MAS.S66
Computational Wireless Sensing

Lecturer
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Website
http://www.mit.edu/~fadel/courses/MAS.S66/index.html

Sign up on Piazza for announcements

Computational Wireless Sensing (CWS)

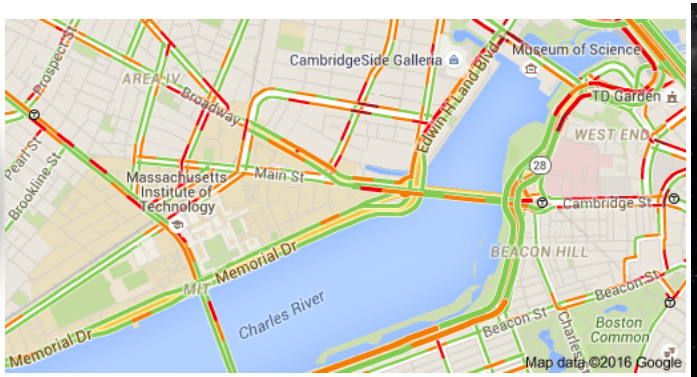
The use of wireless signals for purposes other than communication

- Sensing the world using wireless signals

Dates back to the discovery of radar

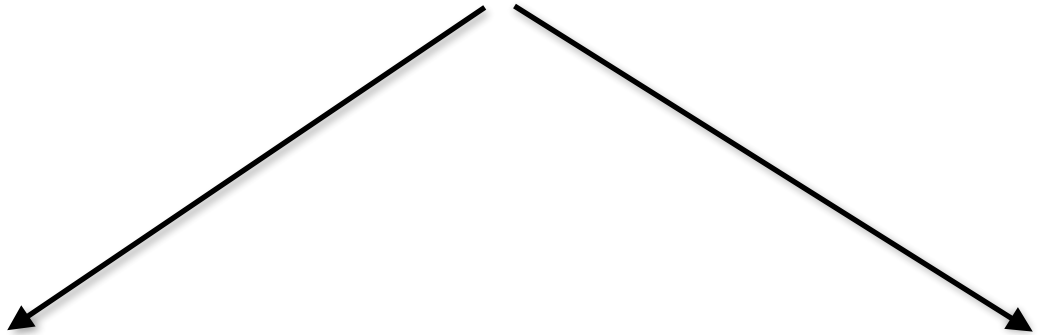
1897, communication between two ships in the Baltic sea

- Interference (beat) when another vessel passes



Computational Wireless Sensing (CWS)

This class will cover



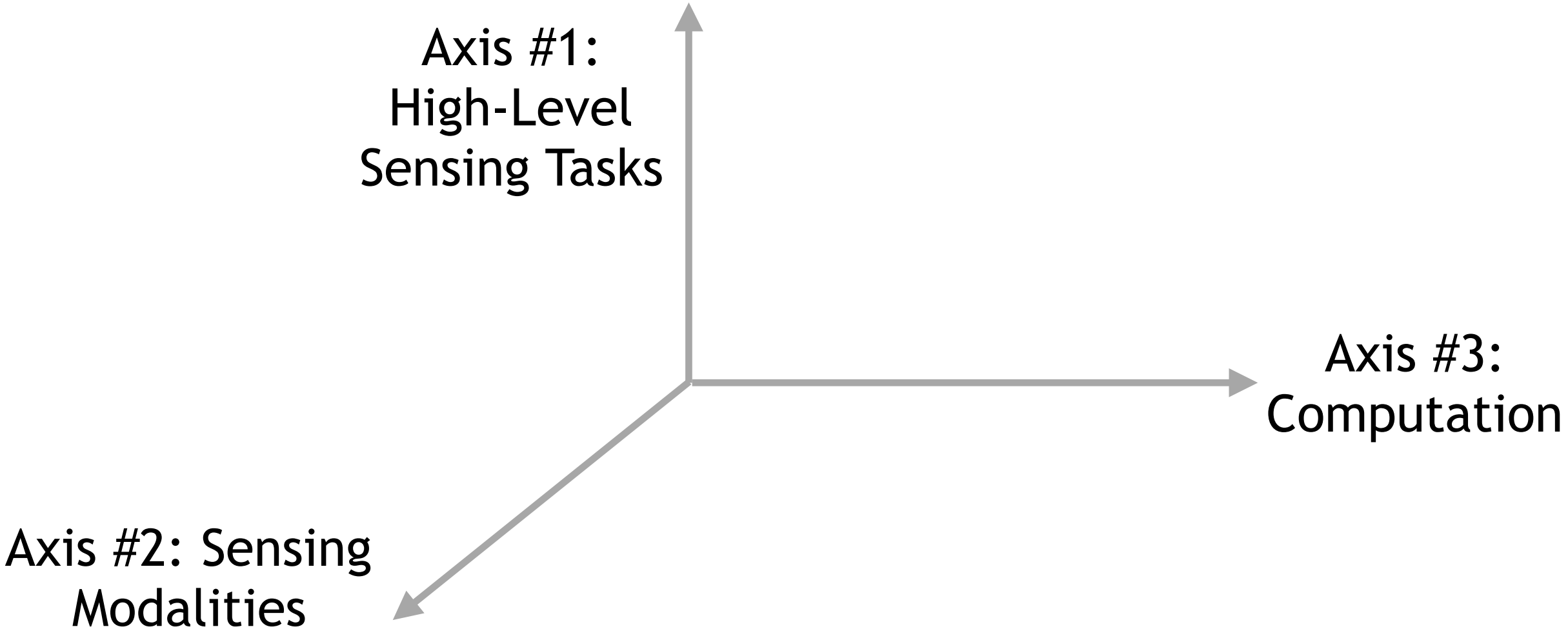
Fundamental primitives

- Signal propagation
- piezoelectricity
- energy harvesting
- …

System design principles

- localization
- networking
- storage
- …

CWS Systems are designed along 3 main axes



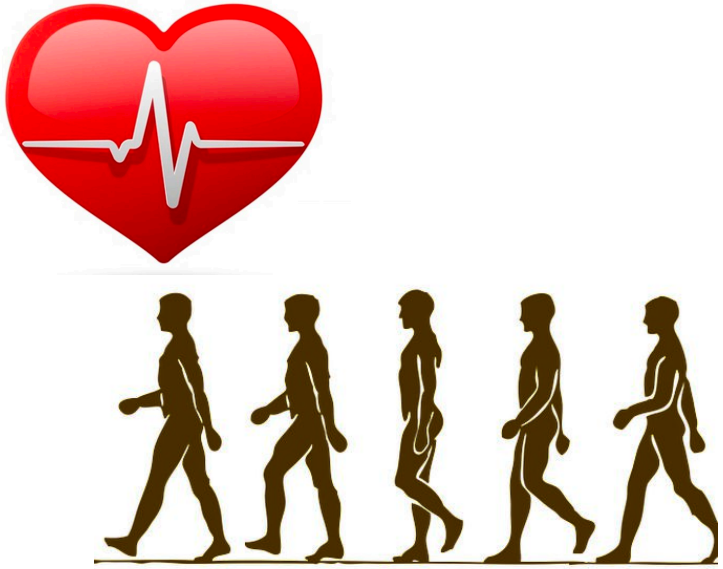
Axis #1: High-Level Sensing Tasks

WHAT do we want to sense?

(1) Location

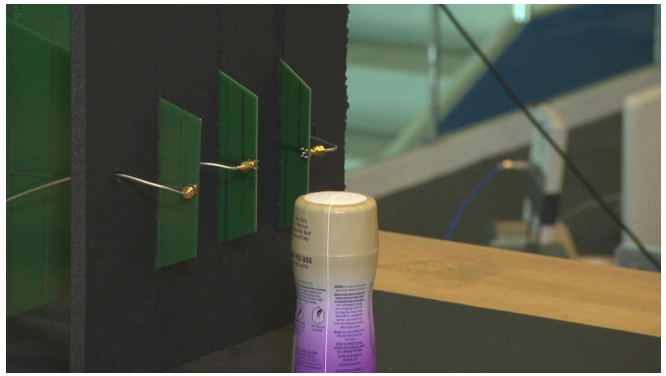
- Outdoors, indoors
- Humans, objects

(2) Dynamics



- Velocity, Acceleration
- Activities, Monitoring

(3) Properties



- Identify, Characterize
- Environment, Humans

Axis #2: Sensing Modalities

HOW will we perform this sensing?

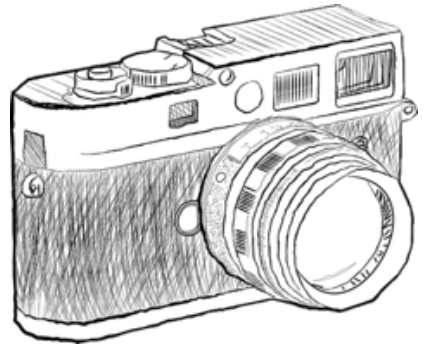
(1) Radio

- Wi-Fi
- Cellular
- Bluetooth

(2) Acoustic/ Ultrasonic

- Voices
- Engines
- Animals

(3) Visual



- Camera
- Infrared
- LIDAR

Axis #3: Computation

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

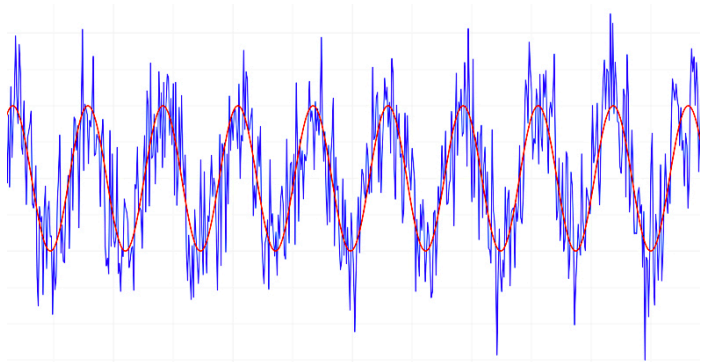
(1) Networking

- Connectivity
- Communication

(2) Data Management

- Storage
- Queries

(3) Signal Processing & Inference



- Digitization
- Inference & Machine Learning

(4) Security

- Digital, Analog
- Trust, Privacy

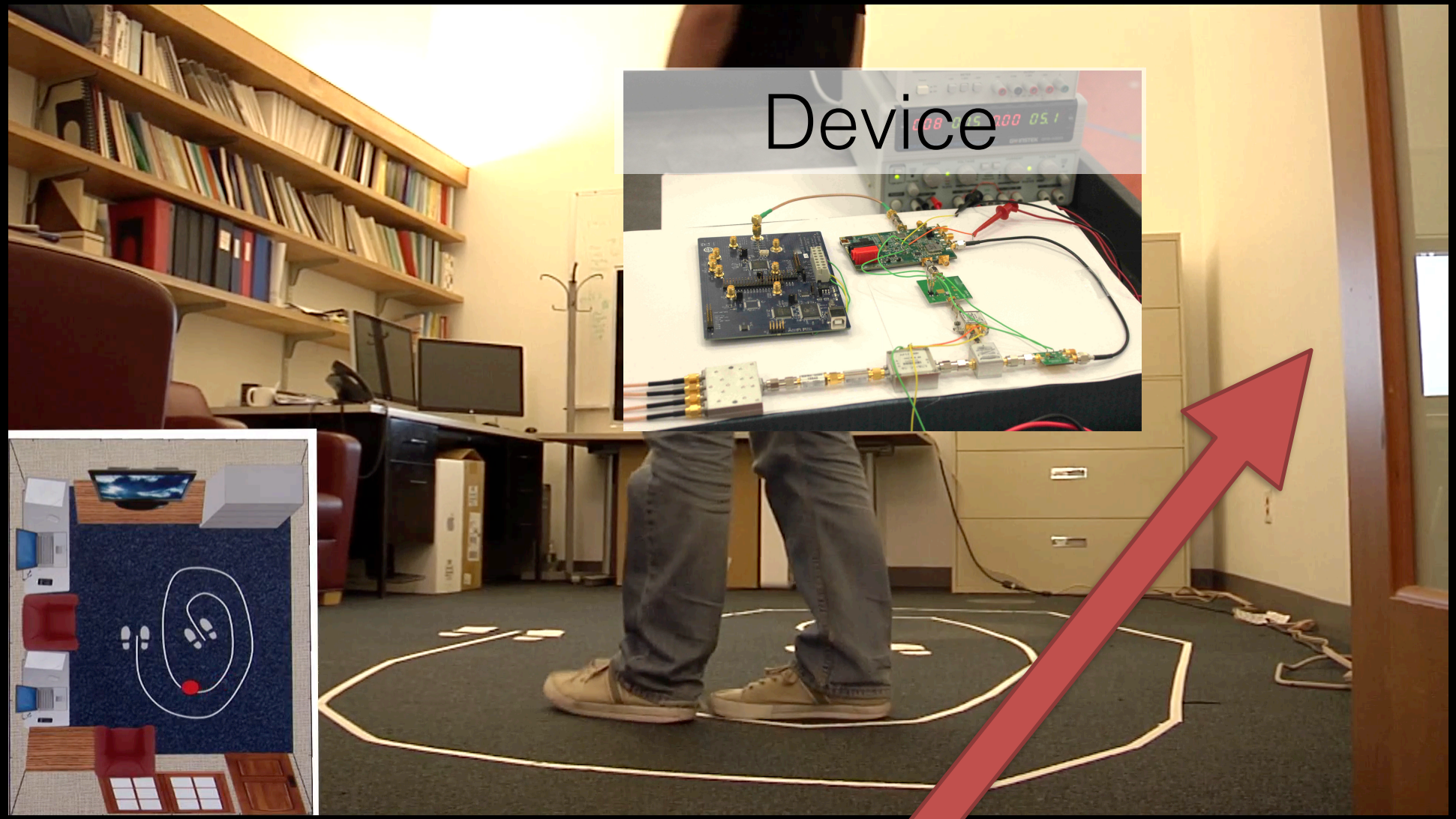
CWS System Architecture

Axis #1: Sensing Tasks	(1) Location	(2) Dynamics	(3) Properties	
Axis #3: Computation	(1) Networking	(2) Data Management	(3) Signal Processing & Inference	(4) Security
Axis #2: Sensing Modalities	(1) Radio	(2) Acoustic/ Ultrasonic	(3) Visual	

Indoor Positioning (Cricket, 2001)

Accurate Localization (Cricket, 2003)

Device-Free Localization (WiTrack, 2014)

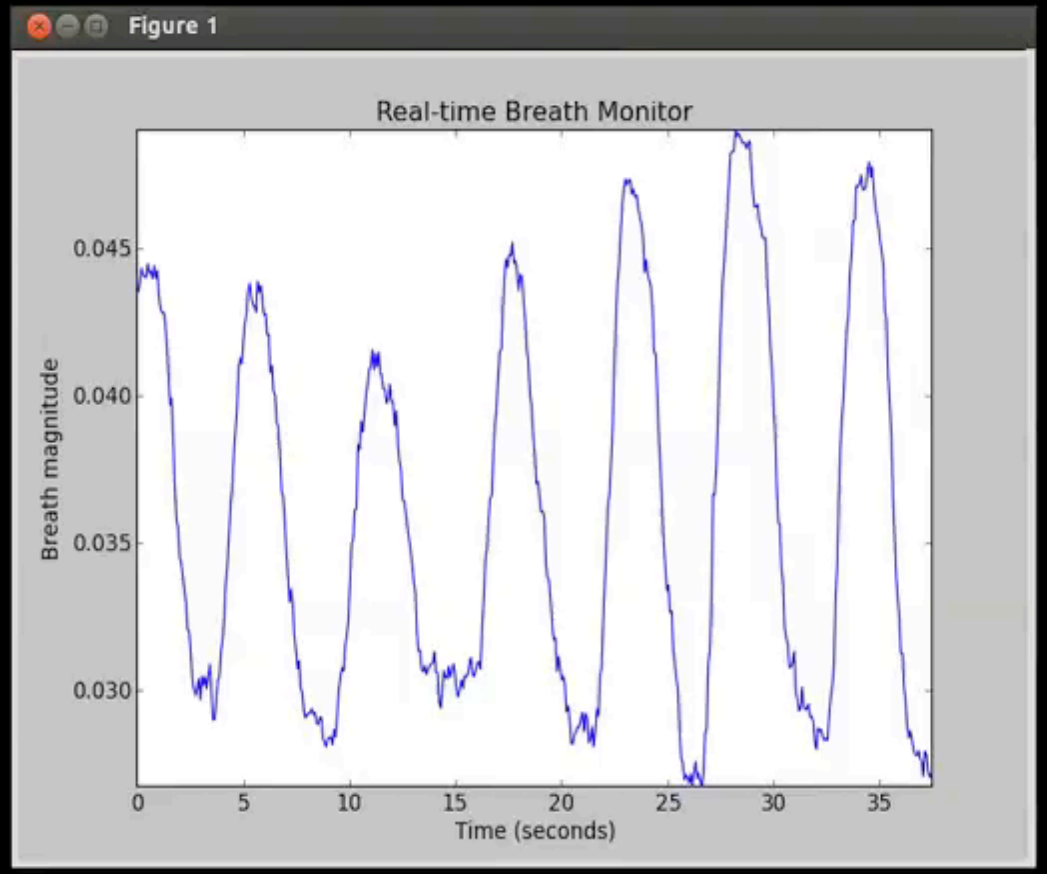


Seeing Through Walls (RF-Capture, 2015)

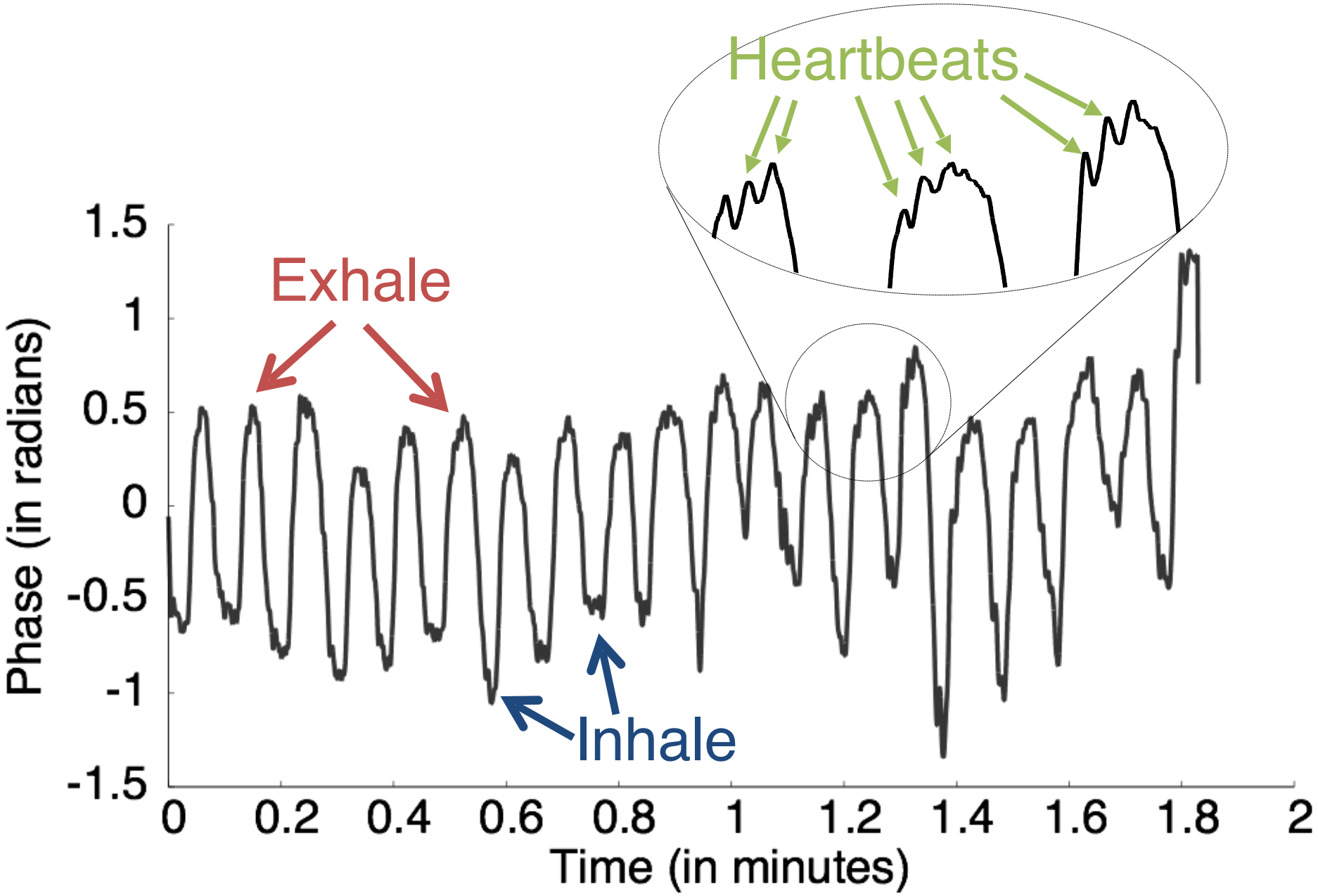
Who is behind the wall?

AI Senses People Through Walls

Breath Monitoring using Wireless (Vital-Radio, 2015)



Let’s zoom in on these signals

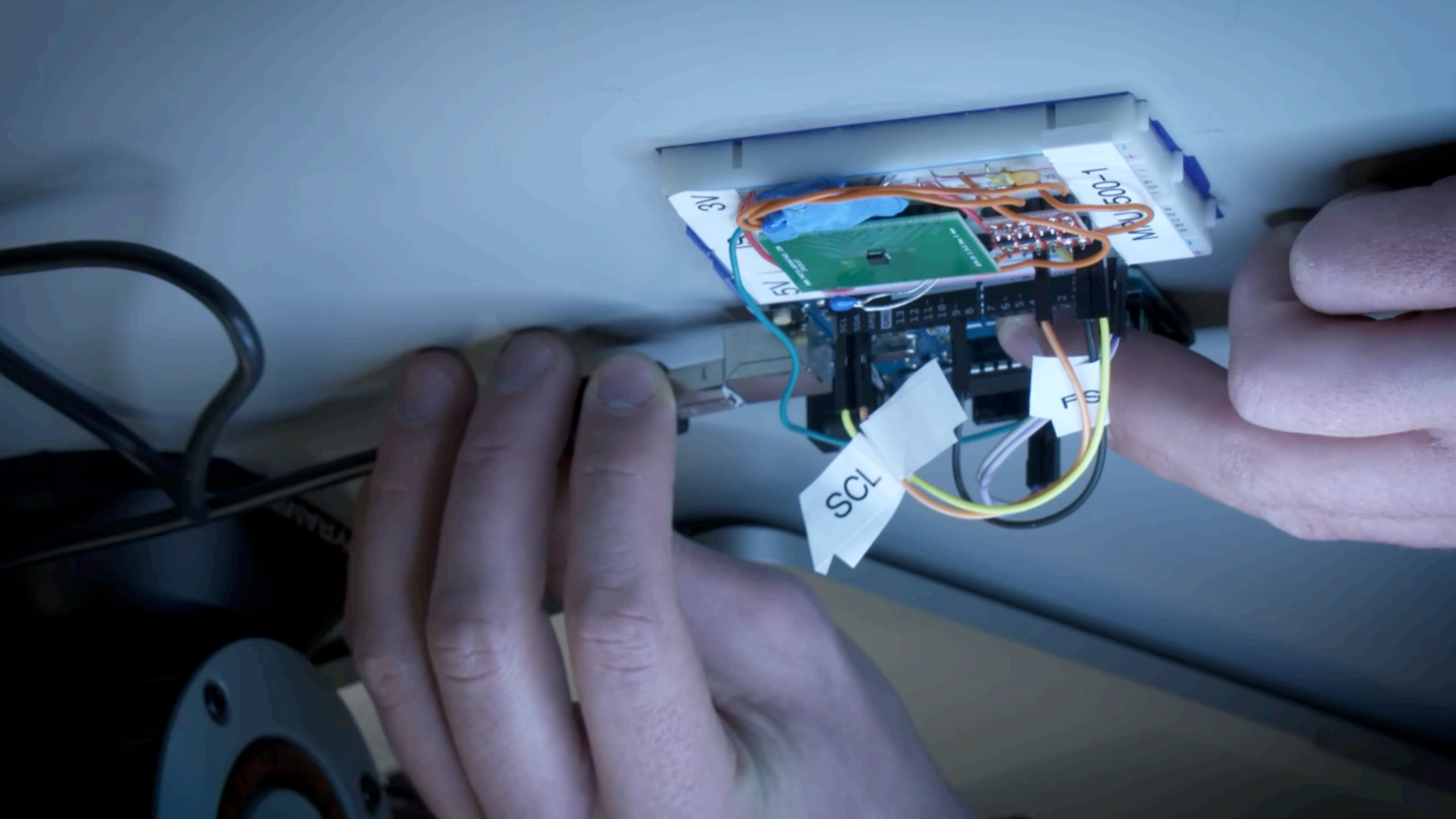

Heartbeats
Exhale
Inhale
Phase (in radians)
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (in minutes)

Baby Monitoring

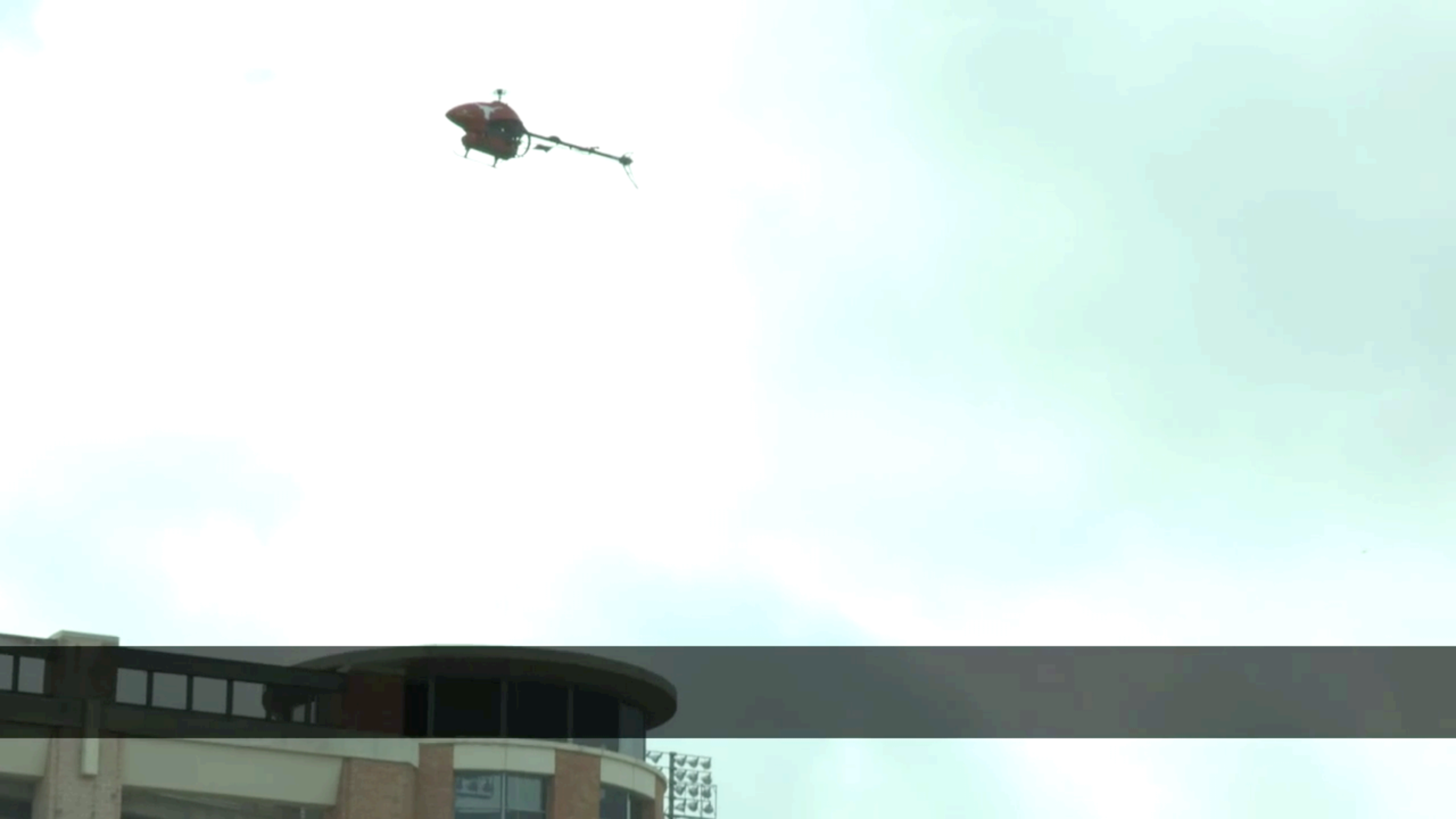
Mobile Security
Case Study: Inaudible Voice Commands

Analog Sensor Security
Acoustic Attacks on MEMS Accelerometers

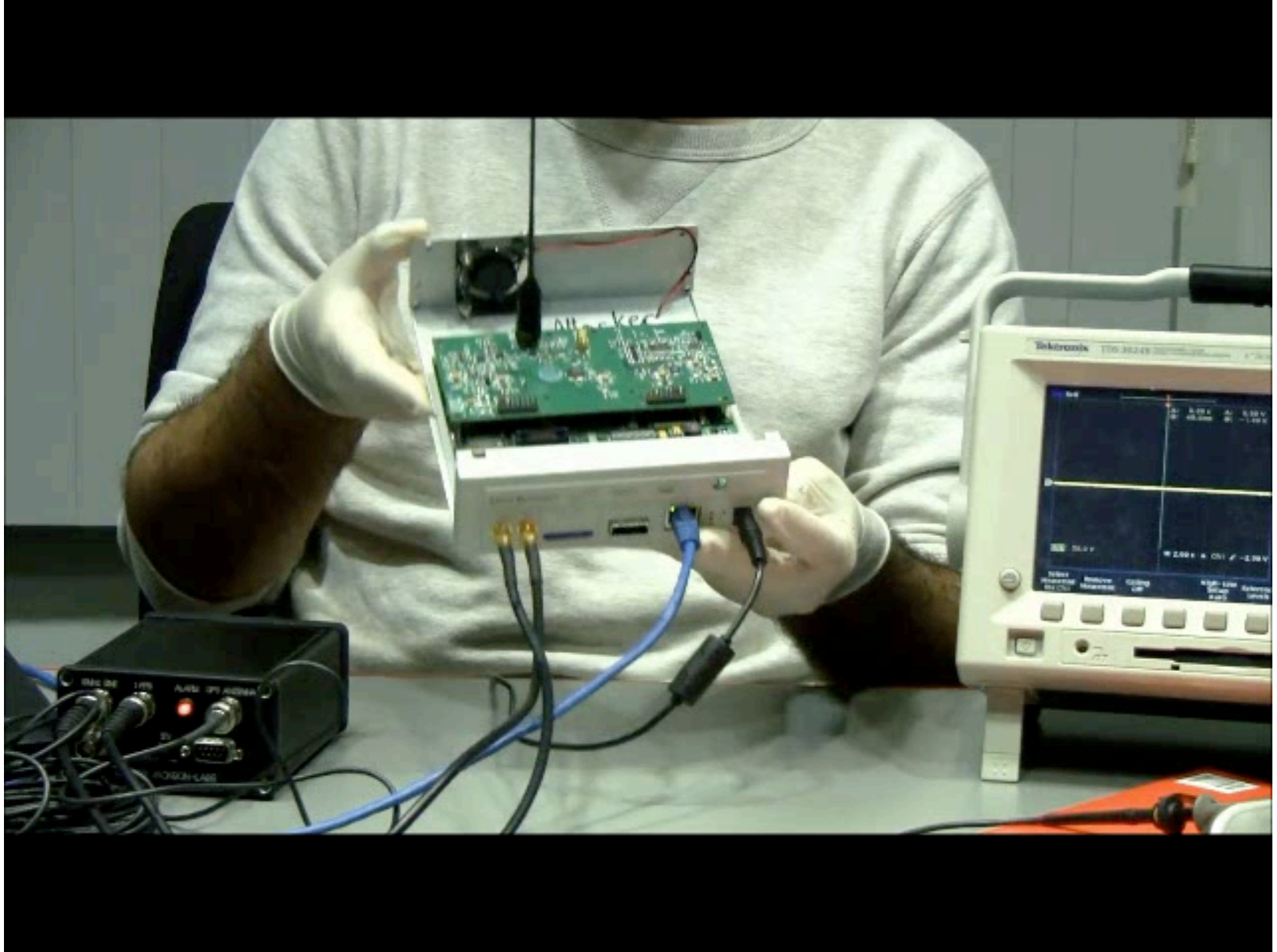

TITANIUM BULLET TWEETER
PYRAMID


3V
5V
MPU-6050
SCL

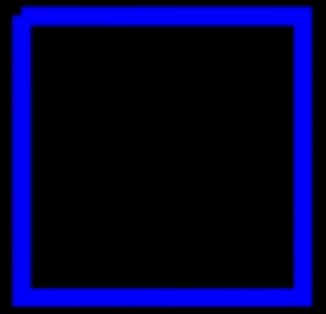
Drone Security
Spoofing GPS Signals



Pacemaker Security
Wireless Control of Pacemaker

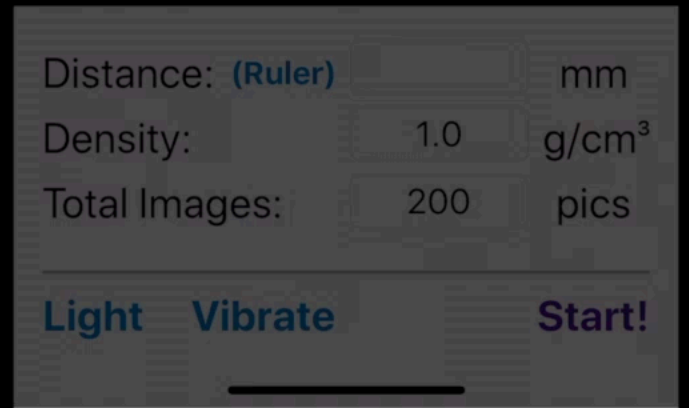

Tektronix

Food & Liquid Sensing



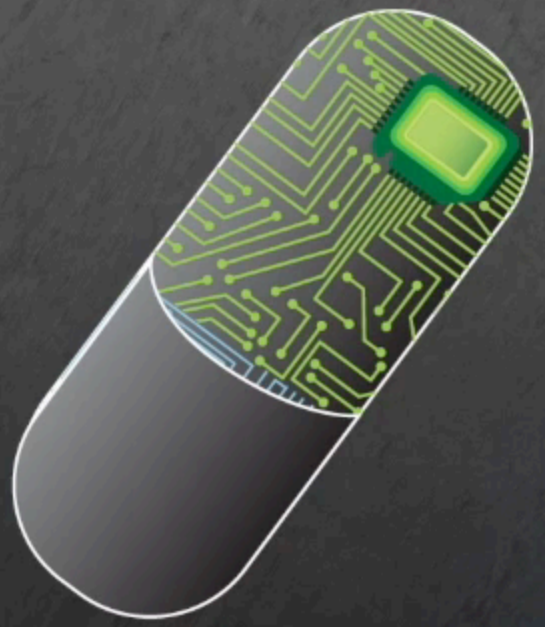
Demo of CapCam

External camera recording is on the left
Corresponding screen recording is on the right



New Domains

Continuous & Long-Term Drug Delivery

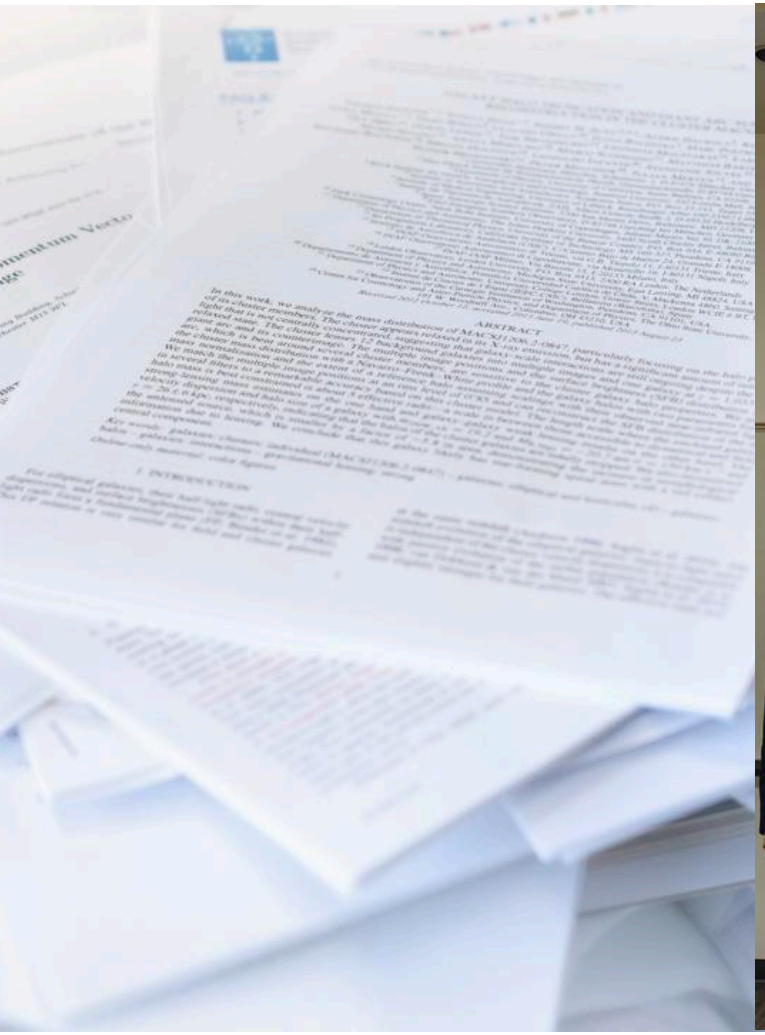


In-body Sensing and Diagnosis

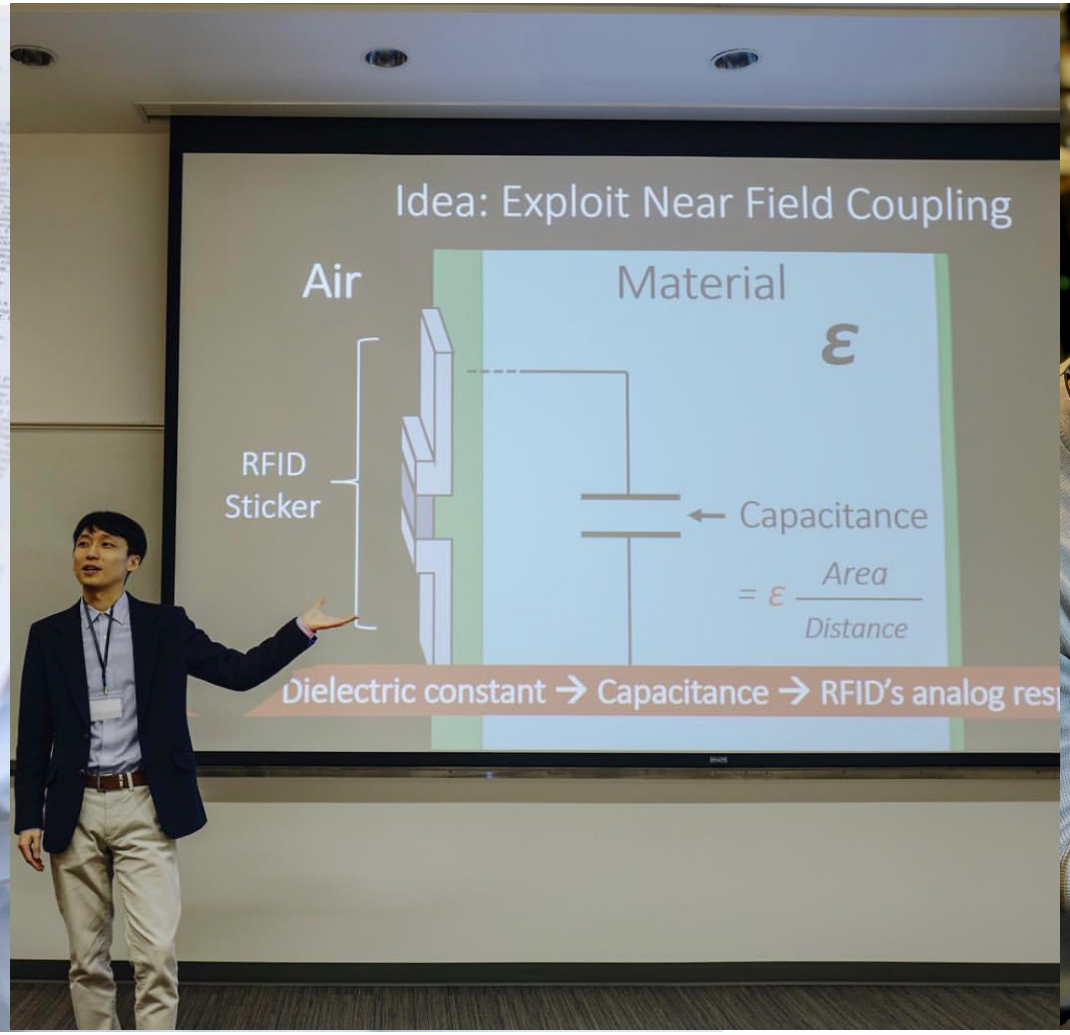
Fundamental Constraints

- Noise
- Distance/Range
- Faults
- Energy (battery, power)
- Communication bandwidth
- Processing on “leaf” nodes (sensors)
- Security is harder than with datacenter servers
    - In uncontrolled areas, act as “servers” providing data, resource-constrained nodes, physical attacks, …

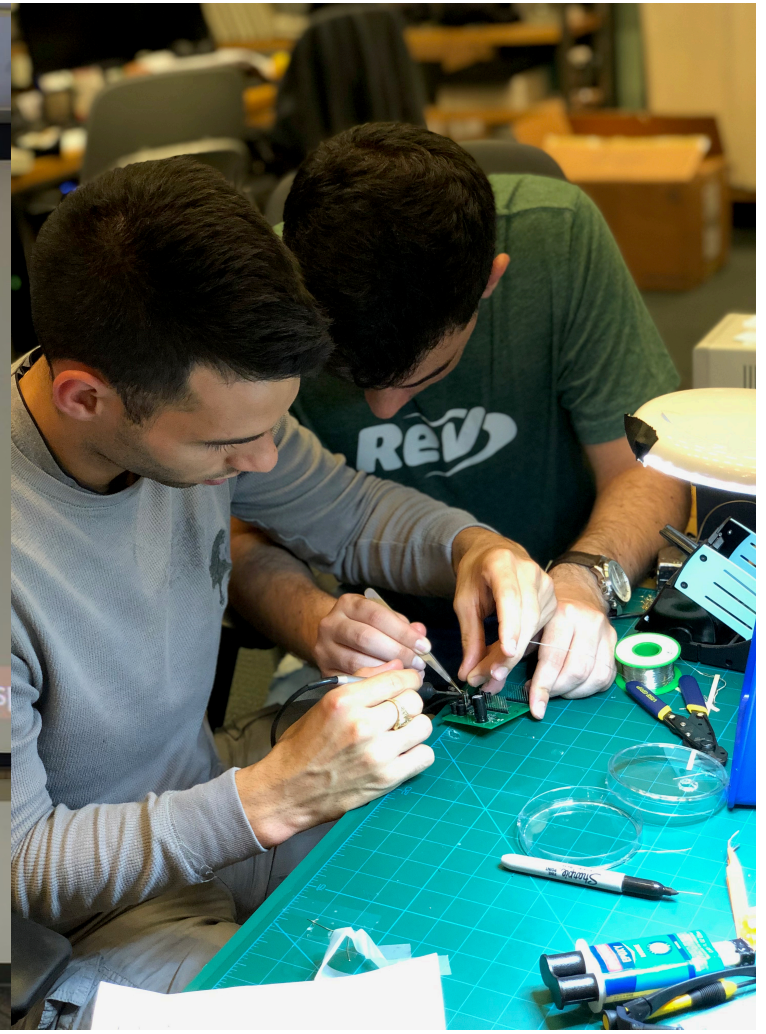
Course Organization



Reading & Reviewing Papers



Presenting & Discussing Papers



Class Project

Logistics

Grading:

- 1 Course Project (60%)
- 1 Paper Presentation (10%)
- Participation (30%)
  - Includes submitting reviews before every lecture (15%)
  - Attendance is mandatory (15%)
  - May skip one review without affecting grade

Website: http://www.mit.edu/~fadel/courses/MAS.S66/index.html

Piazza: https://piazza.com/class/k0bizne3kyh60h

- Ask questions about lectures, labs, etc.

Fadel's office hours by appointment (same week)

Readings & Presentations

We will read 1-3 papers/references per class:

- Everyone is expected to read the papers in advance
- Submit a short review of the required readings by midnight the night before the class
- Say something that is not in the paper

Submit Reviews here:

- http://www.mit.edu/~fadel/courses/MAS.S66/reviews.html

Each student will also present one paper

- Read paper and relevant references
- 25 minute talk; instructions on website

Projects

- All projects involve system implementation
- Work in groups of two (ideally)
- Will suggest project ideas; students can choose their own projects
- Can be (very) related to your research (come talk to me)

Timeline:

- Proposal (1-2 pages): October 7
- Progress Report 1: October 28
- Progress Report 2: November 18
- Final Presentation: December 9
- Final Report (6-8 pages): December 11

We will discuss project updates in class as time permits

Class Introductions

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

How to Review a System Paper

How to think when reviewing a paper?

How to Review a System Paper

How to think when reviewing a paper?

1) Motivation
Is this an important problem?

- New problem? → Worthwhile or artificial?
- Existing problem? (i.e., have others worked on it) → Does it improve over prior work?

2) Related Work

- Does it really outperform prior work?
- Does it accurately represent prior work?
- Do you know past work? If not, search Google Scholar to get a sense of past work

3) Techniques

- Are they novel? intellectually interesting?
- Are they technically sound? Is there a key technical flaw?

How to Review a System Paper

How to think when reviewing a paper?

4) Implementation

- Significant effort?
- Matches the motivation?
- Simulation or real-world prototype?

5) Evaluation

- Comprehensive? Convincing?
- Does the system deliver what it promises?

How to Review a System Paper

How to think when reviewing a paper?

1) Motivation

2) Related Work

3) Techniques

4) Implementation

5) Evaluation

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comments to authors

How to Review a System Paper

How to write a review?

1) Summary

- 5-10 sentences
- If someone hasn't read the paper at all, they should understand what it's about
- Should sound like a "brutally honest and straightforward abstracT"

Rough structure:

This paper presents XXX, a system that does YYY. **The goal is to** XXX. The **main challenge** the authors try to address is YYY.

The key idea is to do XXX. The authors do this by introducing/proposing ZZZ

The authors implement (or simulate) their system and **demonstrated** (results) that it outperforms the baseline?

How to Review a System Paper

How to write a review?

1) Summary

- 5-10 sentences
- If someone hasn't read the paper at all, they should understand what it's about
- Should sound like a "brutally honest and straightforward abstracT"

2) Strengths & Weaknesses

- Use your answers to the questions of "How to think when reviewing"
- List 2-4 pros/cons
- Each should be a direct statement about the paper

<u>Rough structure:</u>

Pros:
+ Statement 1
+ Statement 2

Cons:
-
-
-

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comments to authors

- Detailed comments to authors
- Elaborate on your pros/cons, areas for improvement, key concerns
- Ask questions about techniques, figures, results, etc.
- Based on the 5 points from how to think as well as technical details

Examples:

- If you listed a weaknesses small delta over prior work, specify in details why with references
- If experimental details are missing, state exactly what is missing and why it is problematic
- Include typos/grammar mistakes, potential suggestions to correct

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comm… to authors

- Detailed c… …c…
- Elabor… …r pro…
- …s about t…
- …the 5 points…

Examples:

- If you liste… …all delta o…
- If exper… …ng, state…
- Inclu… …amma… …, potent…

For the sake of this class, we will drop "comments to authors".

Instead, you should add a paragraph on "suggestions for improvement".

- If you could improve this paper, how would you do it?
- How do you envision your proposed technique will improve the work

How to Review a System Paper

How to write a review? (for this class)

1) Summary

2) Strengths & Weaknesses

3) Suggestions for Improvement

Next Class

3 readings

1) Chapter on Localization

Covers fundamentals

2) Cricket Paper

More than 100,000 deployed (hospitals)
Cited > 5,000 times

3) RADAR paper

Transitioned to real-world products (Microsoft, many startups).
Started a new field
Cited > 10,000 times