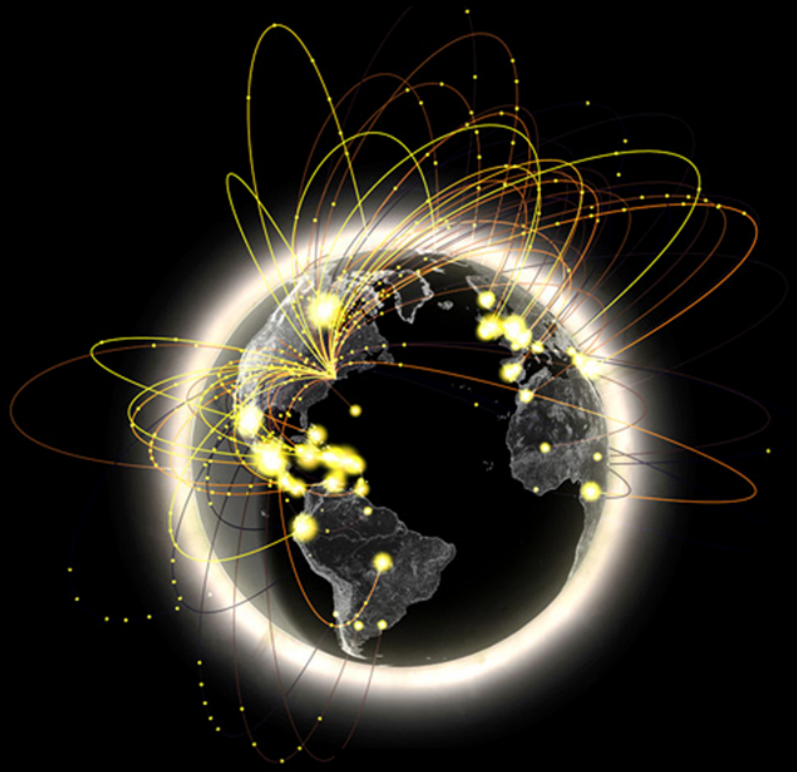


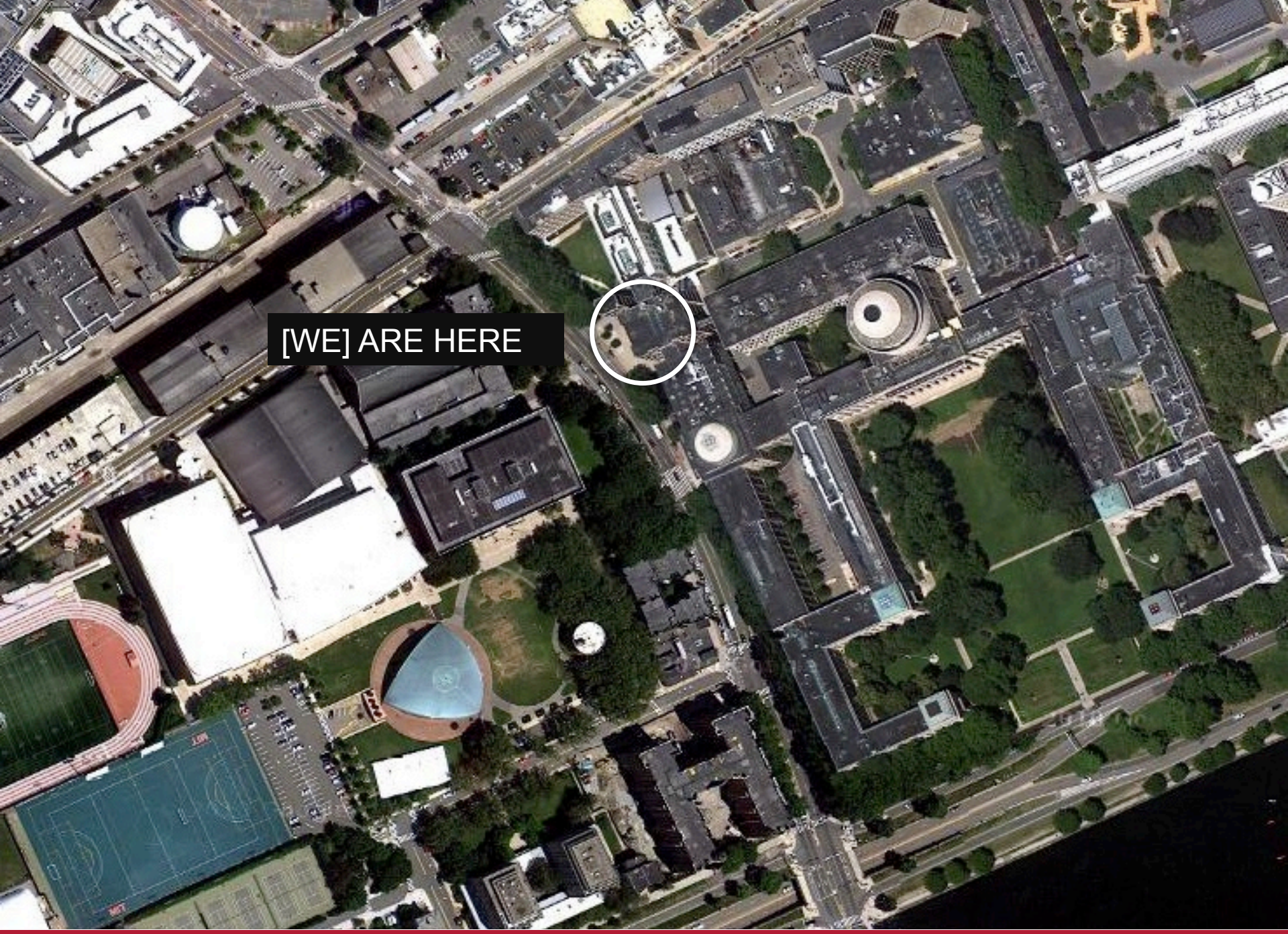
Toward an Innovative and SENSEable City

Erin Baumgartner
Assistant Director, Senseable City Lab
embaum@mit.edu

senseable city lab:.::

Massachusetts Institute of Technology


MCMXVI
MASSACHVSETTS INSTITVTE OF TECHNOLOGY


[WE] ARE HERE

Researchers Carlo Ratti (Director, Professor of the Practice), Assaf Biderman (Associate Director), Erin Baumgartner (Assistant Director), Rex Britter (Advisory Board), Paolo Santi (Visiting Scientist), Chaewon Ahn, Alaa AlRadwan, Ricardo Alvarez, Amin Anjomshoaa, Iva Bojic, Paul Bouisset, Matthew Claudel, Hongyan Cui, Fabio Duarte, Greg Falco, Carlos Gershenson, Newsha Ghaeli, Behrooz Hashemian, Thomas Holleczek, Muhammad Khairul, Daniel Kondor, Pietro Leoni, Lezhi Li, Tracey Li, Martina Maitan, Emanuele Massaro, Dimitrios Milioris, Marguerite Nyhan, Wenzhe Peng, Rachel Seavey, Ian Seiferling, Mohit Shah, Michelle Sit, Jessica Snyder, Jonathan Sun, Remi Tachet Des Combes, Anthony Vanky, Mohammad Vazifeh, Saul Wilson, Hongmou Zhang

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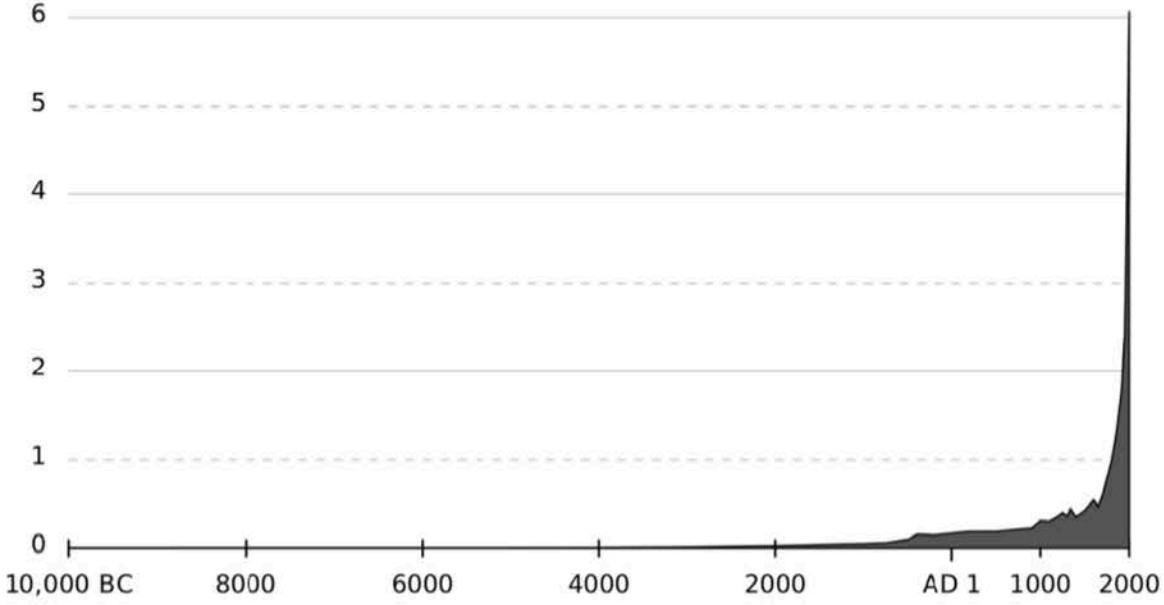
just a bit of context...



1804- 1,000,000,000

1927- 2,000,000,000

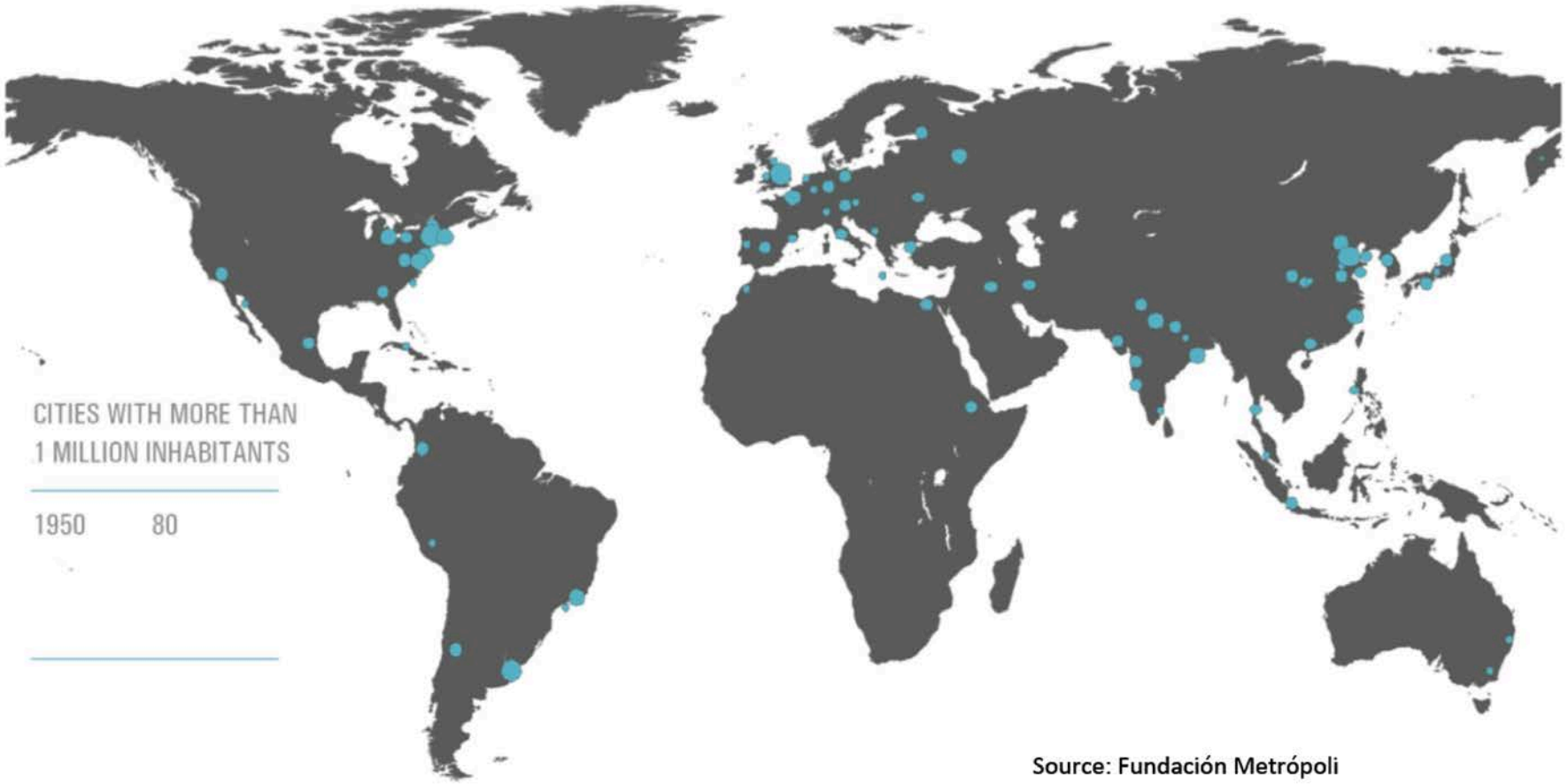
2011- 7,000,000,000

2050- 9,300,000,000

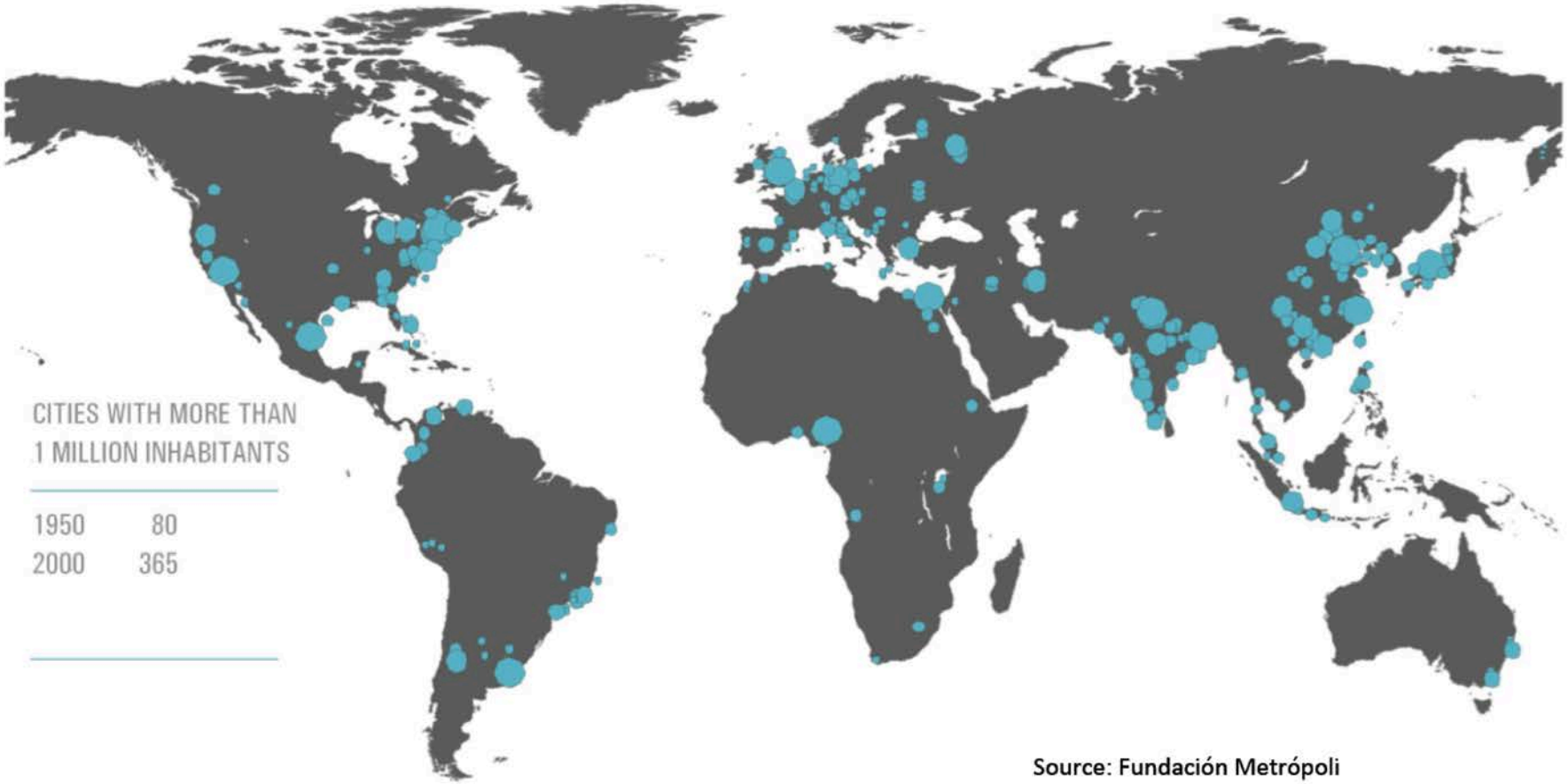
just a bit of context...

1900	2011	2050
.23 BN	3.6 BN	6.3 BN

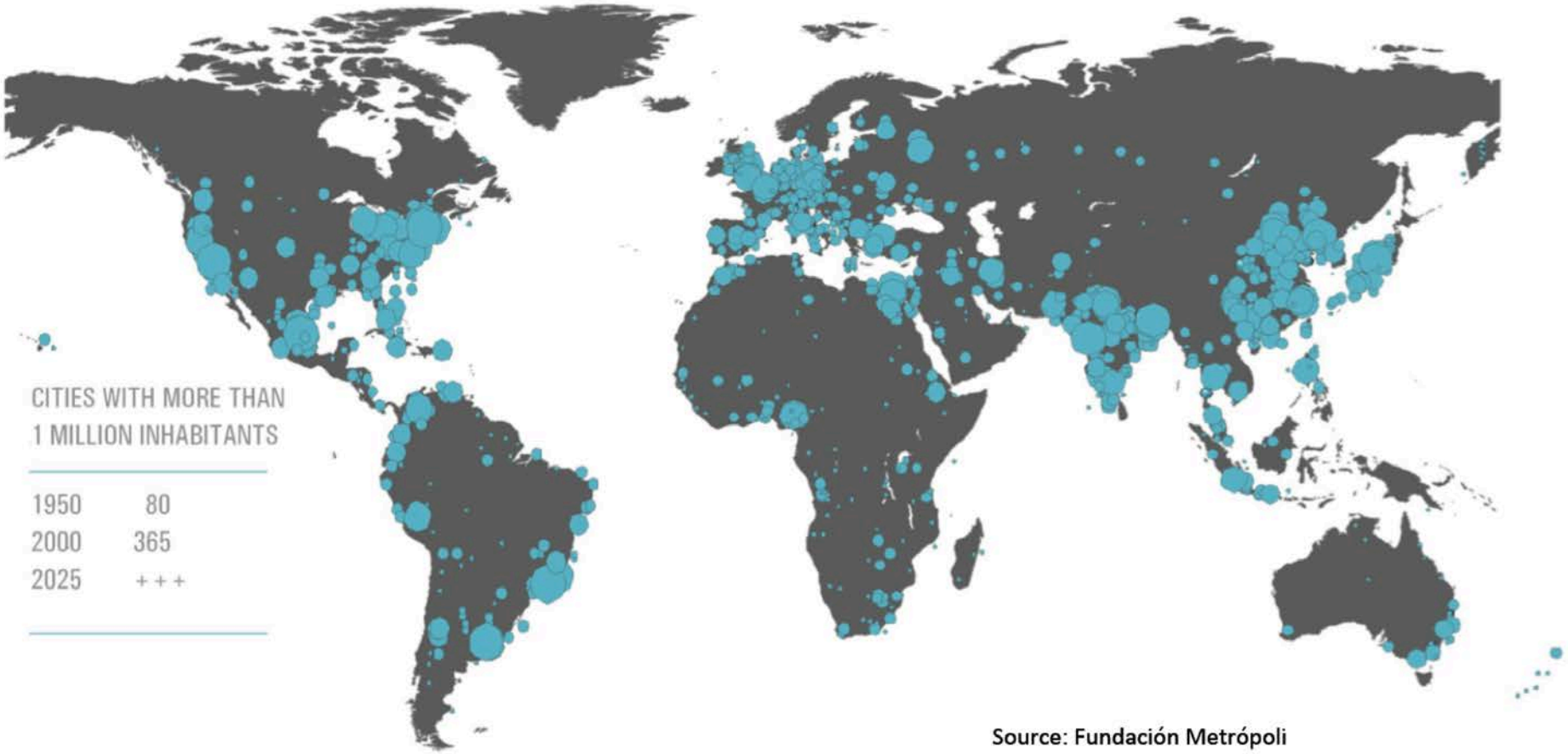
Source: UN World Urbanization Prospects 2012



Source: Fundación Metrópoli

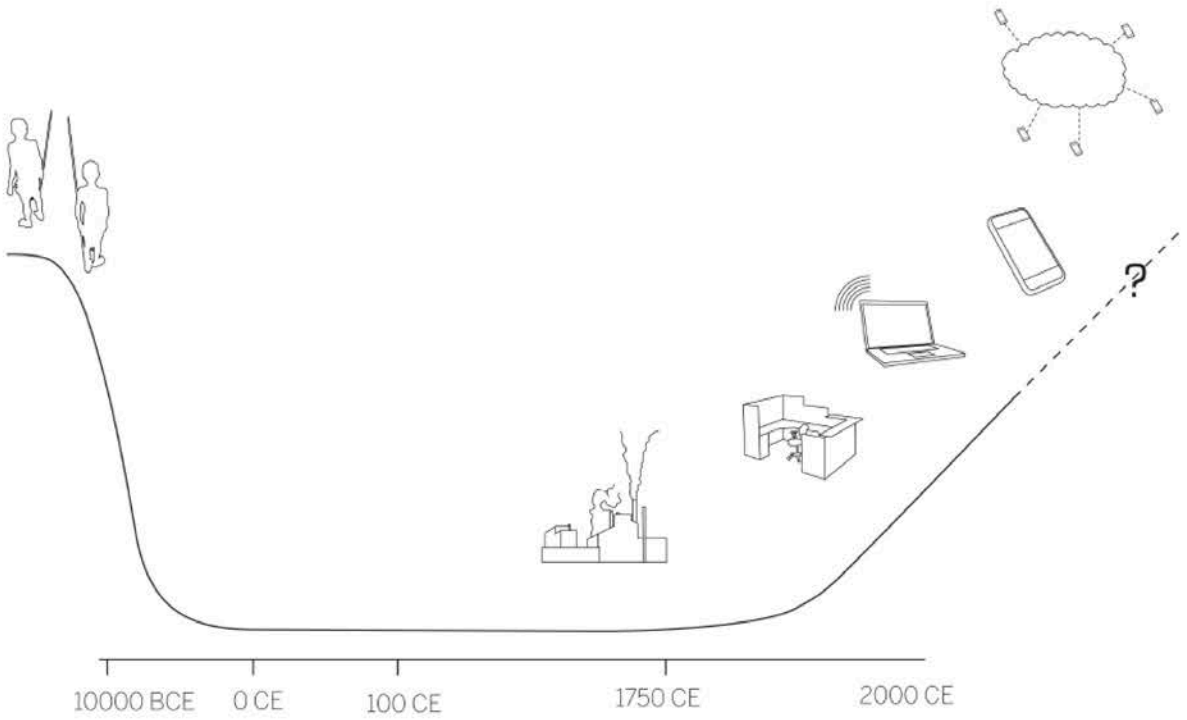


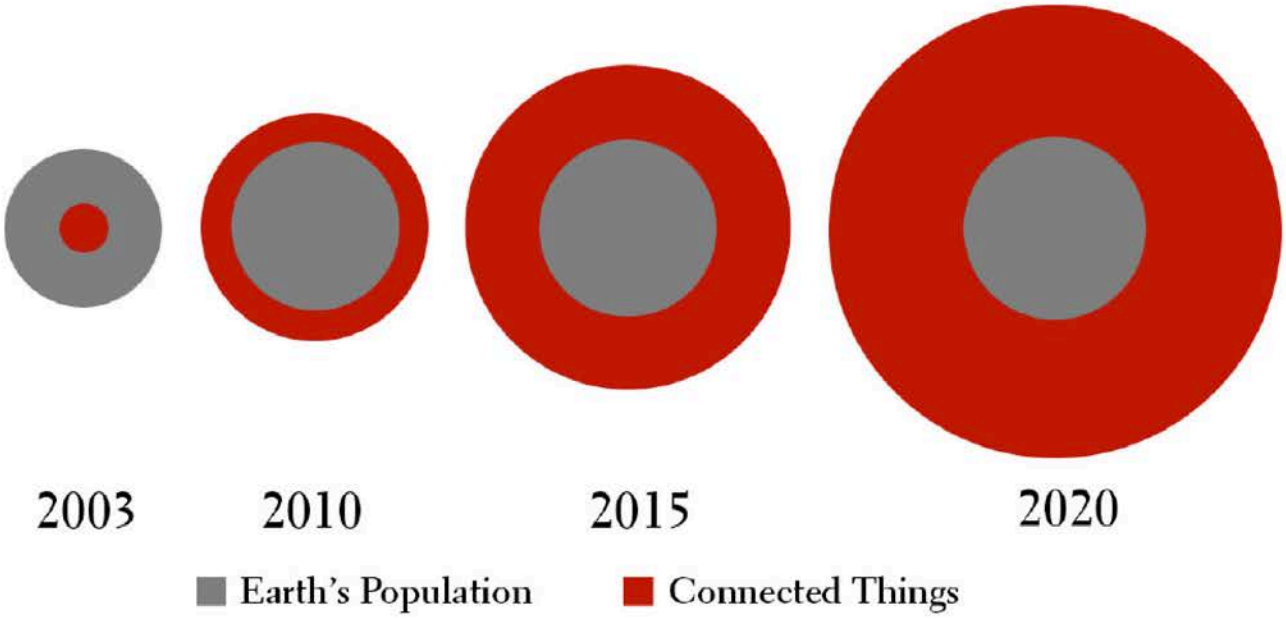
Source: Fundación Metrópoli



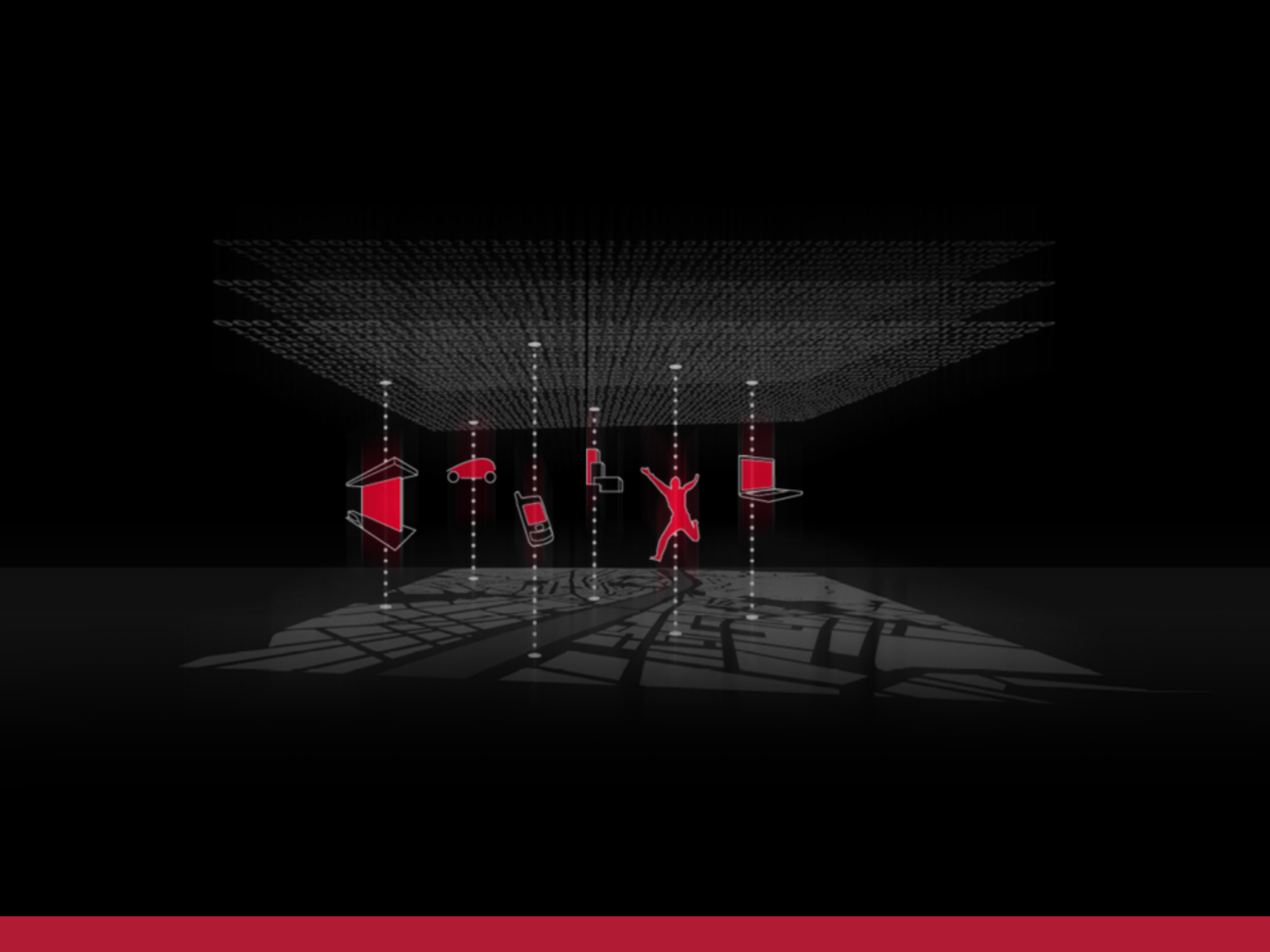
Source: Fundación Metrópoli

digital nomadism





Source: Cisco Systems



when things
talk back.

trash track

seattle + nyc, usa


Sourcemap
Greenland
Iceland
Россия
Russia
Canada
United States
México
Kazakhstan
Mongolia
Iran
Afghanistan
Pakistan
India
Suomi Finland
Sverige Sweden
Norge Norway
United Kingdom
Polska Poland
Ukraine
España Spain
Italia Italy
Türkiye Turkey
Iraq
Algeria
Libya
Egypt
Saudi Arabia
Mauritania
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
DR Congo
Tanzania
Angola
Namibia
Botswana
Madagascar
South Africa
Venezuela
Colombia
Brasil
Brazil
Perú
Bolivia
Chile
Argentina
Indonesia
Papua New Guinea
Australia
New Zealand
Indian Ocean
South Pacific Ocean
South Atlantic Ocean
North Atlantic Ocean
North Pacific Ocean
50
45
20
7
47
38
49
14
35
37
13
32
48
44
41
34
42
28


_television set


_book shelf


_children’s shoe


_blender


_mattress


_keyboard


_cardboard box

_motor oil / glove


_leather case

_dvd player


_phone book


_computer

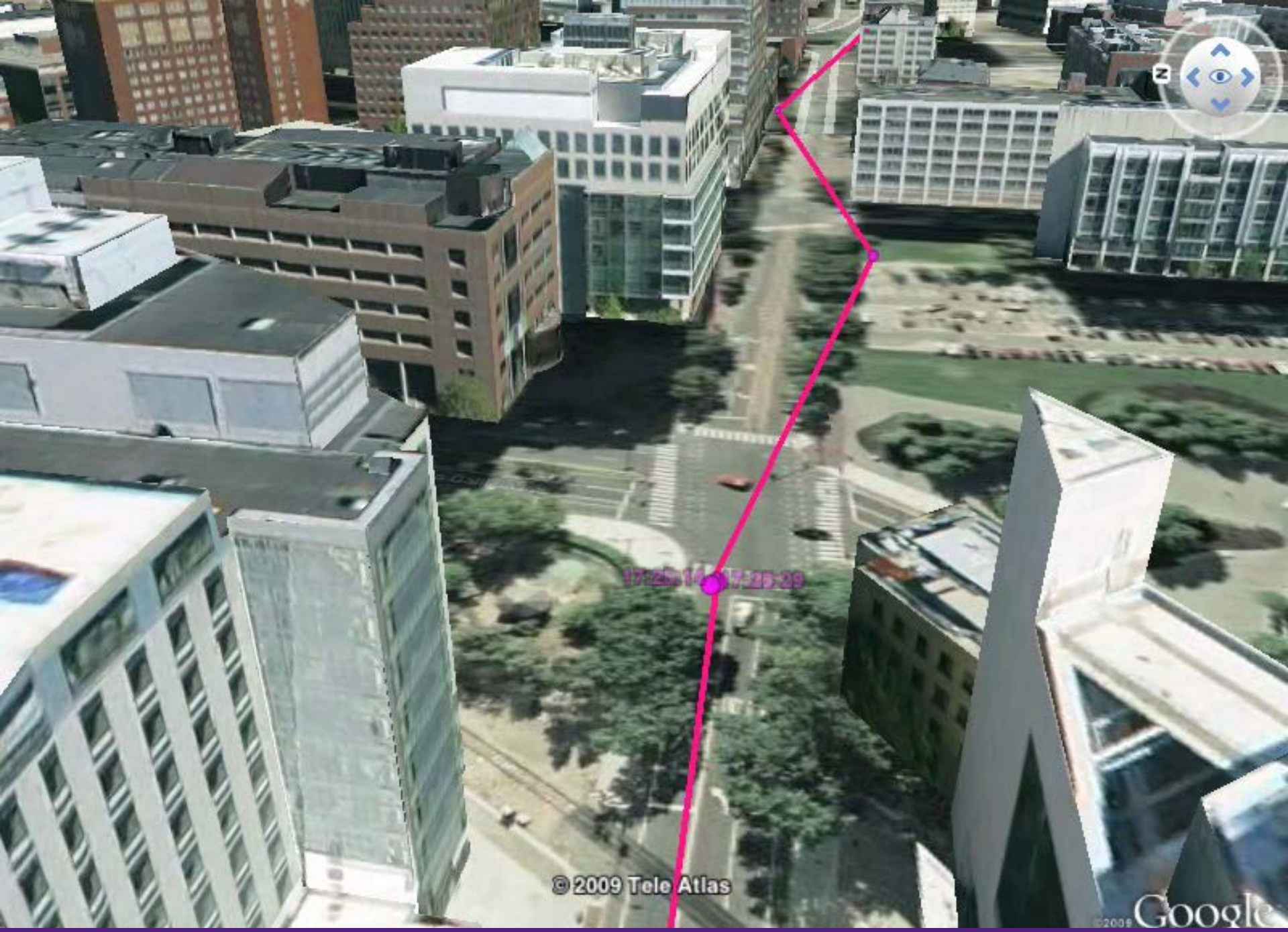

_jeans


_tire


_porcelain soup bowl


ANATEL: 0412-05-2618
FCC ID: RI7GE864
IC: 5131A-GE864
CE 0168
TrashTrack Tag 2.0
mit sensable city lab


STAFF


© 2009 Tele Atlas
Google

How does e-waste travel across the world after disposal?

Sensors (with GPS and SMS)

Sleep mode: sensors wake up once per day
battery lasts more than 2 years

200 devices tracked in the U.S. (CRT, LCD, printers)


MONiTOUR E-TRASH TRANSPARENCY
FILTER ABOUT
by Device Type
CRT 75
LCD 69
Printer 56
by Starting Region
16
84
39
51
by Ending Region
Inside of US 138
Outside of US 62
200
Trackers
4 km
Average Travel Distance
0 days
Average Active Time
Starting cities
Ending cities
Traveling paths
Selected paths
Highlights
11/11
LCD from Waukegan, IL
LCD from Cadillac, MI
LCD from Wapakoneta, OH
LCD from Oxford, MI
LCD from Willard, OH
LCD from Orlando, FL
CRT from Youngstown, OH
CRT from Norcross, GA
CRT from Doraville, GA
CRT from Doraville, GA

SATELLITE STREET

Dec 2014

Jan 2015

Stop 7

LCD FROM WAUKEGAN, IL

Tracker ID 351564053163523
Travel Distance 14,579 km
Travel Duration 71 days

STOP 07

CASTLE PEAK ROAD
~130 Castle Peak Road.

City Ping Shan
Coordinate 114.002787 | 22.436384
Date Sat Jan 10 2015 21:29:26

Media Content

Abandoned gaylord boxes filled with various electronics. Previous business owners had moved out and left this material behind. BAN's tracker had reported here about 10 months earlier.

Taiwan

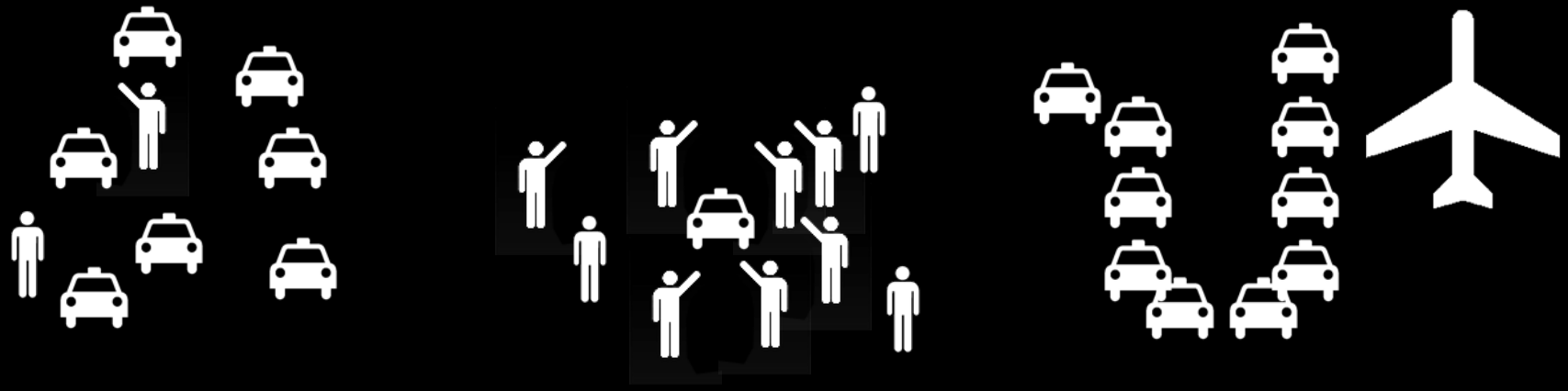
Hong Kong

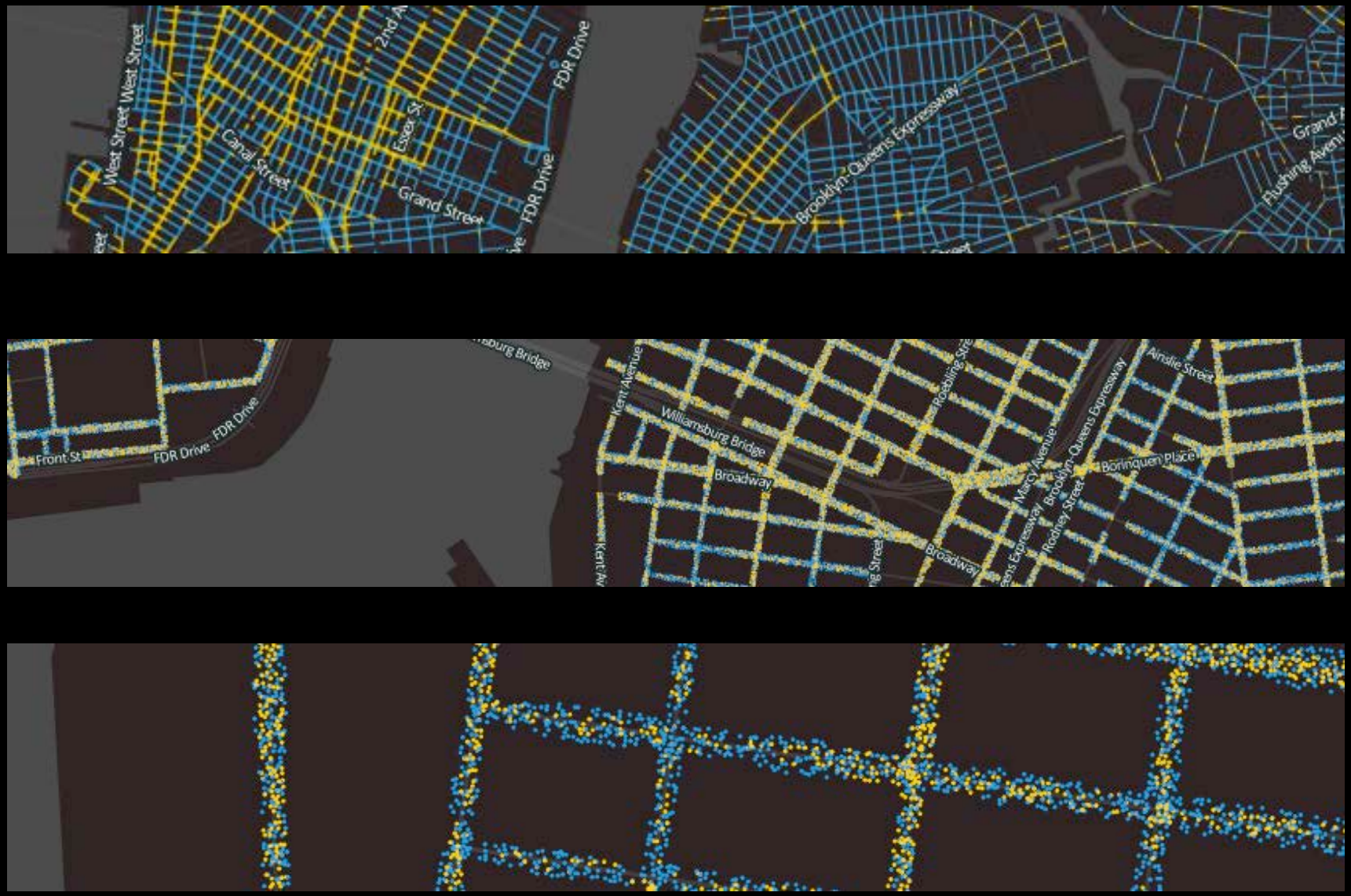
Malaysia

hubcab

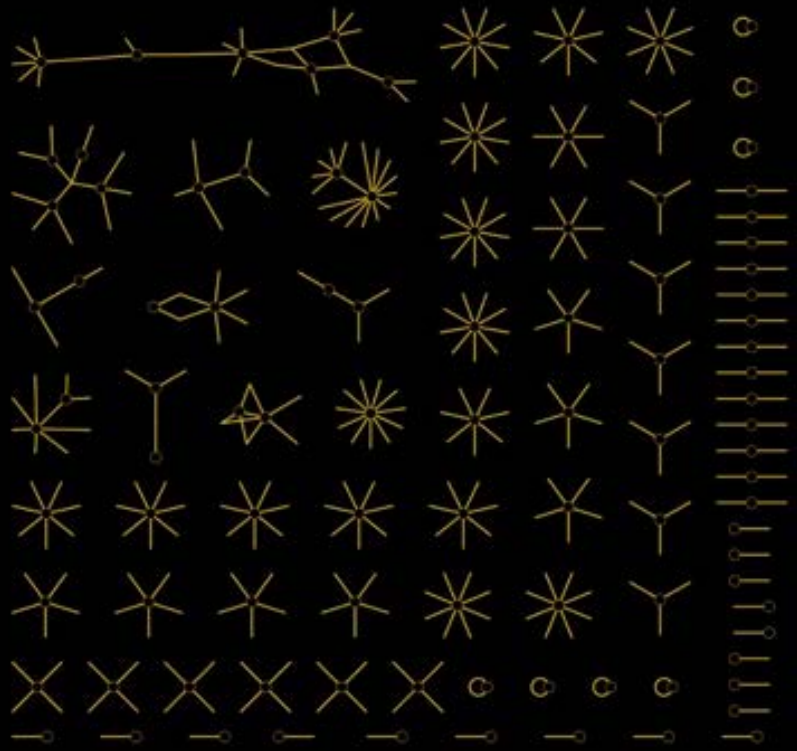
new york city


TAXI




West Street West Street
Canal Street
Essex St
FDR Drive
Grand Street
FDR Drive
Brooklyn-Queens Expressway
Front St
FDR Drive
FDR Drive
Williamsburg Bridge
Kent Avenue
Broadway
Broadway
Marcy Avenue
Rodney Street
Brooklyn-Queens Expressway
Bedford Avenue
Ainslie Street
Borinquen Place
Pickups
Dropoffs

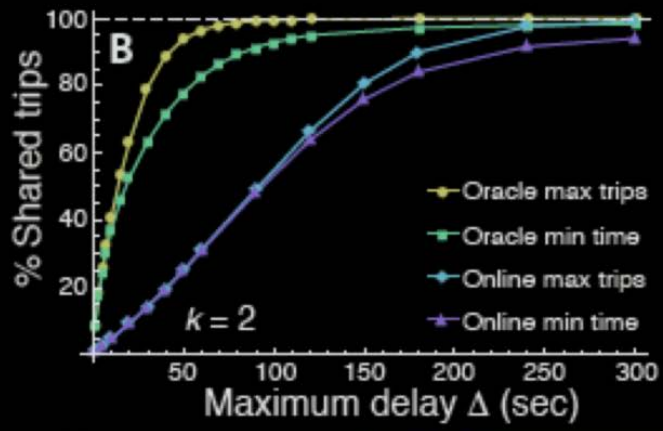
Maximum time delay Δ

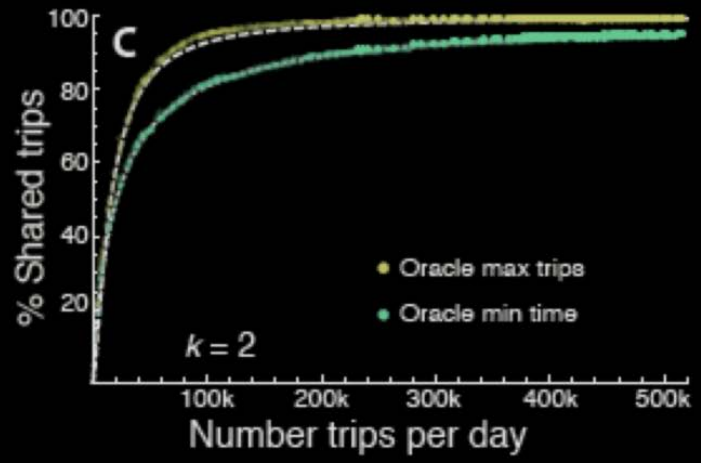


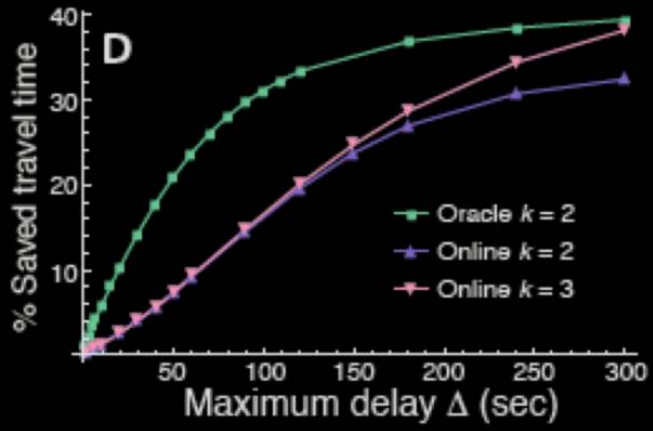
Δ = 60 sec

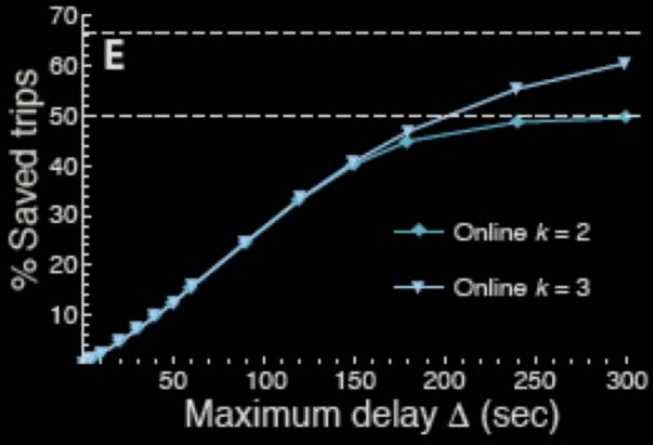
More tolerance = denser network = more sharing opportunities

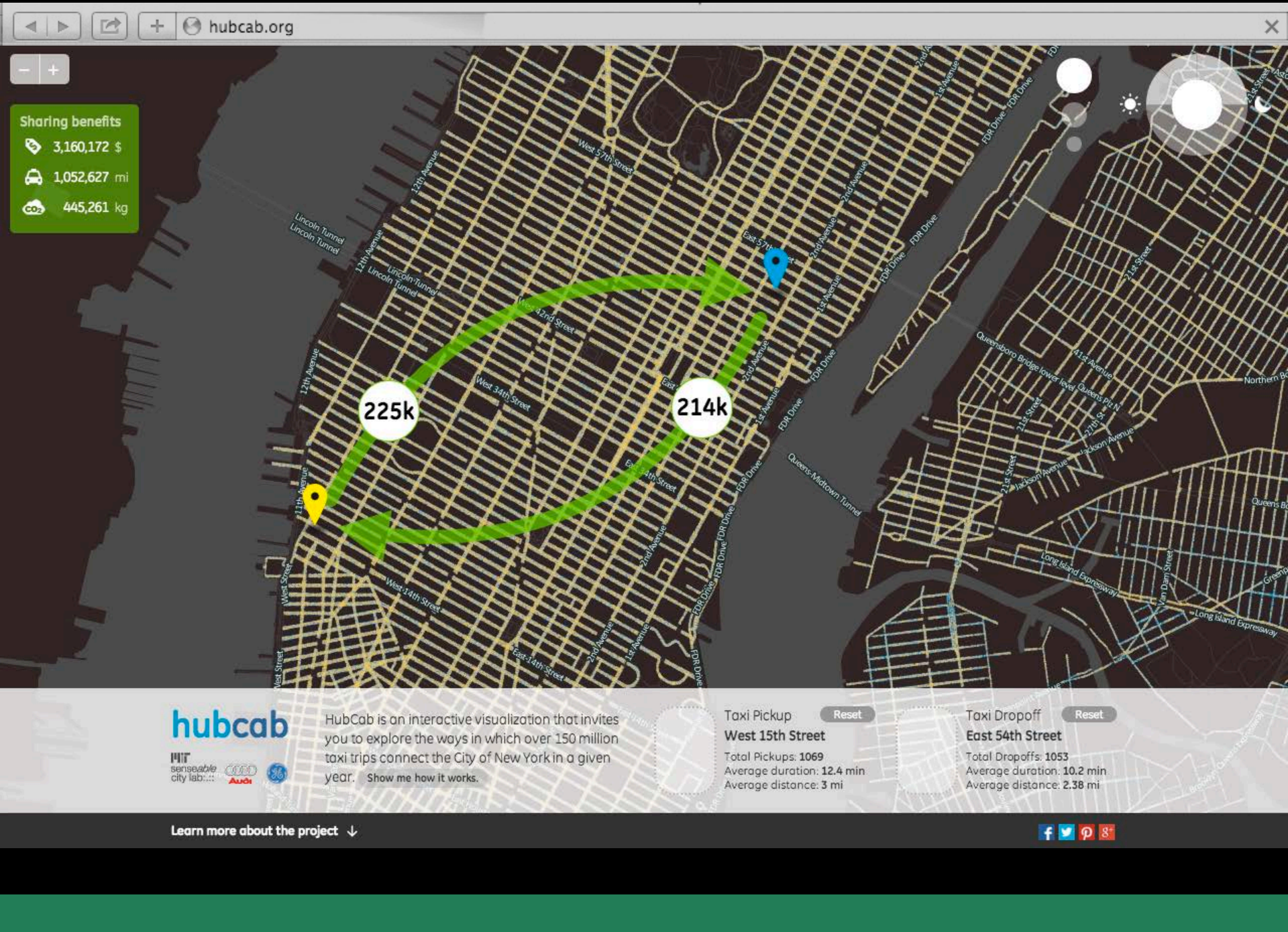
Krings et al, EPJ Data Sci 1 (2012)


B
% Shared trips
100
80
60
40
20
k = 2
Oracle max trips
Oracle min time
Online max trips
Online min time
50
100
150
200
250
300
Maximum delay Δ (sec)


C
% Shared trips
100
80
60
40
20
k = 2
Oracle max trips
Oracle min time
100k
200k
300k
400k
500k
Number trips per day


D
% Saved travel time
40
30
20
10
Oracle k = 2
Online k = 2
Online k = 3
50
100
150
200
250
300
Maximum delay Δ (sec)


E
% Saved trips
70
60
50
40
30
20
10
Online k = 2
Online k = 3
50
100
150
200
250
300
Maximum delay Δ (sec)


hubcab.org
Sharing benefits
3,160,172 $
1,052,627 mi
445,261 kg
225k
214k
hubcab
HubCab is an interactive visualization that invites you to explore the ways in which over 150 million taxi trips connect the City of New York in a given year. Show me how it works.
Taxi Pickup
Reset
West 15th Street
Total Pickups: 1069
Average duration: 12.4 min
Average distance: 3 mi
Taxi Dropoff
Reset
East 54th Street
Total Dropoffs: 1053
Average duration: 10.2 min
Average distance: 2.38 mi
Learn more about the project


hubcab.org
Sharing benefits
77,174 $
9,117 mi
3,857 kg
West 53rd Street
West 54th Street
6th Avenue
5th Avenue
Madison Avenue
7th Avenue
West 49th Street
West 50th Street
East 54th St
East 53rd Street
22.8k
22.4k
6th Avenue
West 49th Street
East 46th Street
Madison Avenue
East 49th Street
hubcab
HubCab is an interactive visualization that invites you to explore the ways in which over 170 million taxi trips connect the City of New York in a given year.
Show me how it works.
Taxi Pickup
Reset
West 50th Street
Total Pickups: 724
Average duration: 11.4 min
Average distance: 2.64 mi
Taxi Dropoff
Reset
West 51st Street
Total Dropoffs: 1704
Average duration: 10.8 min
Average distance: 2.06 mi
Learn more about the project

light traffic

Light Traffic

Improving traffic efficiency through slot-based intersections

DriverlessCities: enablers

Communication technology

cellular and short-range radio technology can be used for **V2V** and **V2I** communication

Vehicle-smartphone integration

Short range radio communication

Self-driving vehicles

currently being tested in several cities worldwide and will soon become widespread

Google self driving car

Self driving technology

Traffic lights

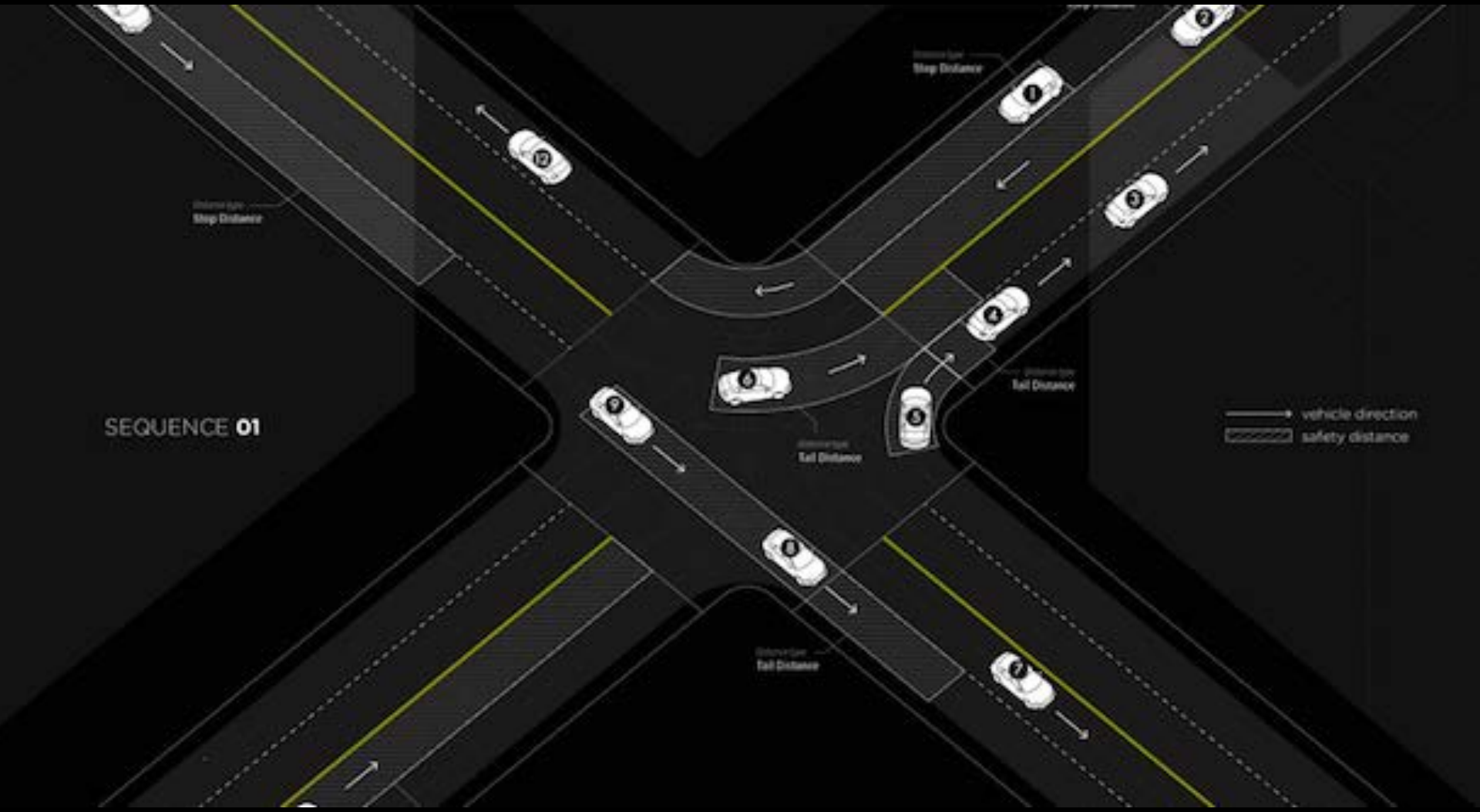
Traffic lights are **150 years** old technology, conceived for **horses**

The death of traffic lights?

Driverless vehicles will just optimize traffic light operation (**modern horses**), or can we do **something better**?

Slot-based intersection

From **flow-based** to **vehicle-based** intersection management

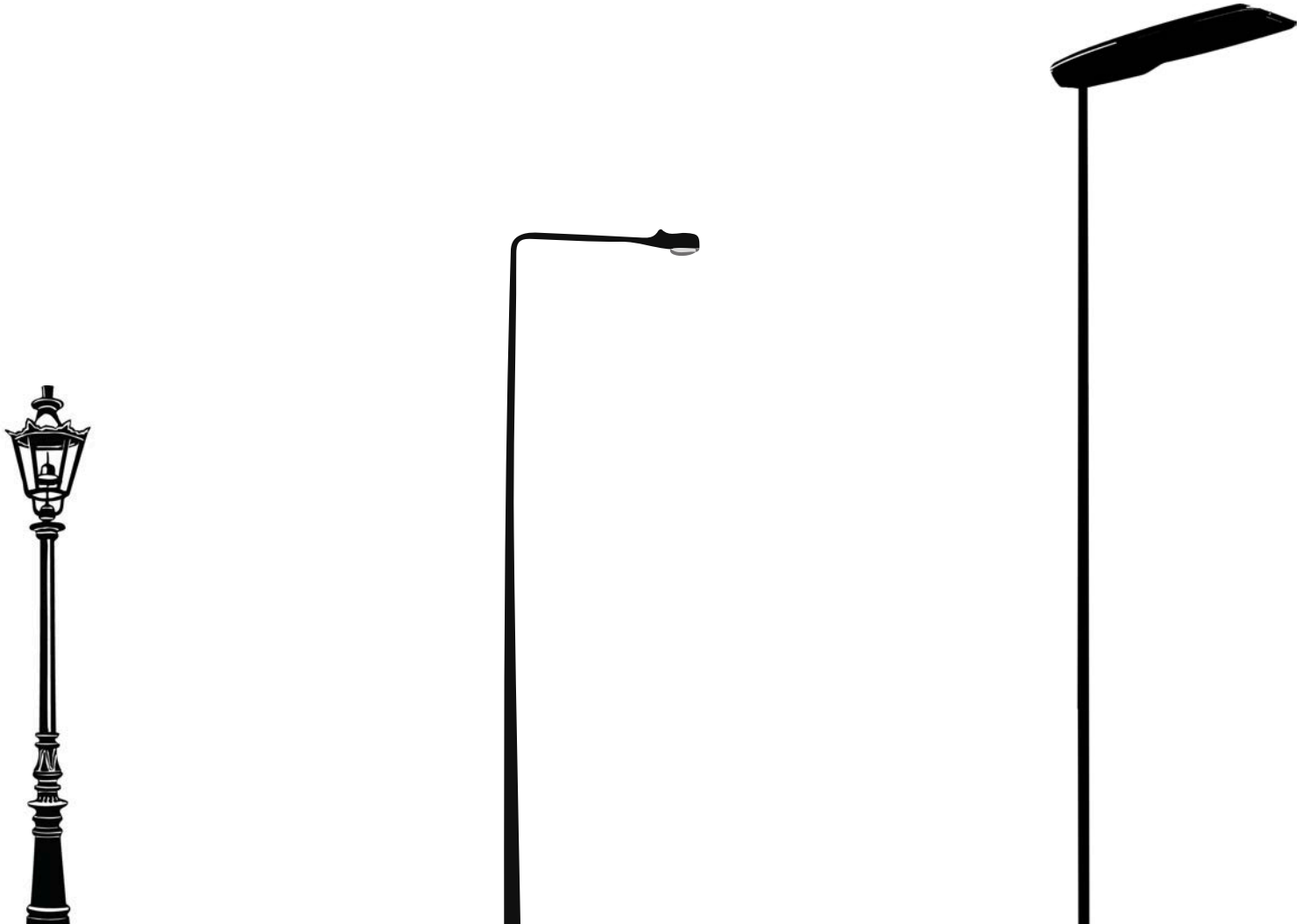


Light Traffic

Double intersection capacity vs. traffic light: with current traffic, **queues would disappear**

as above,
so below

Let’s talk about
street lights

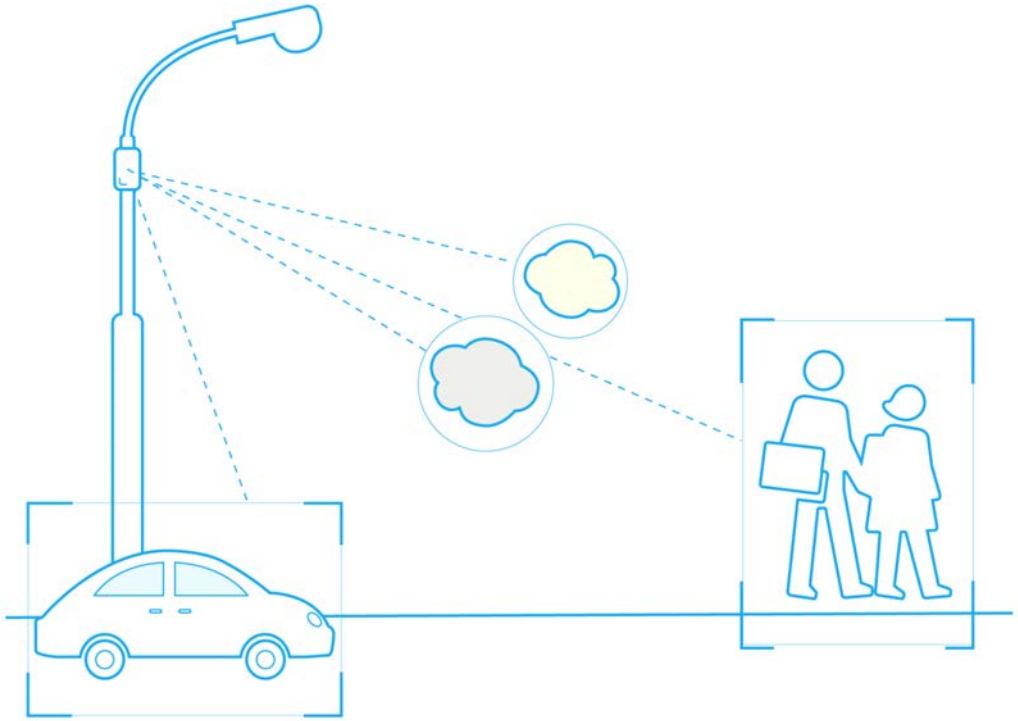



An incredible
presence
26 million streetlights
in the United States

RESEARCH OBJECTIVE 1

Transform streetlights into an urban knowledge platform that senses the urban space.

Embed cheap, scalable sensors to provide insights into areas of difficult measurement about cities.




sensors/
actuators
use
cases
urban
needs

IDEATION REPORT

Dec 2015 – Jan 2016

A.Q monitoring mesh

Bio acoustic mapping

Microclimate monitoring

Networked cameras

Soundscapes mapping

Crowd monitoring wireless signals

Auto detection of emergency situations

Stress mapping

Local warming

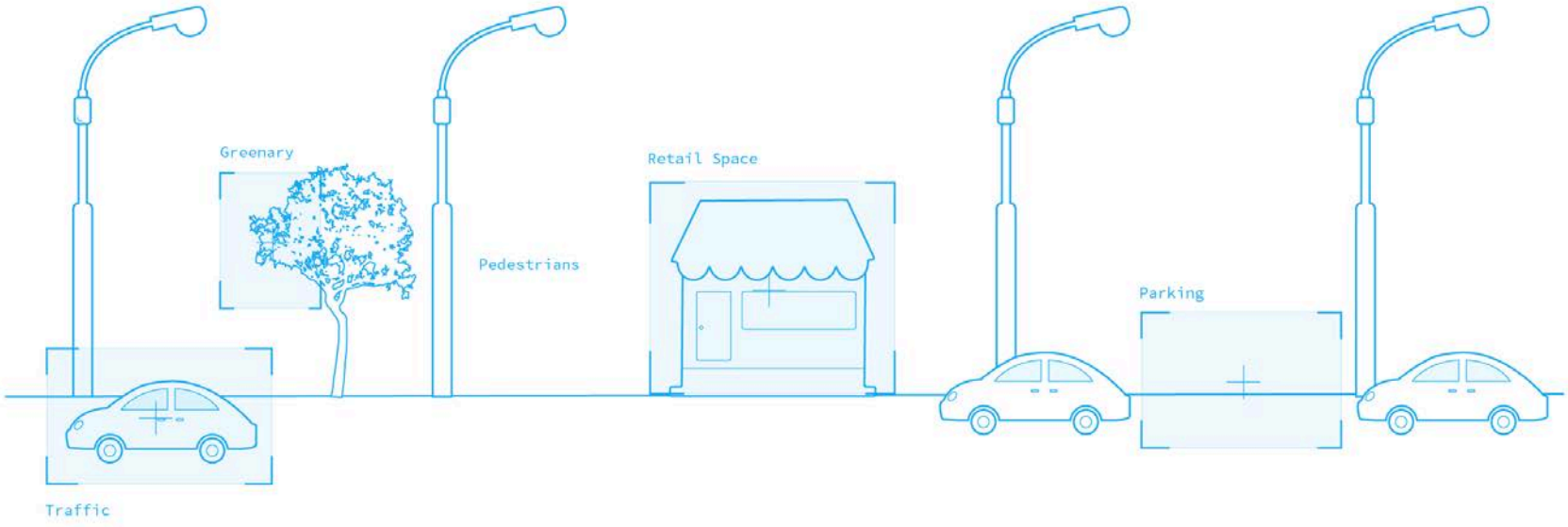
Urban flows mapping using sound wave propagation

LIDAR 3D mapping

Dynamic lights as public infrastructure

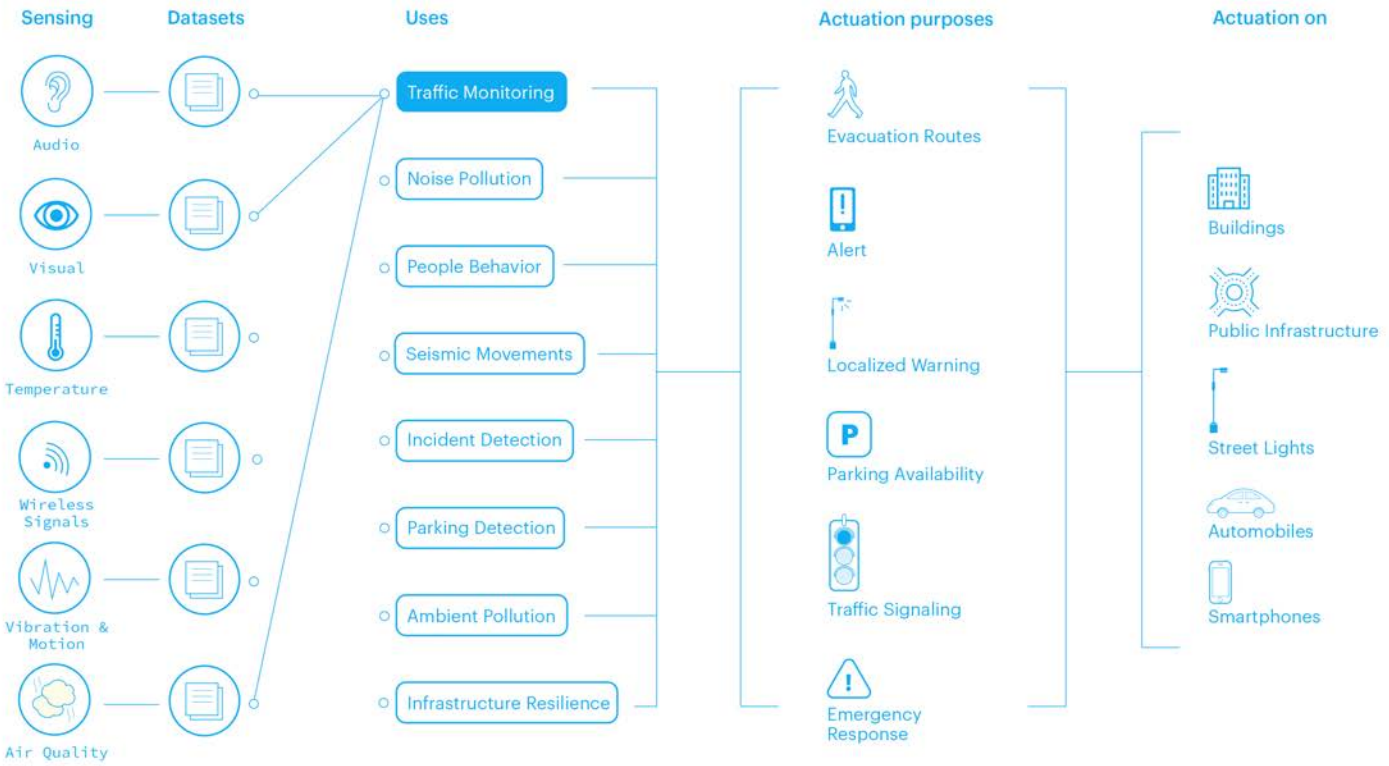
Active noise control

ONE SENSOR, MULTIPLE APPLICATIONS



COMBINING SENSORS

Ideation



Create a human centric and environmentally friendly street crossing integrating automated actuation cycles in traffic lights using real-time data from air quality and image sensors placed in streetlights.

1. Sensing and Processing

2. Actuation

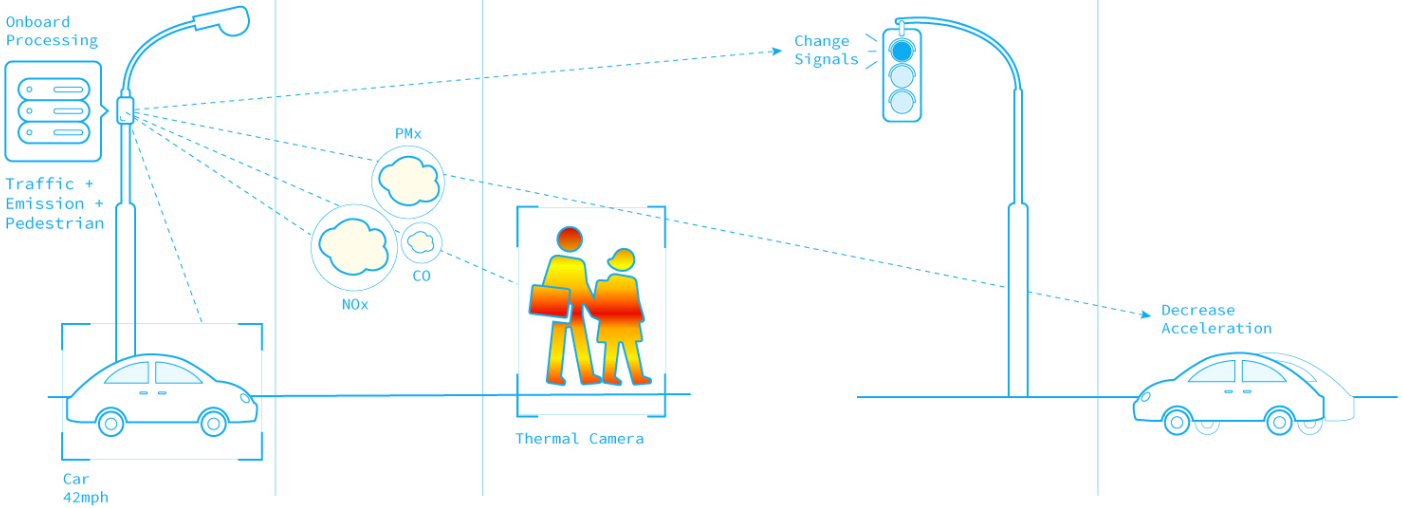
Vehicles
Counts
Velocity
Classification

Air Quality
PMx*
NOx
CO
*Particulate Matter

Pedestrians
Presence and Flows

Traffic Lights

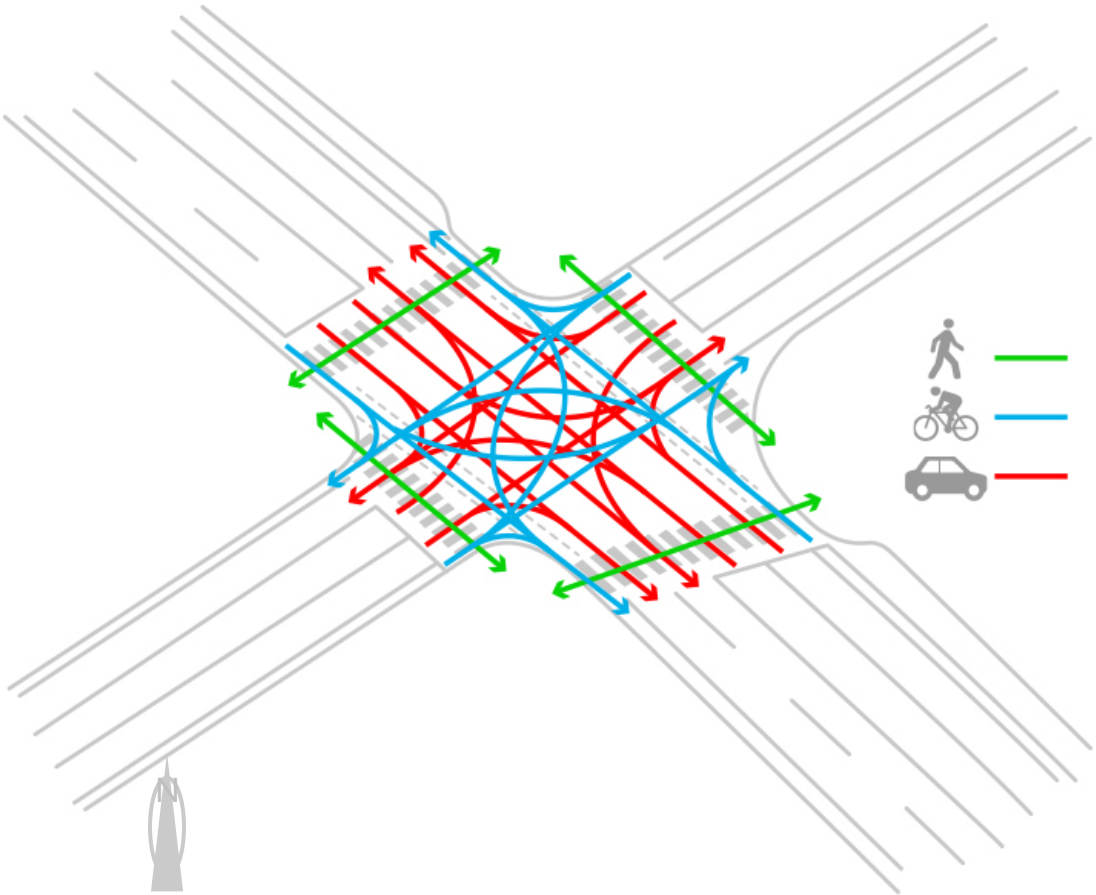
(Semi-) Autonomous Cars

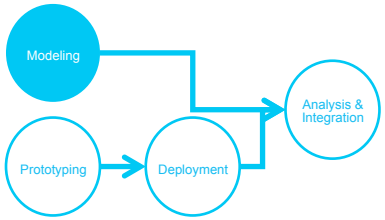


STREET CROSSING

Flows directionality on Mass. Ave. & Vassar St.

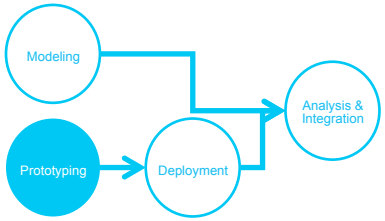
- Complex environment
- Simultaneous mobility of automobiles, bicycles and pedestrians
- 34 possible directions of discrete flows
- 8 for pedestrians
- 12 for bicycles
- 14 for automobiles





Traffic model of intersection

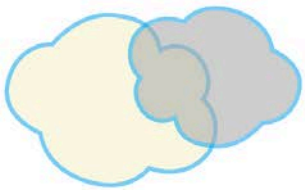
Loading the Model...

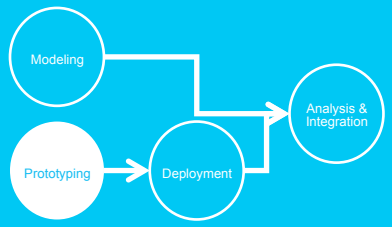


Thermal Imaging

Cameras

Air Q. Sensors

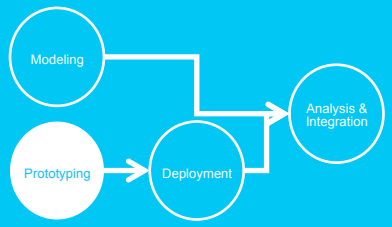




PROTOTYPING

Networked cameras & Hyper spectral Imaging

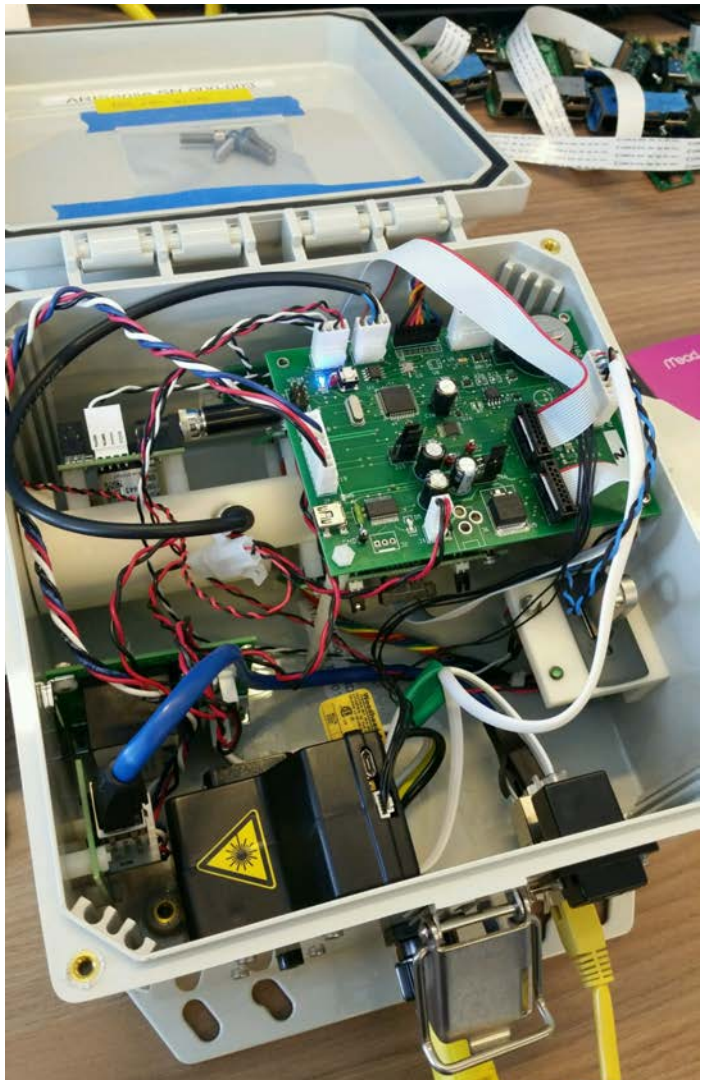
- Networked camera system (Wi-Fi 2.4 GHz)
- Cloud based trigger and synchronization control
- Low cost on board computer (RPi 2/3 based)
- Image sensor (5MP sensor programmable resolution and frame rate / 1080p 30fps video capable)
- Pi NOIR Infrared image sensor (5MP sensor)
- FLIR Lepton Thermal sensor (80 x 60 px)

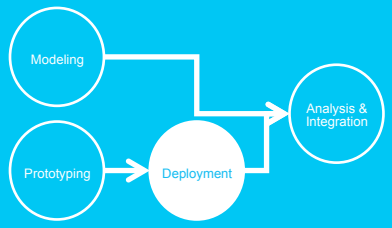


PROTOTYPING

Air Quality Nodes

- Gas phase pollutant concentrations: CO, NO, NO2, O3 + NO2) and CO2.
- Size-resolved particulate matter with estimated PM1, PM2.5, and PM10.
- Additional measurements: Barometric pressure, noise, ambient light intensity, wind speed, wind direction, relative humidity, and temperature

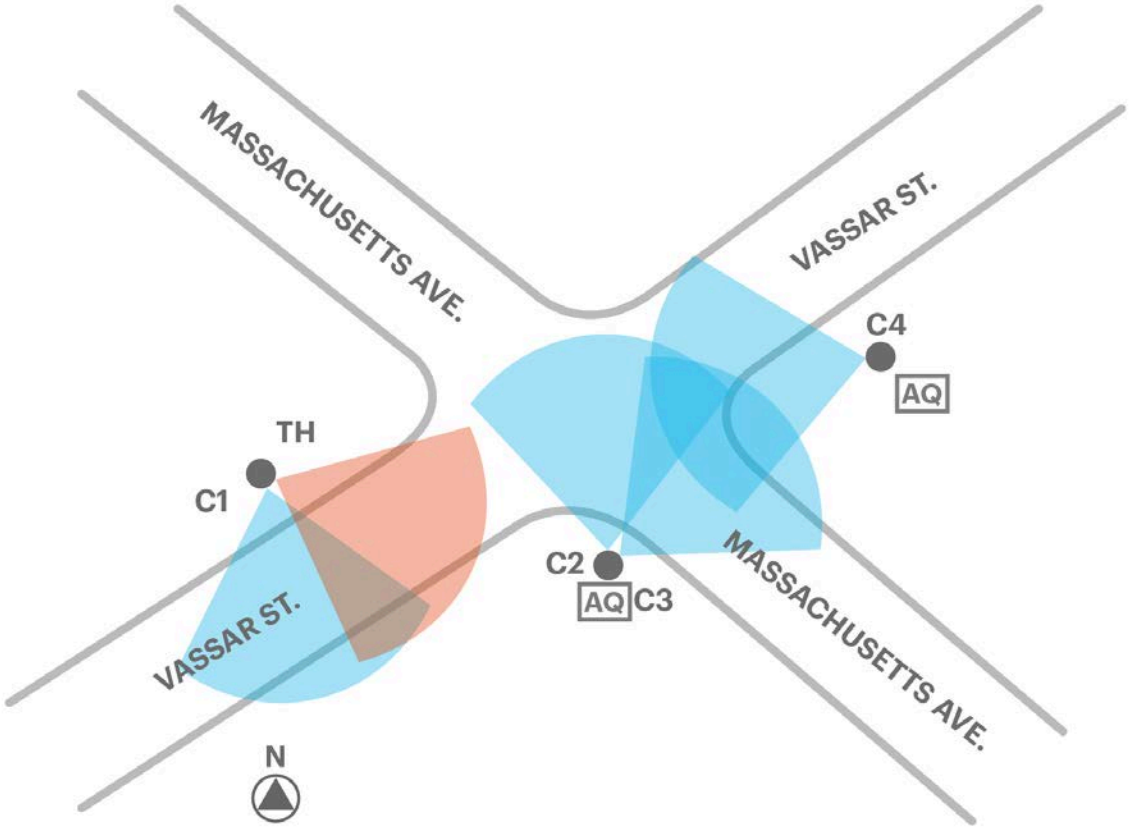




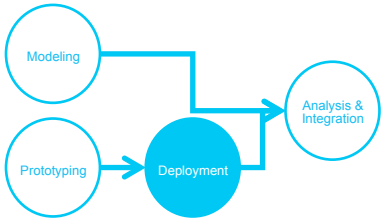
SENSOR DEPLOYMENT & DATA COLLECTION

Corner of Mass. Ave. & Vassar St.

- Synchronized data acquisition from multiple sensors
- Continuous data acquisition for A.Q. sensor nodes (one minute frequency sampling).
- Batch data sampling for video (1600x1200 px/15 FPS/H.264) for 15 min-2hr distributed periods throughout the day.
- Batch data sampling for thermal sensor (80x60px/2-20 FPS



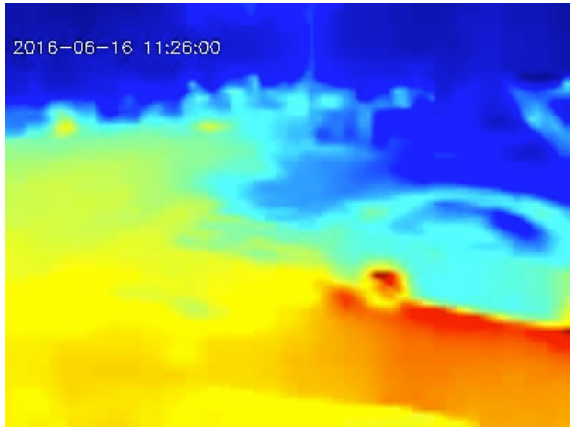
SENSEABLE CITY LAB



PRIMARY DATA SAMPLING

Thermal and image sensors

Thermal sensor



Camera 4

Camera 2

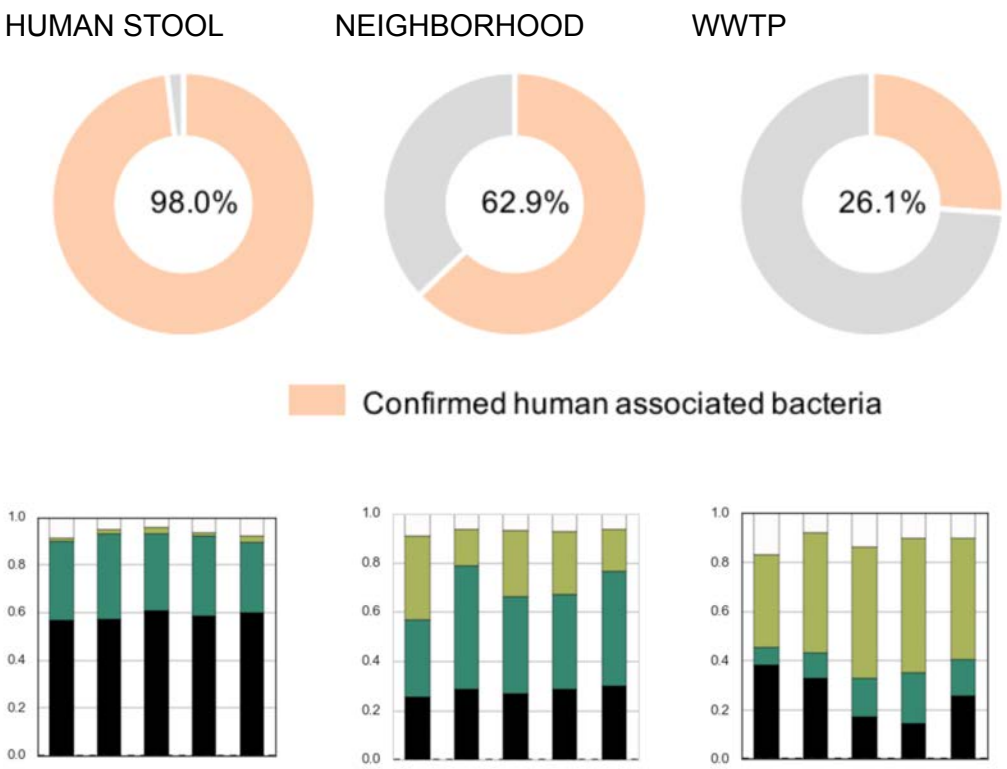

UNDERWORLDS


WHAT IS IN OUR COLLECTIVE GUT?
E.COLI
CAFFEINE
NOROVIRUS
ESOMEPRAZOLE
BACTEROIDES

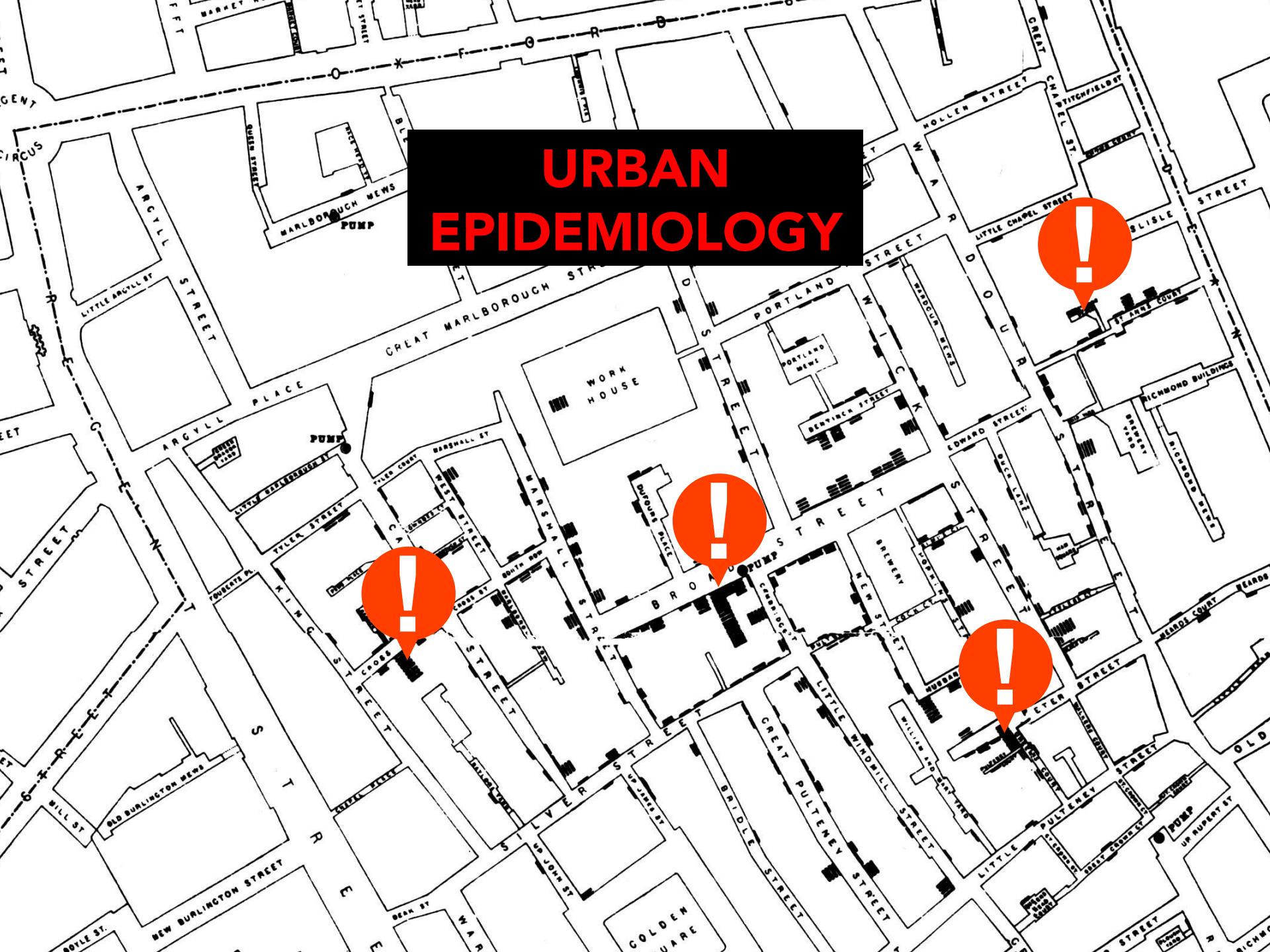
600,000 people
8+ hours travel time

1,500 people
15 minutes travel time

HUMAN GUT MICROBIOME SIGNATURE




REAL-TIME
DETECTION


URBAN
EPIDEMIOLOGY
GREAT MARLBOROUGH STREET
ARGYLL PLACE
ARGYLL STREET
LITTLE ARGYLL ST.
MARLBOROUGH MEWS
PUMP
WORK HOUSE
PORTLAND STREET
PORTLAND MEWS
BERNERS STREET
WARDOUR STREET
LITTLE CHAPEL STREET
ST ANNE COURT
RICHMOND BUILDINGS
EDWARD STREET
BROAD STREET
BROADWICK STREET
MARSHALL STREET
TYLER COURT
TYLER STREET
DUFOURS PLACE
CROSS STREET
KINGLY STREET
BREWER STREET
CAMBRIDGE COURT
NEW STREET
BREWERY
LITTLE WINDMILL STREET
GREAT PULTENEY STREET
BRIDLE STREET
PULTENEY STREET
LITTLE PULTENEY STREET
PETER STREET
REGENT STREET
OLD BURLINGTON MEWS
NEW BURLINGTON STREET
MILL ST.
BOYLE ST.
GOLDEN SQUARE
UP JOHN ST.
UP RUPERT ST.
OLD

3:35

+ Queue

Download

Embed

Transcript

PUBLIC HEALTH

To Keep Polio At Bay, Israel Revaccinates A Million Kids

September 2, 2013 · 3:24 AM ET

Heard on Morning Edition

JASON BEAUBIEN

In early August, Israel launched a mass campaign to vaccinate children against polio, including this little girl at a clinic in Rahat.

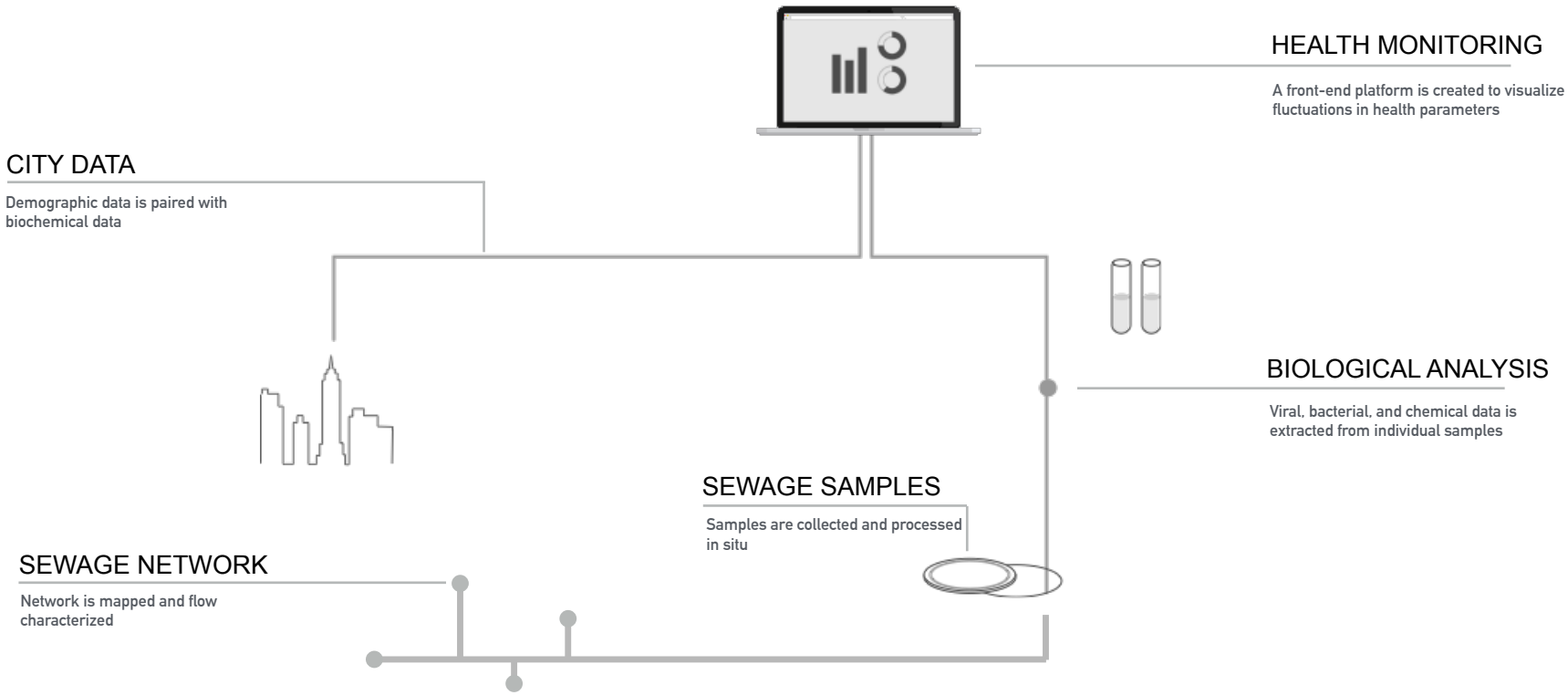
David Buimovitch/AFP/Getty Images

Israel is in the midst of a massive, emergency immunization drive of all children under the age of 9 against polio.

Why?

Health workers detected the virus in southern Israel in February. Since then, they've found it in 85 different sewage samples across the country, the Global Polio Eradication Initiative said Wednesday. Yet so far, no children have gotten sick or been paralyzed by the virus.

MULTISTEP PROJECT DEVELOPMENT

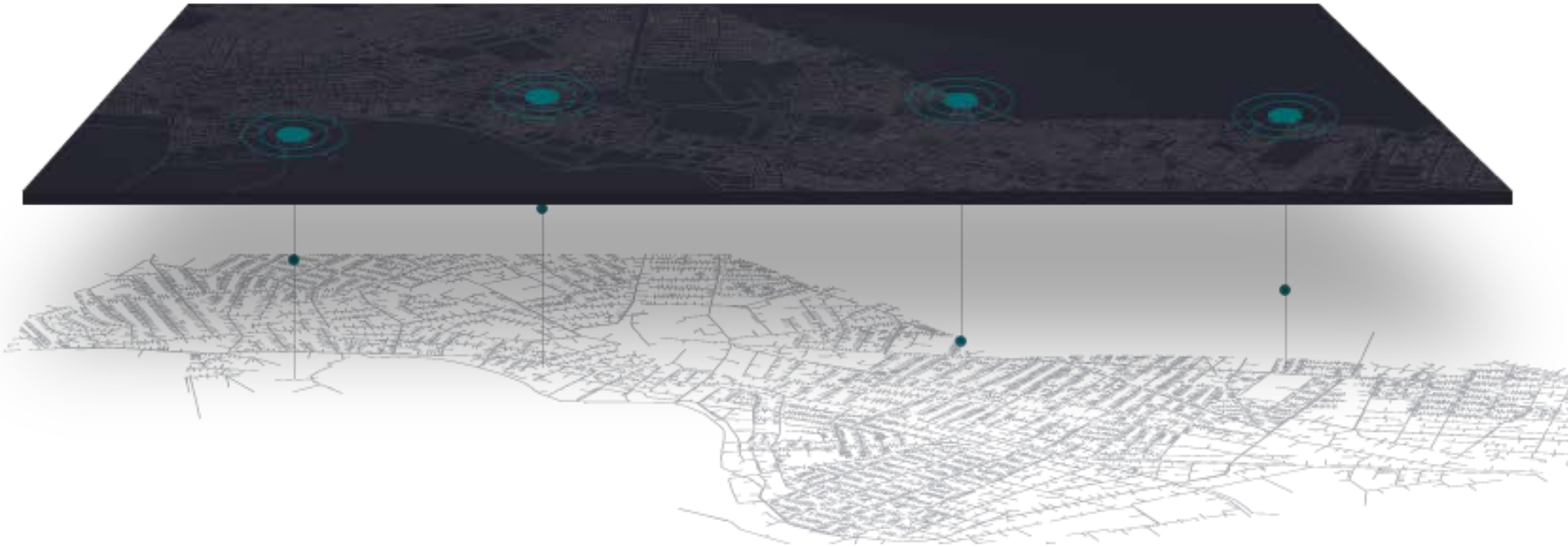


WHAT ARE WE LOOKING FOR?
A combination of discovery-mode (untargeted) and targeted protocols:

VIRUSES: REAL-TIME DISEASE TRACKING (human viral pathogen qPCR assays)

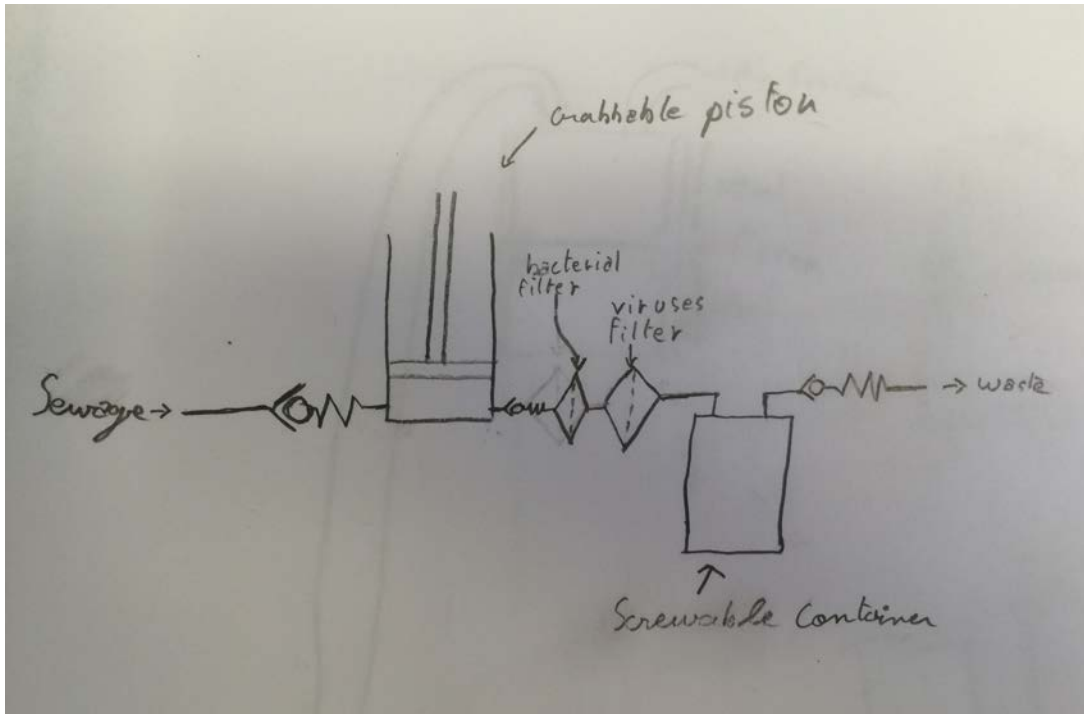
BACTERIA: MICROBIOME, ANTIBIOTIC RESISTANCE (16S and WGSS sequencing)

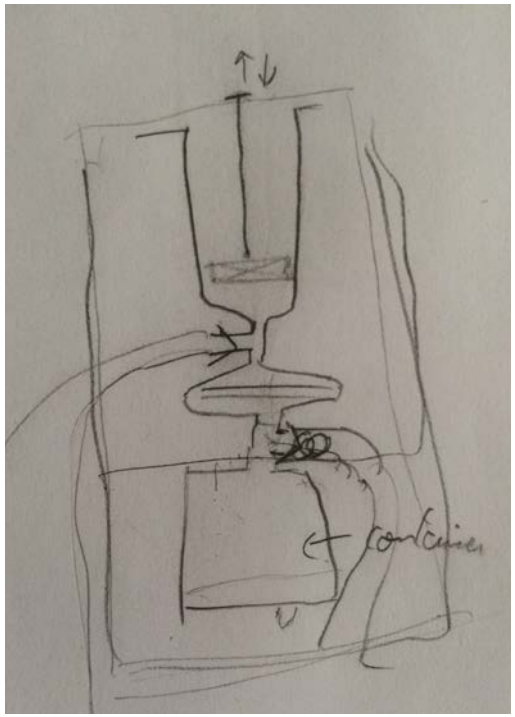
CHEMICALS: DETECTION, POLICY EVALUATION (mass spec & targeted metabolomics)

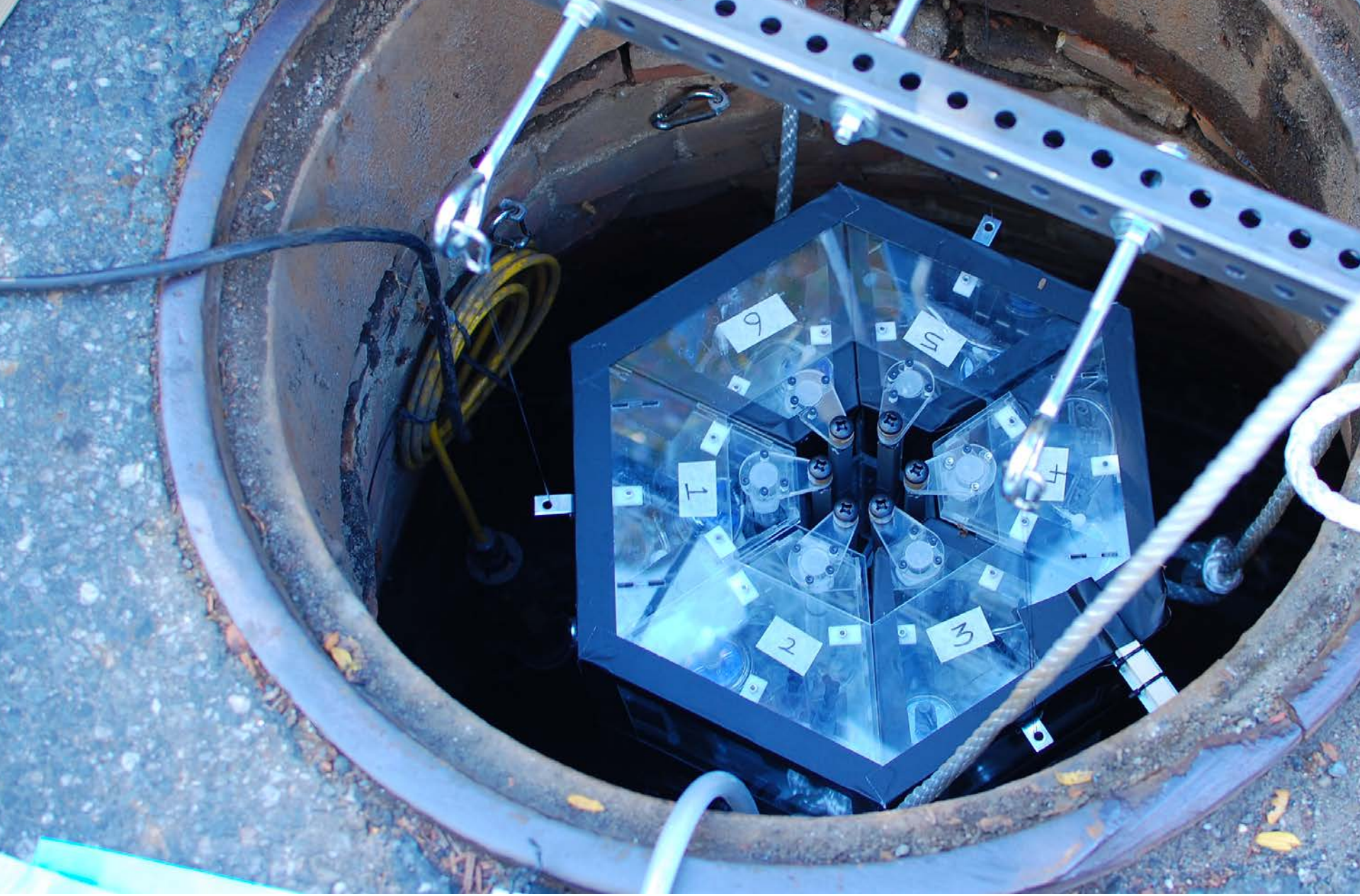



Underworlds
ABOUT
PROJECTS
PARTNERS
TEAM
BLOG
Pipe Count
Area
Population*
Median Age*
Median Income*
White
Black
Asian
Other
Water Travel Time of This Area
0
30min.
60min.
Arlington
East Arlington
Medford Hillside
Wellington
West Everett
Everett
Mystic River Reservation
Hendersonville
Revere Beach Parkway
Belmont Country Club
Belmont High School
Alewife Brook Reservation
BALL SQUARE
NORTH CAMBRIDGE
WEST SOMERVILLE
WINTER HILL
TEN HILLS
Mystic Power Station
ADMIRALS HILL
Chelsea
Danehy Park
SPRING HILL
Somerville
AVON HILL
EAST SOMERVILLE
Fresh Pond Golf Course
HURON VILLAGE
STRAWBERRY HILL
LARCHWOOD
OLD CAMBRIDGE
Harvard University
Cambridge
HARVARD SQUARE
CHARLESTOWN
EAST BOSTON
MOUNT AUBURN
COOLIDGE HILL
Oakley Country Club
Watertown
Mount Auburn Cemetery
EAST WATERTOWN
Cambridge Cemetery
Harvard University Harvard Stadium
EAST CAMBRIDGE
NORTH END
WEST END
JEFFRIES POINT
NONANTUM
Charles River Reservation
CAMBRIDGEPORT
Massachusetts Institute of Technology
Boston
BEACON HILL
NEWTON CORNER
NORTH BRIGHTON
FANEUIL
ALLSTON
Charles River Esplanade
Boston Common
FINANCIAL DISTRICT
Newtonville
BRIGHTON
Boston University
BACK BAY
CHINATOWN
Massachusetts Turnpike
COOLIDGE CORNER
ABERDEEN
Newton Commonwealth Golf Course
Boston College
Boston College—Newton Campus
FENWAY
Fenway Park
SOUTH END
Northeastern University
Newton

PROTOTYPING A NETWORK OF AUTOMATED SAMPLING INSTRUMENTS
That are dynamically operated and sense information in situ






9
5
1
4
2
3

MAR.IO

LUIGI

completed:

MECHANICAL
- cable coil
- geared DC motor
- peristaltic pump

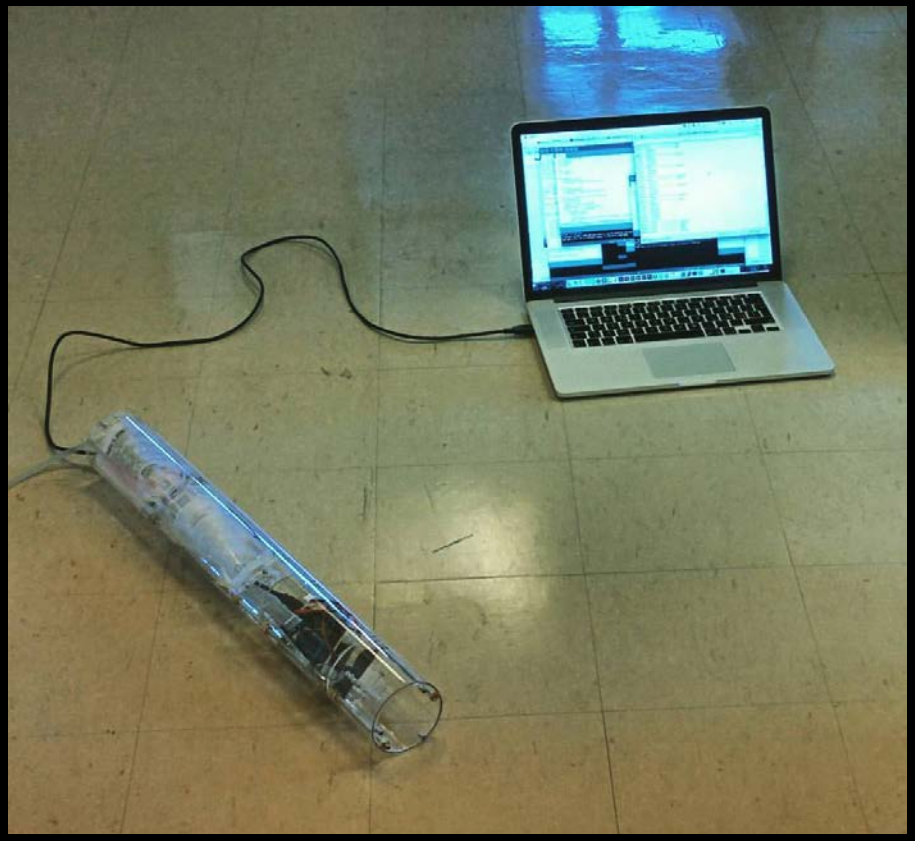
ELECTRICAL
- micro-controller & battery
- fluid counter
- infrared distance sensor

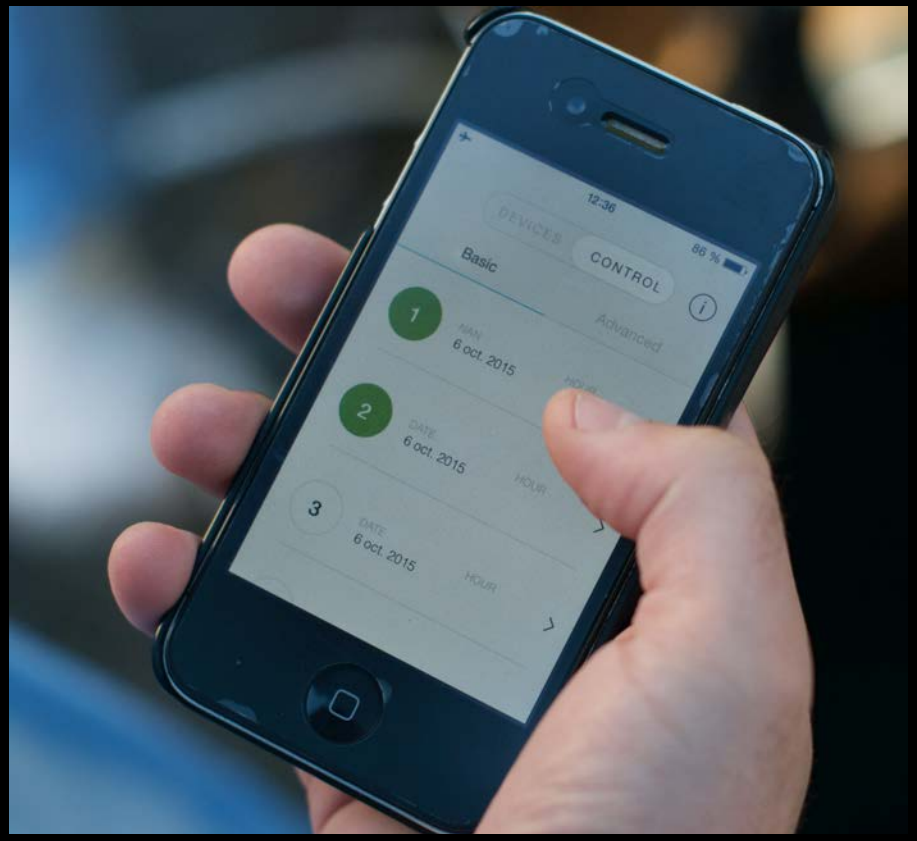
FLUID
- preprocessing filter
- collection bottle
- intake & outtake tubing

in progress:

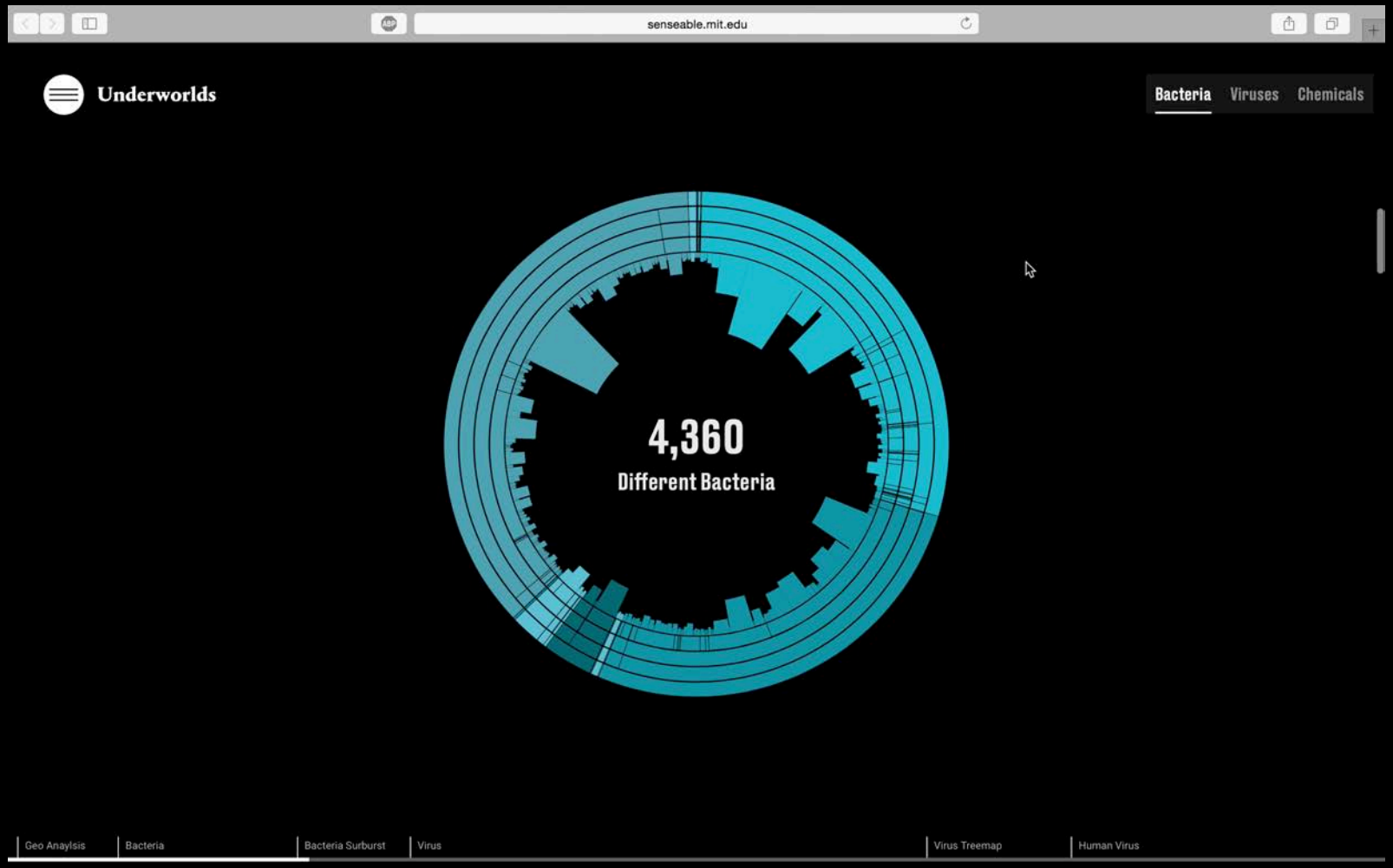
SENSORS
- temperature
- flow
- water & moisture
- microfluidics device
- targeted bio sensors

COMMUNICATION
- data collection and storage
- preprogrammed deployment




12:36
86 %
DEVICES
CONTROL
Basic
Advanced
1
MIN
6 oct. 2015
2
DATE
6 oct. 2015
HOUR
3
DATE
6 oct. 2015
HOUR


CNN Money


senseable.mit.edu
Underworlds
Bacteria
Viruses
Chemicals
4,360
Different Bacteria
Geo Anaylsis
Bacteria
Bacteria Surburst
Virus
Virus Treemap
Human Virus

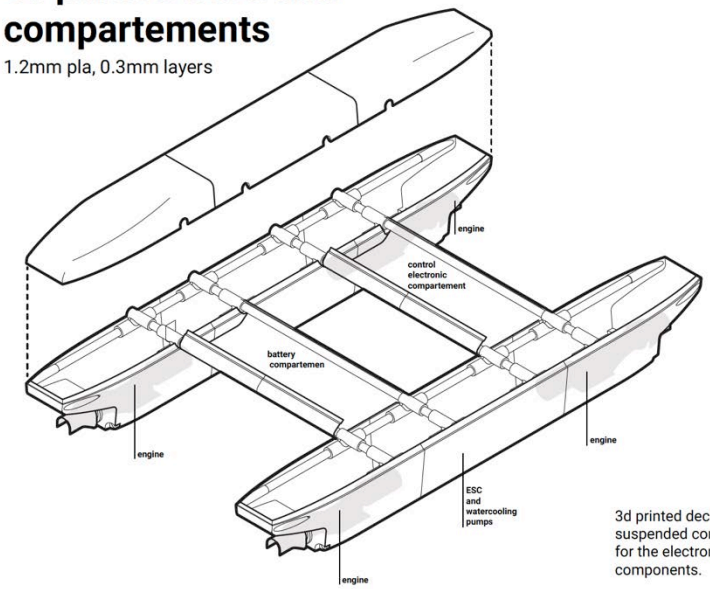

„DE COST GAET VOOR DE BAET UYT."
The Grasshopper
plas
plas
plas
AMS | MIT
roboat


FRAGILE
HANDLE WITH CARE

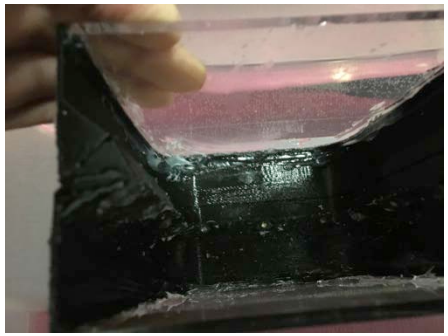
roboat prototyping

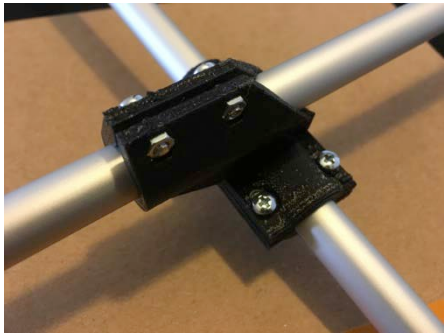
3d printed deck and compartements

1.2mm pla, 0.3mm layers



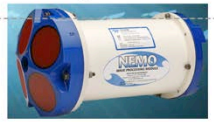
3d printed deck sections, suspended compartments for the electronics components.



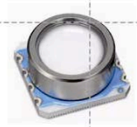


ASV, technology overview

- **GPS (Global Positioning System)**
- **Doppler Velocity Logger (DVL)**: an instrument that measures the vehicle's relative velocity according to the Doppler effect.
- **Pressure sensor:** estimate the surrounding flow conditions.
- **Inertial Measurement Unit (IMU):** measures the robot attitude (yaw, pitch and roll), and the angular velocities.



DVL



Pressure sensor

IMU

For our roboat that requires docking and self-assembly, only GPS-based navigation is insufficient, vision-based localization system or Inertial Navigation System should be developed.

urban research and data


launch event

senseable city lab:.::

Massachusetts Institute of Technology

embaum@mit.edu | senseable.mit.edu