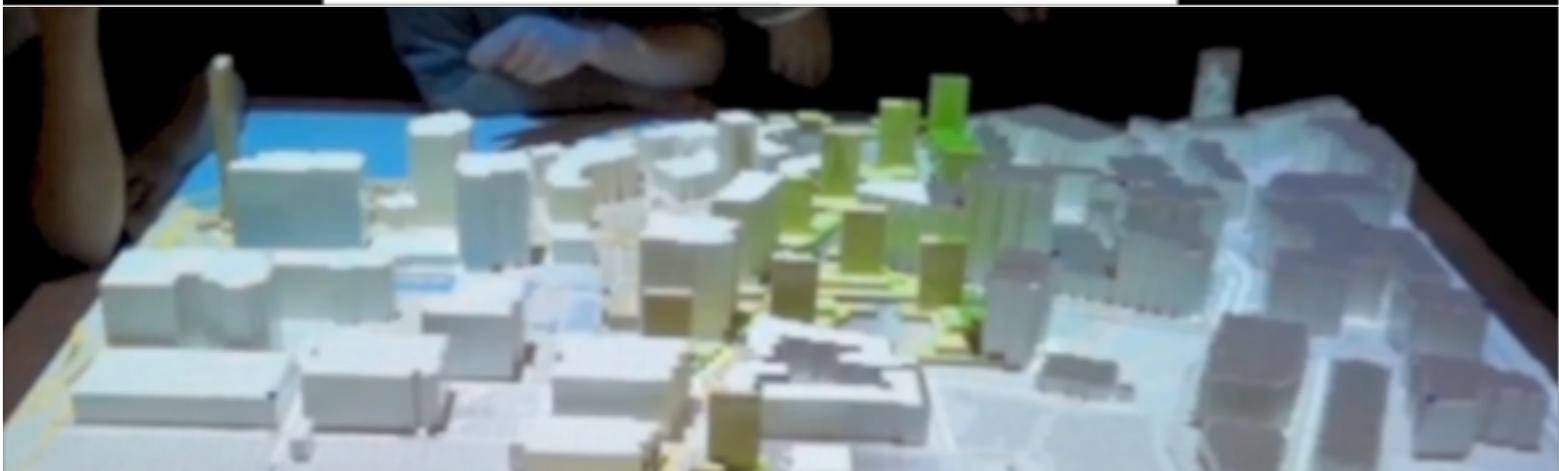
Smithsonian.com

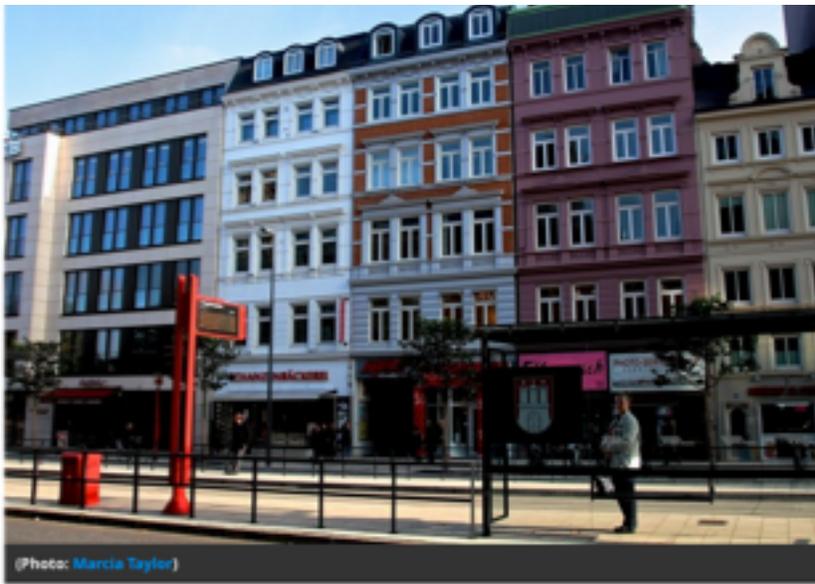
q | f | t | s



(Photo: Marcia Taylor)

Hamburg Plans to Become Car-Free By 2034





## Hamburg Plans to Become Car-Free By 2034



Persuasive Electric Vehicle (PEV)

Ryan Chin  
Carson Sreets  
Waleed Gewherji

Wolfgang Gruel  
Michael Lin  
Luis Alonso

Kent Larson

# 4

## Hyper-efficient Places of



Persuasive Electric Vehicle (PEV)

Ryan Chin  
Carlton Sreets  
Walid Gontarji

Wolfgang Gruel  
Michael Lin  
Luis Alonso

Keet 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





300sf Manhattan Micro-Unit



Exercise

**What if** 200ft<sup>2</sup> could be 3x larger?



# Exercise

**What if** 200ft<sup>2</sup> could be 3x larger?

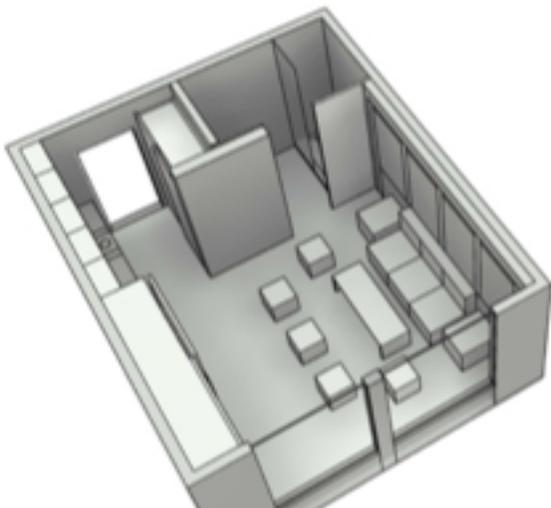


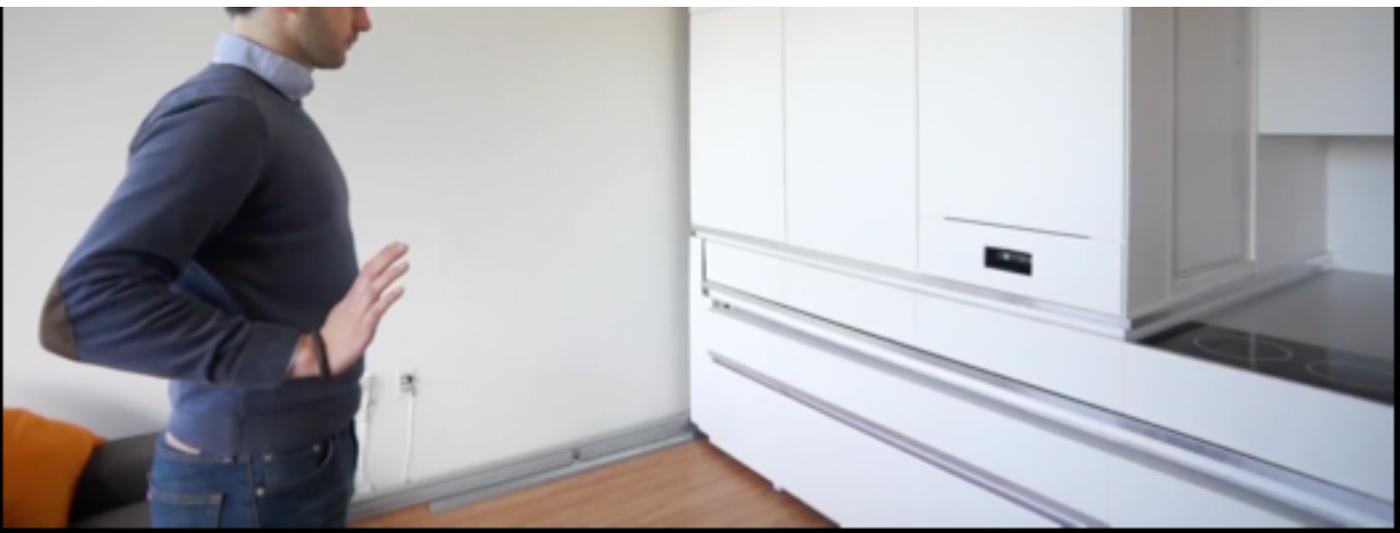
What if 200ft<sup>2</sup> could be 3x larger?



Hester Larso  
Daniel Goodman  
Phillip Ewing  
Oliver Arino

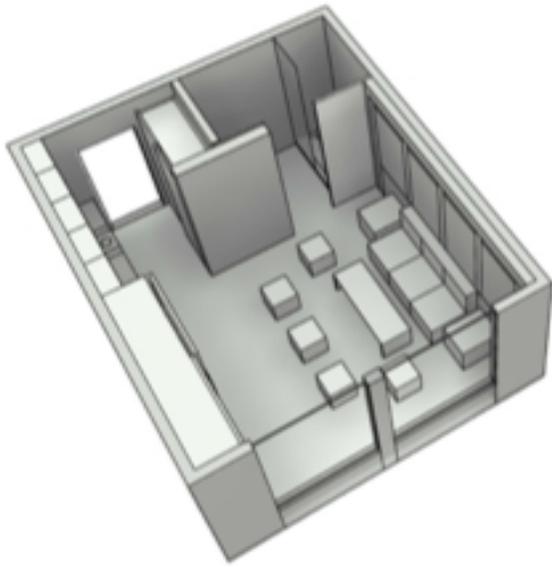
Kent Larson





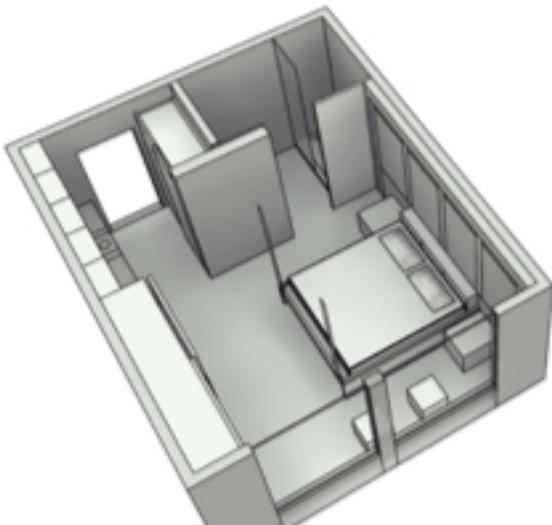
Hazel Larra  
Daniel Goodman  
Philip Ewing  
Oliver Arino

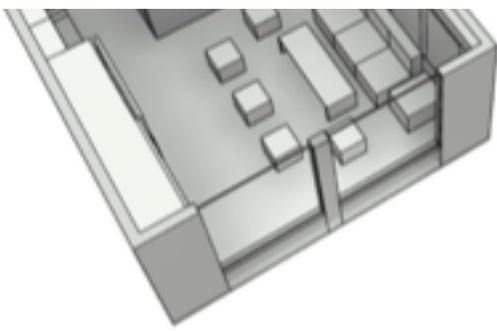
Kent Larson



# 313ft<sup>2</sup> (29m<sup>2</sup>) Transformable CityHome

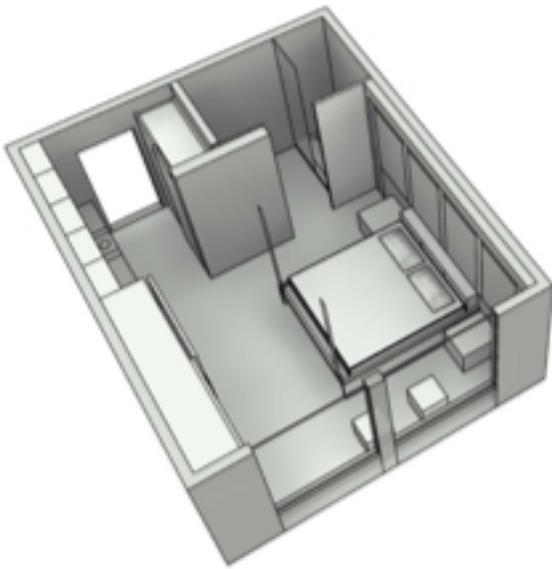
Zbode Systems





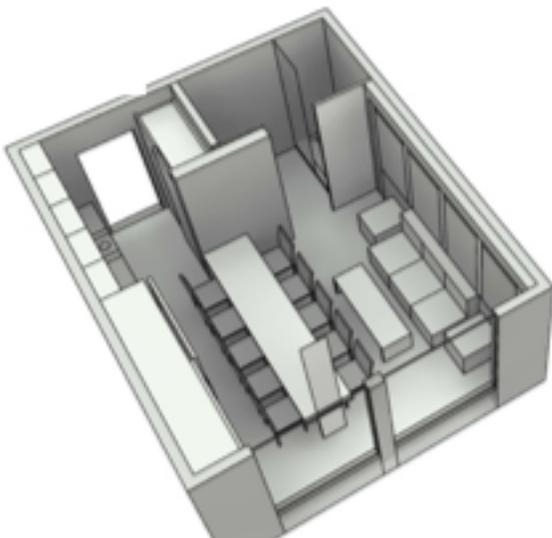
## 313ft<sup>2</sup> (29m<sup>2</sup>) Transformable CityHome

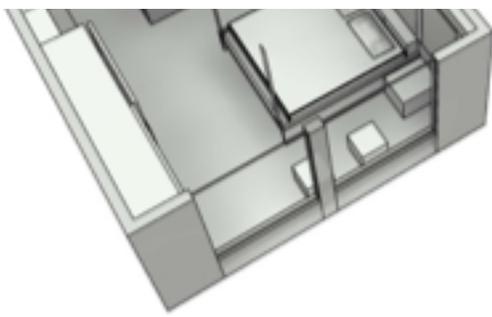
Zbode Systems



## 313ft<sup>2</sup> (29m<sup>2</sup>) Transformable CityHome

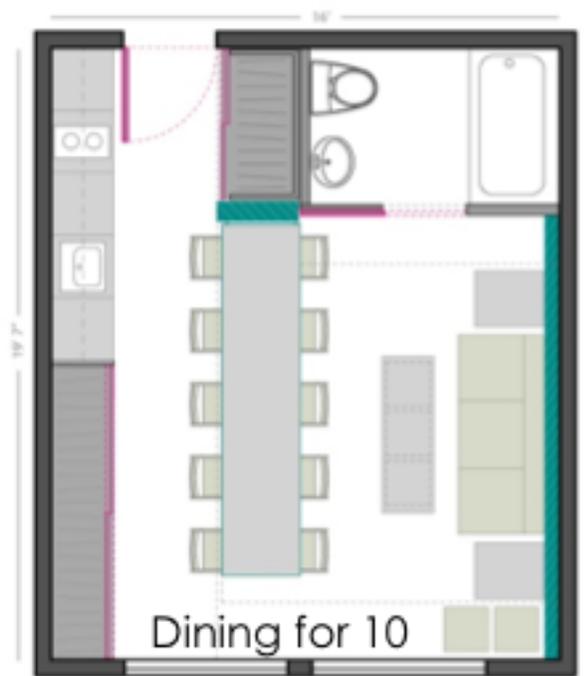
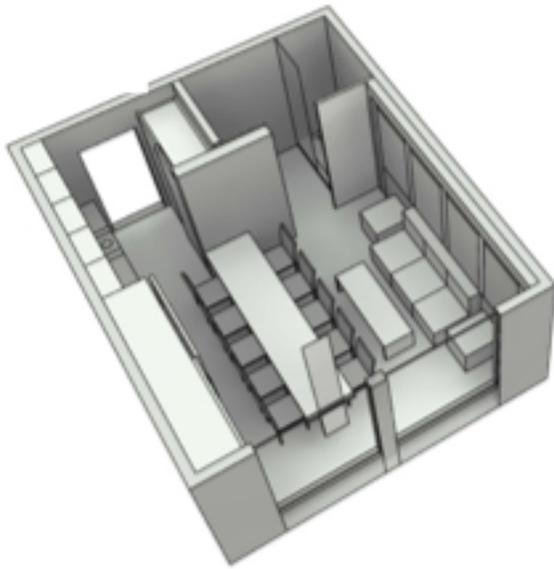
Zbode Systems





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Zbode Systems



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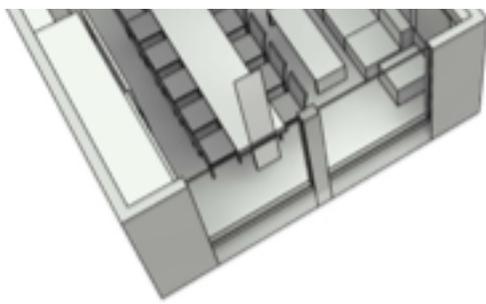
Horizontal Translation



Vertical Translation



Vertical Translation



# 313ft<sup>2</sup> (29m<sup>2</sup>) Transformable CityHome



Horizontal Translation



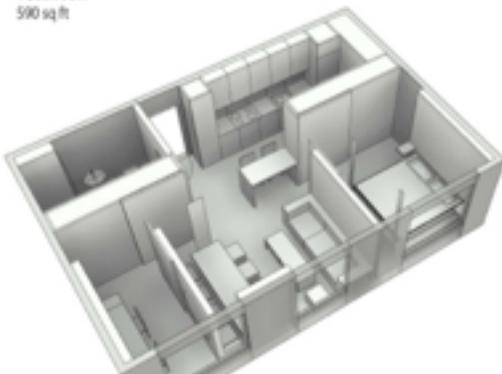
Vertical Translation

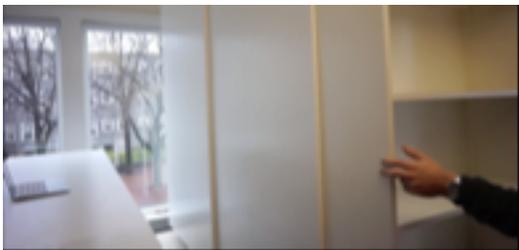


Vertical Translation

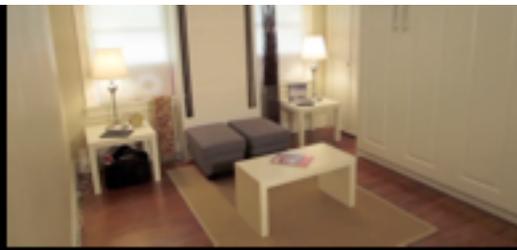
Zbode Systems

**Three Bay Apartment**  
2 Bedroom  
1 Bathroom  
590 sq ft





Horizontal Translation



Vertical Translation

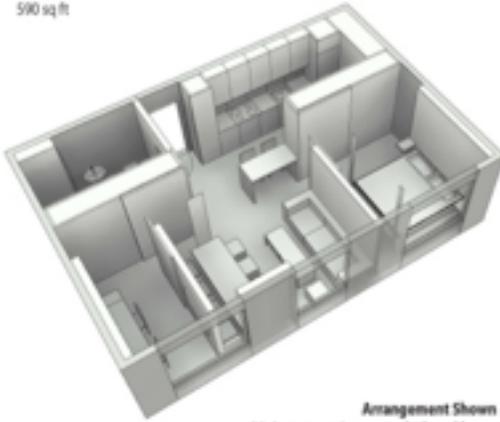


Vertical Translation

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 office is maintained behind transforming wall.

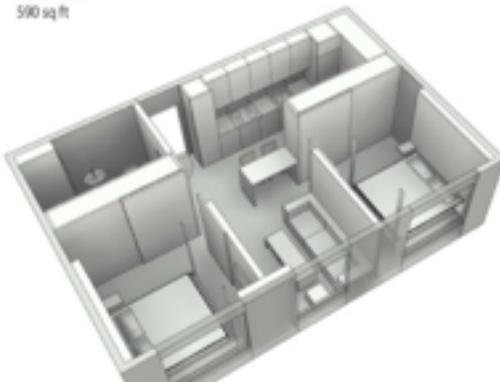
**Zbode Technologies:**

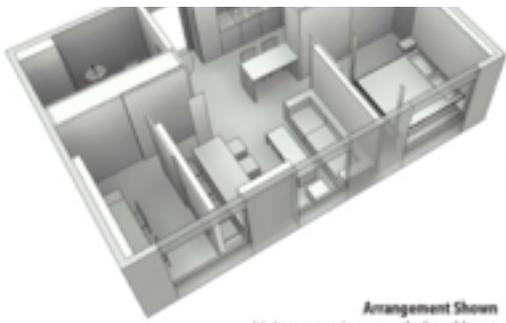
- 2 RoboWalls
- 1 Ceiling-Deployed Table
- 2 Ceiling-Deployed Bed w/ Desk



**Three Bay Apartment**

2 Bedroom  
1 Bathroom  
590 sq ft





**Arrangement Shown**

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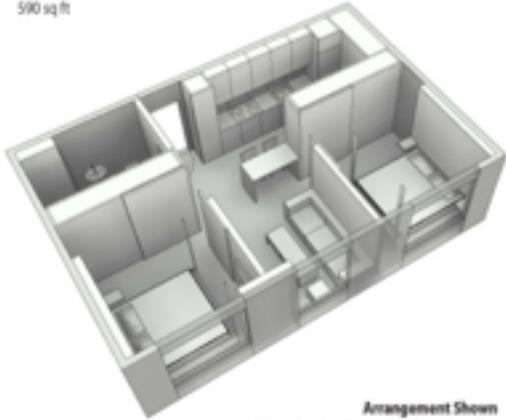
**Zbode Technologies:**

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



**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.

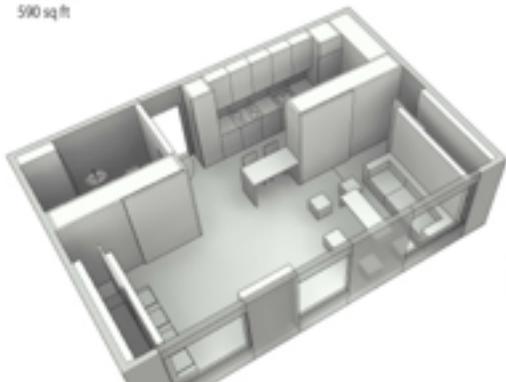
**Zbode Technologies:**

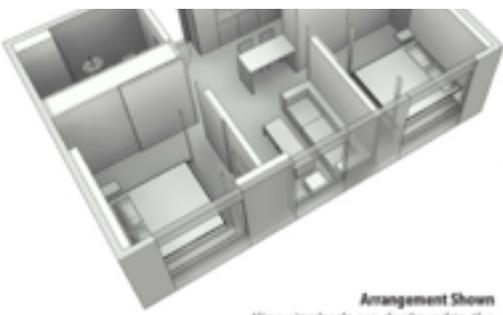
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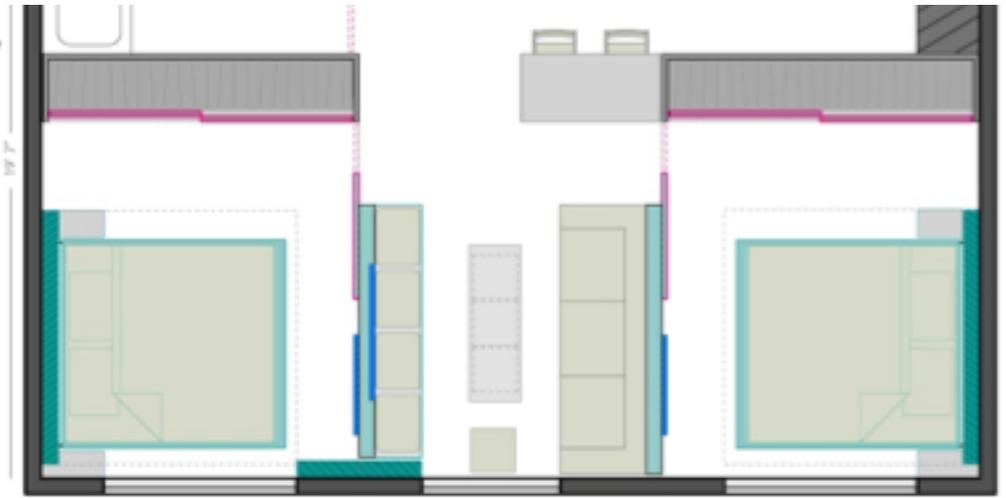


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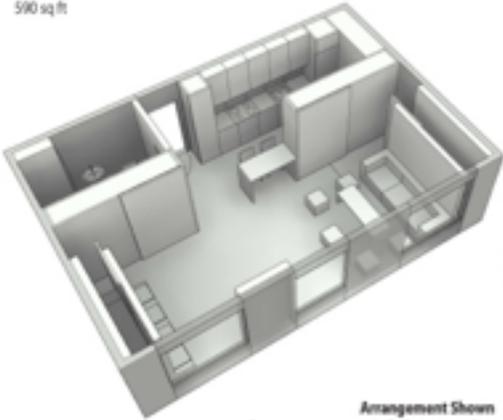
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**Three Bay Apartment**

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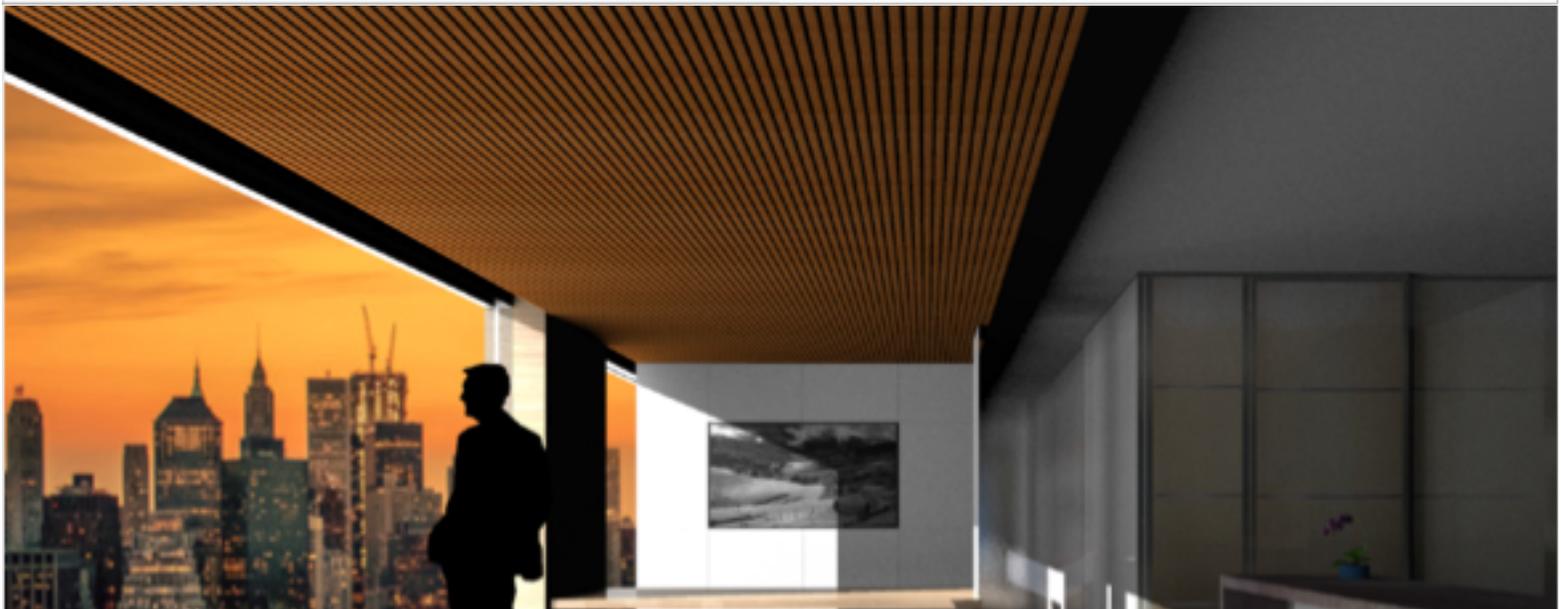


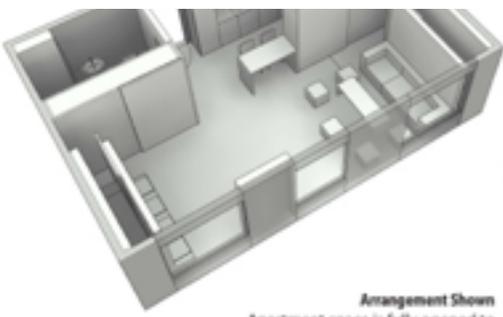
**Arrangement Shown**

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



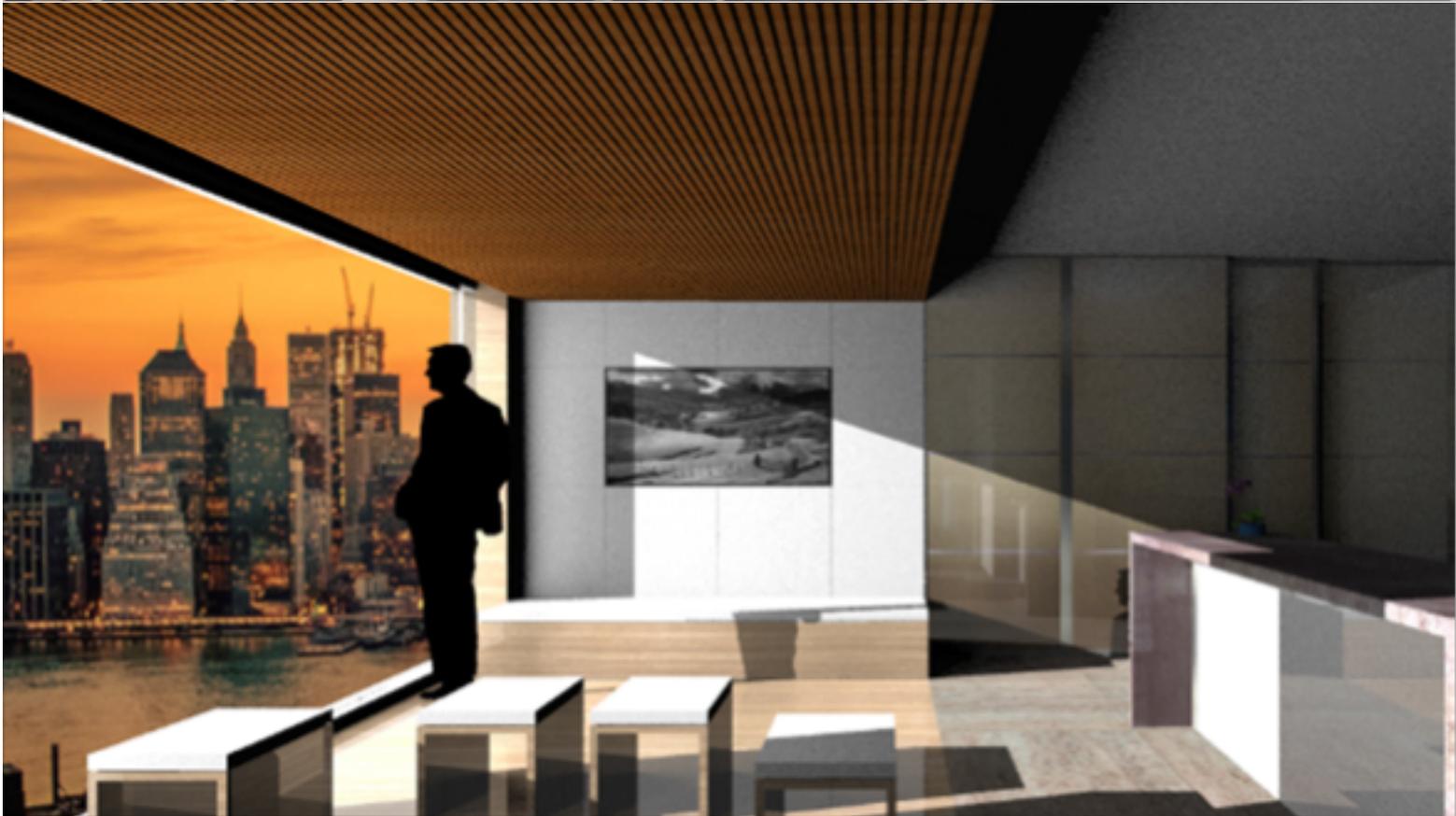


**Arrangement Shown**  
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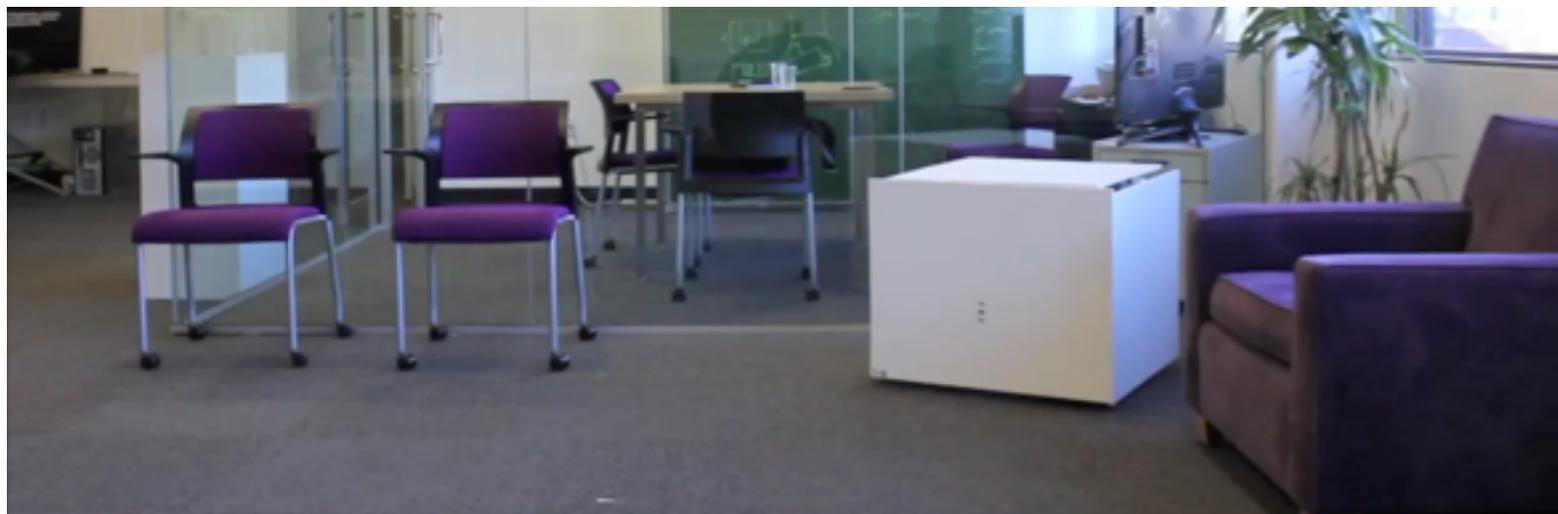




5

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

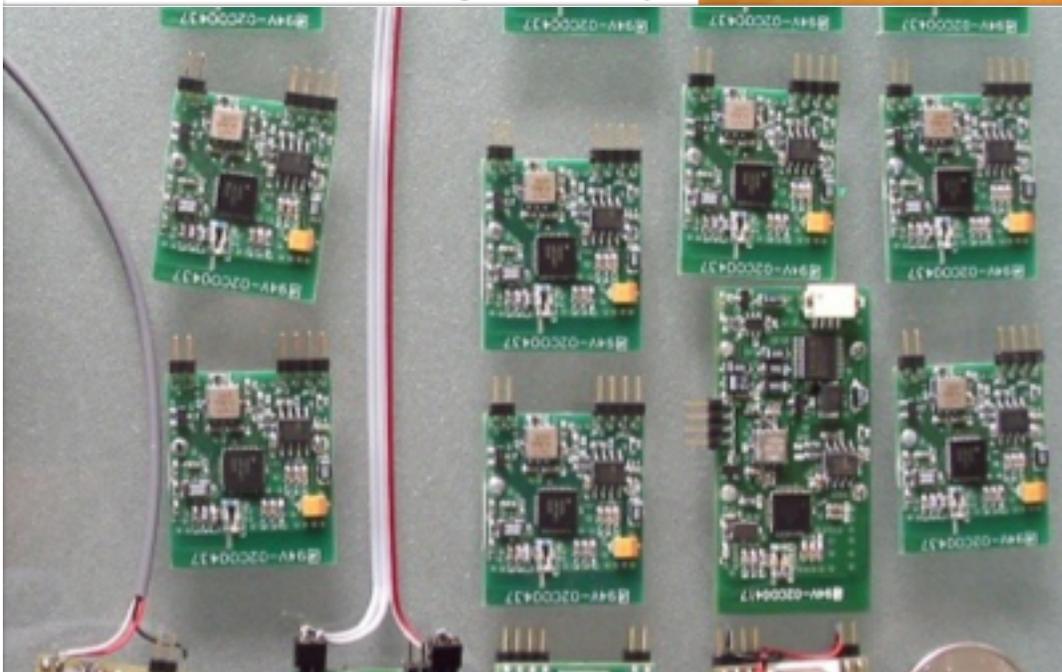
- hinged panels to micro-controllers
- speakers
- air quality sensors
- IR illuminators
- hinged panels to sensor bus
- cabinet door switches
- countertop activity cameras
- refrigerator use sensors
- microwave use sensors
- oven & range use sensors
- cabinet drawer sensors
- hot water use sensor
- cold water use sensor
- hinged panels to sensor bus





## Place Lab

- hinged panels to micro-controllers
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- cabinet drawer sensors
- hot water use sensor
- cold water use sensor
- hinged panels to sensor bus
- cabinet door switches
- sensor network connections
- internet connections
- temperature sensors
- Power integrated into cabinetry

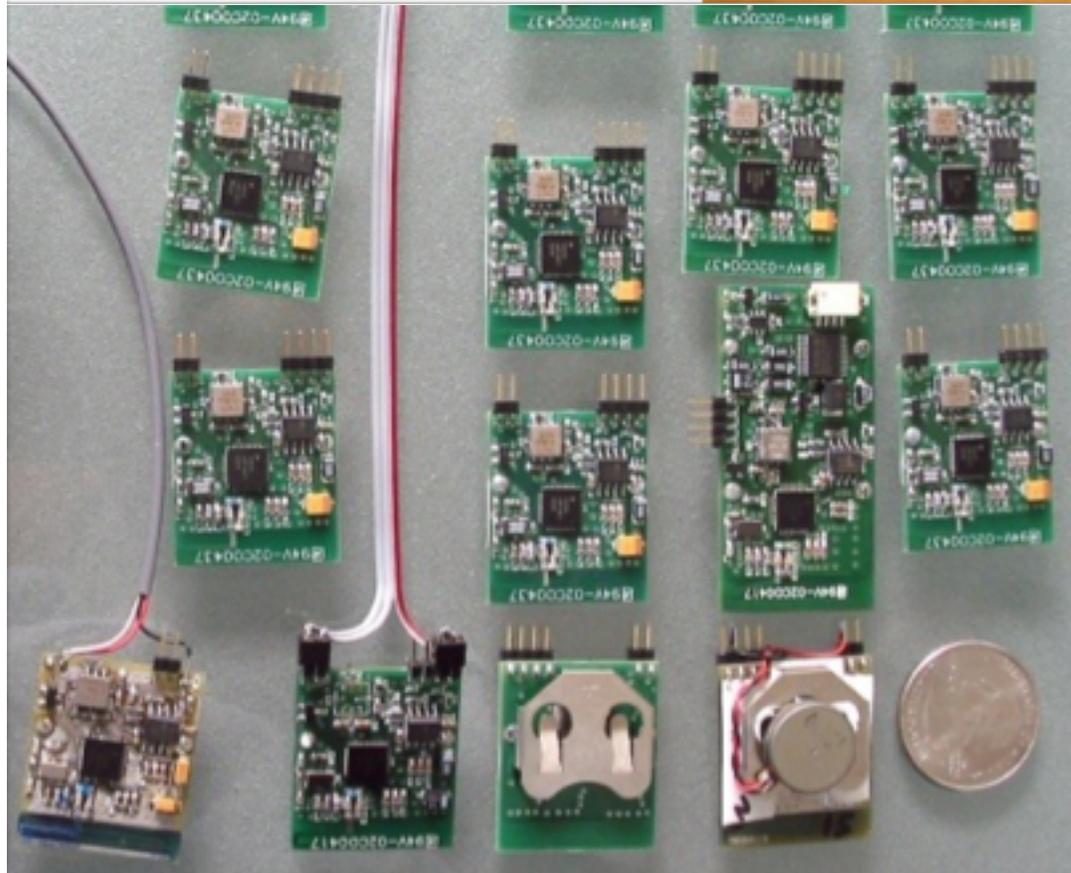
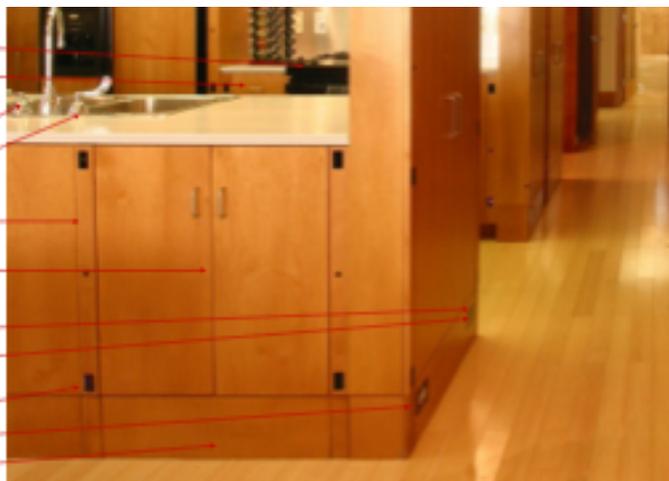


## MITes

(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

oven & range use sensors  
 cabinet drawer sensors  
 hot water use sensor  
 cold water use sensor  
 hinged panels to sensor bus  
 cabinet door switches  
 sensor network connections  
 internet connections  
 temperature sensors  
 Power integrated into cabinetry



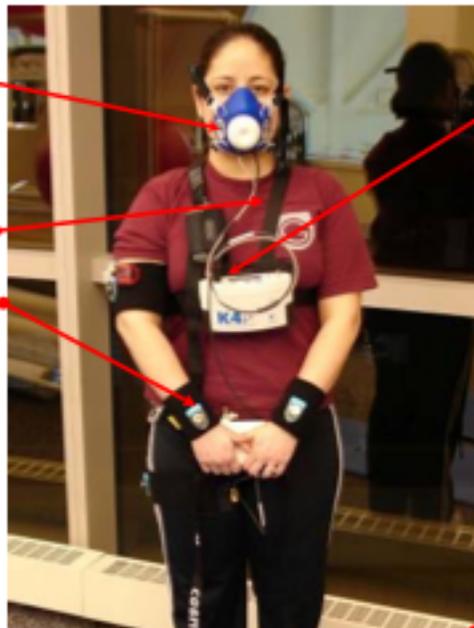
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Emmanuel Muguia Tapia, MAS PhD Thesis, energy expenditure recognition

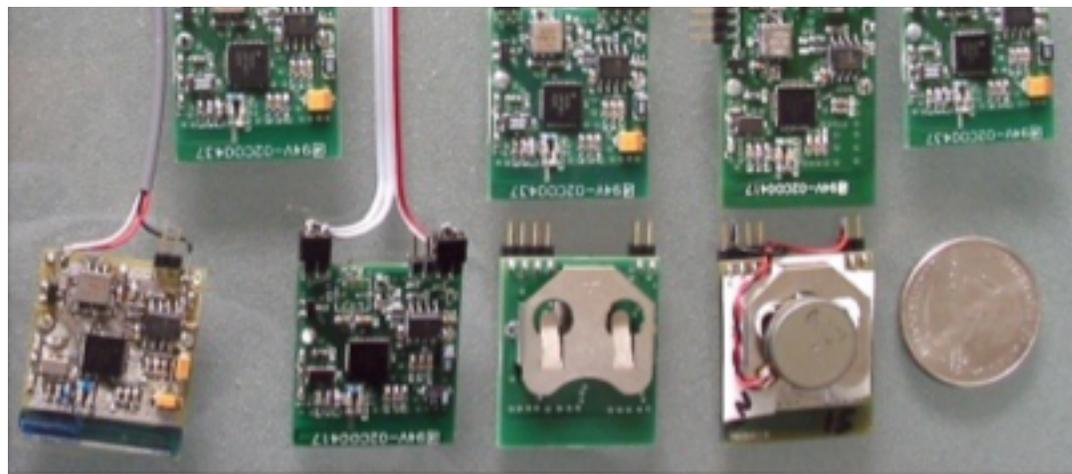
Portable indirect  
 calorimeter  
 (EE Ground truth)

BodyBug  
 Actigraph



Heart rate

Motion MITes



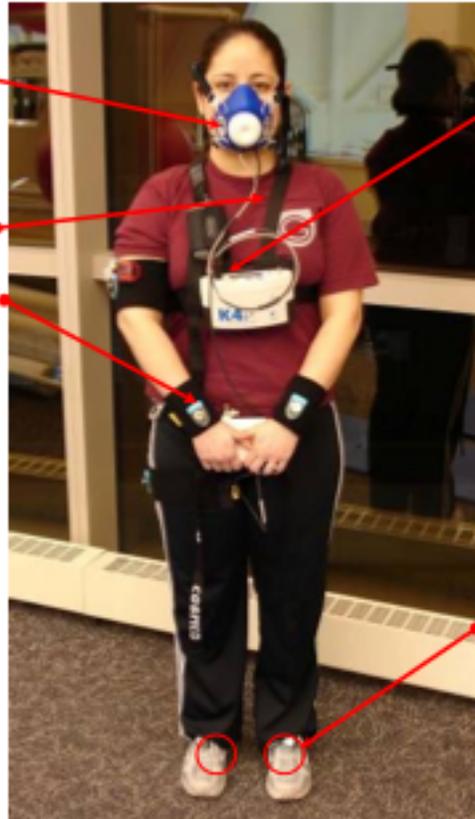
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Emmanuel Muguia Tapia, MAS PhD Thesis, energy expenditure recognition

Portable indirect calorimeter (EE Ground truth)

BodyBug

Actigraph



Heart rate

Motion Mites  
3 axis accelerometers @ 30Hz

Exercise activities





Motion Mites  
3 axis  
accelerometers  
@ 30Hz

### Exercise activities



### Domestic activities





## Domestic activities



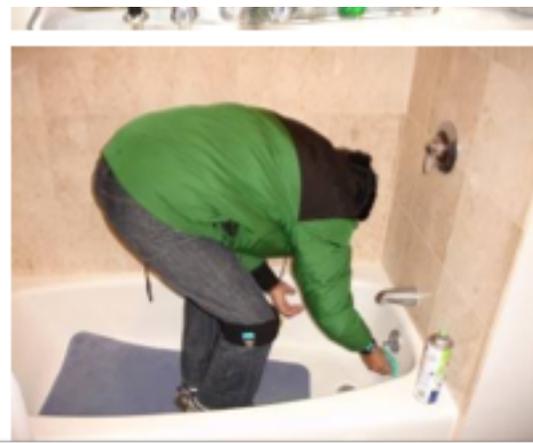
## Activity recognition results (52 activities)

### 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



Activity recognition results (52 activities)

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Sweeping	
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Cycling	100 rpm, light
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	-14.9 %

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 %

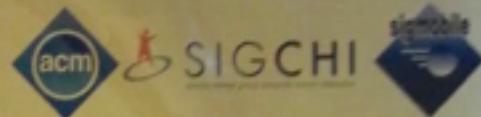
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Hip	-8.4 %
DFoot	-14.9 %
DThigh	-15.1 %
DUpperArm	-15.4 %
DWrist	-19.6 %

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DWrist + DFoot	-13.0 %
Hip + DWrist	-15.6 %
Hip + DFoot	-18.9 %
DUpperArm	26.5 %
DWrist	-27.7 %
Hip	-28.5 %
DFoot	-34.8 %
DThigh	-42.7 %



The International Joint Conference on  
Pervasive and Ubiquitous Computing

### UbiComp 2014 TEN YEAR IMPACT AWARD

*Presented to*

Ling Bao, Emmanuel Tapia,  
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"

	-7.2 %
DWrist + DFoot	-7.7 %
Hip	-8.4 %
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DUpperArm	-15.4 %
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DWrist	-27.7 %
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DThigh	-42.7 %



Kent Larson, and Stephen S. Intille

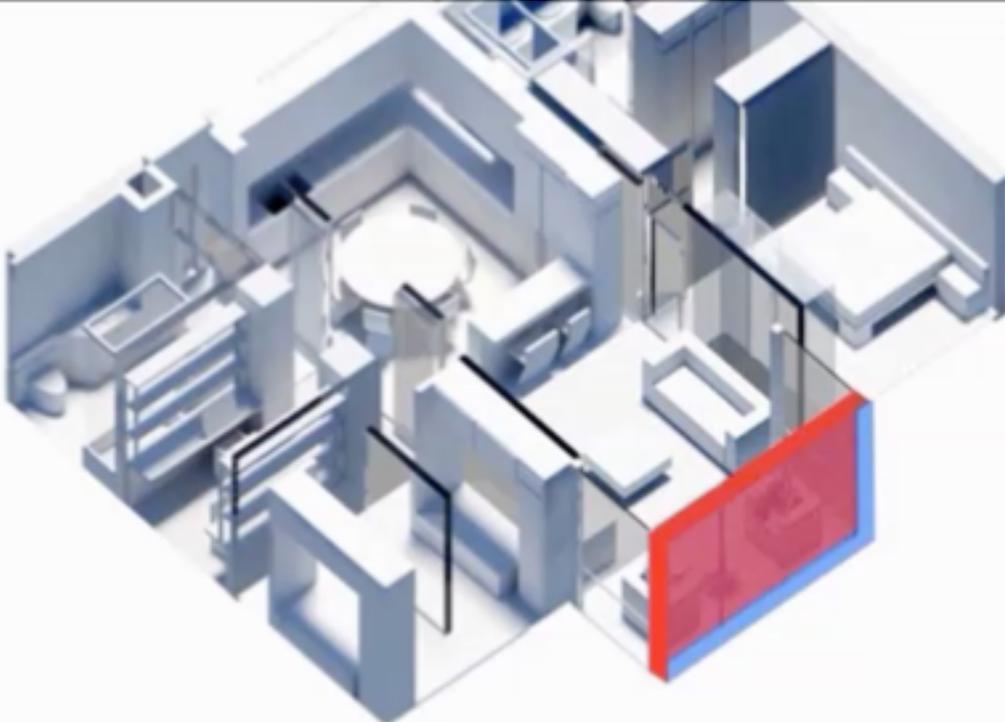
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UbiComp 2014 SEATTLE  
September 13- 17 2014

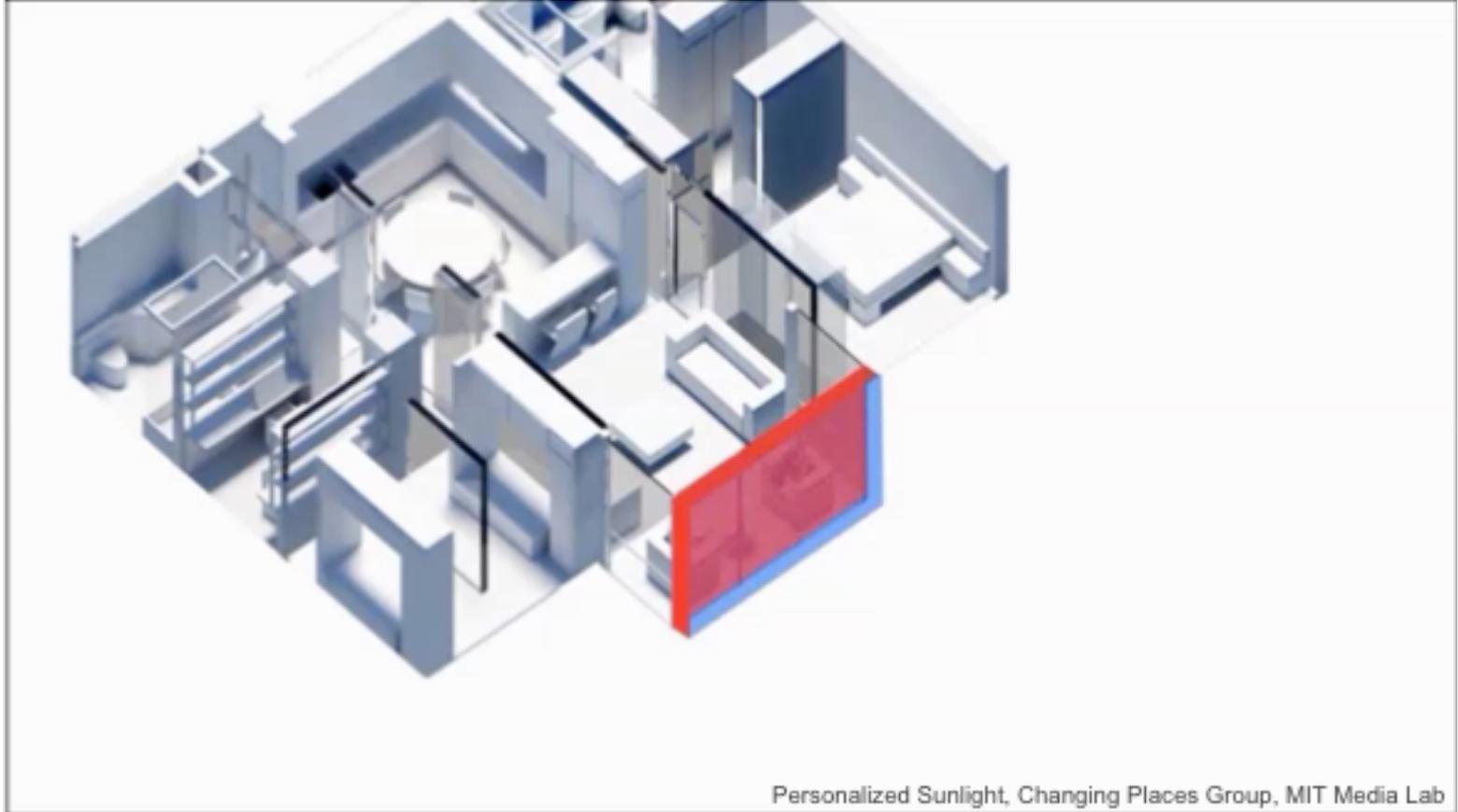


Dynamic Tunable Lighting, Changing Places Group, MIT Media Lab





Dynamic Tunable Lighting, Changing Places Group, MIT Media Lab



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)