Welcome!

6.808: Mobile and Sensor Computing

aka IoT Systems

http://6808.github.io

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Internet of Things

Convergence of micro-sensing, computation, and communication that allows us to:

- *Acquire* (*sense*) data from the environment
- *Pre-process* data locally (on-device / “edge”)
- *Deliver* data to servers (“cloud”)
- *Draw inferences* and *provide insights* about the world from the data:
    - Sensor fusion, data integration
    - Signal processing
    - Machine learning
- *Control* actions in the environment

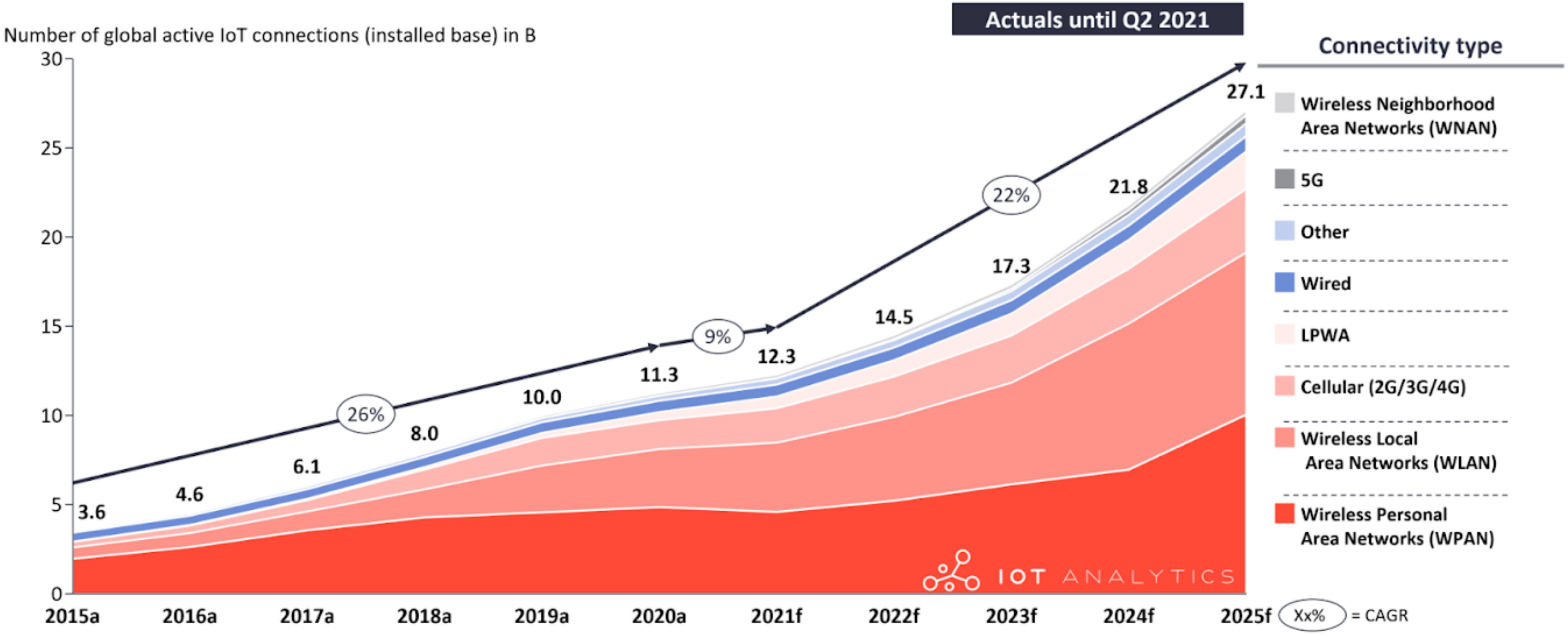
Focus of 6.808: how we got to now and how could it transform the future

IOT ANALYTICS

September 2021

Your Global IoT Market Research Partner

Global IoT market forecast (in billion connected IoT devices)

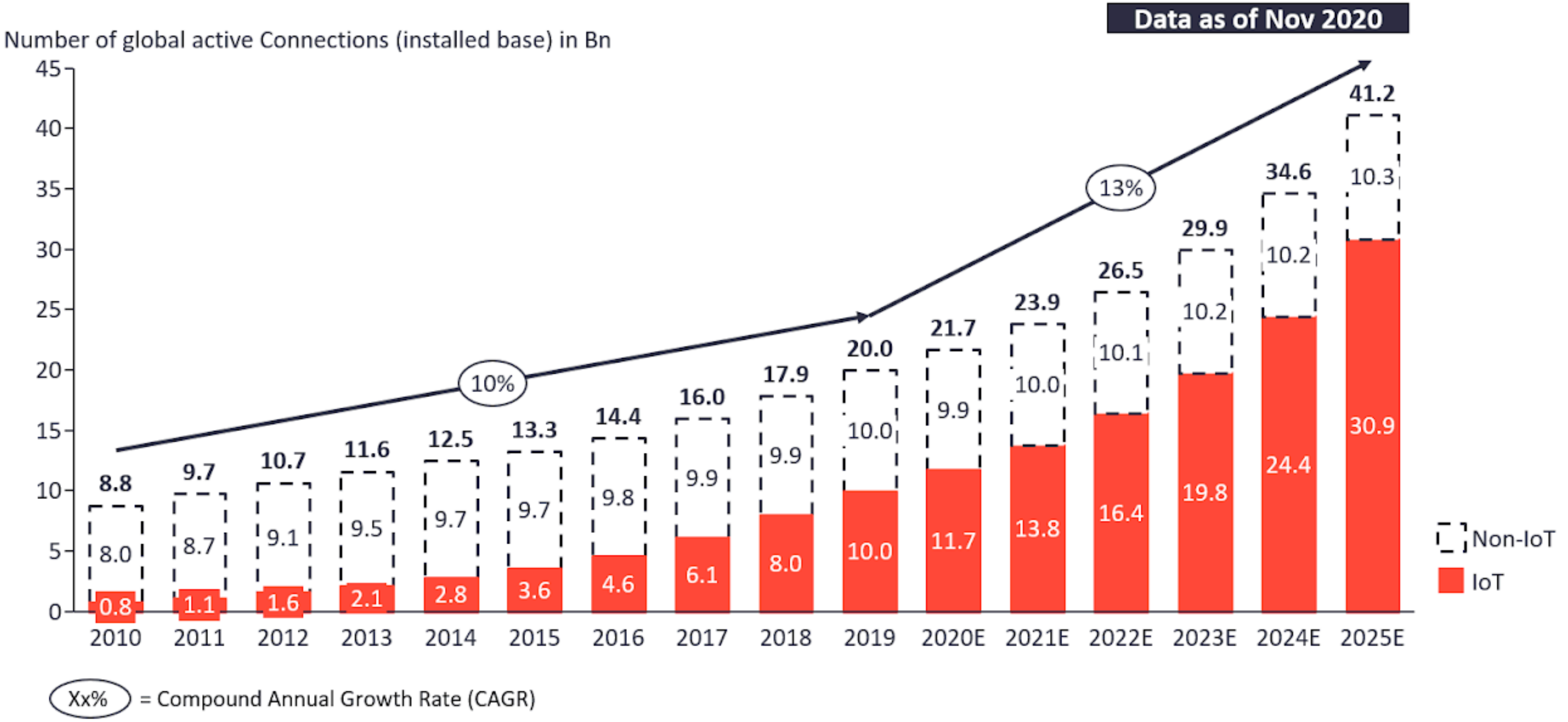


Note: IoT Connections do not include any computers, laptops, fixed phones, cellphones or tablets. Counted are active nodes/devices or gateways that concentrate the end-sensors, not every sensor/actuator. Simple one-directional communications technology not considered (e.g., RFID, NFC). Wired includes ethernet and fieldbuses (e.g., connected industrial PLCs or I/O modules). Cellular includes 2G, 3G, and 4G. LPWAN includes unlicensed and licensed low-power networks. WPAN includes Bluetooth, Zigbee, Z-Wave, or similar. WLAN includes Wi-Fi and related protocols. WNAN includes non-short-range mesh, such as Wi-SUN. Other includes satellite and unclassified proprietary networks with any range.

Source: IoT Analytics Research, September 2021 – Please remember to cite IoT Analytics as the source (with link) when re-sharing this content as per our copyright policy

Total number of device connections (incl. Non-IoT)

20.0Bn in 2019– expected to grow 13% to 41.2Bn in 2025



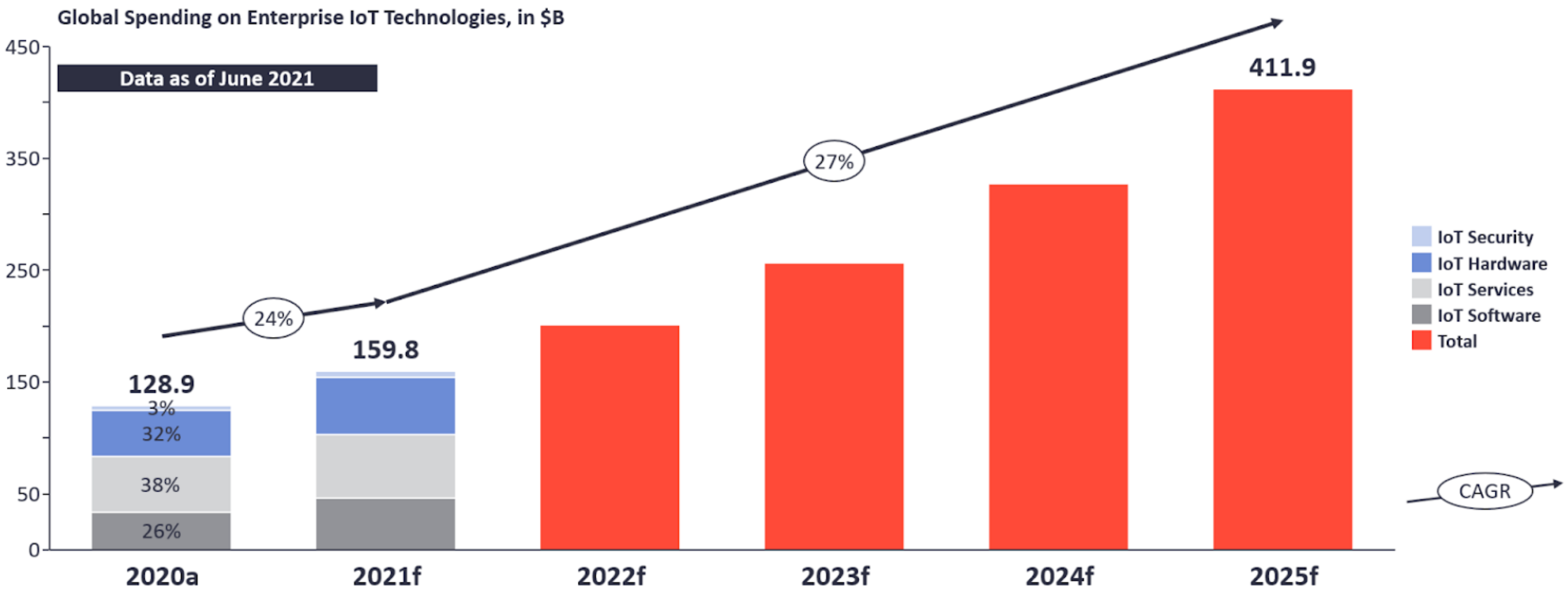
Note: Non-IoT includes all mobile phones, tablets, PCs, laptops, and fixed line phones. IoT includes all consumer and B2B devices connected – see IoT break-down for further details

Source(s): IoT Analytics - Cellular IoT & LPWA Connectivity Market Tracker 2010-25

IOT ANALYTICS

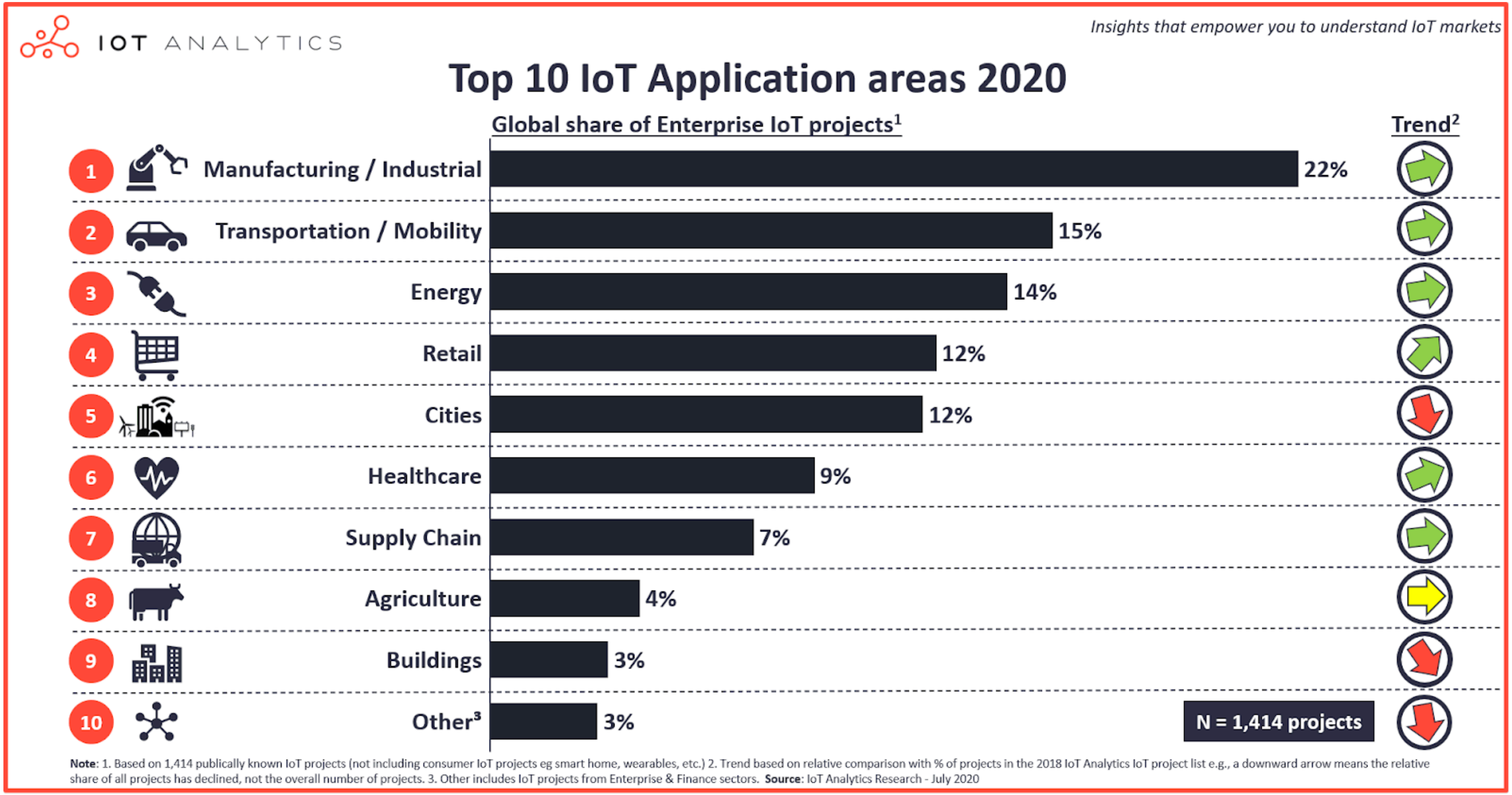
Your Global IoT Market Research Partner

IoT Enterprise Spending 2020 – 2025



Note: IoT Analytics defines IoT as a network of internet-enabled physical objects. Objects that become internet-enabled (IoT devices) typically interact via embedded systems, some form of network communication, or a combination of edge and cloud computing. The data from IoT-connected devices is often used to create novel end-user applications. Connected personal computers, tablets, and smartphones are not considered IoT, although these may be part of the solution setup. Devices connected via extremely simple connectivity methods, such as radio frequency identification or quick response codes, are not considered IoT devices. . a: Actuals, f: Forecast

Source: IoT Analytics Research 2021

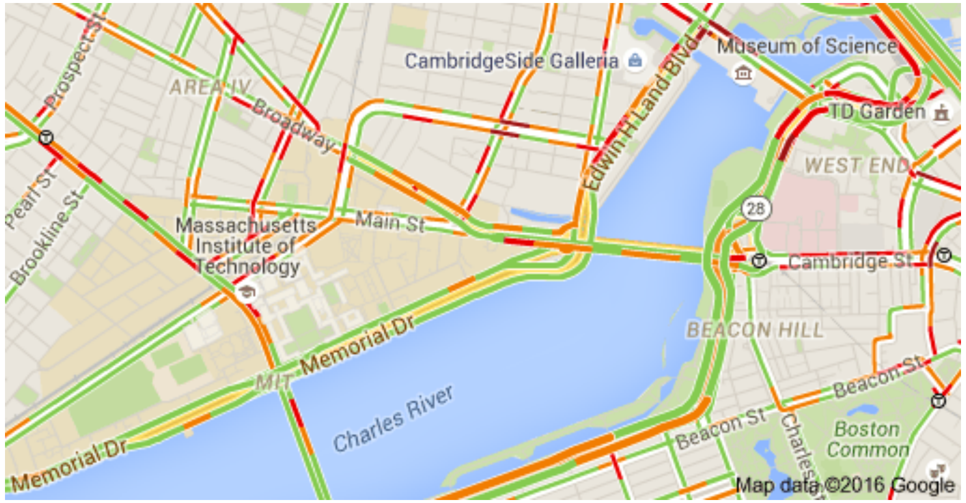


Connected solutions bring increased vehicle uptime for our customers, better safety for drivers, operators and other road users and of course – less emissions of carbon dioxide.

– *Martin Lundstedt, CEO of the Volvo Group, Oct 2019*

IoT is Transforming Industries

Transportation & Smart Cities



Medicine

Smart Homes

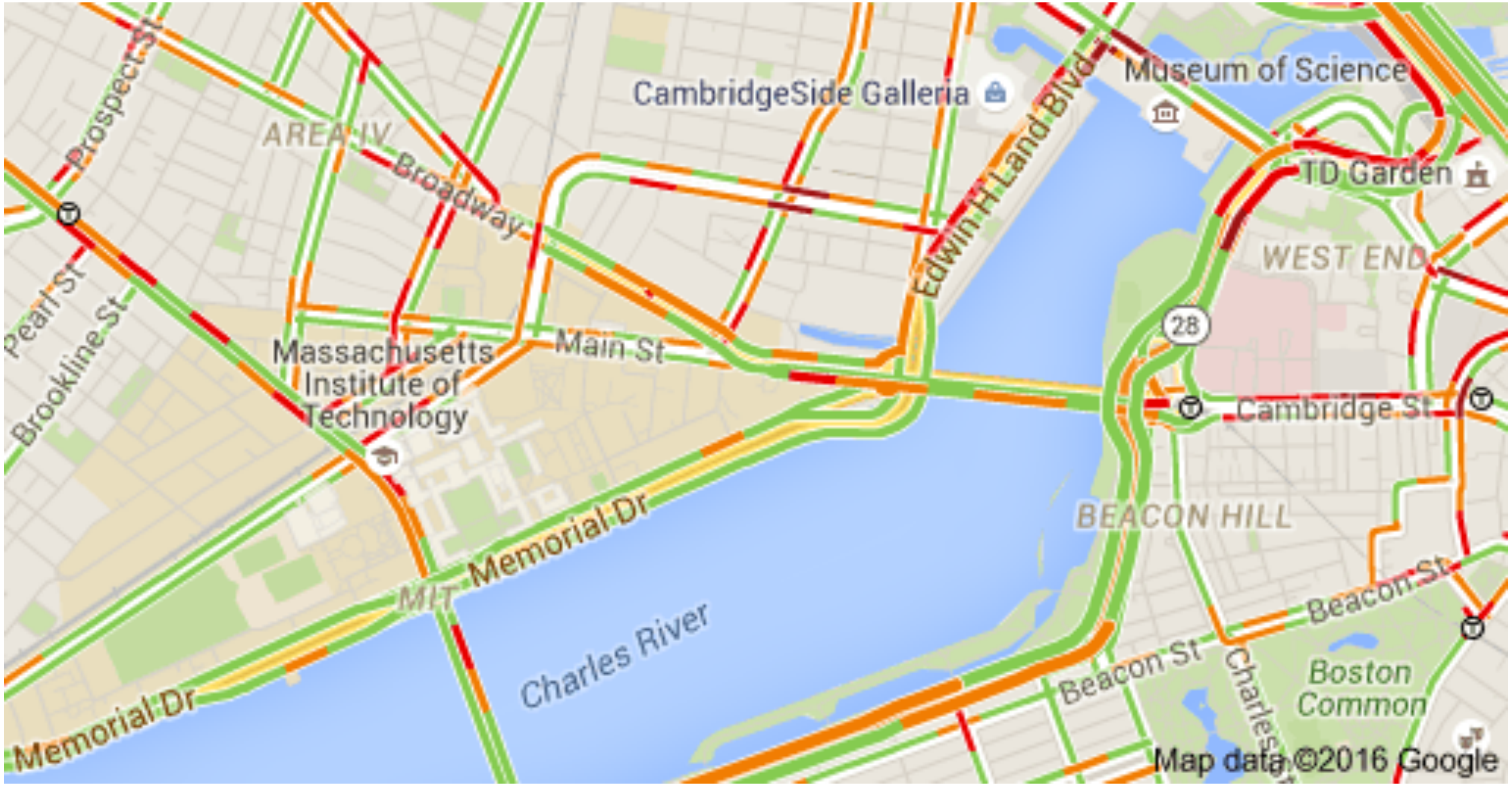
Health & Wellness

Connected Vehicles

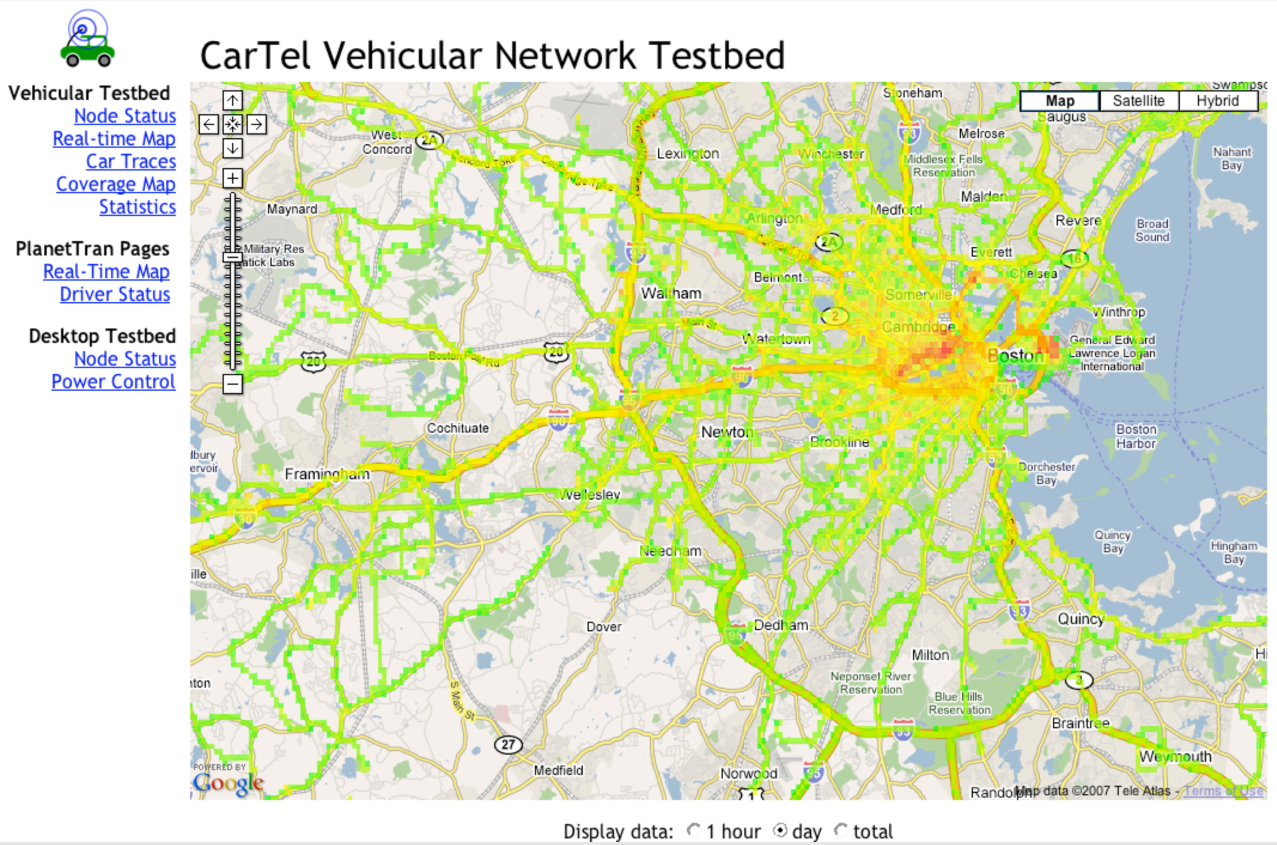
Precision Agriculture

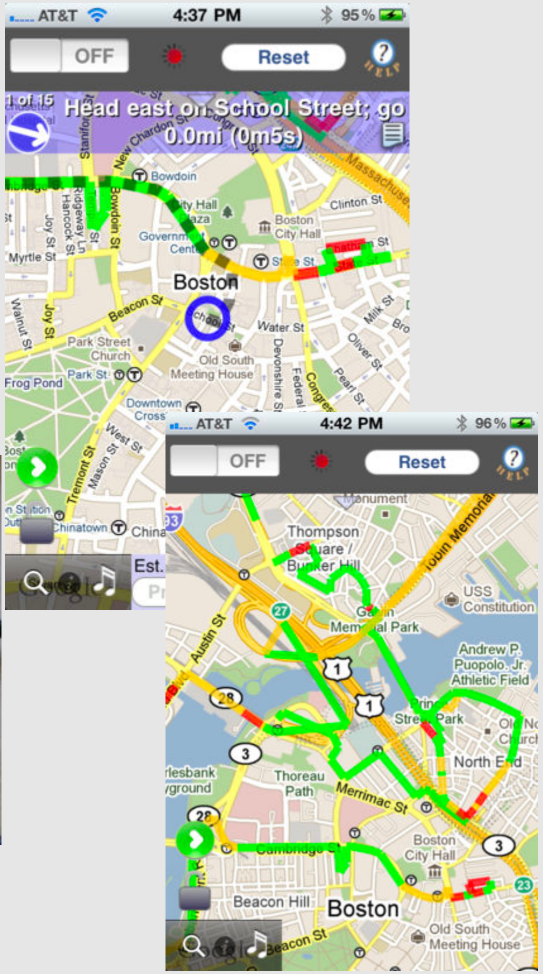
Example systems we will cover

Transportation & Smart Cities

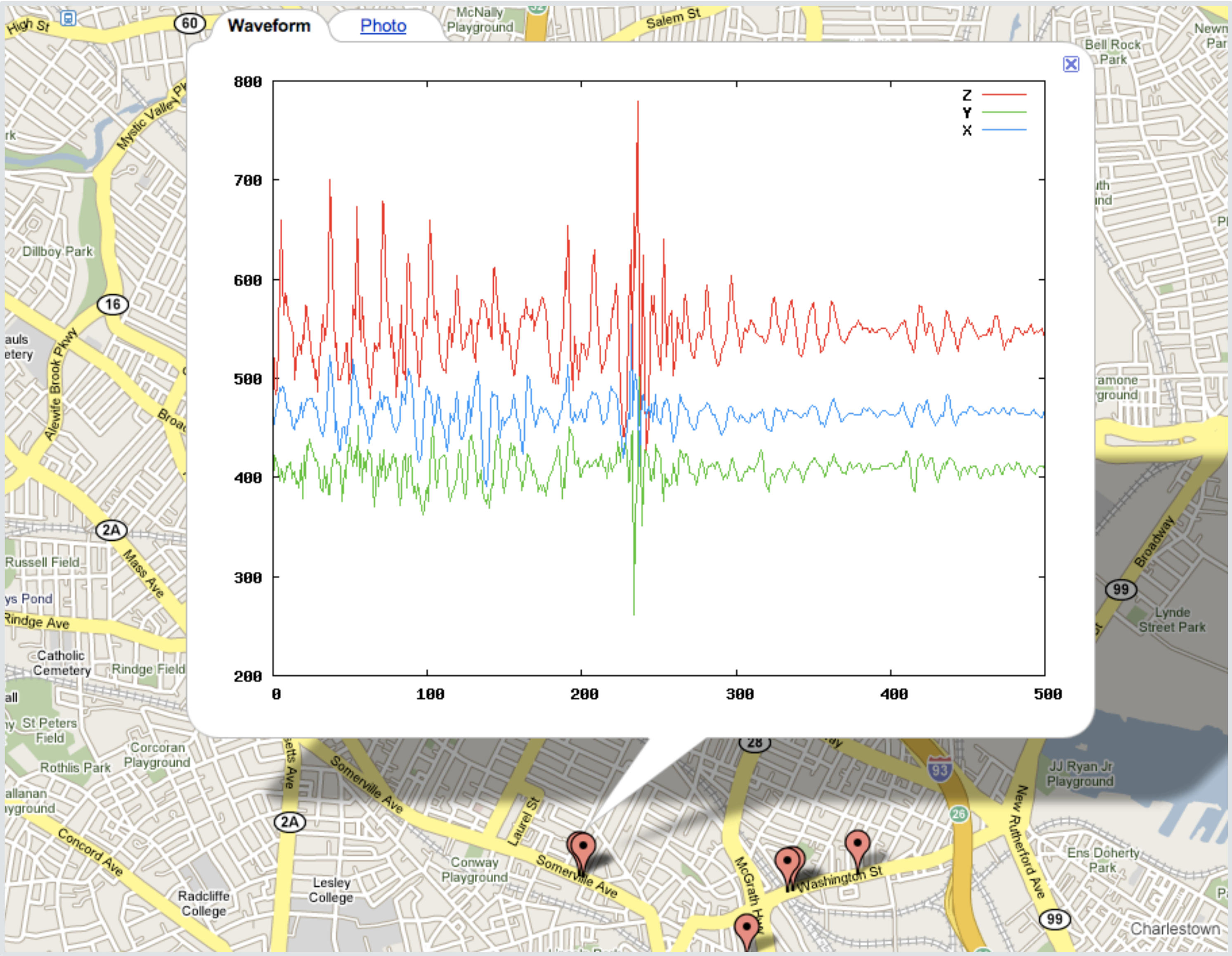


CarTel Project at MIT (2005-2011)





Pothole Patrol

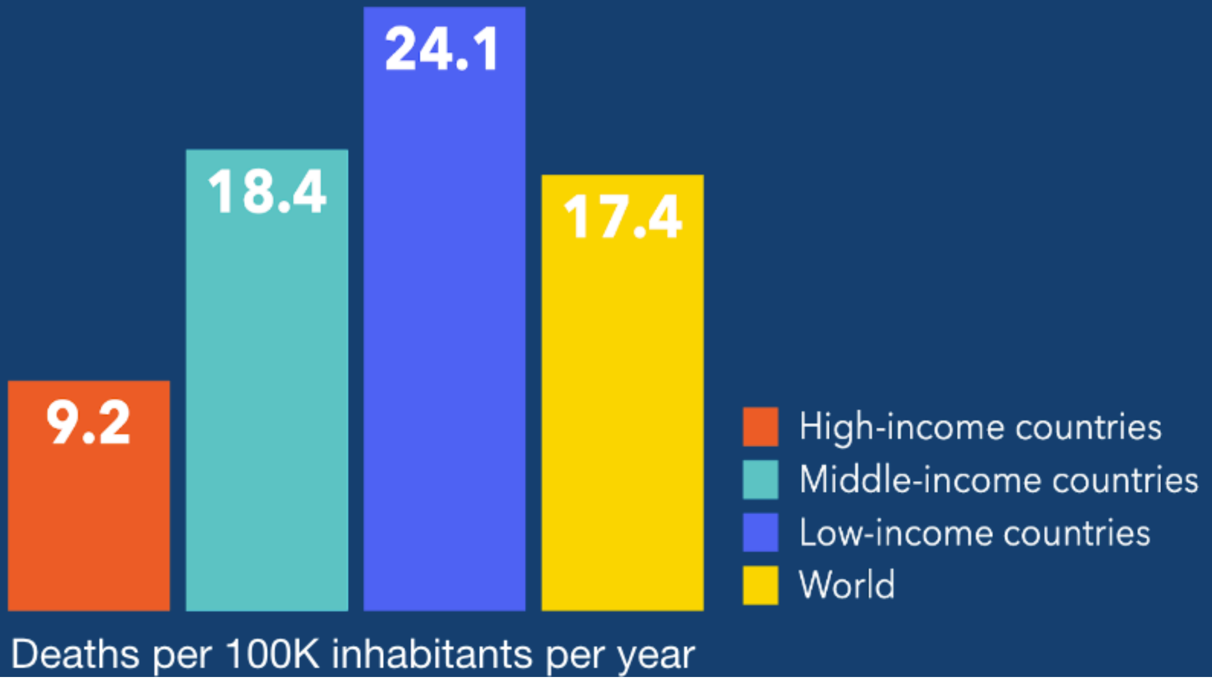


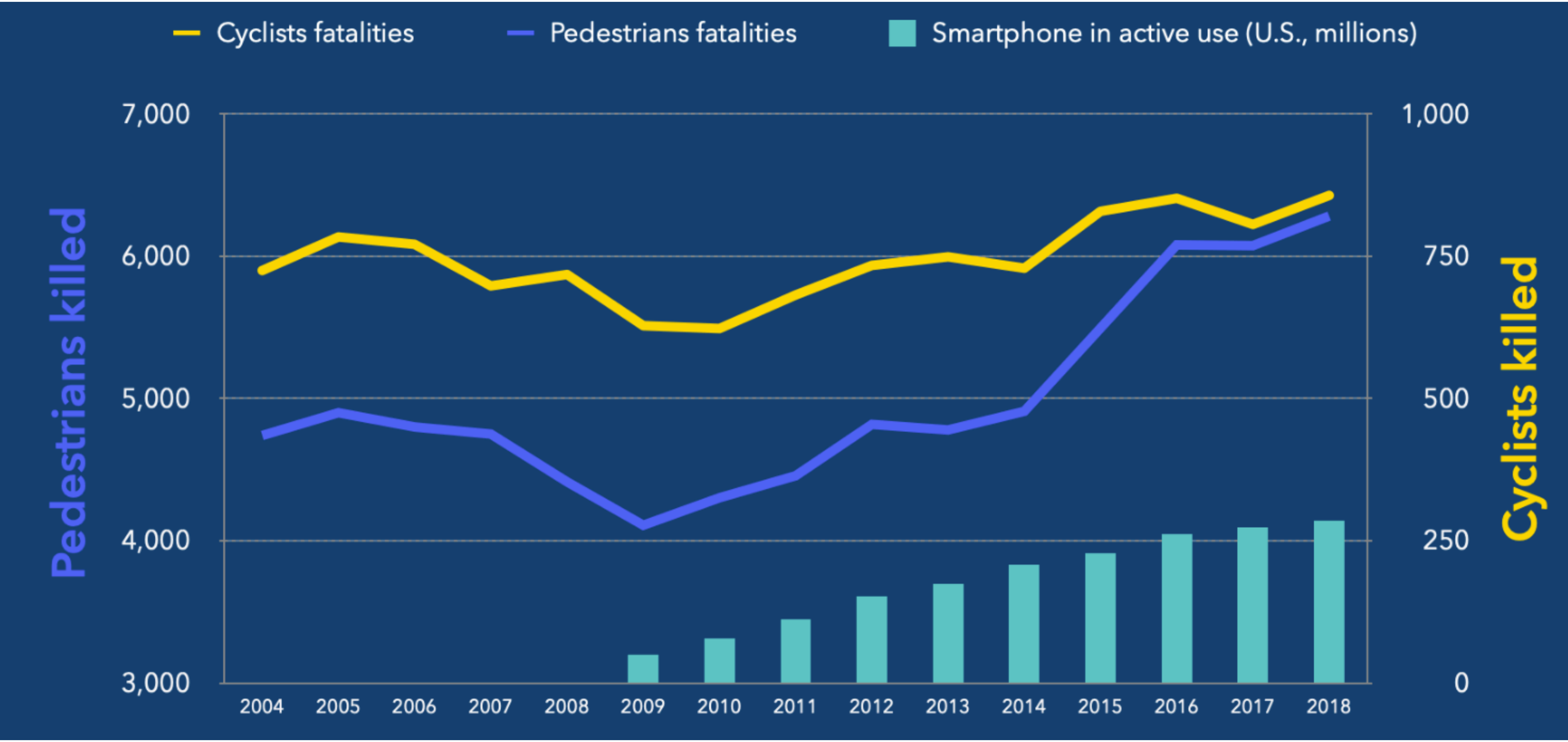
Road Safety

50 MILLION
Road injuries per year

$1.8 TRILLION
Loss costs per year

1.35 MILLION
Road deaths per year
(50% of COVID)





Cyclists fatalities
Pedestrians fatalities
Smartphone in active use (U.S., millions)
Pedestrians killed
Cyclists killed
7,000
6,000
5,000
4,000
3,000
1,000
750
500
250
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

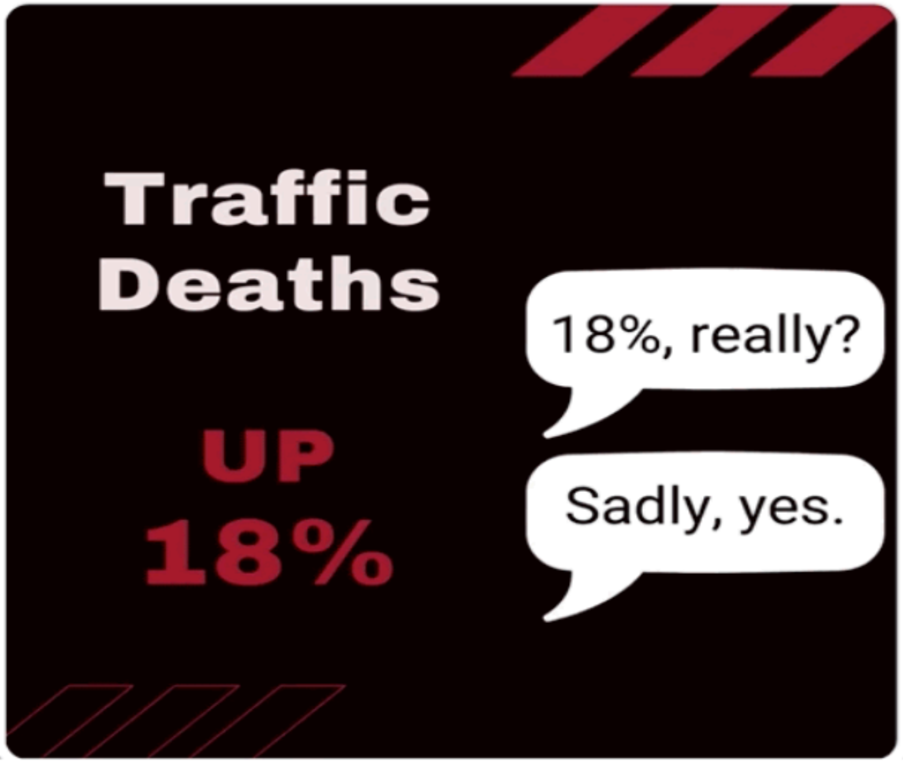
Traffic Fatalities Up 18% in H1 2021

20,160 U.S. Traffic Fatalities

Largest 6-Month Increase Ever Recorded

nhtsagov
@NHTSAgov

Really? Yes, really.



← NEWS

2020 Fatality Data Show Increased Traffic Fatalities During Pandemic

Collect raw sensor data

IoT sensors

Phone sensors

Connected car sensors

Video

Fleet devices

Deliver insights to your systems & processes

Risk

Crash assistance

Claims

Behavior change

- Vehicle dynamics
- Map-matching
- Distraction
- Transport mode & driver/ passenger
- Mileage & speed
- Real-time crash detection

Automatic recording

Low battery drain

Sensor data → Trip details

80 programs

20 countries

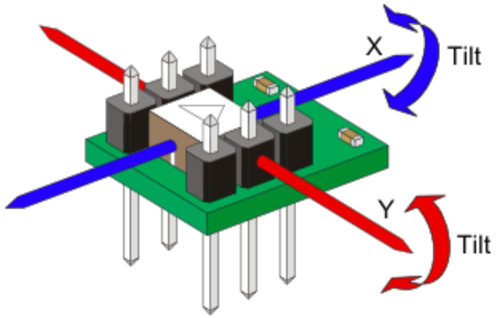
22M IoT devices shipped

CAMBRIDGE MOBILE TELEMATICS

IoT Systems are designed along 4 quadrants

IoT Systems are designed along 4 quadrants

Sensing Tasks & Modalities



Computation

Power/Energy

Connectivity

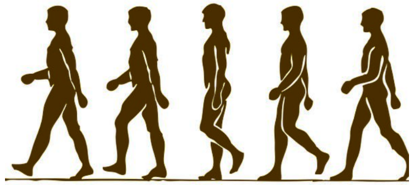
Sensing Tasks and Modalities

WHAT?

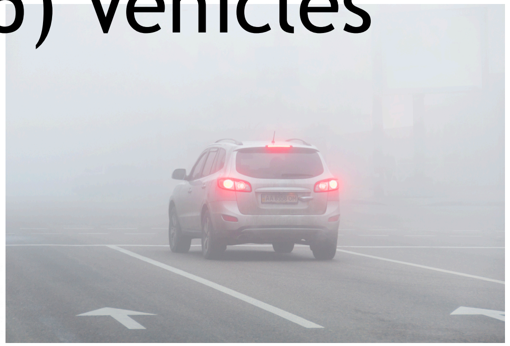
(1) Locations

(2) Health

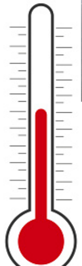
(3) Activity



(5) Vehicles



(4) Environment

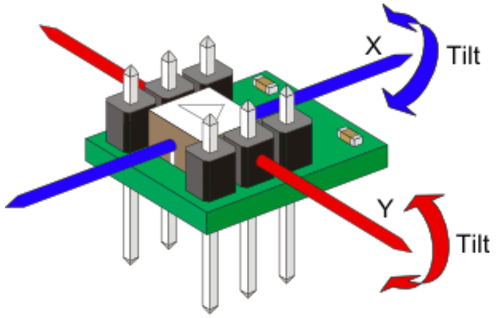


HOW?

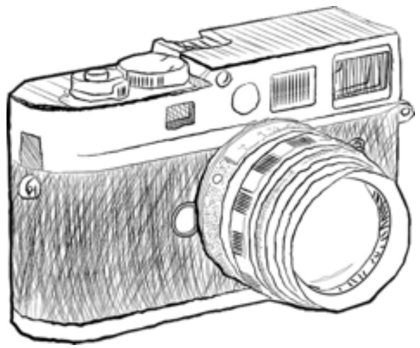
(1) Radio

(2) Acoustic/ Ultrasonic

(3) Inertial



(4) Visual



Computation

HOW can we use the sensing modalities to achieve the sensing task?

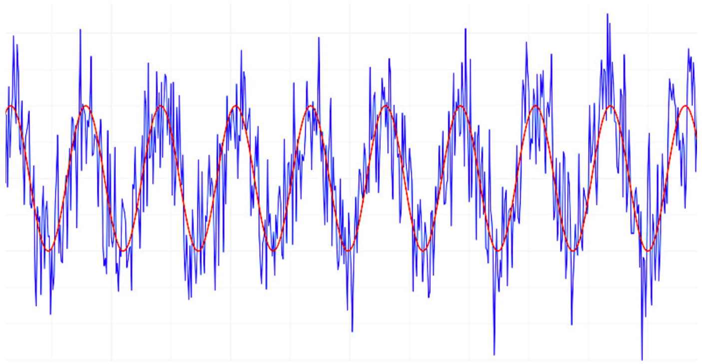
(1) Programming model

- Embedded
- Mobile
- Edge/Cloud

(2) Data Management

- Storage
- Queries

(3) Signal Processing & Inference

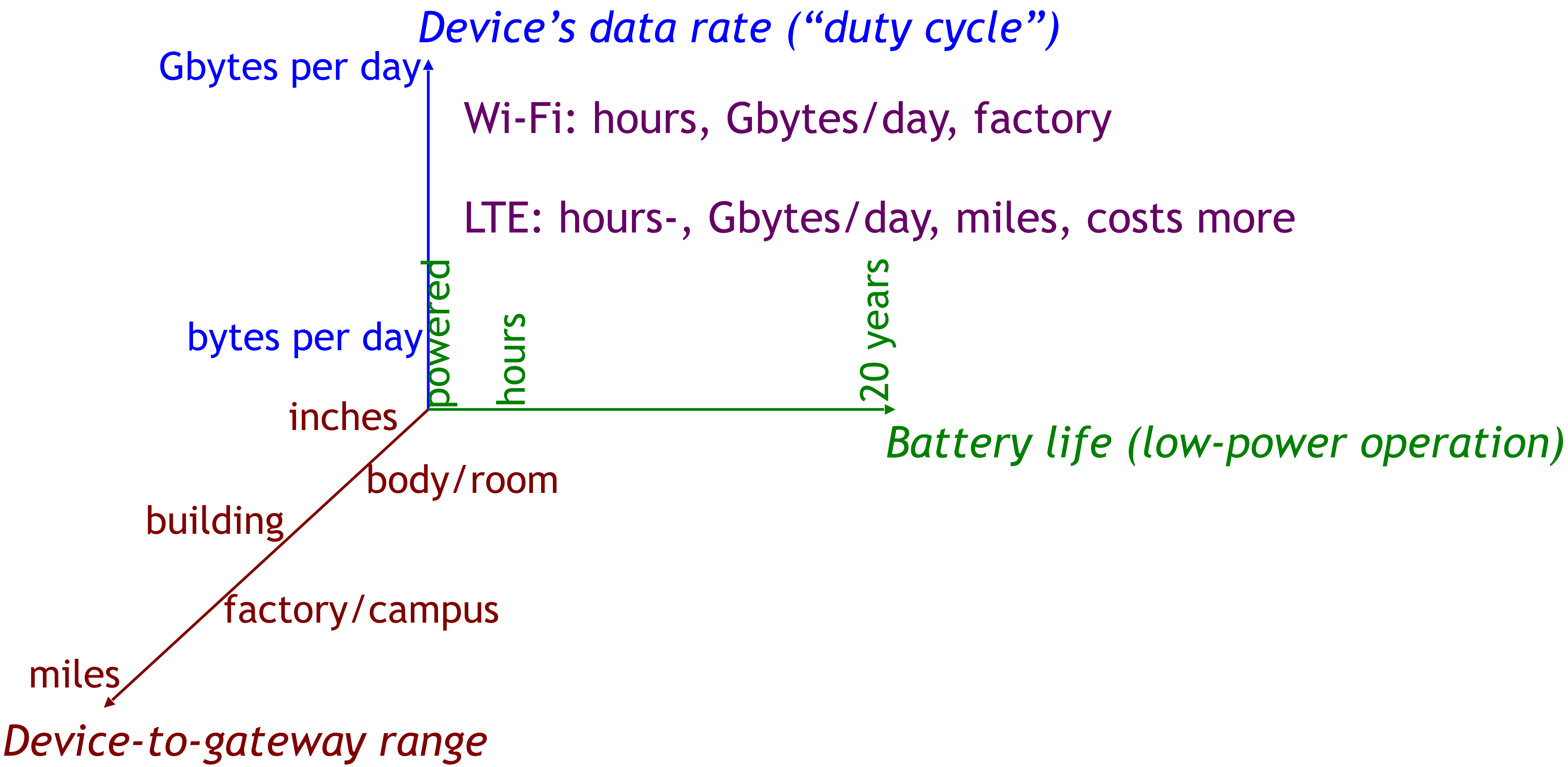


- Digitization
- Inference & Machine Learning

(4) Security

- Digital, Analog
- Trust, Privacy

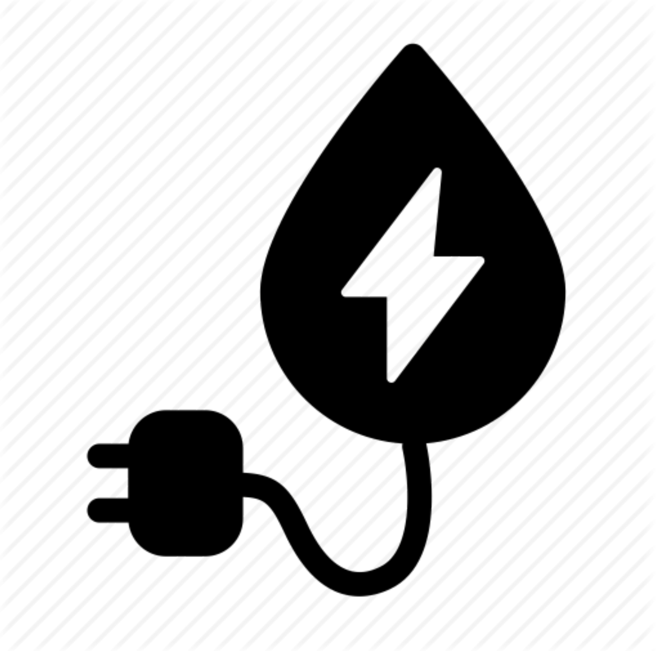
Connectivity



Power/Energy

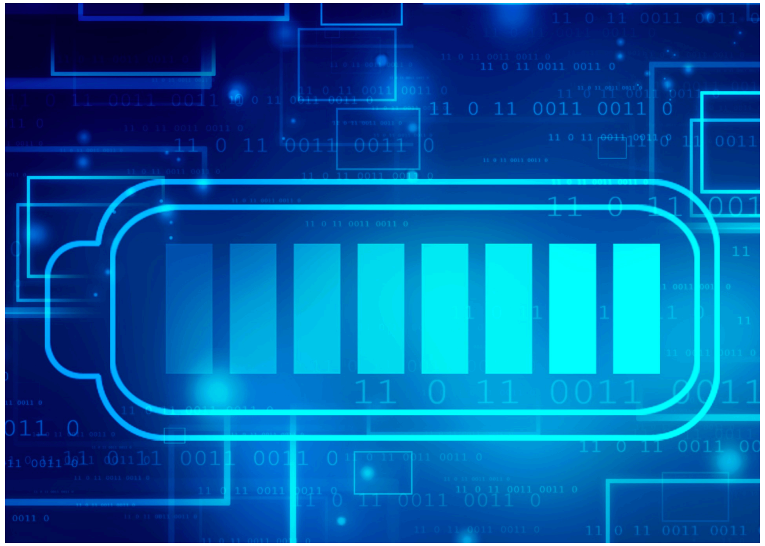
HOW will we power the nodes? And what are the energy constraints?

(1) Infrastructure



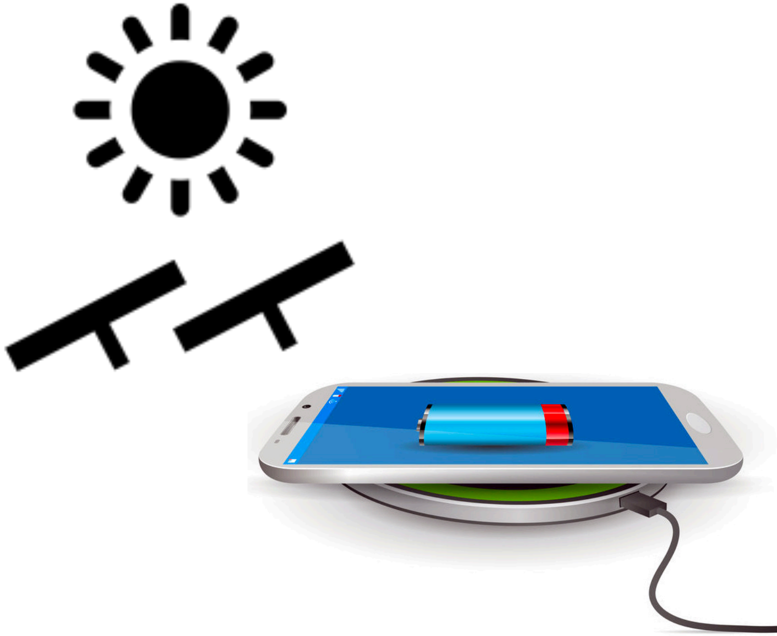
- Electricity, Network

(2) Battery



- Rechargeable/Non

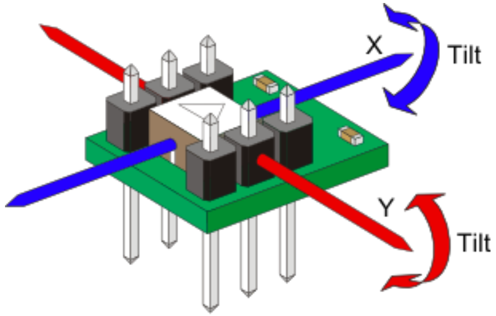
(3) Energy Harvesting



- Ambient, Wireless power
- Solar, Waves, Human Activity, RF

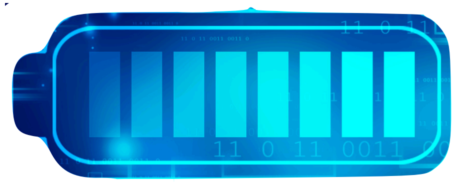
IoT Systems are designed along 4 quadrants

Sensing Tasks & Modalities



Computation

Power/Energy

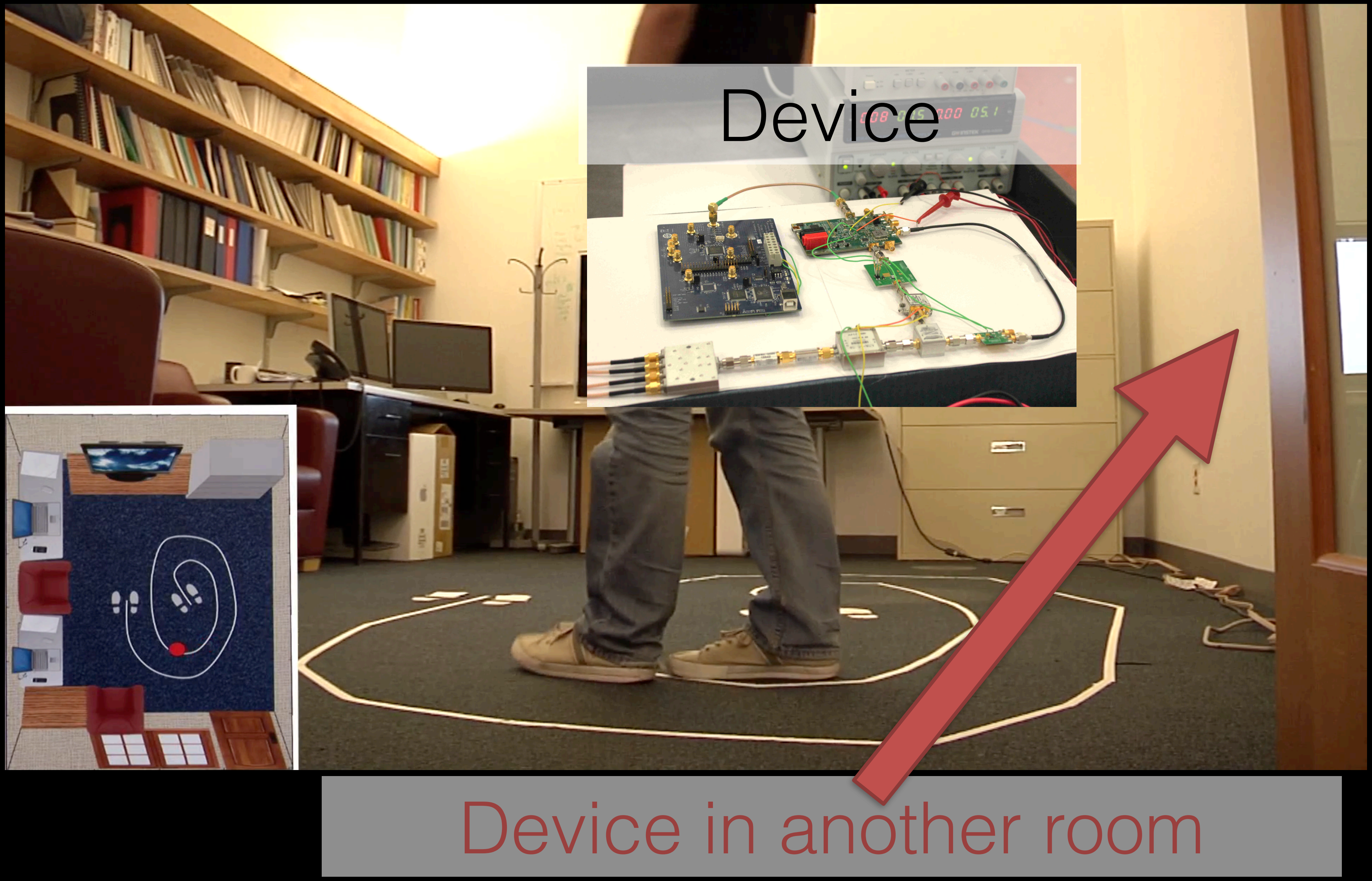


Connectivity

Indoor Positioning (Cricket, 2001)

Accurate Localization (Cricket, 2003)

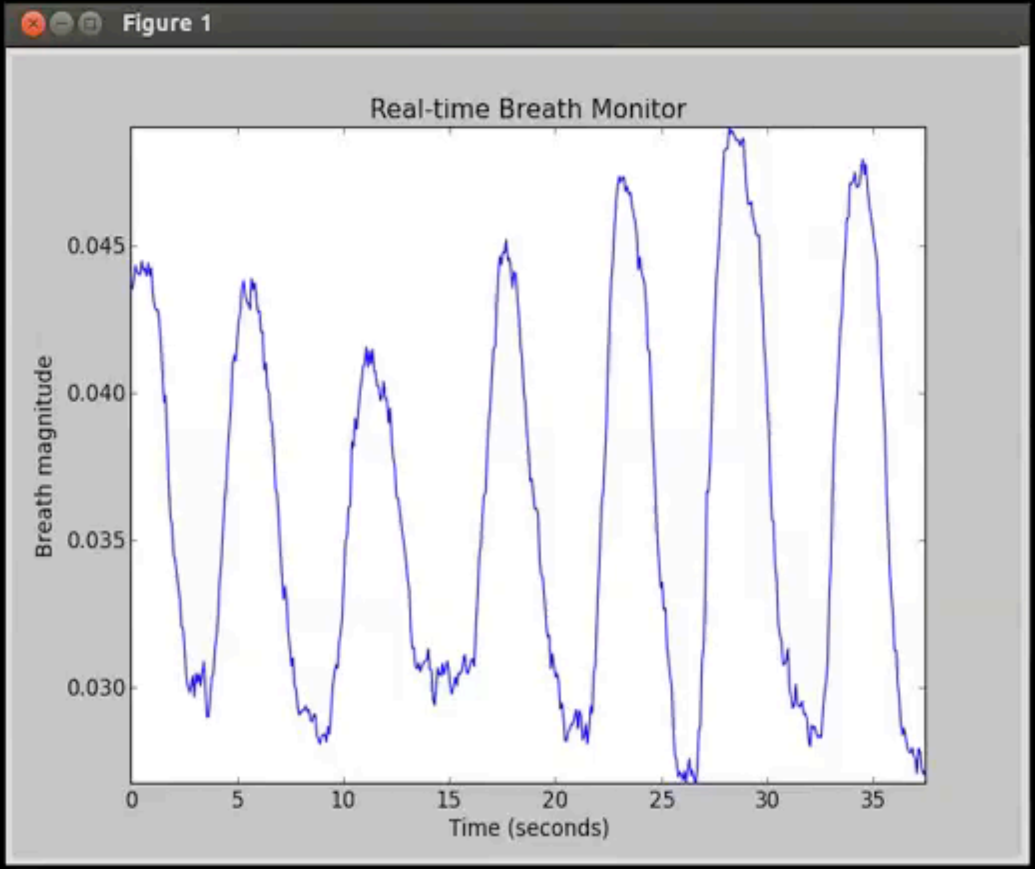
Device-Free Localization (WiTrack, 2014)



Seeing Through Walls (RF-Capture, 2015)


AI Senses People Through Walls

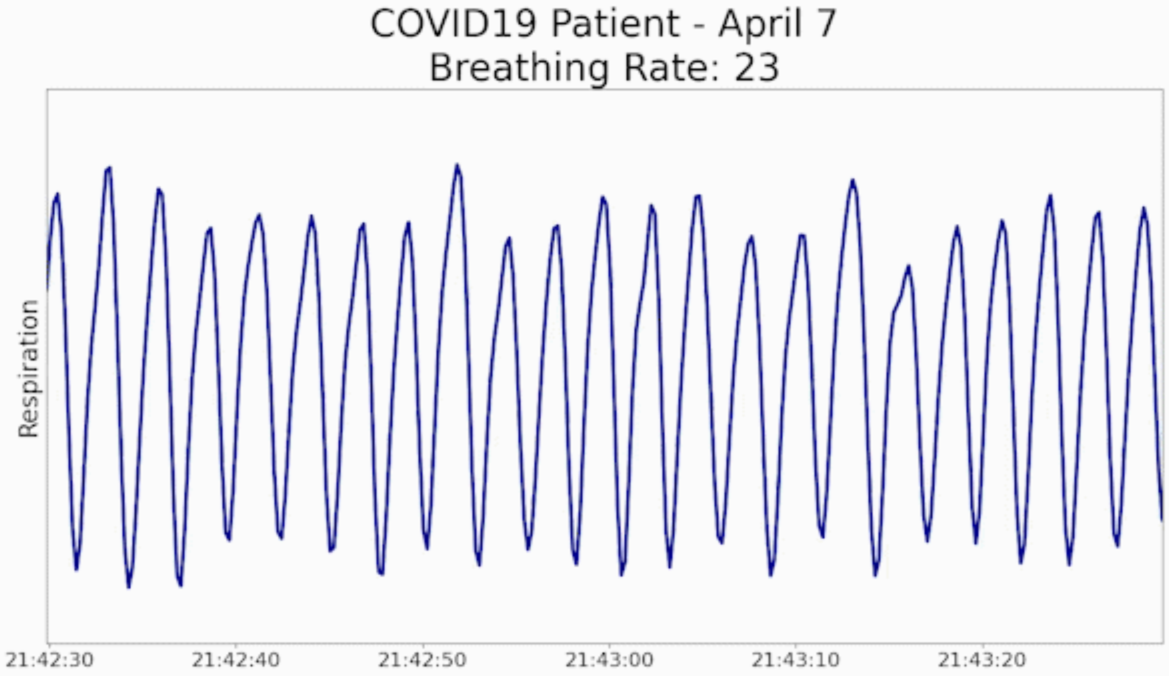
Breath Monitoring using Wireless (Vital-Radio, 2015)

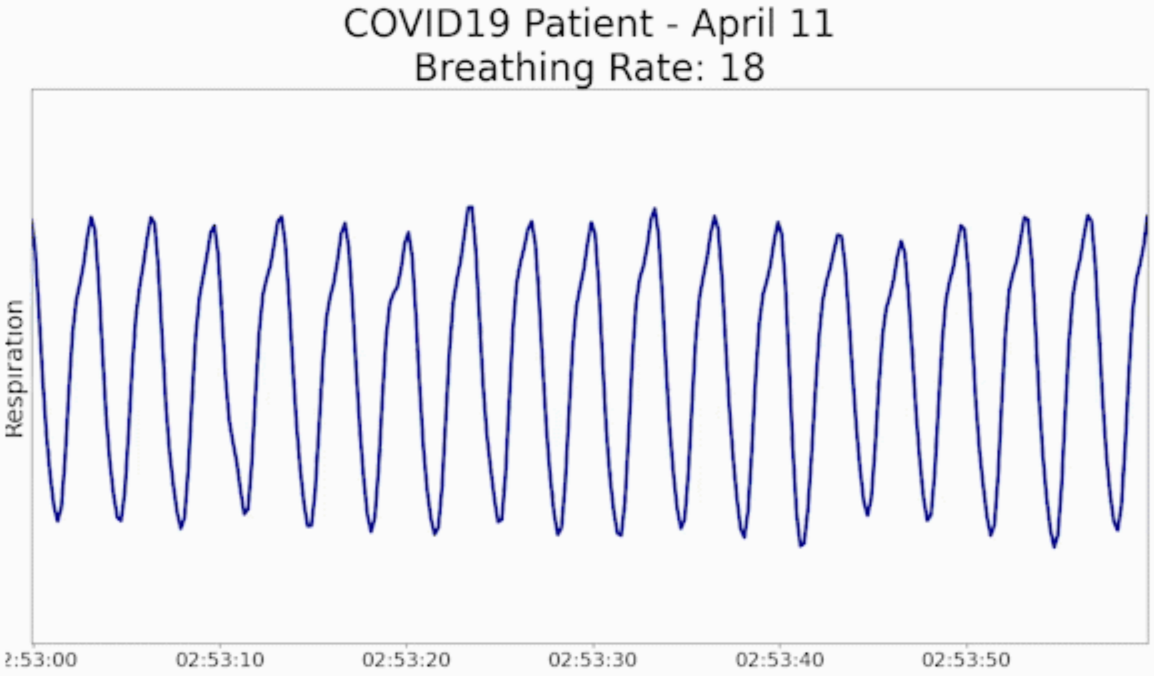


Non-contact Respiration Monitoring

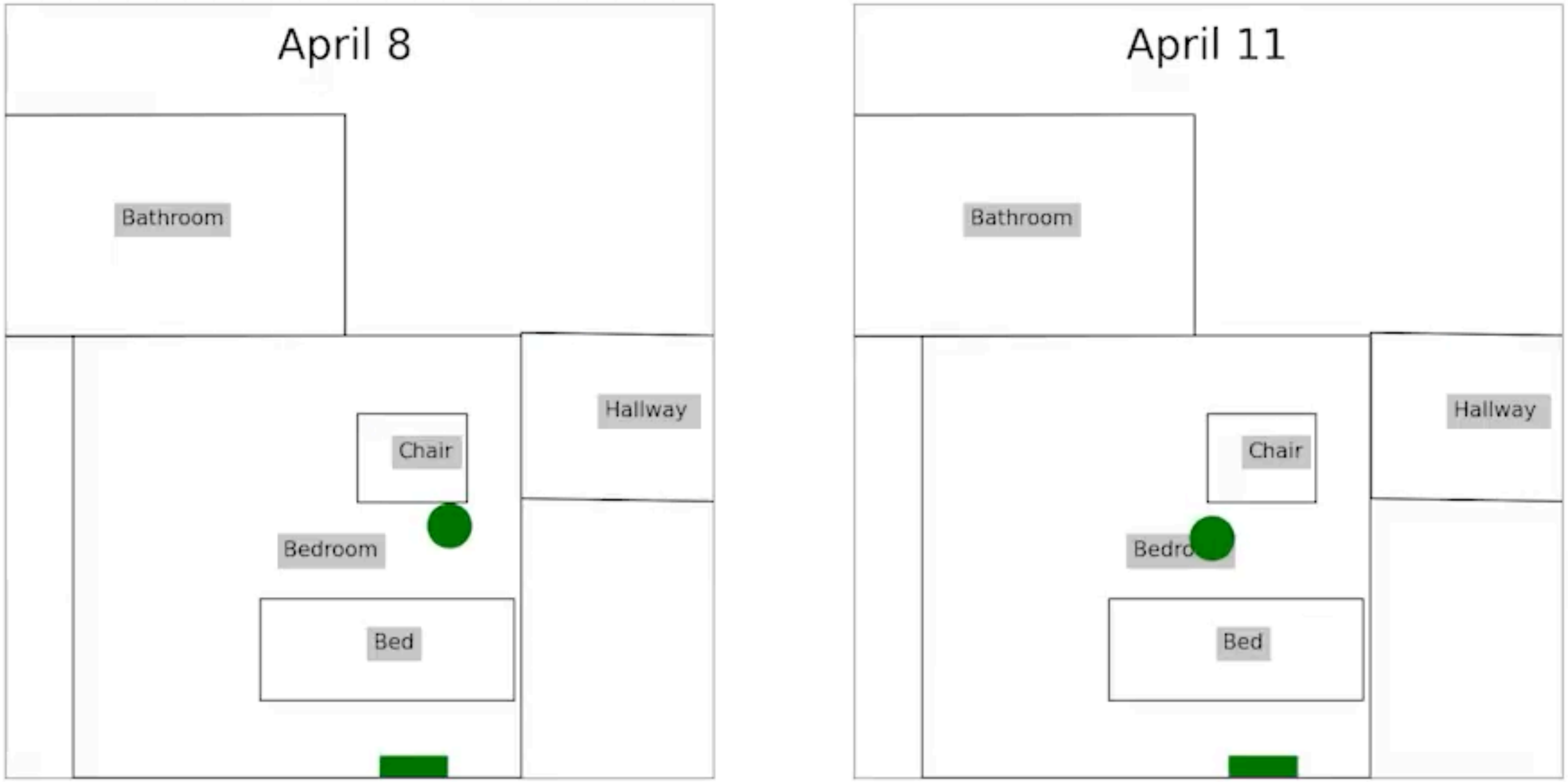
- Technology has been used in monitoring a COVID-19 Patient
- Deployed in ***Heritage Assisted Living*** in Boston suburb
- Medical doctors from Harvard Medical School analyzed remotely

Monitoring COVID-19 Patient



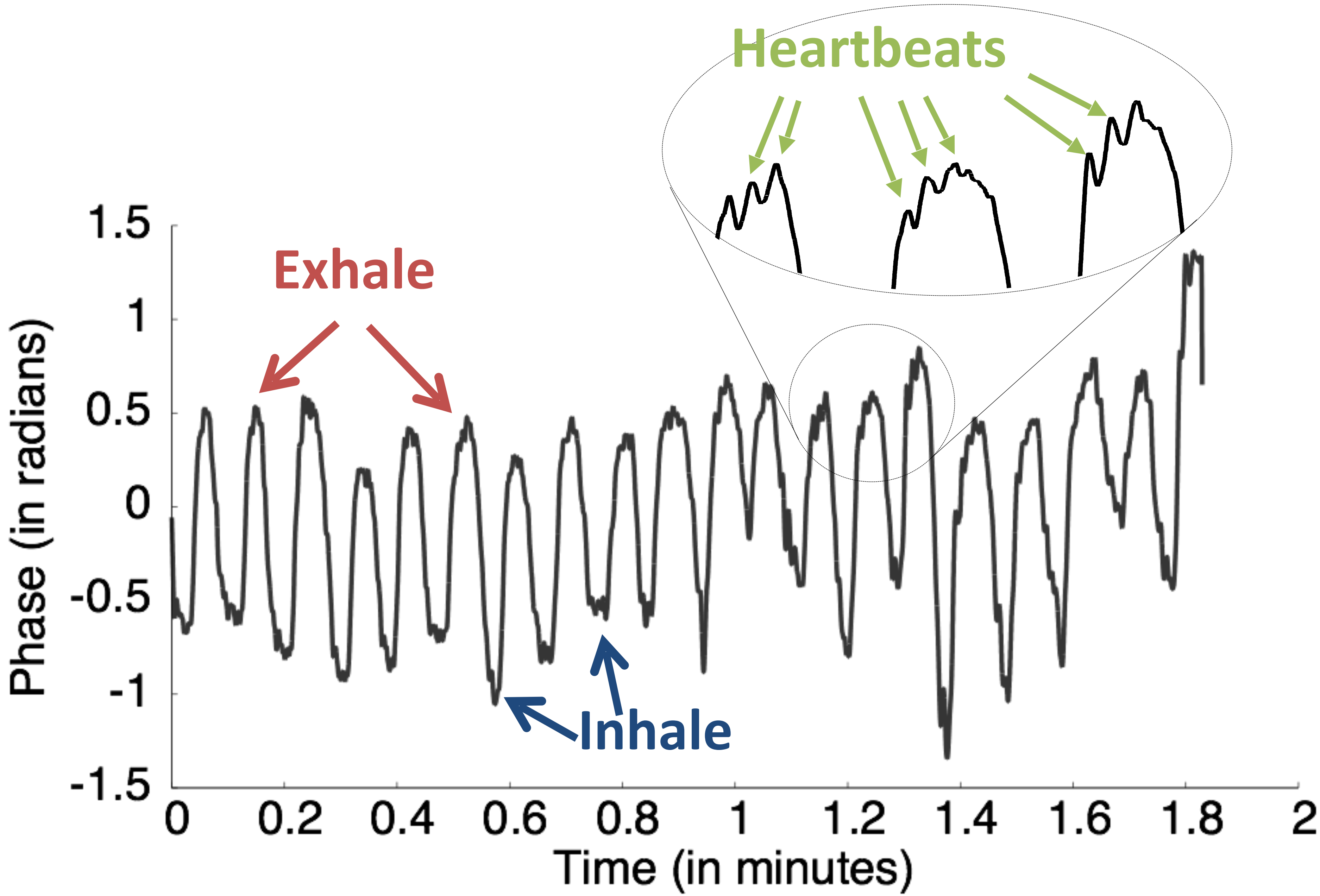


The patient's breathing decreased as it went back to normal



The patient's movements also demonstrate a marked improvement.

Let’s zoom in on respiration signals


Heartbeats
Exhale
Inhale
Phase (in radians)
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (in minutes)

Baby Monitoring

Mobile Security
Case Study: Inaudible Voice Commands

Can hack Android/Alexa using inaudible voice commands

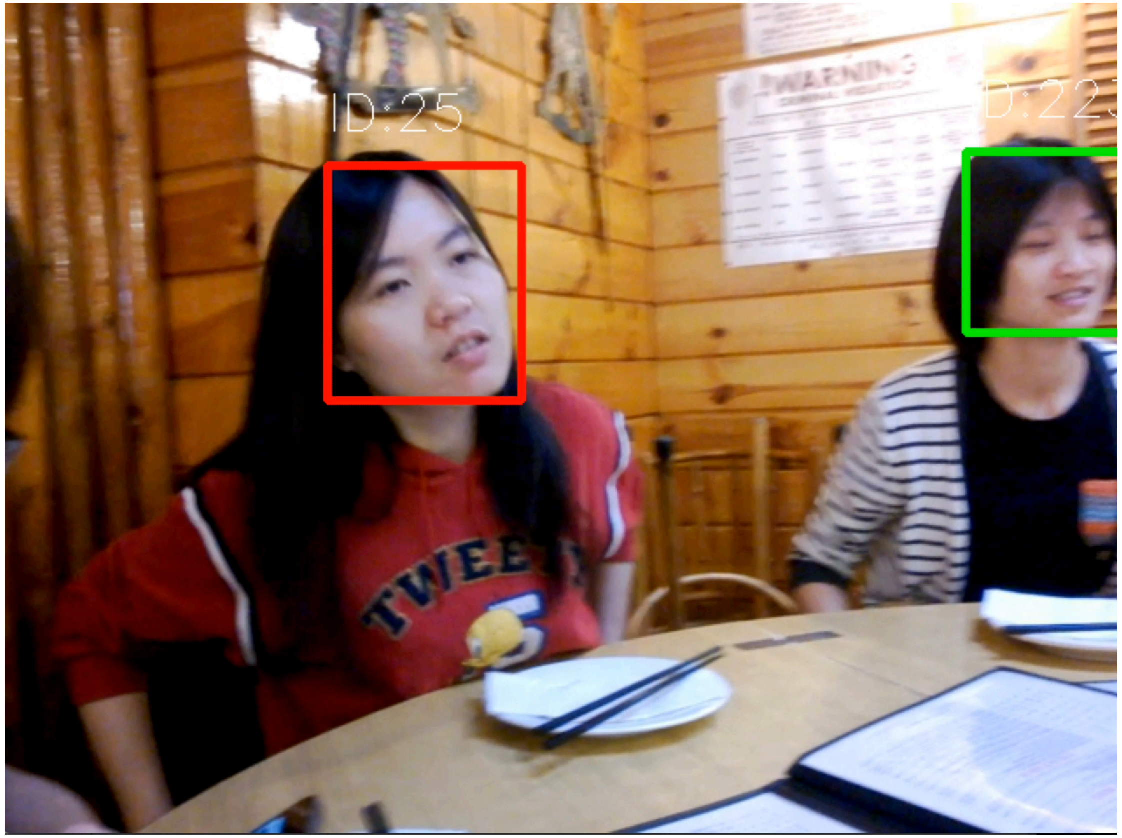
Split Processing

Case Study: Continuous Object Recognition

Continuous Object Recognition (Glimpse, 2015)

All processing done on server

With Glimpse with on-phone object tracking assistance



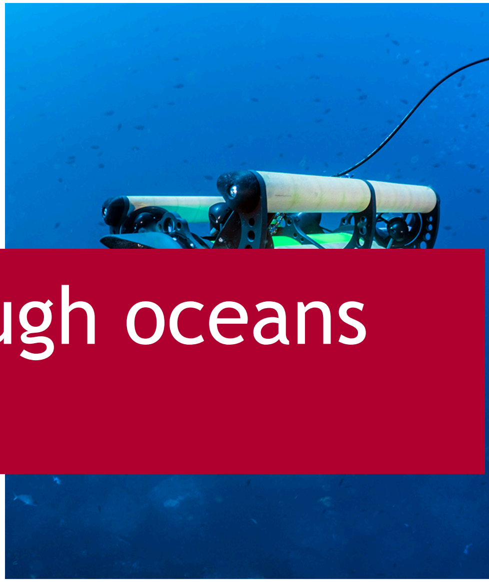
End-to-end IoT System

Case Study: Precision Agriculture

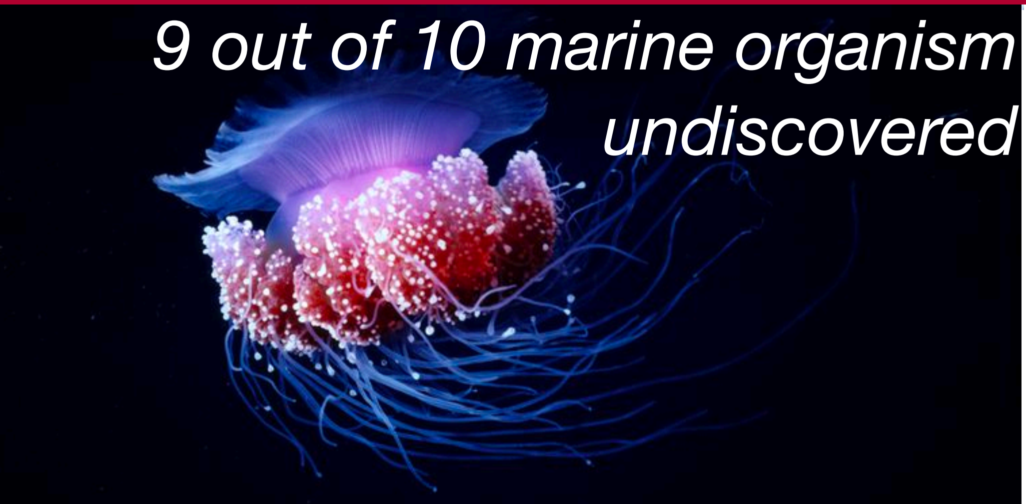
Taking the Internet of Things Underwater

“More than 95% of ocean remains unobserved and unexplored.”

- NOAA, 2018

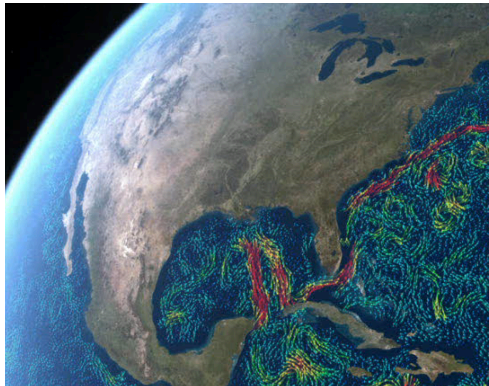


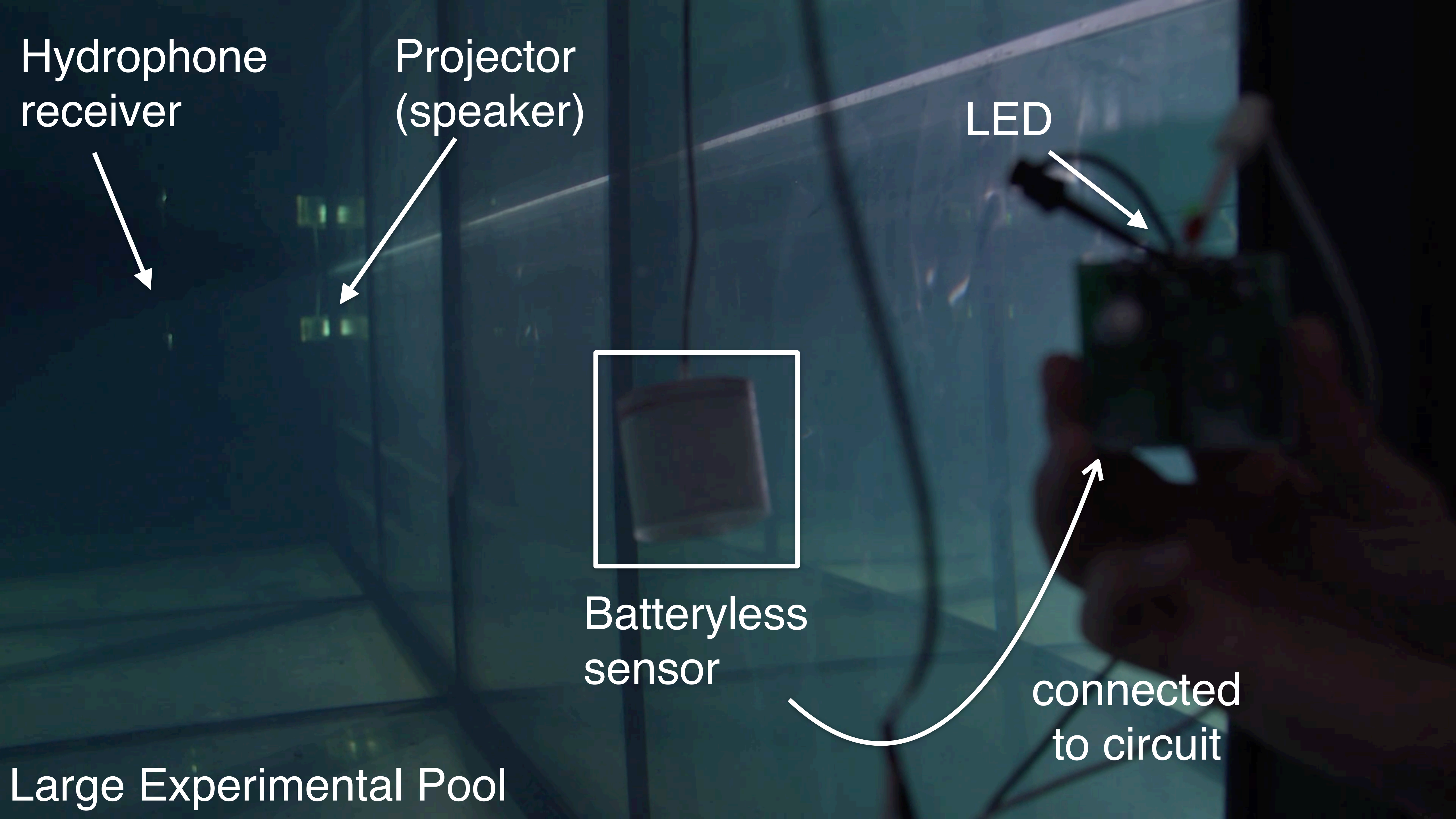
Less than 1 in a million of IoT is underwater, even though oceans cover more than 70% of the planet

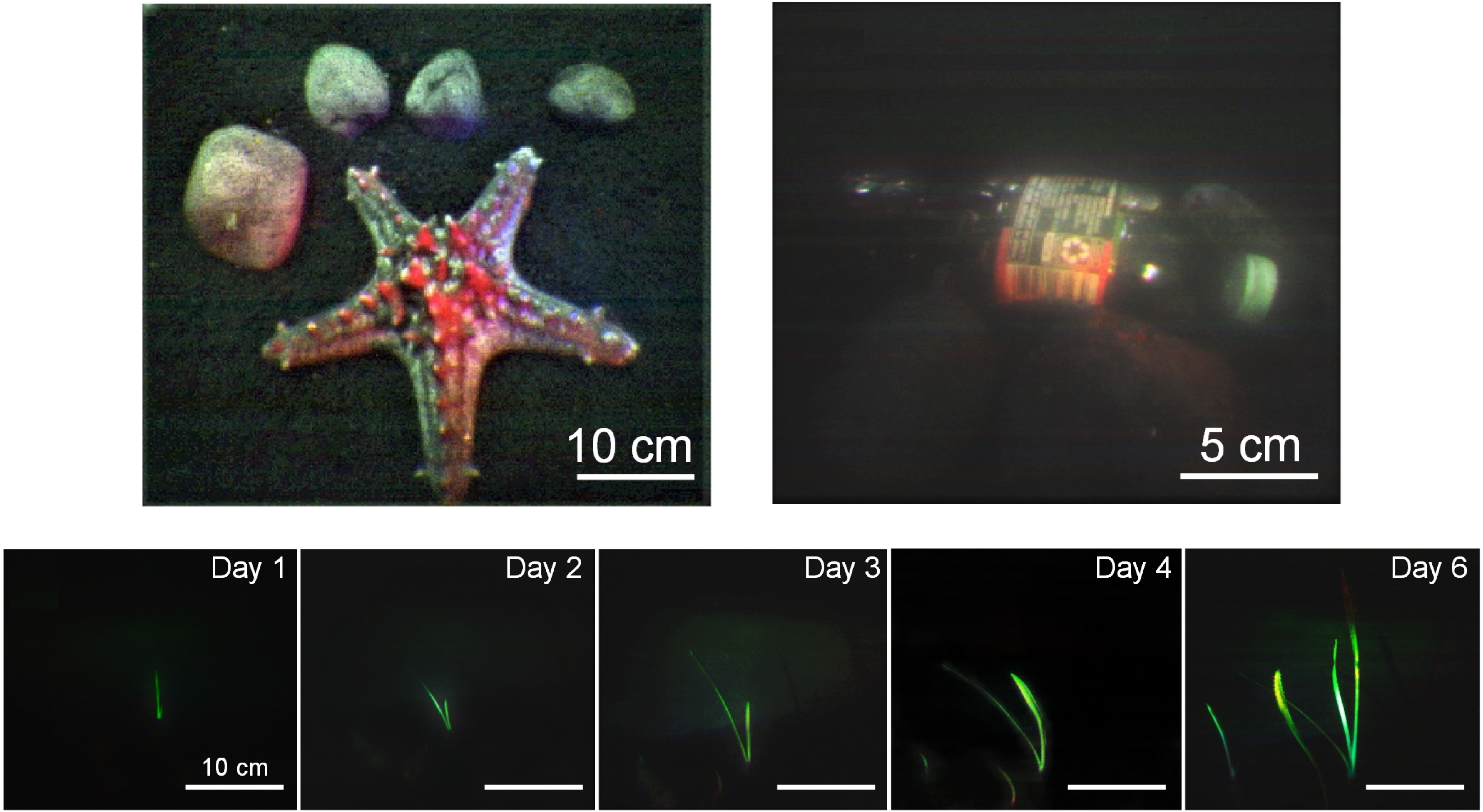


Aquaculture is the “fastest growing food sector”

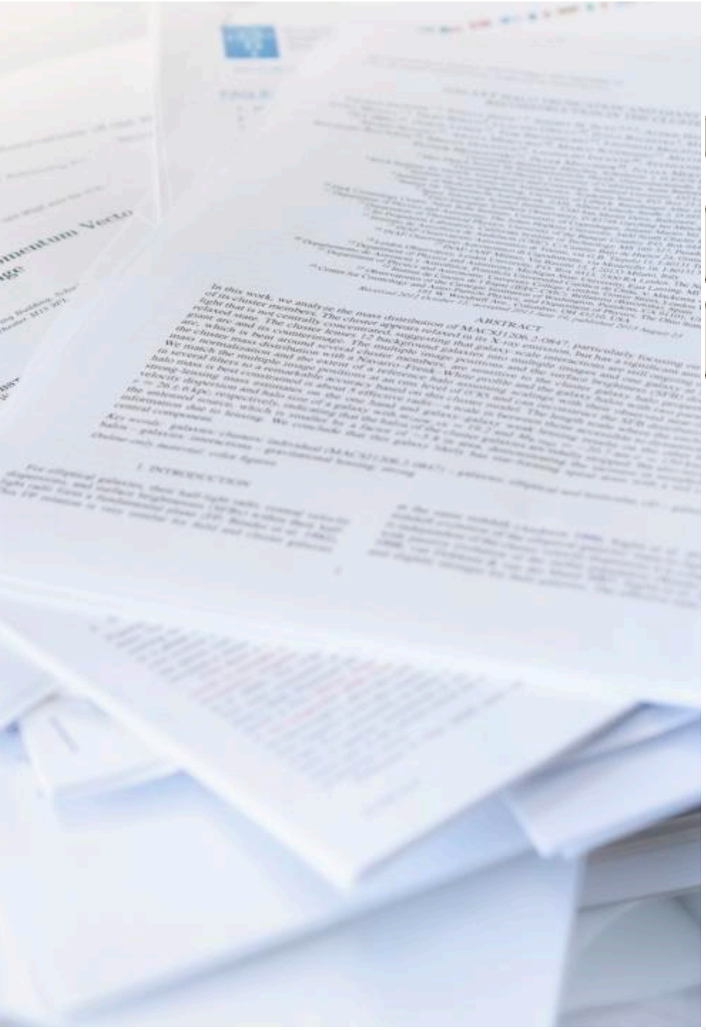
- UN Food & Ag org, 2022



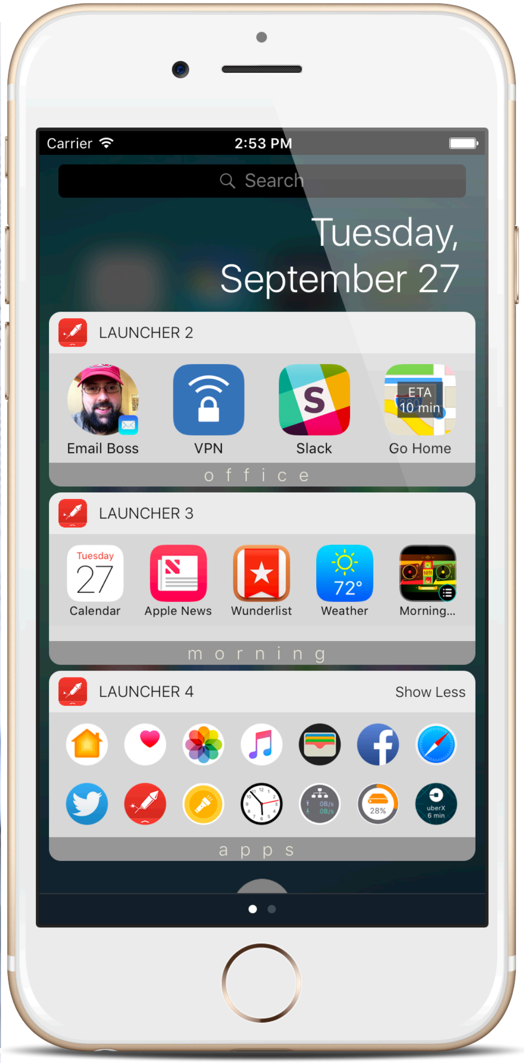

Hydrophone receiver
Projector (speaker)
LED
Batteryless sensor
connected to circuit
Large Experimental Pool


10 cm
5 cm
Day 1
10 cm
Day 2
Day 3
Day 4
Day 6

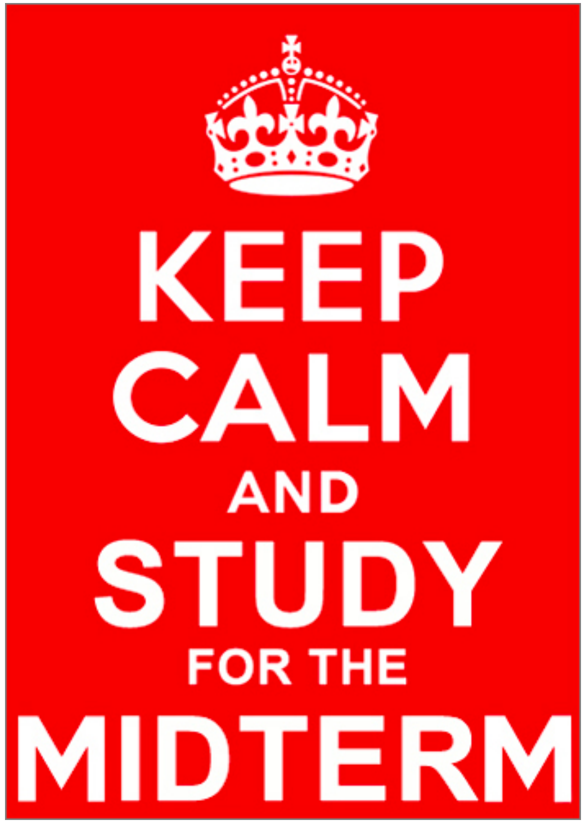
Course Organization



Reading & Reviewing Papers



Mobile (iOS) Labs



Class Project

Logistics

Grading:

- 1 Course Project (40%)
- 4+1 Labs (25%)
- 1 Quiz: April 13, during lecture (15%)
- 2 PSets (10%)
- Participation (10%)
    - Includes answering questions before every lecture
    - May skip one review without affecting grade
    - Attendance is mandatory

Attendance is mandatory
Zoom will be fall-back for medical reasons

Website: http://6808.github.io

Slack: https://mit-6808-2022.slack.

slack

Late +Pset lab policy: 72 hours

Upcoming: iOS Tutorial (time & place TBA based on poll)

Counts toward: AUS2, DLAB2, II requirements

Complete Poll Now

iOS Labs (Need iPhone/iPad and Mac)

iPad loaner:

- request via this form http://kb.mit.edu/confluence/x/QYK6CQ
- We also have some iPhones to loan if IS&T run out

Mac loaner (first-come first-serve):

- request via this form http://kb.mit.edu/confluence/x/GQdS

Please request them asap, will send the links in Slack

Projects

Students have most fun & learn most from the projects

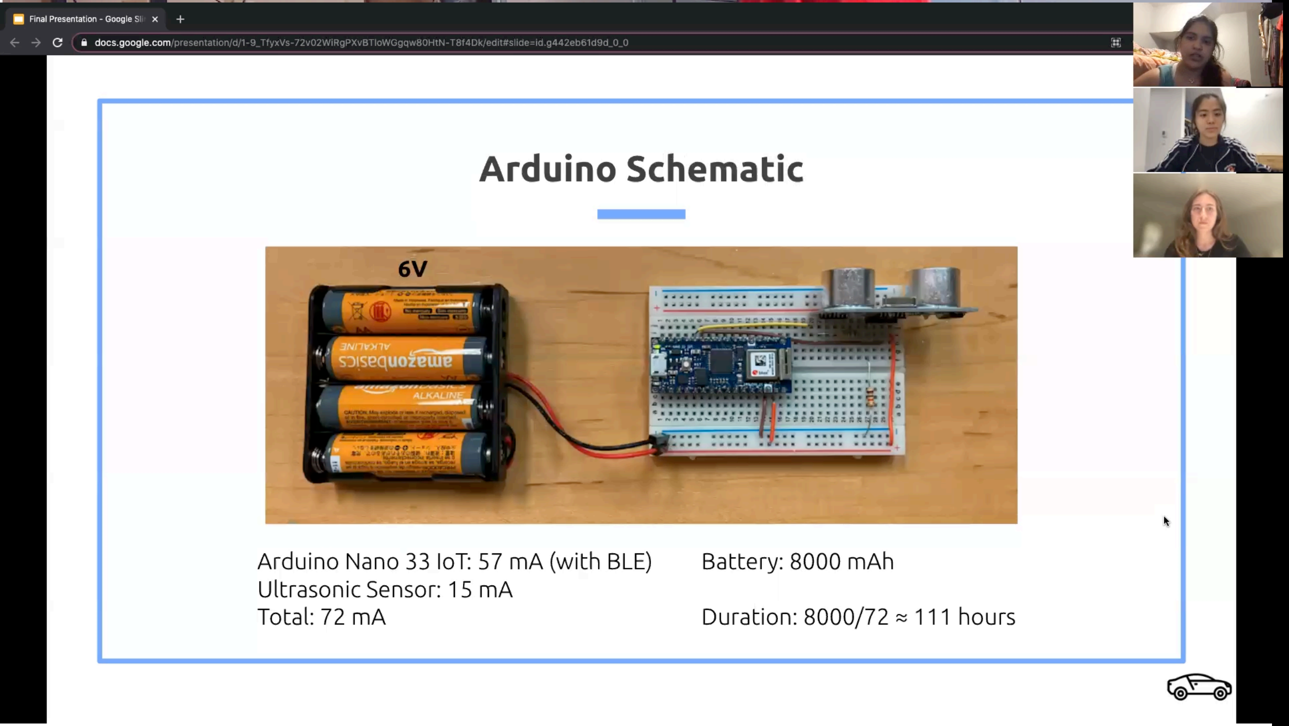
- All projects involve system implementation
- Ideal group size: 3
- Will suggest project ideas; students can choose their own projects

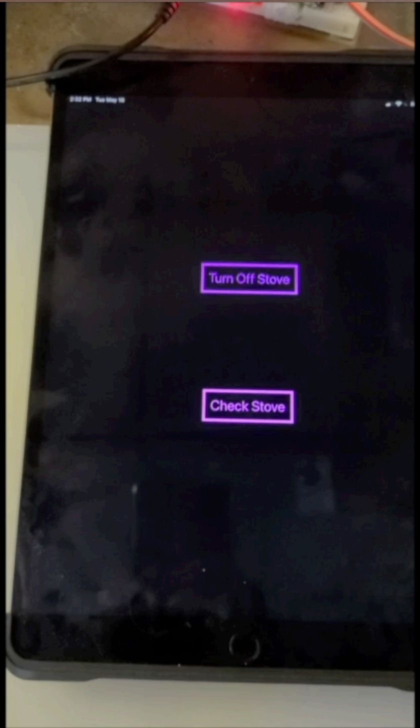
Timeline:

- Proposal (1-2 pages): March 16
    - We meet on March 30 & April 4 (during class time) to give feedback
- Project Final Components Due: April 6
- Project titles & abstracts: May 12
- Project demos & presentations: May 19

Sample 6.808 Projects 2021


1. ATTACH SENSORS


Final Presentation - Google Sli
docs.google.com/presentation/d/1-9_TfyxVs-72v02WiRgPXvBTloWGgqw80HtN-T8f4Dk/edit#slide=id.g442eb61d9d_0_0
Arduino Schematic
6V
Arduino Nano 33 IoT: 57 mA (with BLE)
Ultrasonic Sensor: 15 mA
Total: 72 mA
Battery: 8000 mAh
Duration: 8000/72 ≈ 111 hours


Turn Off Stove
Check Stove

Monday	Tuesday	Wednesday	Thursday	Friday
Jan 31 *First day of classes* **LEC 1:** Introduction and Key Ideas **Assigned:** Lab 0	Feb 1	Feb 2 **LEC 2:** Fundamentals of IoT Localization **Preparation:** Read Location-based Services, Wikipedia: GPS (Questions)	Feb 3	Feb 4 *iOS Tutorial*
Feb 7 **LEC 3:** Practical Device-based Localization (indoor & outdoor) **Preparation:** Read Cricket, RADAR (Questions) **Assigned:** Lab 1 **Assigned:** Pset 1 **DUE:** Lab 0	Feb 8	Feb 9 **LEC 4:** Seeing through Walls & Device-Free Localization **Preparation:** Read WiTrack (Questions)	Feb 10	Feb 11
Feb 14 **LEC 5:** Network Connectivity (BLE, low-power WAN, Wi-Fi, cellular, 5G) **Assigned:** Lab 2 **DUE:** Lab 1	Feb 15	Feb 16 **LEC 6:** Mesh and Multi-Hop Wireless Networks **Preparation:** Read ETX (Questions)	Feb 17	Feb 18
Feb 21 *Presidents' Day*	Feb 22 *Monday schedule* **LEC 7:** Batteryless Connectivity & Smart Cities **Preparation:** Read Hacking RFIDs and Caraoke (without section 8) (Questions)	Feb 23 **LEC 8:** Intro to Inertial Sensing; Activity Recognition **Preparation:** Read Developments of Inertial Sensing and Principles of Inertial Sensing (Section 3.1 and 3.2 only) (Questions) **Assigned:** Lab 3 **DUE:** Lab 2		
Feb 28 **LEC 9:** Pothole detection **Preparation:** Read Pothole Patrol (Questions) **DUE:** Pset 1	Mar 1	Mar 2 **LEC 10:** Crash Mapping **Preparation:** Read Improving Street Maps (Questions)		
Mar 7 **LEC 11:** Health & Vitals sensing **Preparation:** Read Vital-Radio and Smartphone-based Hemoglobin sensing (plus Optional Reading on HemaApp) (Questions) **Assigned:** Lab 4 **Assigned:** Pset 2 **Assigned:** Project Proposal Instructions **DUE:** Lab 3	Mar 8	Mar 9 **LEC 12:** Attacks on Acoustic Sensing **Preparation:** Read BackDoor (Questions)		
Mar 14 **LEC 13:** Mobile & Augmented/Mixed Reality (real-time object recognition) **Preparation:** Read Glimpse (Questions)	Mar 15	Mar 16 **LEC 14:** Agriculture IoT **Preparation:** Read FarmBeats (Questions) **DUE:** Project Proposals	Mar 17	Mar 18
Mar 21 *Spring Break*	Mar 22 *Spring Break*	Mar 23 *Spring Break*	Mar 24 *Spring Break*	Mar 25 *Spring Break*
Mar 28 **LEC 15:** Ocean IoT Read Underwater Backscatter Networking (Questions) **DUE:** Lab 4	Mar 29	Mar 30 Project meetings (No lecture; meet with staff during class time)	Mar 31	Apr 1
Apr 4 Project meetings (No lecture; meet with staff during class time) **DUE:** Pset 2	Apr 5	Apr 6 TBD **DUE:** Ship project components	Apr 7	Apr 8 *Quiz Review Session*
Apr 11 **Midterm during lecture time**	Apr 12	Apr 13 Project meetings (No lecture; meet with staff during class time)	Apr 14	Apr 15
Apr 18 *Patriots' Day*	Apr 19 *Drop date*	Apr 20 Project meetings (No lecture; meet with staff during class time)	May 21	Apr 22
Apr 25 Project meetings (No lecture; meet with staff during class time)	Apr 26	Apr 27 Project meetings (No lecture; meet with staff during class time)	Apr 28	Apr 29
May 2 Project meetings (No lecture; meet with staff during class time) **DUE:** Project Titles and Abstracts	May 3	May 4 Project meetings (No lecture; meet with staff during class time)	May 5	May 6
May 9 **Presentation** **DUE:** Presentations and Demos	May 10 *Last day of classes*	May 11	May 12	May 13 *Finals begin*

New Topics:

- IoT startups
- Predicting road crash rates
- Augmented reality

Deep learning helps predict traffic crashes before they happen

A deep model was trained on historical crash data, road maps, satellite imagery, and GPS to enable high-resolution crash maps that could lead to safer roads.

Rachel Gordon | MIT CSAIL

October 12, 2021

How to Read a Paper

First Pass:

- Title, Abstract
- Figures (illustrations? important results?)
- skim intro & conclusions
- References

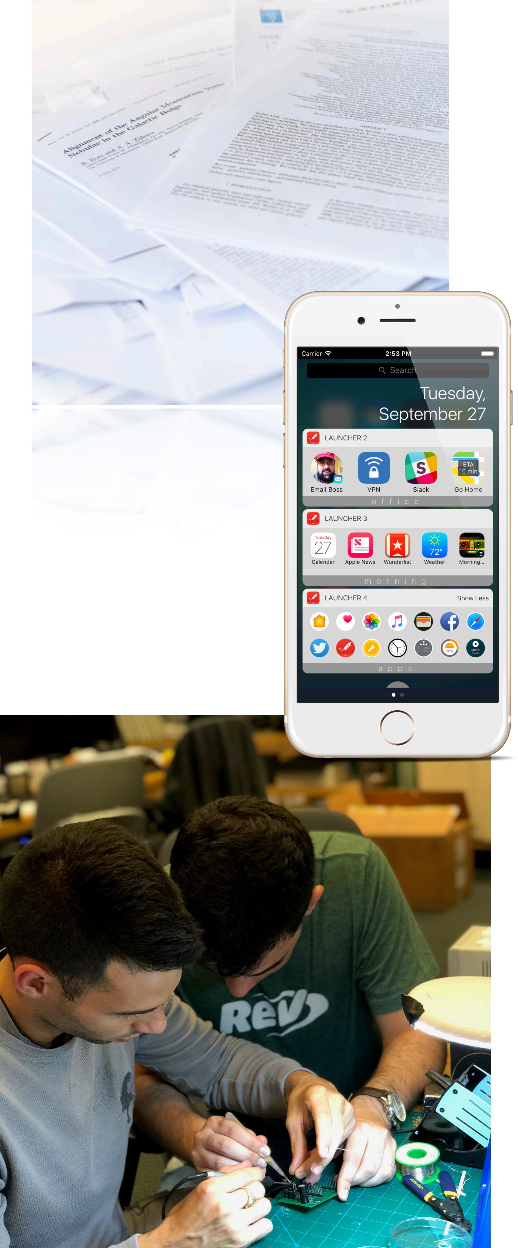
Second Pass

- Intro in details
- Overview, related work, or background sections
- Figures in details

Third pass:

- Read in detail
- Mark references for future read

What you are Expected to Learn from This Class



Lectures & Papers:

- Fundamentals of IoT technologies (mobile and sensor computing)
- How is IoT applied across various industries?
- What are emerging IoT domains and what does the future of IoT look like?

Labs:

- iOS APIs, including Bluetooth, inertial, UI programming
- Hacking wireless signals (New)

Project:

- Build a Physical IoT project using material learnt from class
- Collaboration (groups of 3)

Introductions

- Name
- Year
- Major
- Why are you interested in this class?

Next Class

1) Chapter on Localization + GPS

Covers fundamentals and GPS

2) Following Class

2 case studies of localization: Cricket and RADAR papers

TODO:

- Lab0 is out
- Fill in survey
- Attendance is mandatory
- Join Slack!
- Read assigned papers + answer pre-class question