CURIE Academy 2021
Design Project: Computing at the Edge

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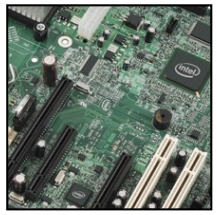
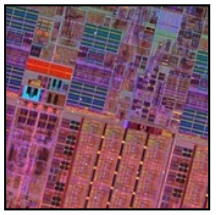
School of Electrical and Computer Engineering
Cornell University

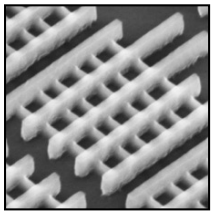
`https://www.csl.cornell.edu/curie2021`

11:45	(11:00-11:55) Zoom	**Icebreaker** (11:45) Zoom	**Icebreaker** (11:45) Zoom	(11:45) Zoom	**Icebreaker** (11:45) Zoom
12:00-12:40	**ORIE** Banerjee Zoom	**CS** Zoom	**EAS** Prof. Katie Keranen Zoom	**CEE** McLaskey Zoom	**AEP** Kourkoutis Zoom
5 min	*Break*	*Break*	*Break*	*Break*	*Break*
12:45-3:45	**Electrical and Computer Engineering** Batten Zoom	Batten Zoom	Batten Zoom	Zoom	Batten Zoom
30 min	*Break*	*Break*	*Break*	*Break*	*Break*
4:15-4:55	**CBE** Prof. Rong Yang Zoom	**Information Session** **Engineering Admissions** Beth Kunz Zoom	**MSE** Dshemuchadse Zoom	**BME** Meulen Zoom	**MAE** Andarawis-Puri Zoom
35 min	*Break*	*Break*	*Break*	*Break*	*Break*
5:30-	Escape Room	Cornell e-Tour & Trivia	Game Night	Talent Show	Program Closing (5:30-6:20 pm) & Presentations


Power Systems

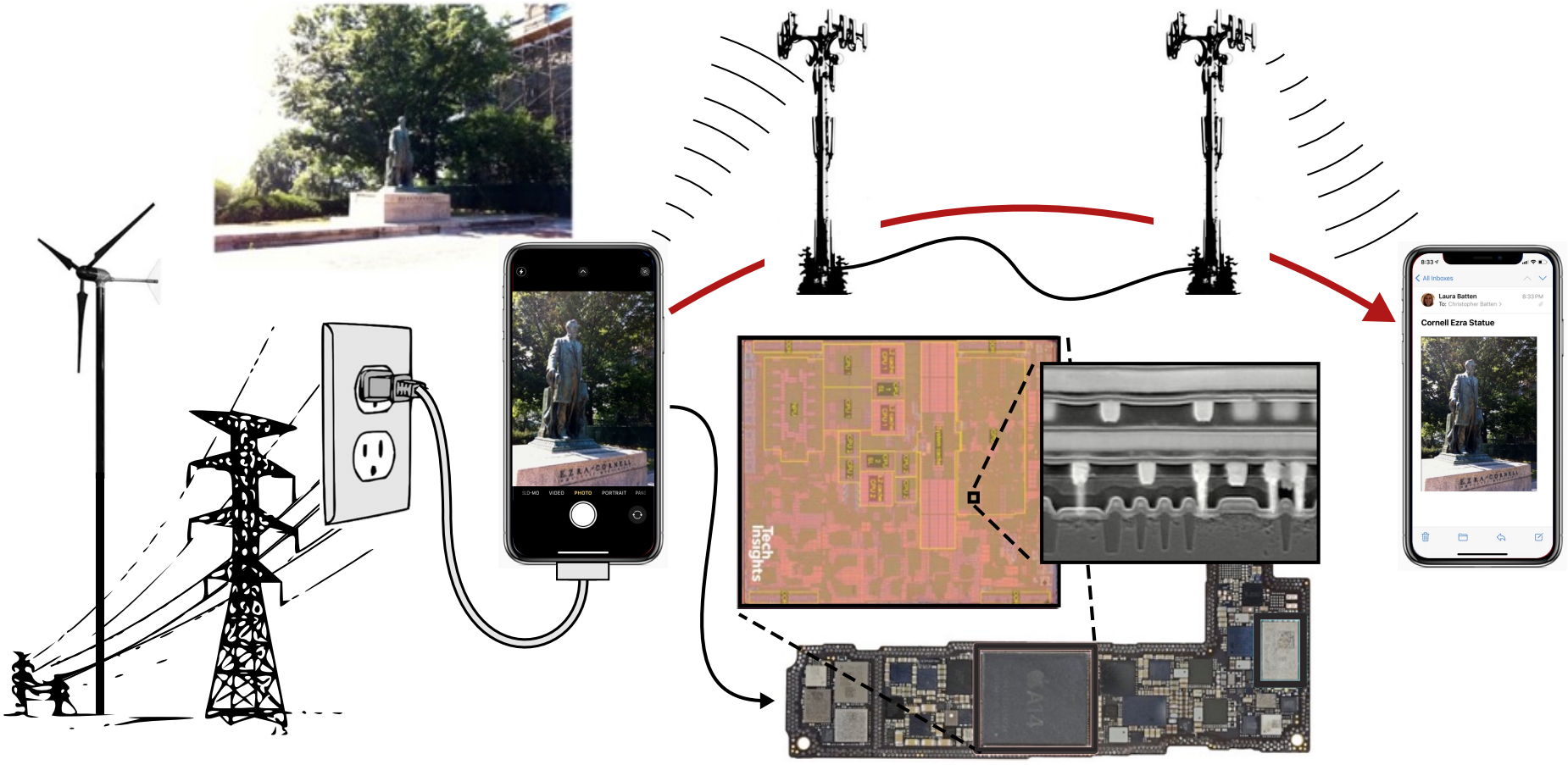

Computer Engineering


Electrical Circuits

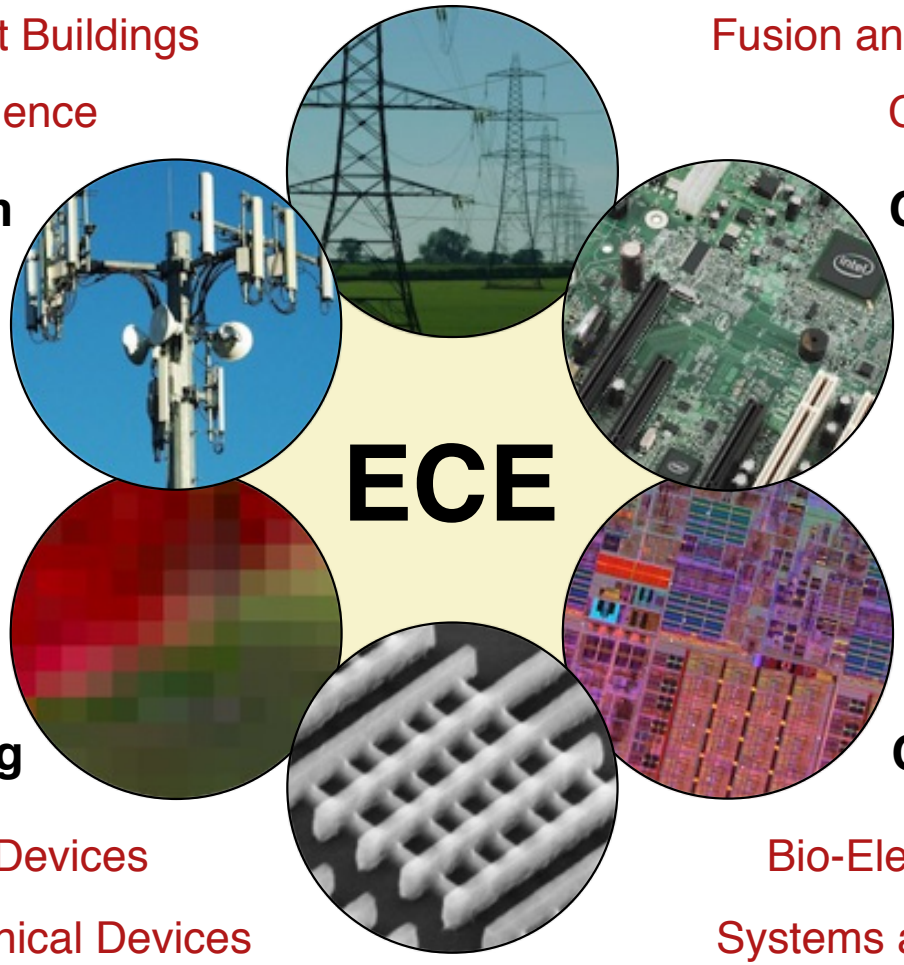

Electrical Devices


Signal Processing


Telecomm



ECE is the Study and Application of Electricity, Micro-Electronics, and Electro-Magnetism

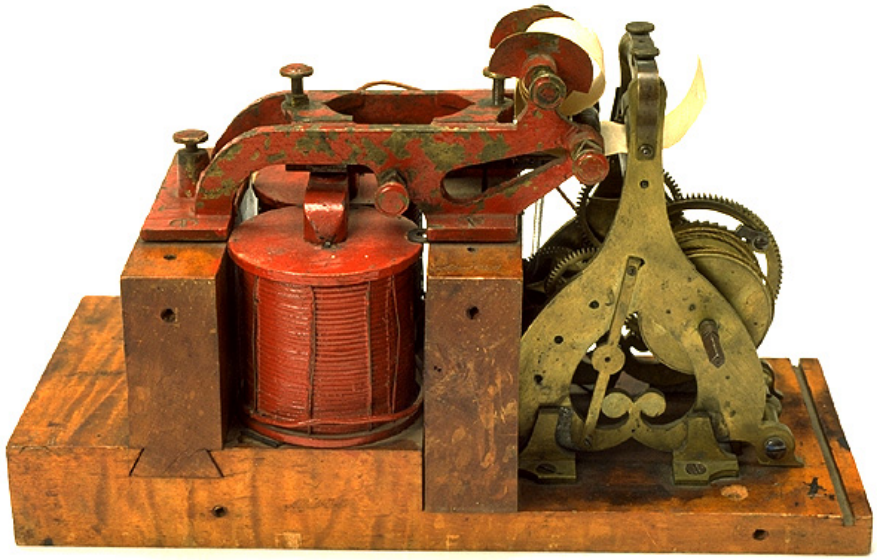


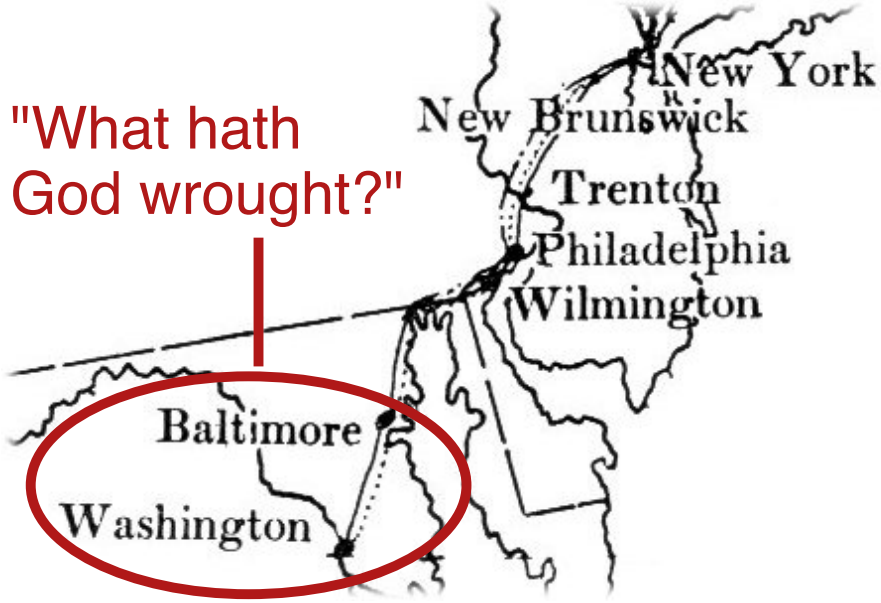
ECE is everywhere!

Cornell was founded because of ECE!

Samuel Morse invented the telegraph (a digital communication device), but needed help building the network

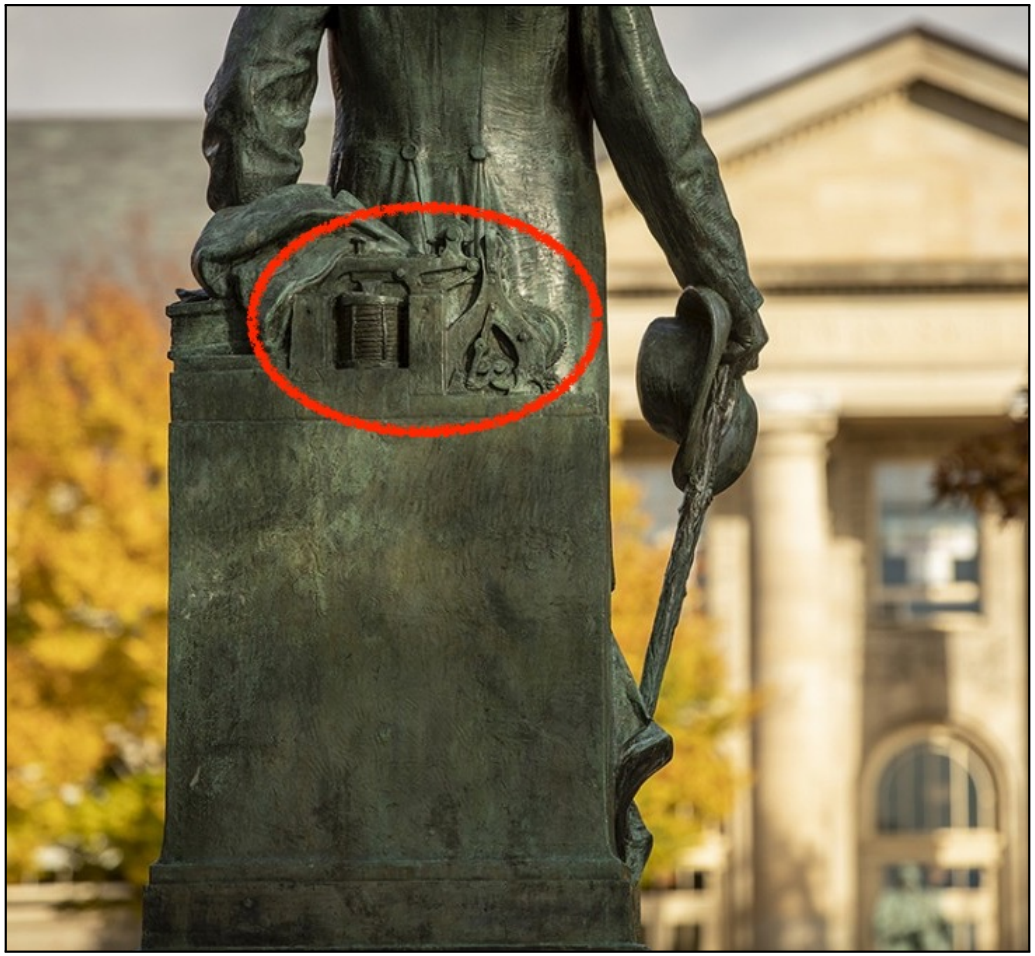
Ezra Cornell built the first telegraph line (the beginning of telecommunications), and invested in the Western Union Telegraph Co





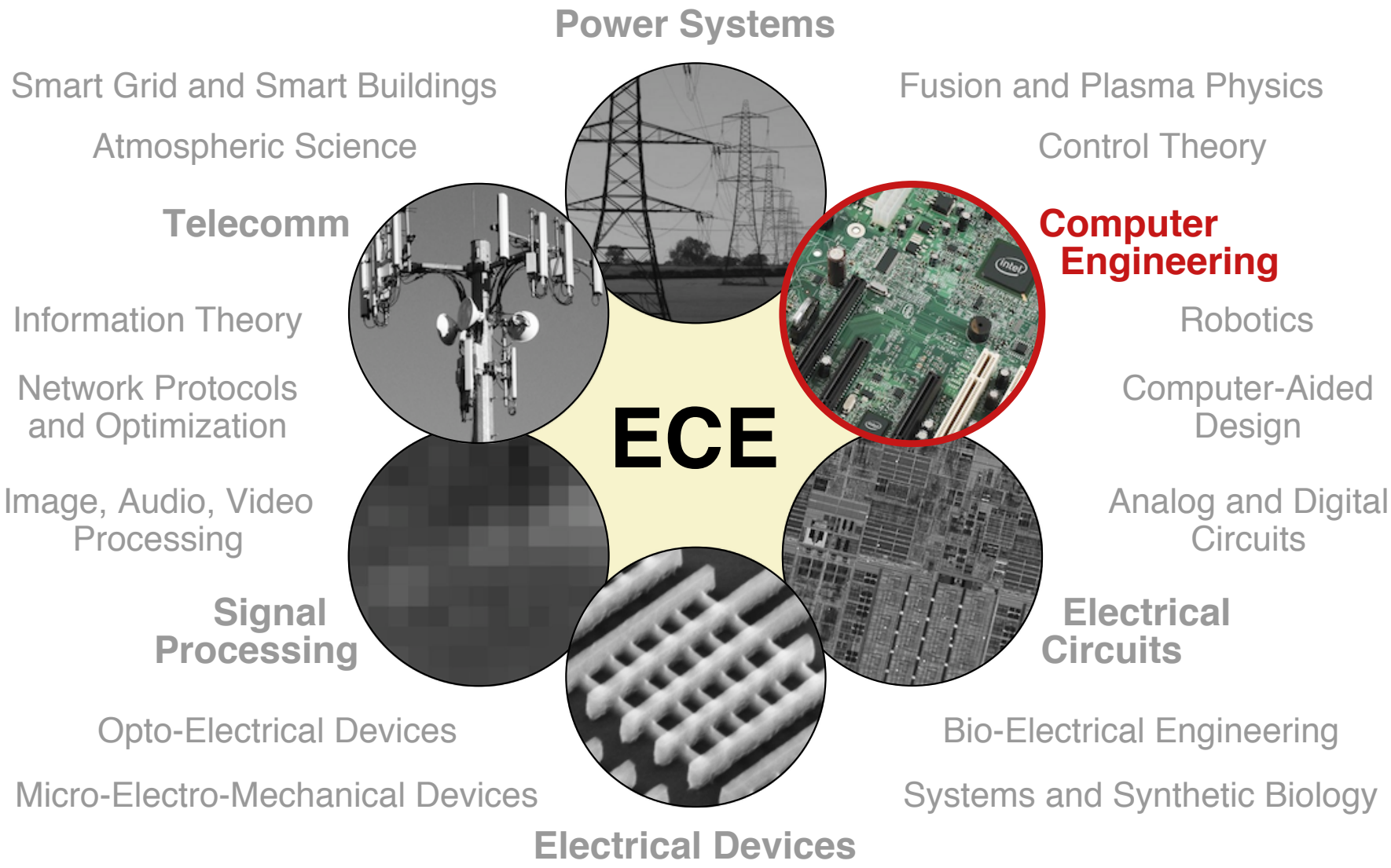
Ezra Cornell's investments created the fortune that eventually enabled the founding of Cornell University

How important is ECE at Cornell?

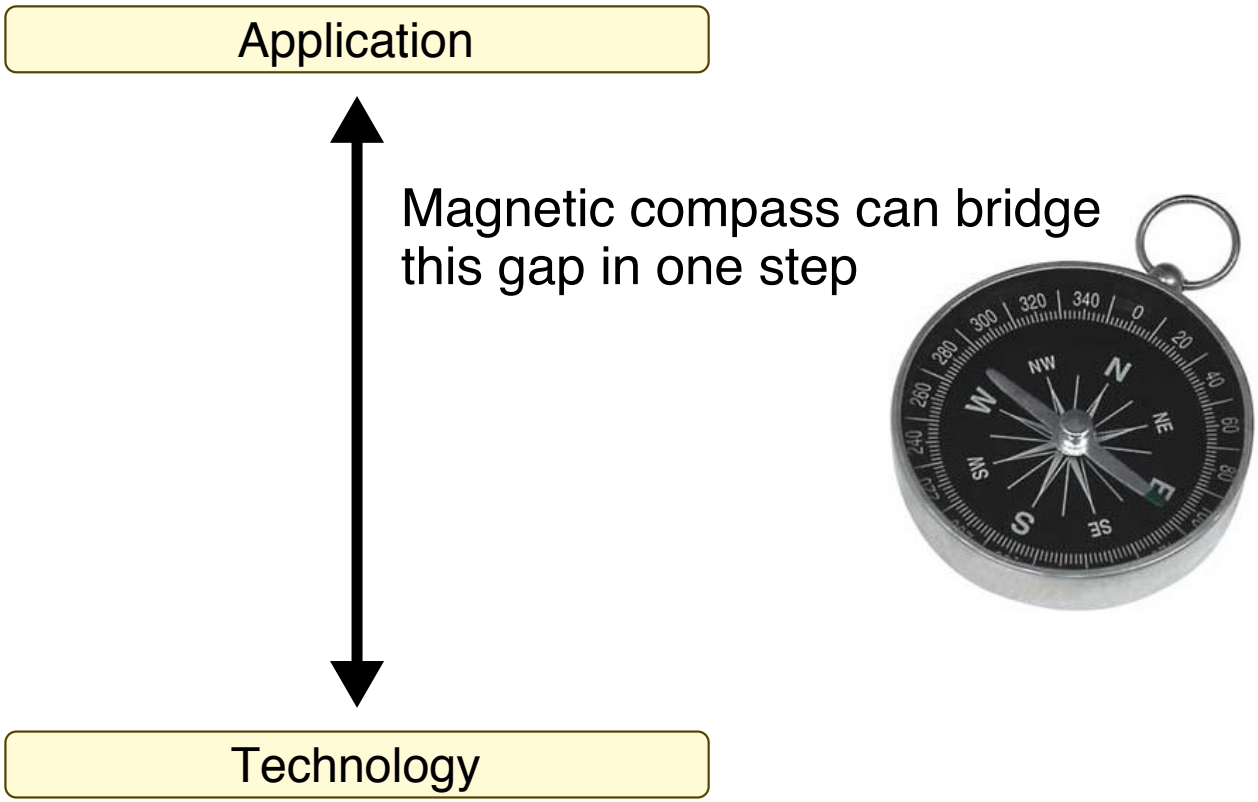


(right) Photo from Cornell Chronicle

Computer Engineering

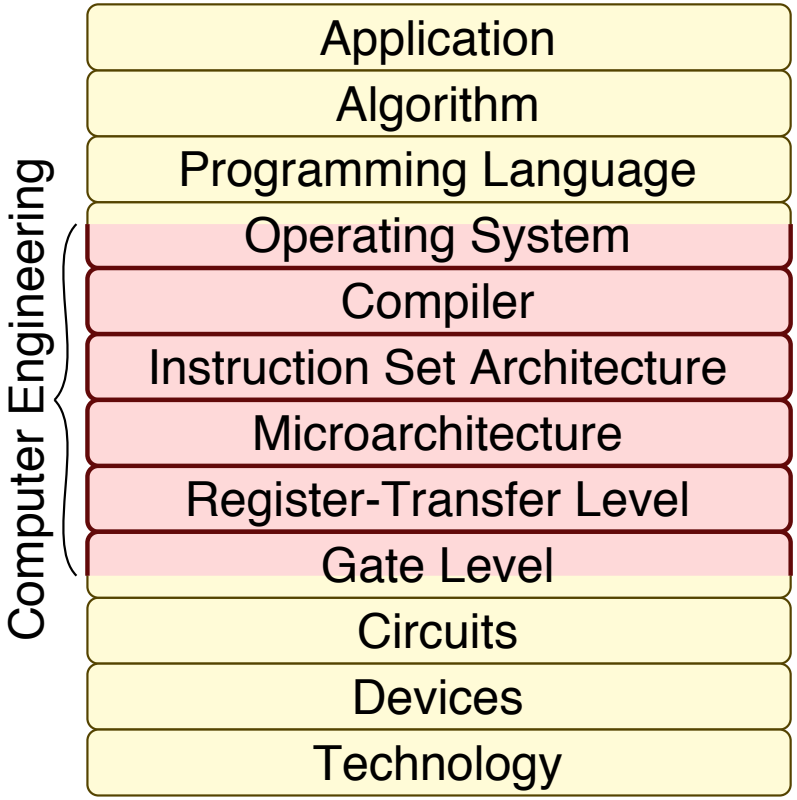


The Computer Systems Stack



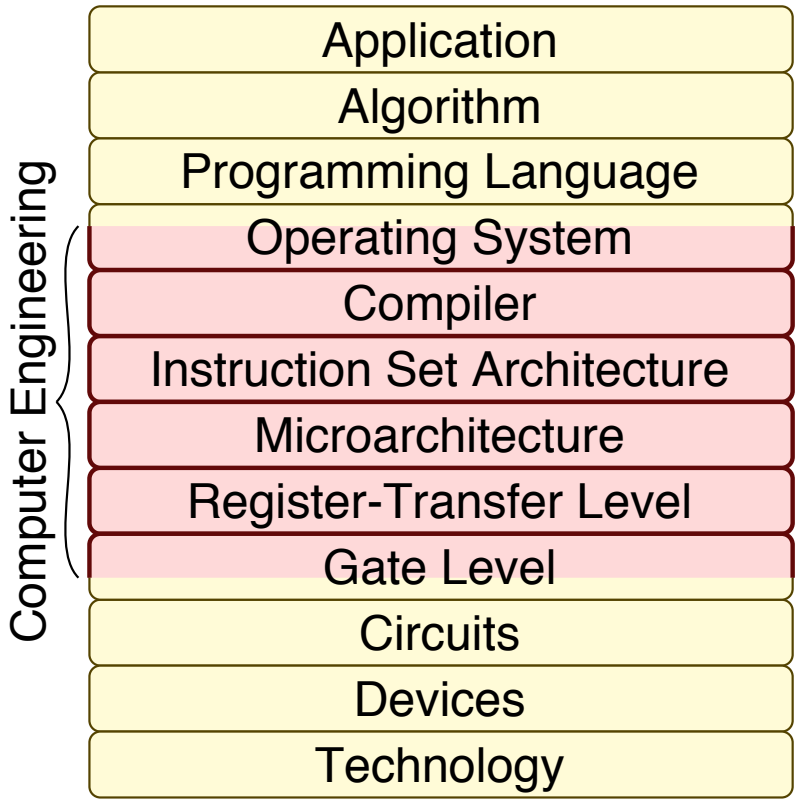
Magnetic compass can bridge this gap in one step

The Computer Systems Stack



In its broadest definition, computer engineering is the development of the abstraction/implementation layers that allow us to execute information processing applications efficiently using available manufacturing technologies

The Computer Systems Stack



Sort an array of numbers

2,6,3,8,4,5 -> 2,3,4,5,6,8

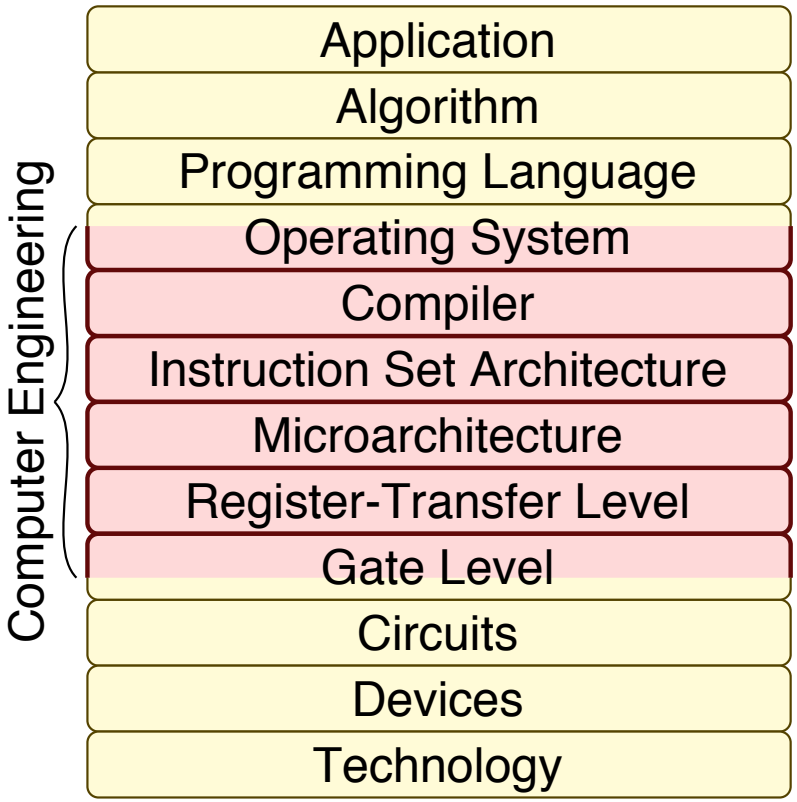
Out-of-place selection sort algorithm

1. Find minimum number in array
2. Move minimum number into output array
3. Repeat steps 1 and 2 until finished

C implementation of selection sort

```
void sort( int b[], int a[], int n ) {
  for ( int idx, k = 0; k < n; k++ ) {
    int min = 100;
    for ( int i = 0; i < n; i++ ) {
      if ( a[i] < min ) {
        min = a[i];
        idx = i;
      }
    }
    b[k]   = min;
    a[idx] = 100;
  }
}
```

The Computer Systems Stack



Mac OS X, Windows, Linux

Handles low-level hardware management

C Compiler

Transform programs into assembly

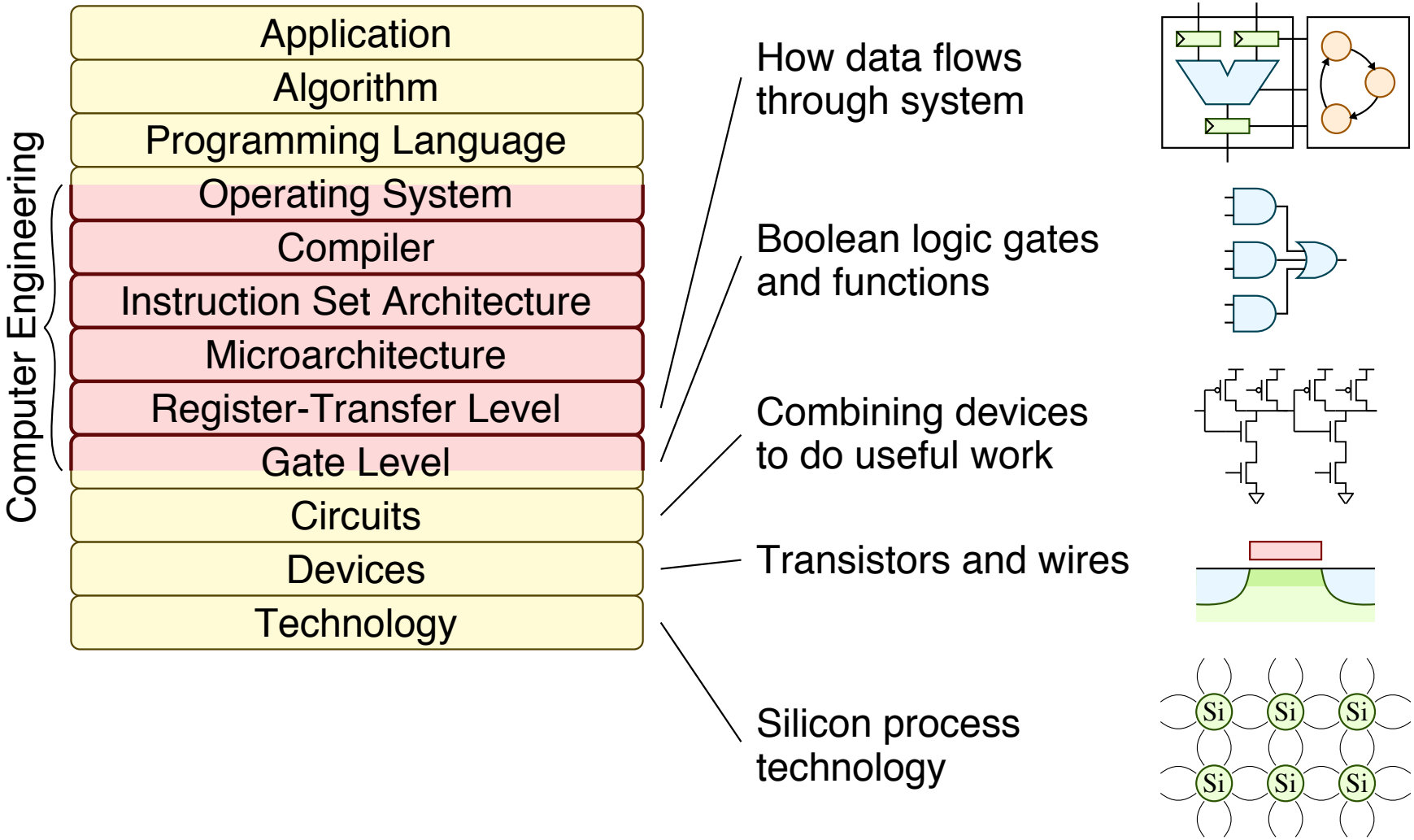
```
int a = b + c;          addu $t0, $t1, $t2
A[i] = a;               sw   $t0, 0($t3)
```

MIPS32 Instruction Set

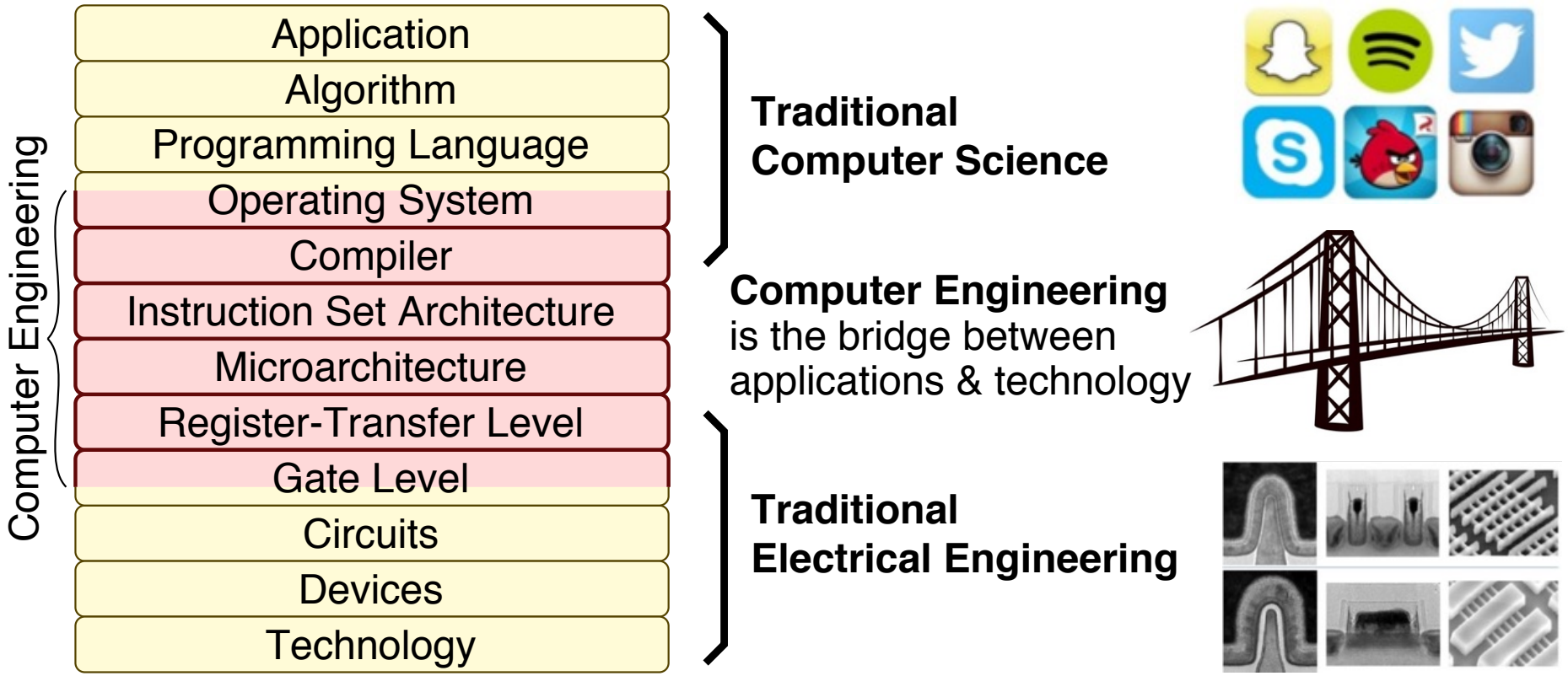
Instructions that machine executes

```
blez $a2, done
move $a7, $zero
li   $t4, 99
move $a4, $a1
li   $a3, 99
lw   $a5, 0($a4)
```

The Computer Systems Stack



Computer Systems: CS vs. EE vs. CE



In its broadest definition, computer engineering is the development of the abstraction/implementation layers that allow us to execute information processing applications efficiently using available manufacturing technologies

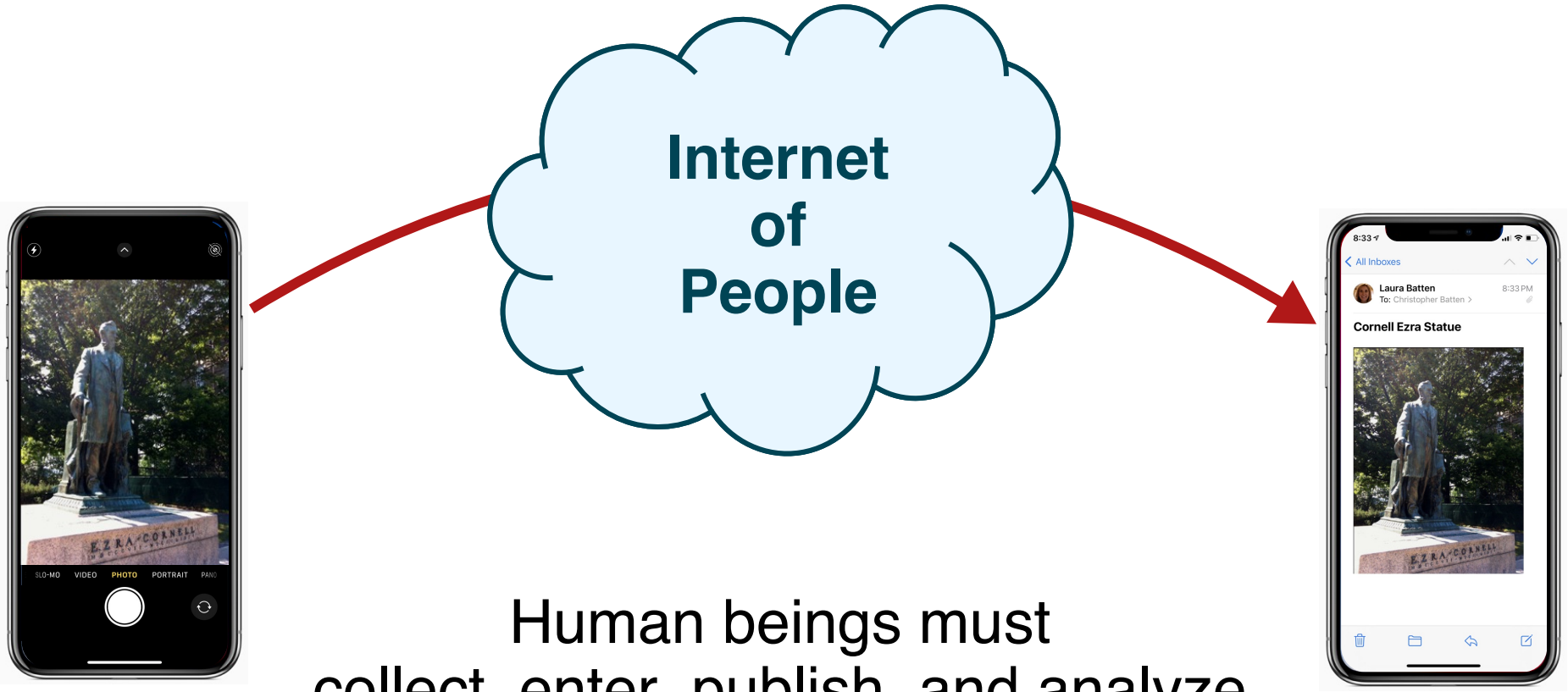
Talk Outline

Computer Engineering

The Internet of Things

CURIE Design Project

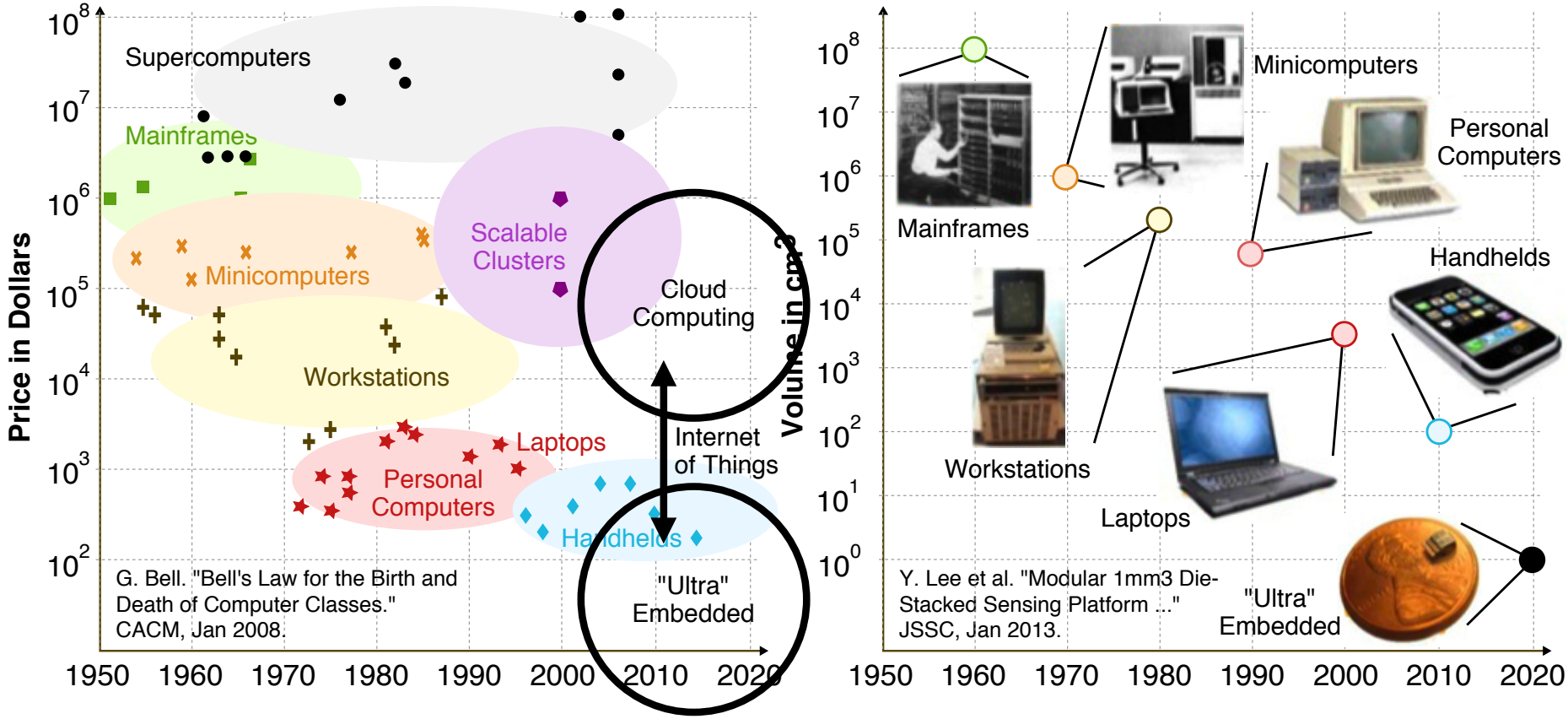
The "Traditional" Internet



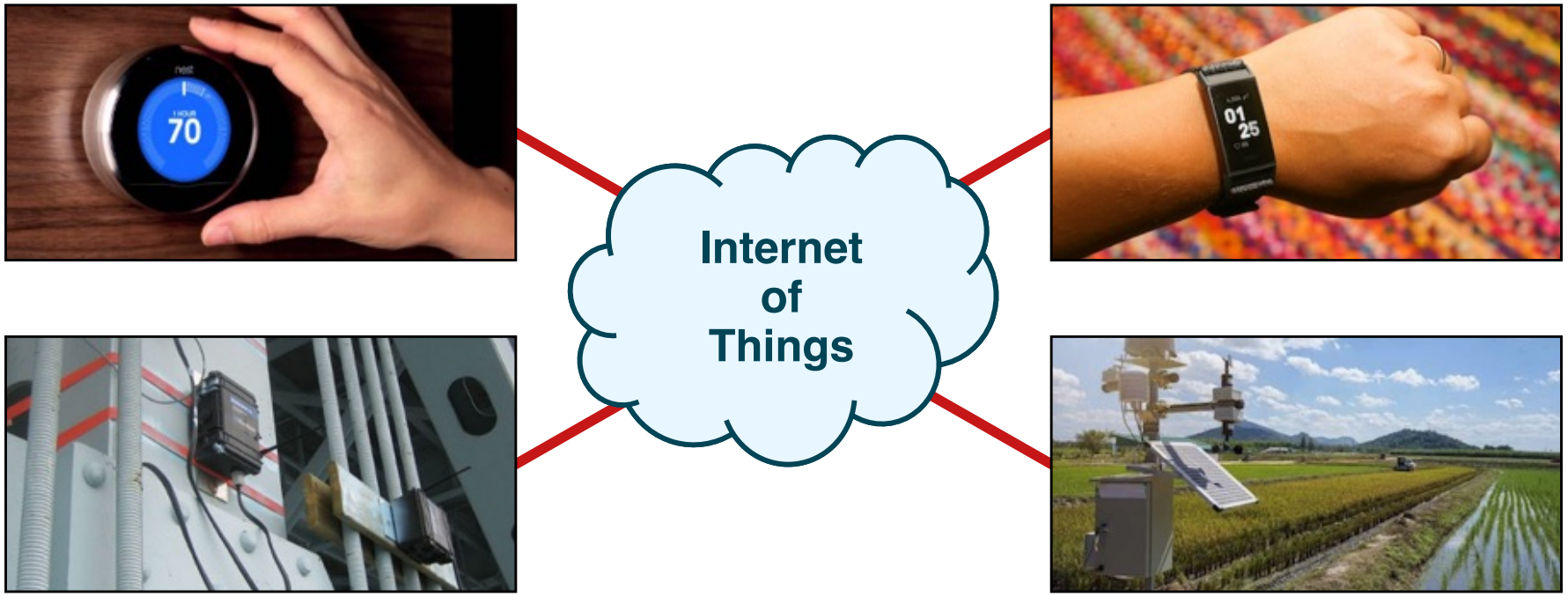
Human beings must
collect, enter, publish, and analyze
almost all of the information
that is transmitted over the Internet

Bell's Law

Roughly every decade a new, smaller, lower priced computer class forms based on a new programming platform resulting in entire new industries

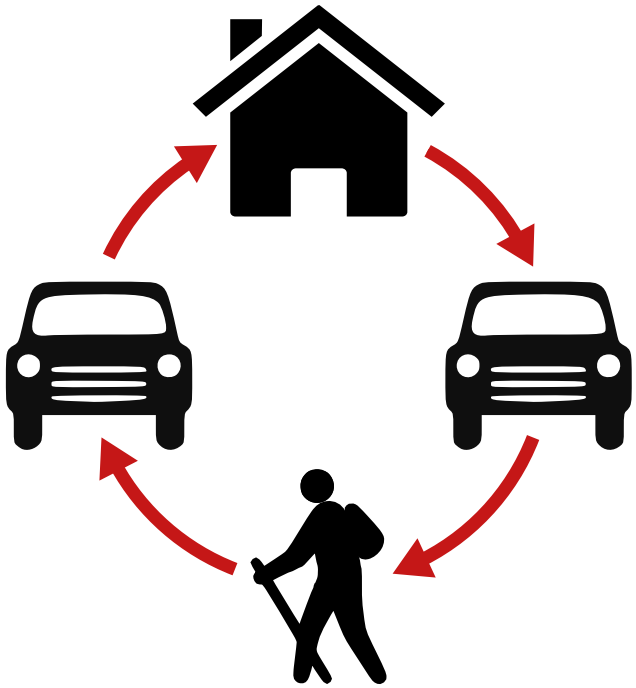


Emerging Trend Towards an Internet of Things

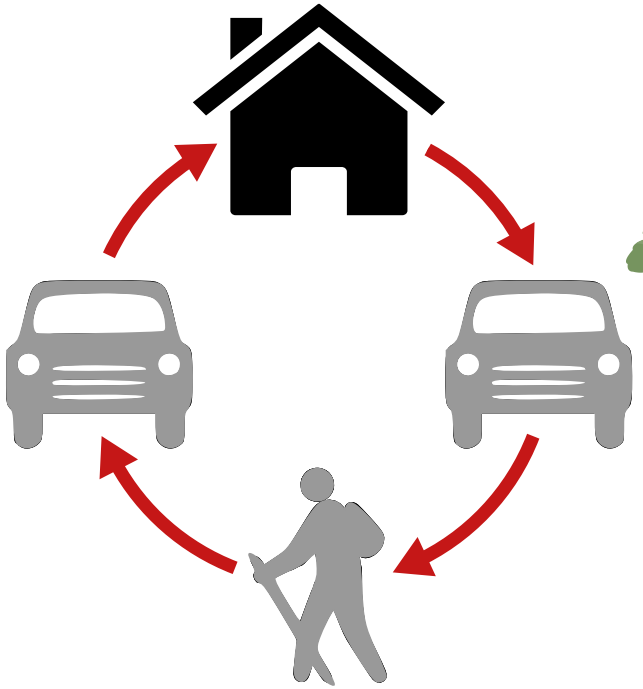


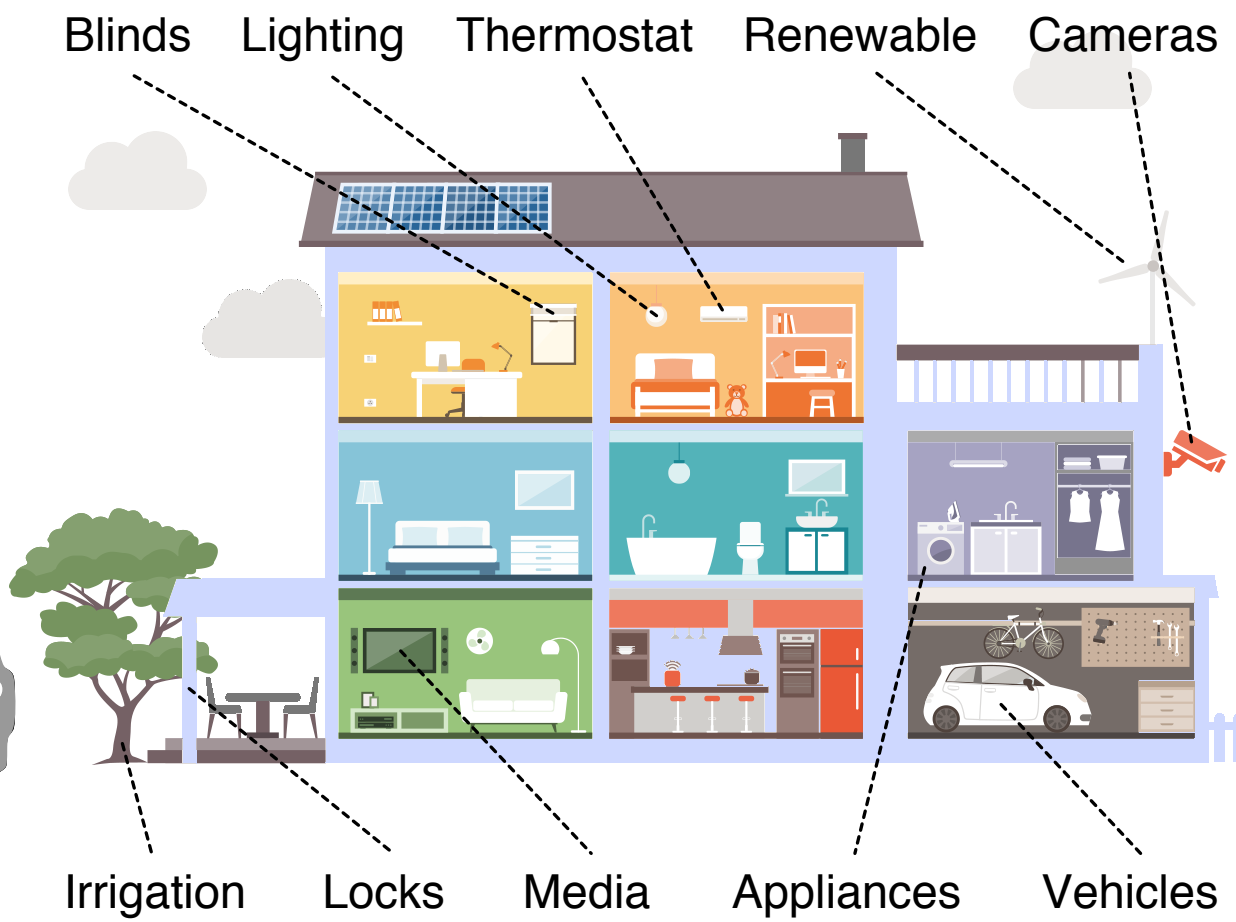
Interconnected "things" augmented with inexpensive embedded controllers, sensors, actuators to collect information and interact with the world

IoT Example: Spending the Day Hiking

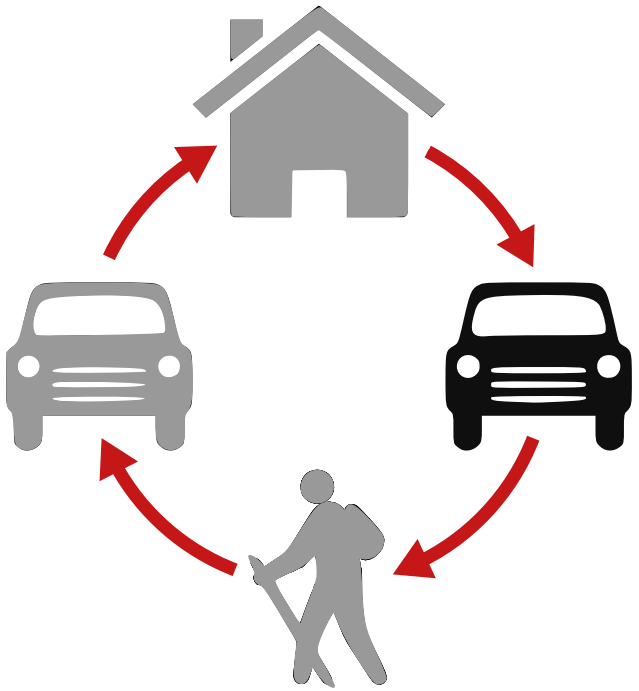


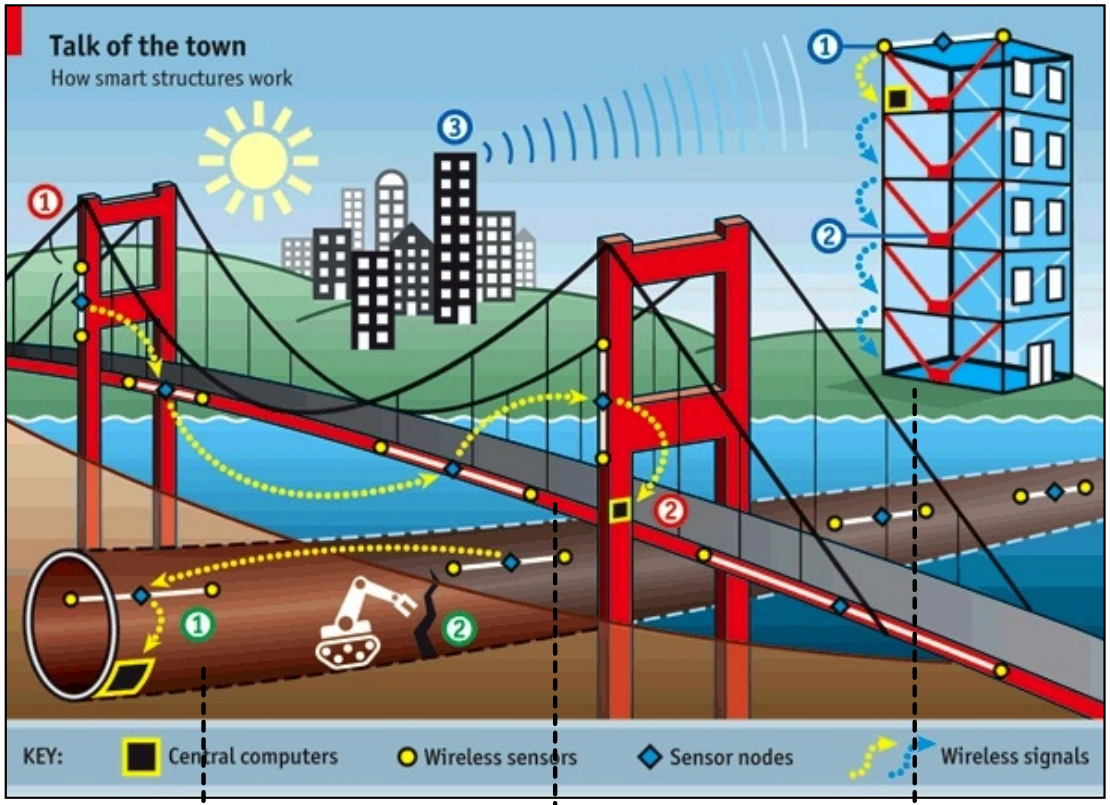
IoT Smart Home





IoT Early Disaster Warning System





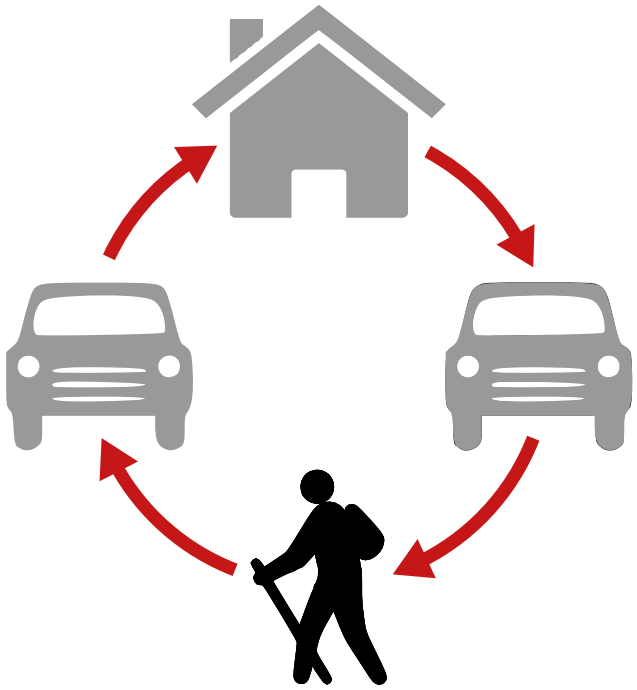
Smart Tunnels

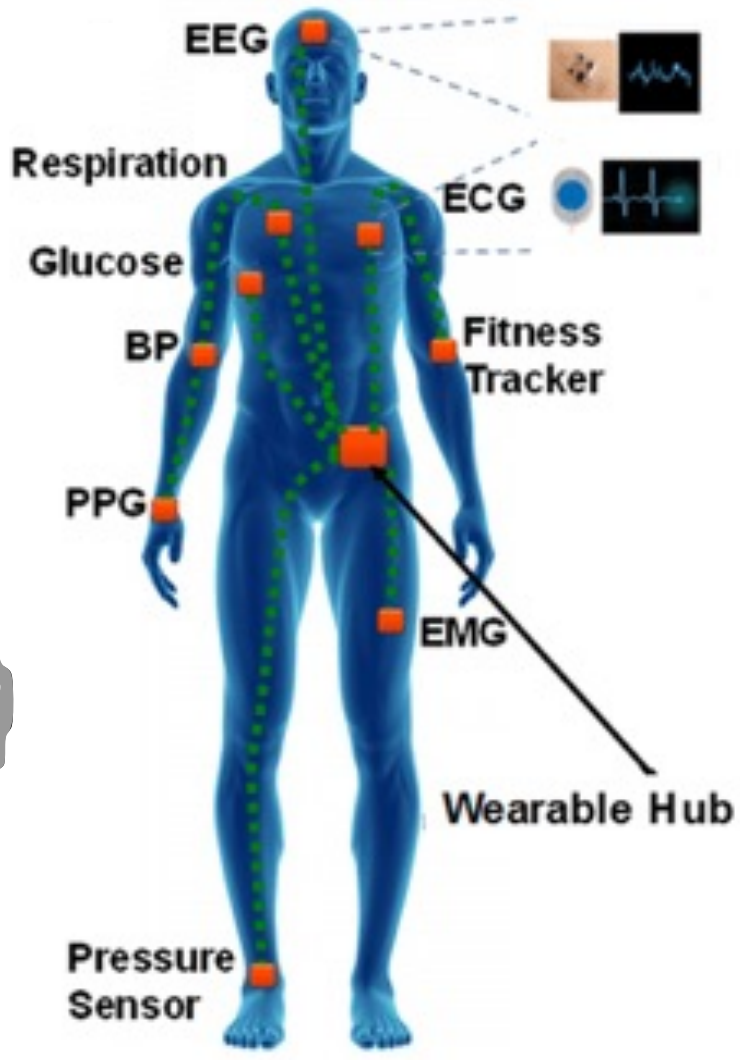
Smart Bridges

Smart Buildings

Adapted from “Inside Story: Superstructures,” The Economist, Dec 2010

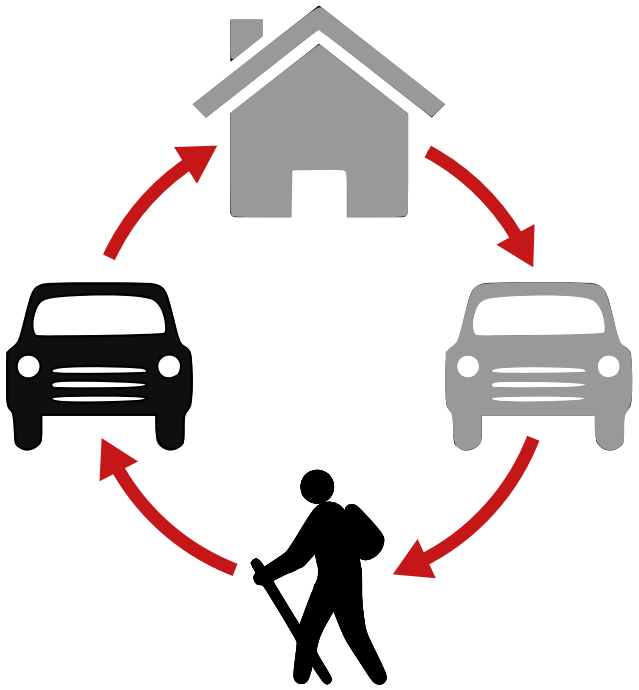
IoT Wearable Health Monitor

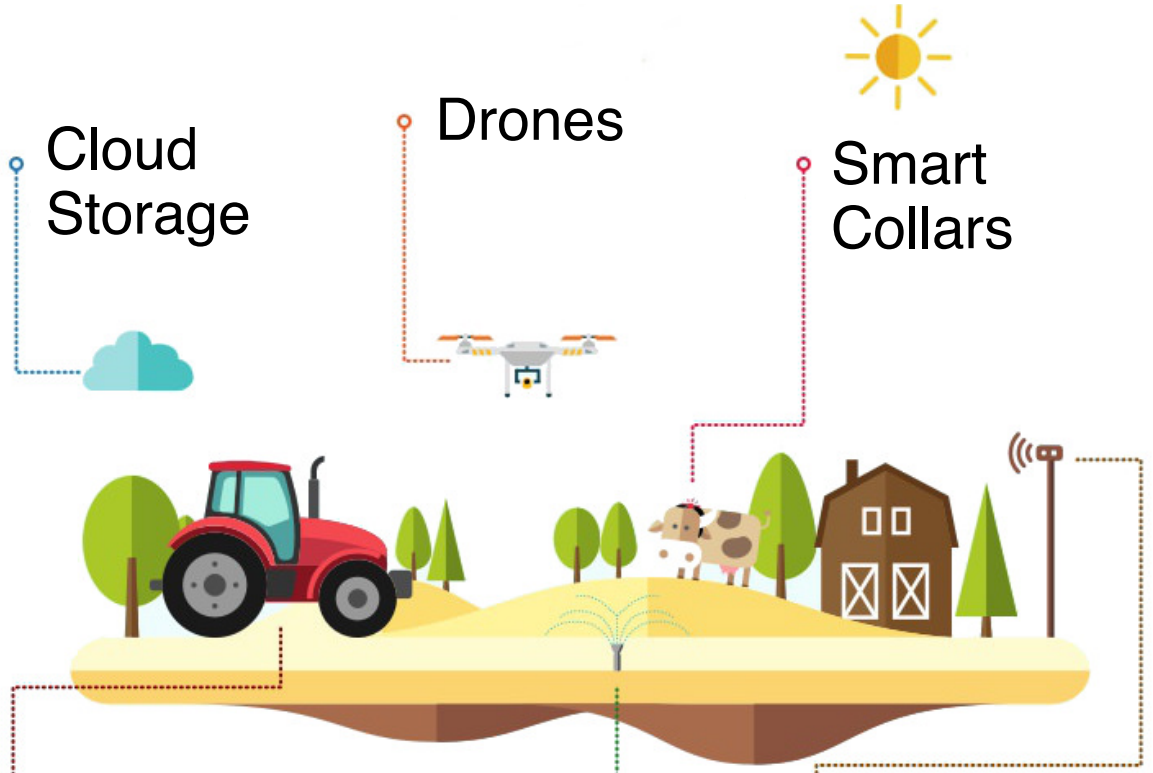




Adapted from Maity et al., IEEE Engineering in Medicine and Biology Society, July 2017

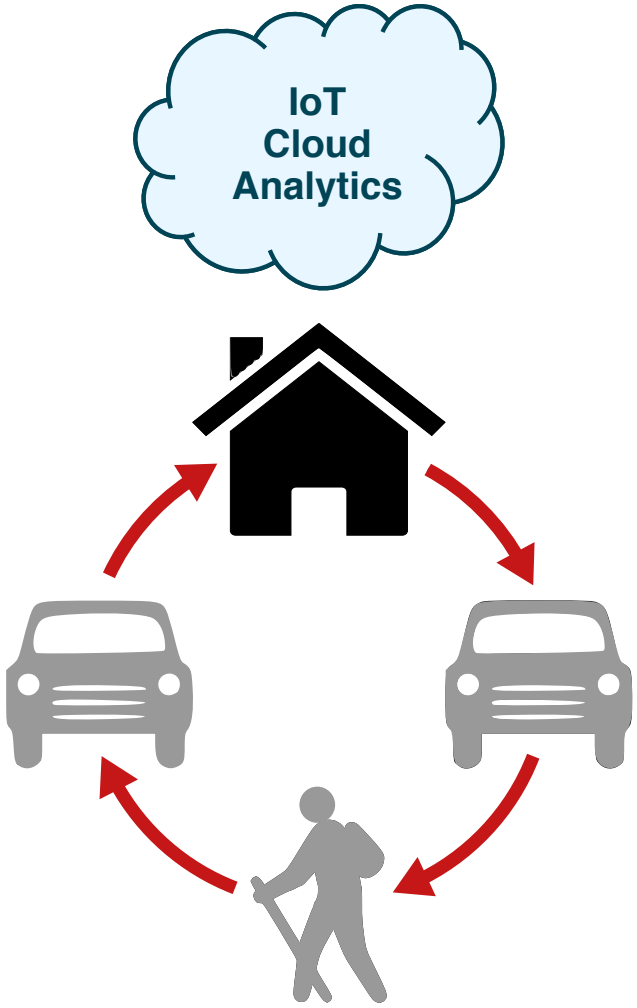
IoT Digital Agriculture

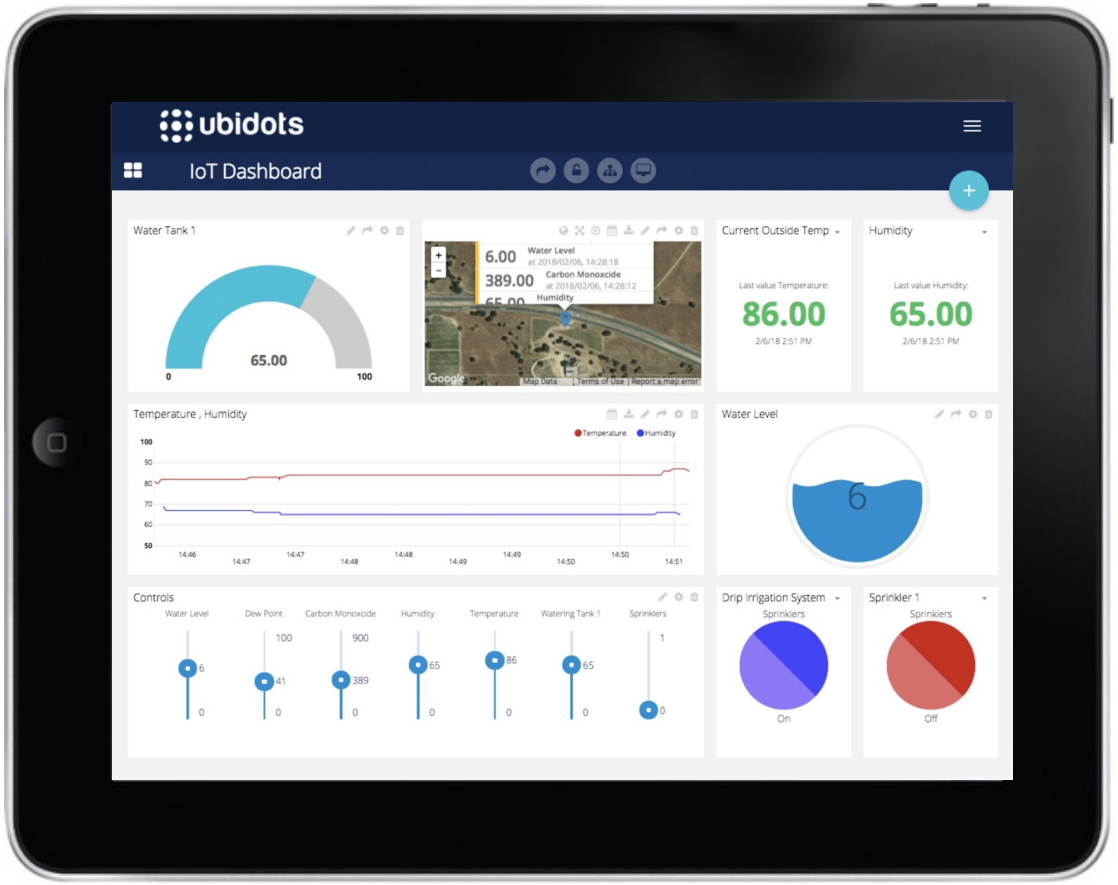




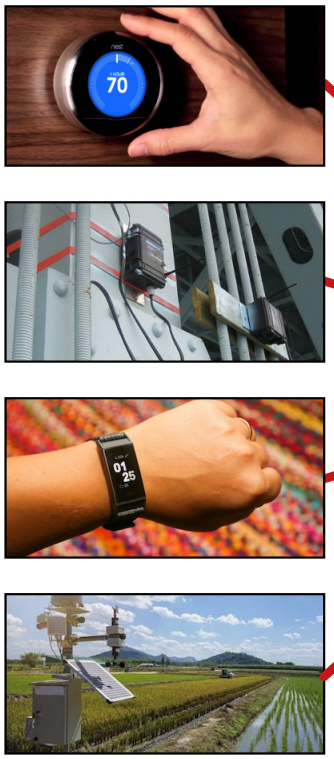
Adapted from `https://www.iberdrola.com/innovation/smart-farming-precision-agriculture`

IoT Cloud Analytics





Internet of Things + Computer Engineering



Internet of Things

Computer Engineering

- Application
- Algorithm
- Programming Language
- Operating System
- Compiler
- Instruction Set Architecture
- Microarchitecture
- Register-Transfer Level
- Gate Level
- Circuits
- Devices
- Technology

Field of computer engineering is well-situated to serve as a foundation for students interested in this emerging area

Talk Outline

Computer Engineering

The Internet of Things

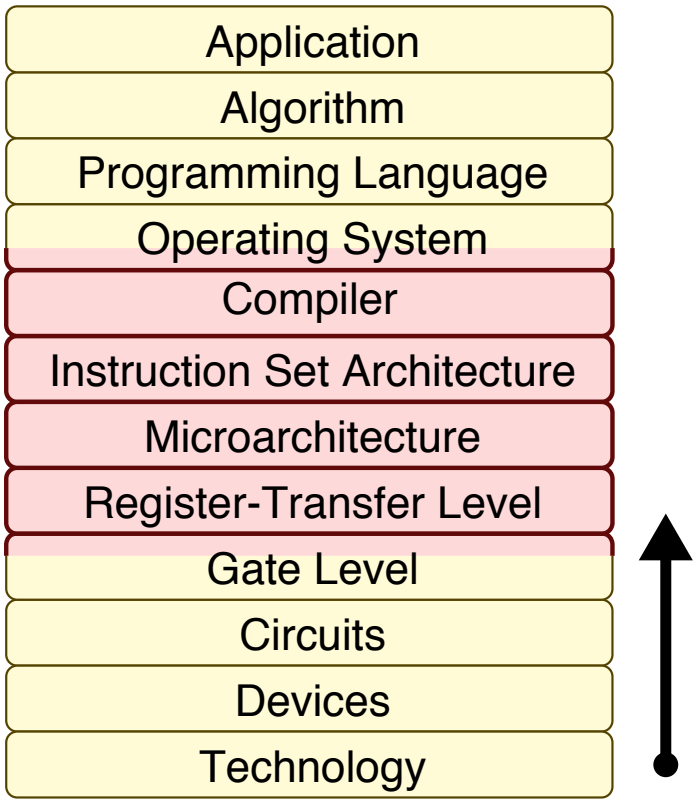
CURIE Design Project

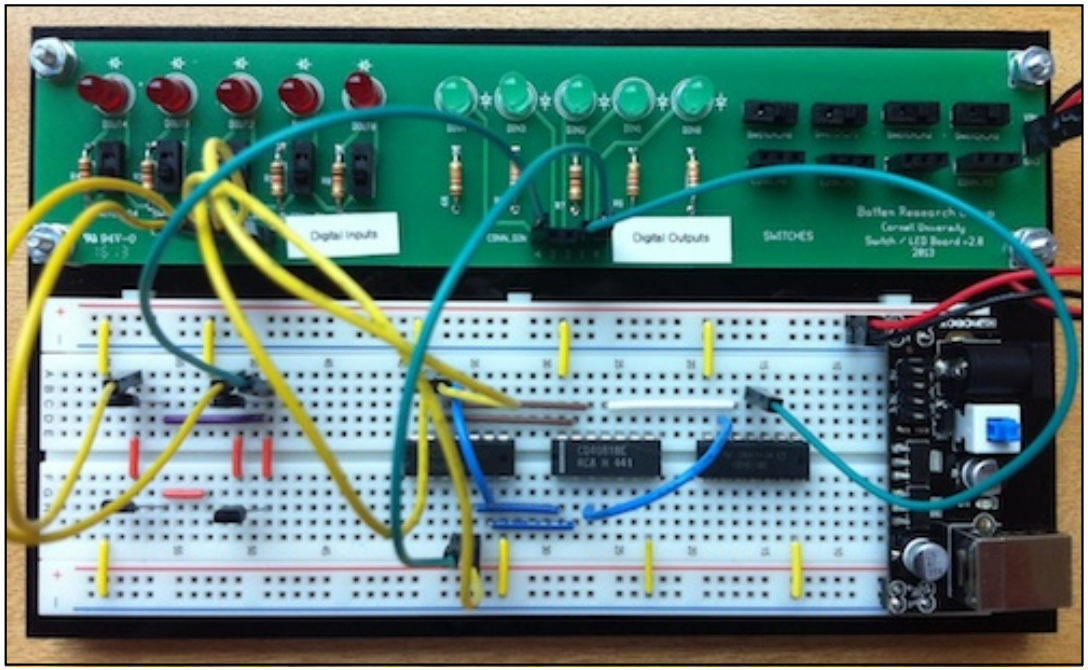
CURIE Design Project Schedule

Monday	Lab 1: Computer Engineering – Hardware Perspective Assemble basic logic gates to implement binary adder
Tuesday	Lab 2: Computer Engineering – Software Perspective Program microcontroller to implement “smart light”
Wednesday	Begin Designing IoT System for Project
Thursday	Design, Implement, and Test IoT System
Friday	Test IoT System; Prepare Project Presentation Final Presentations

Optional lab/office hours from 7:30–8:30pm

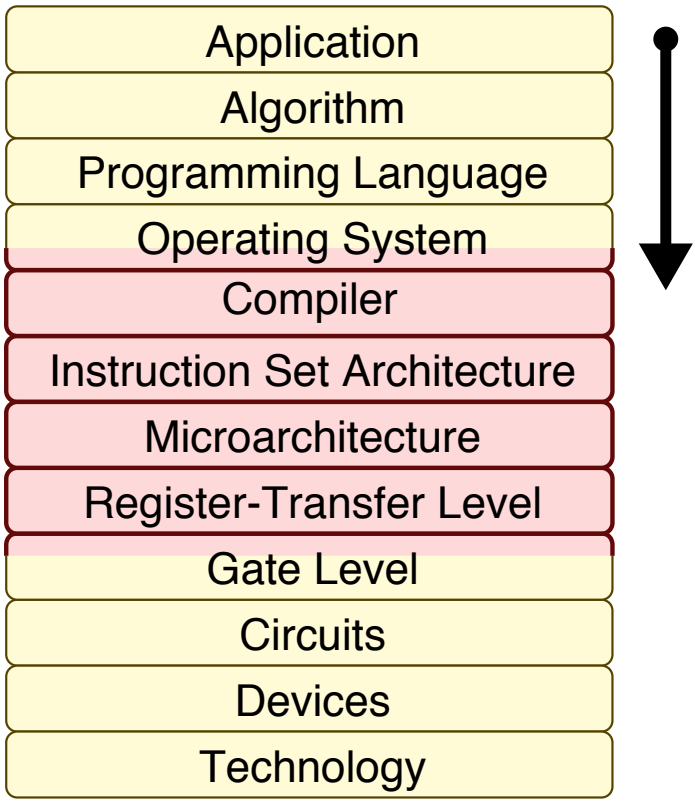
Lab 1: Computer Engineering – Hardware Perspective

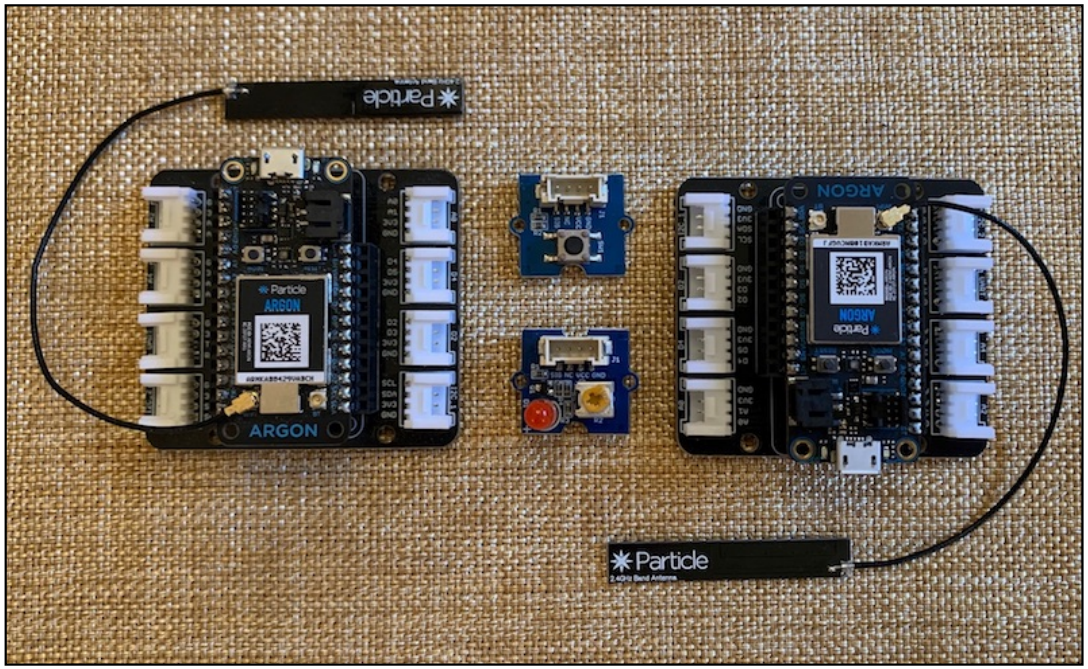




Scholars will assemble basic logic gates to implement a simple "calculator" for adding small binary numbers

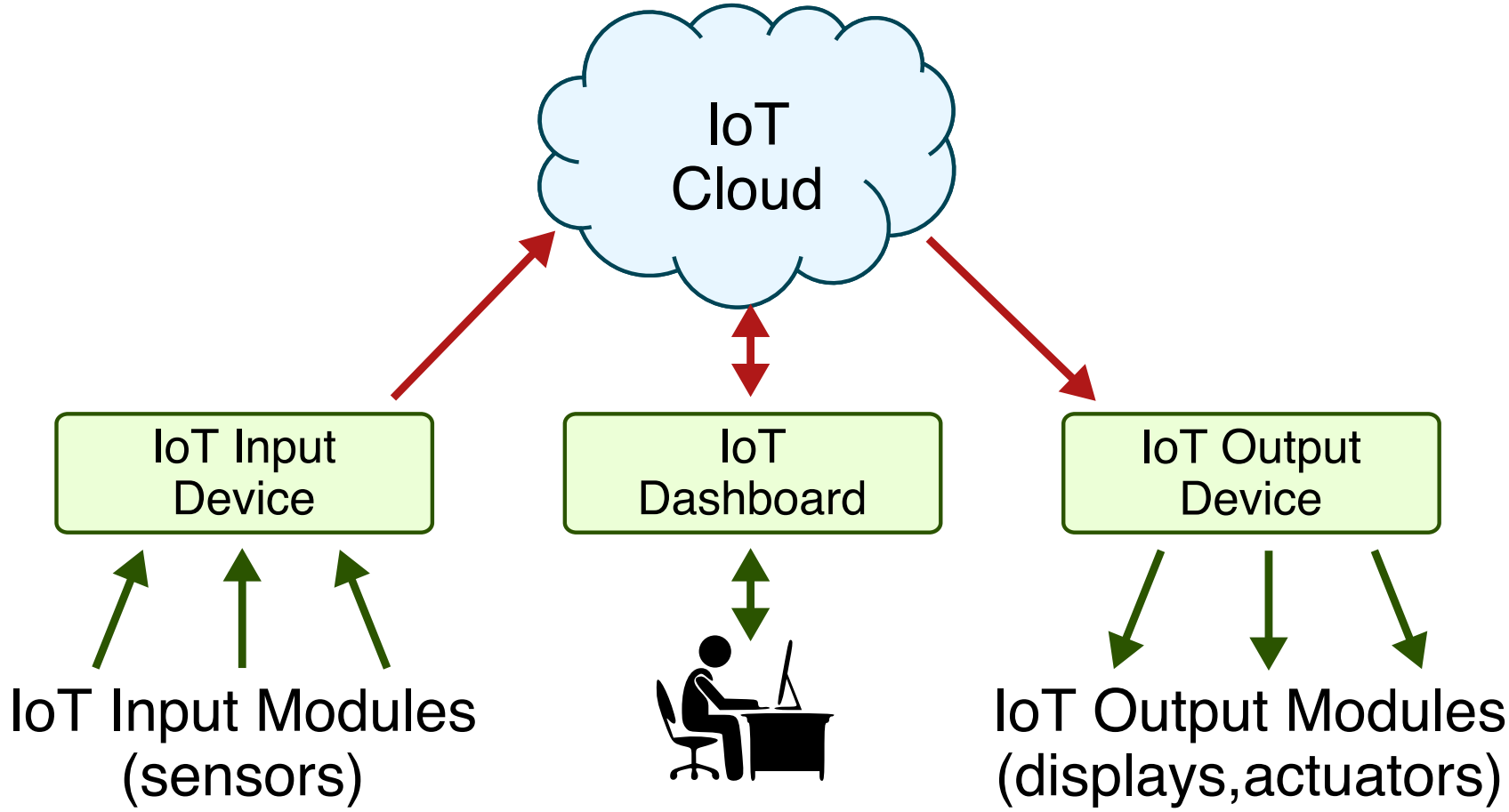
Lab 2: Computer Engineering – Software Perspective



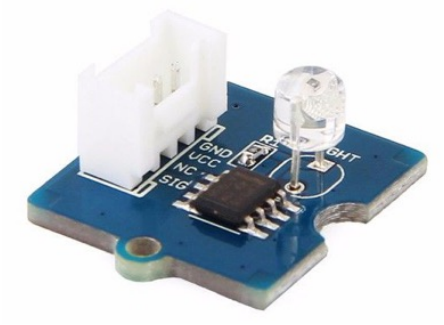


Scholars will incrementally program a microcontroller in C++ to implement an IoT "smart light" system

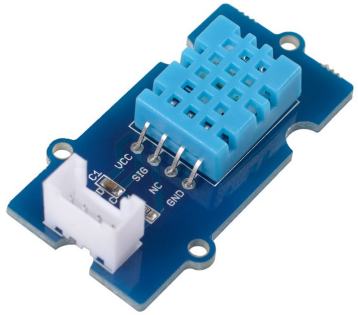
CURIE IoT Design Projects



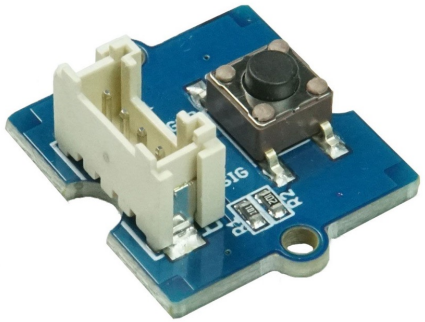
CURIE IoT Input Modules



Light

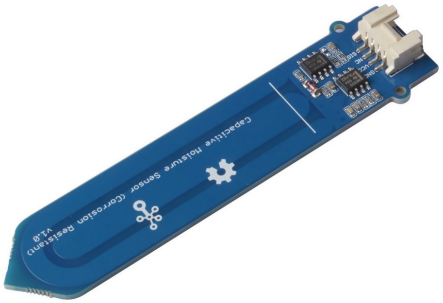


Temp & Humidity



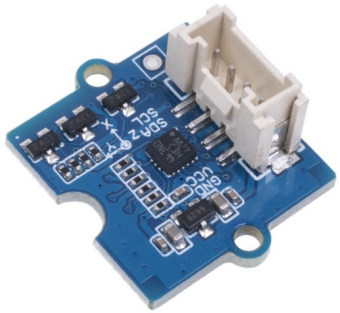
Button

Rotation



Soil Moisture

Water



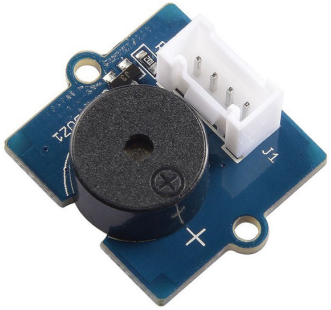
Acceleration

Range

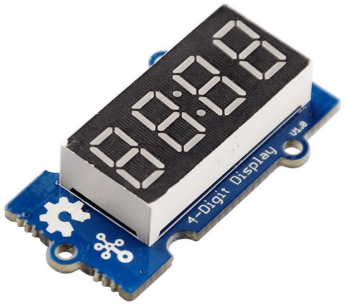
CURIE IoT Output Modules

LED

Multi-Color LED



Buzzer



4-Digit Display

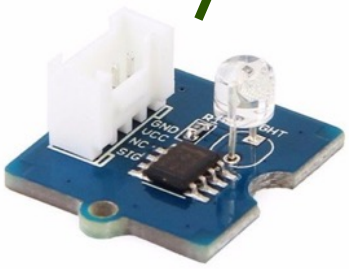
CURIE IoT Smart Home

IoT Cloud

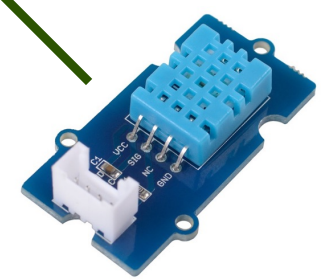
IoT Input Device

IoT Dashboard

IoT Output Device



Light



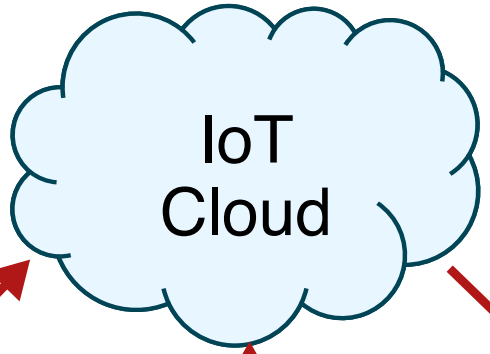
Temperature

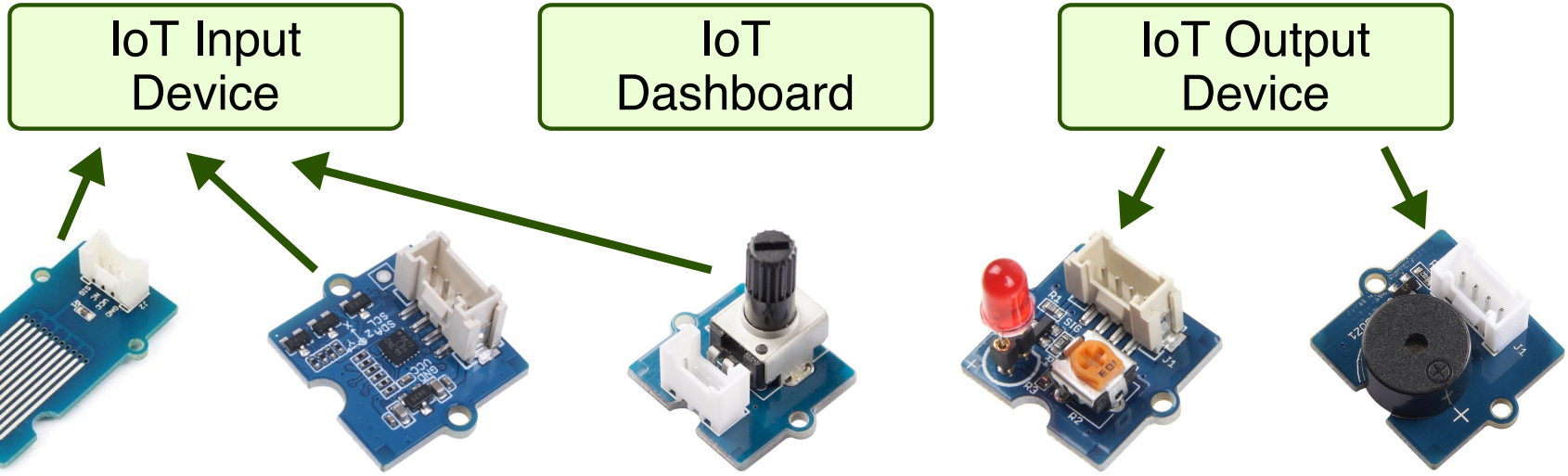
Range

Multi-Color LED

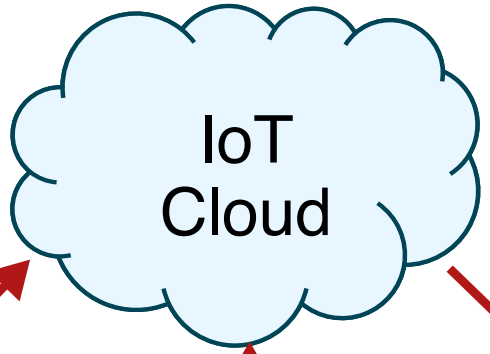
Buzzer

CURIE IoT Early Disaster Warning System





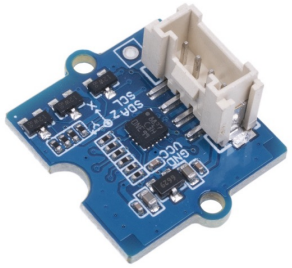
CURIE IoT Wearable Health Monitor



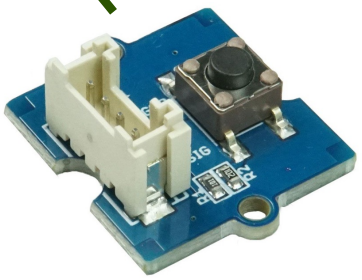
IoT Input Device

IoT Dashboard

IoT Output Device

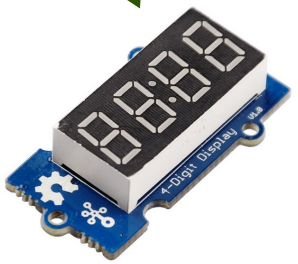


Acceleration



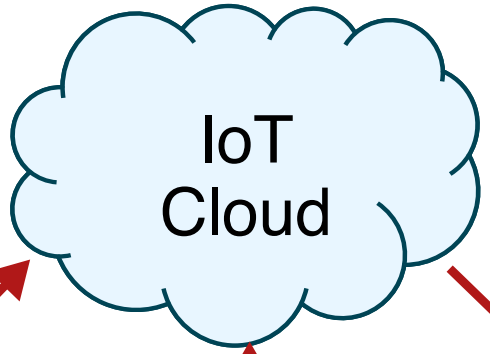
Button

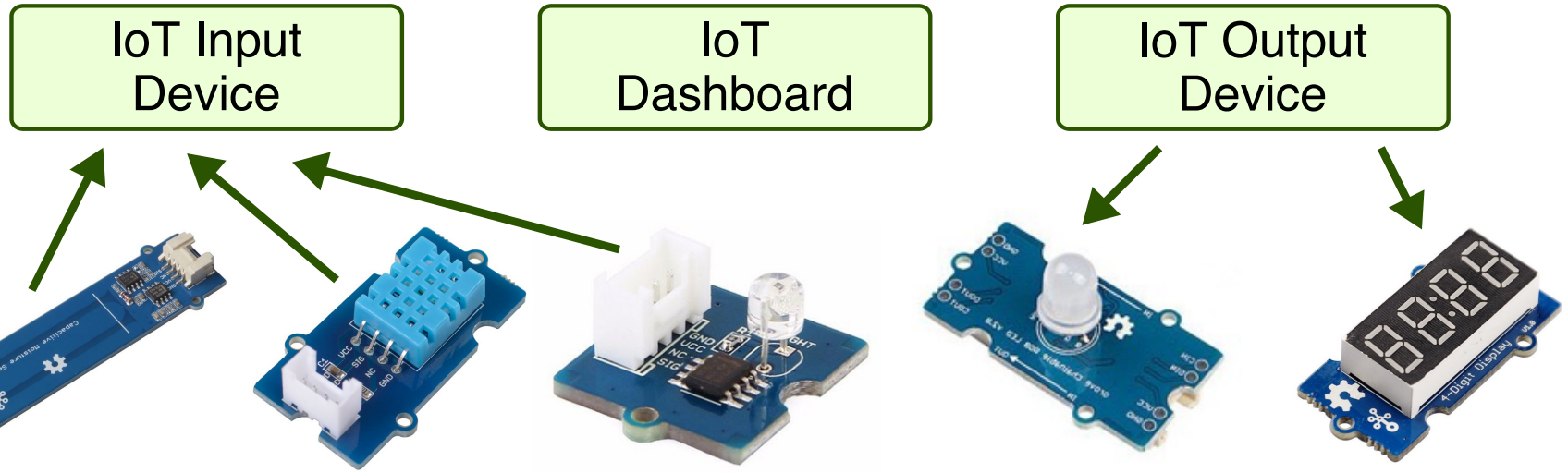
Multi-Color LED



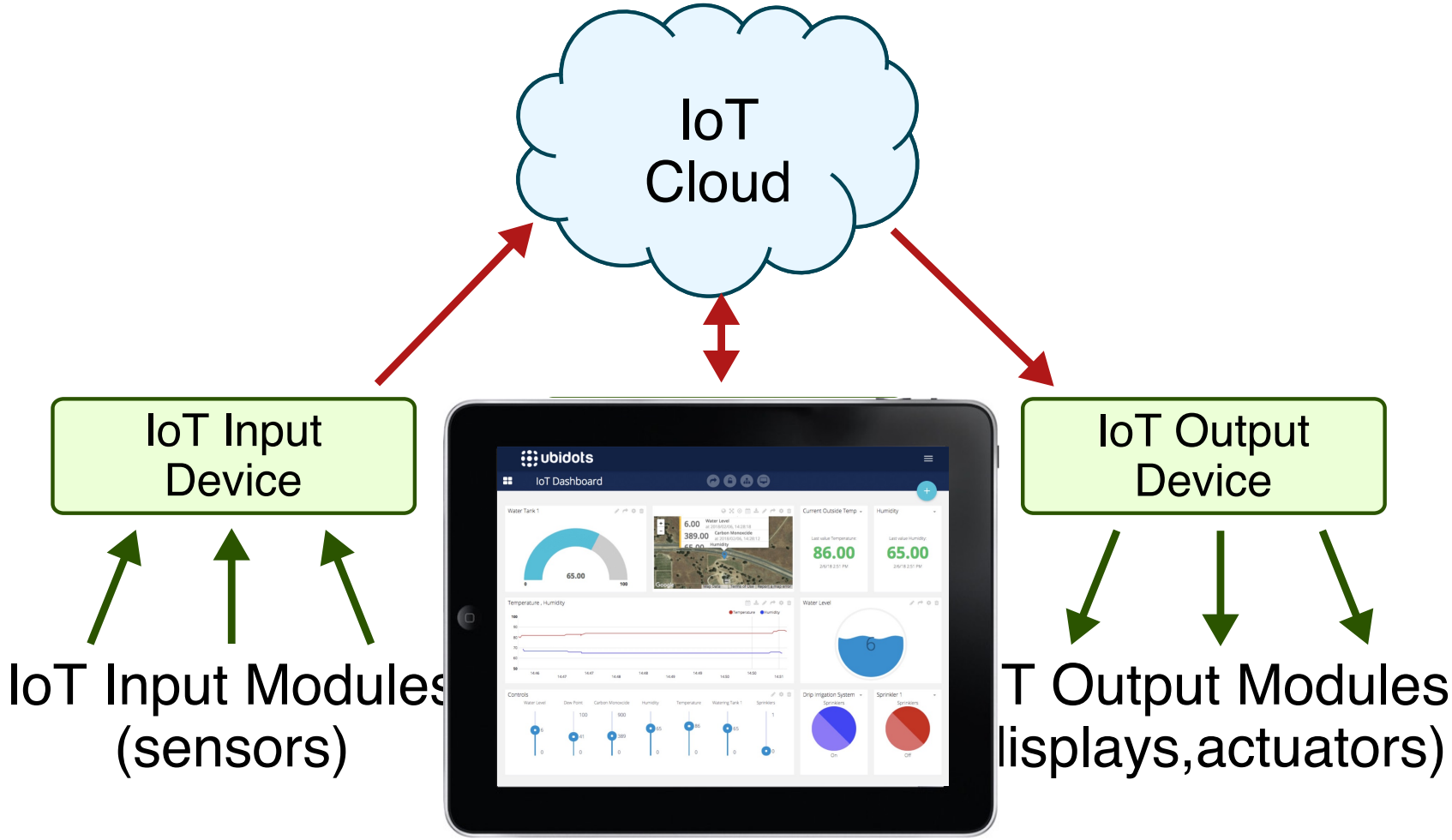
4-Digit Display

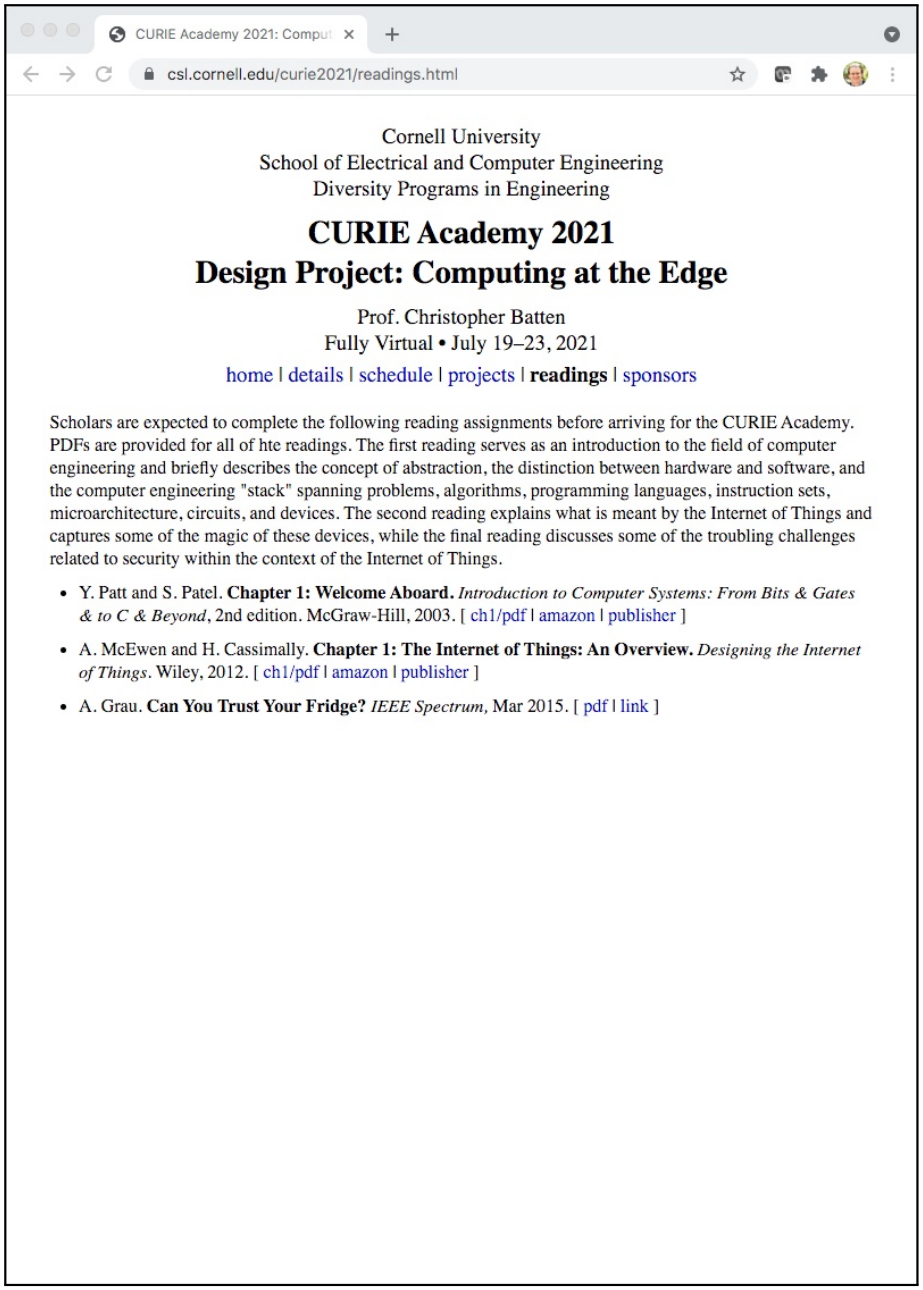
CURIE IoT Digital Agriculture





CURIE IoT Dashboard





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Design Project: Computing at the Edge

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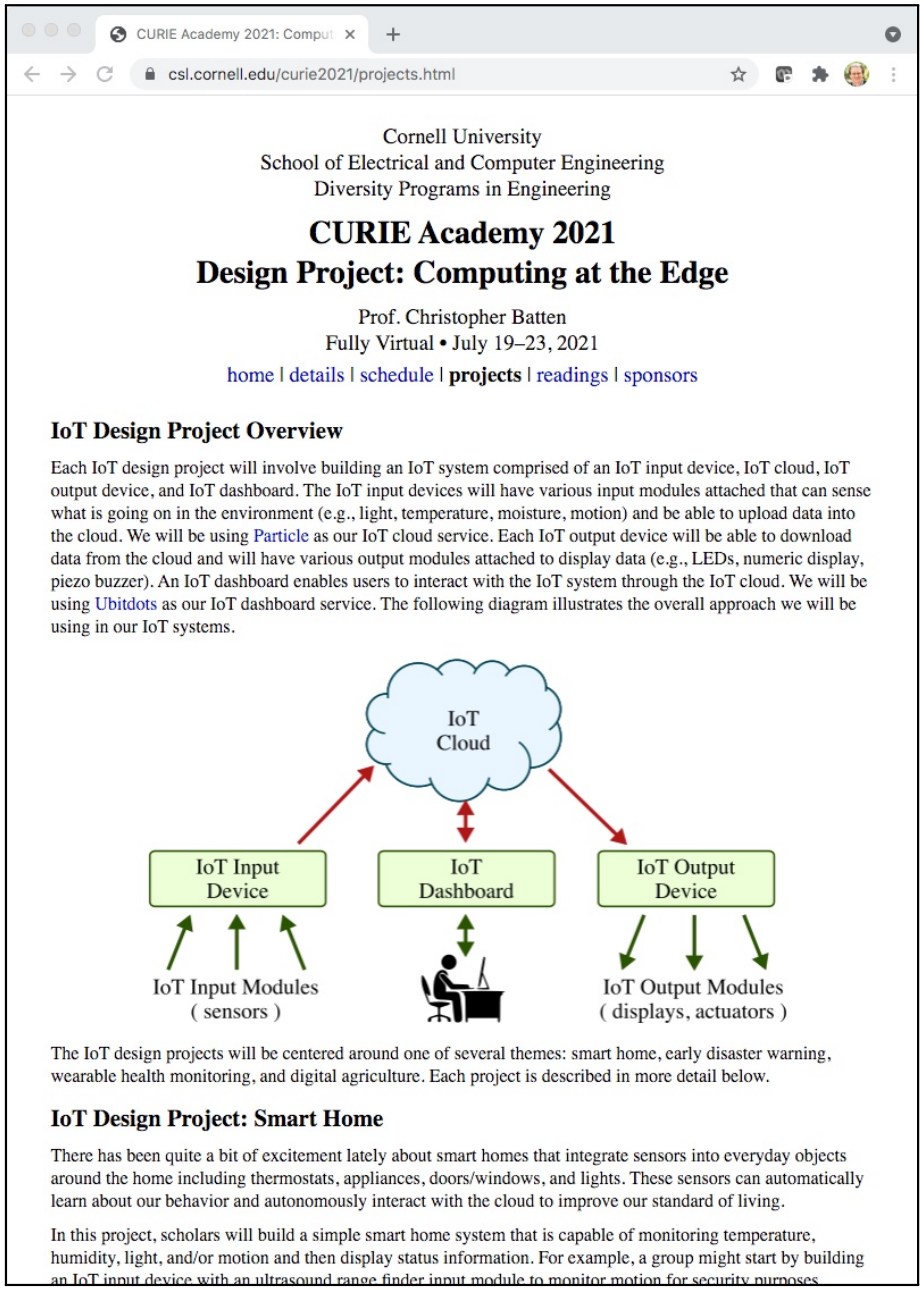
Scholars are expected to complete the following reading assignments before arriving for the CURIE Academy. PDFs are provided for all of hte readings. The first reading serves as an introduction to the field of computer engineering and briefly describes the concept of abstraction, the distinction between hardware and software, and the computer engineering "stack" spanning problems, algorithms, programming languages, instruction sets, microarchitecture, circuits, and devices. The second reading explains what is meant by the Internet of Things and captures some of the magic of these devices, while the final reading discusses some of the troubling challenges related to security within the context of the Internet of Things.

- Y. Patt and S. Patel. **Chapter 1: Welcome Aboard.** *Introduction to Computer Systems: From Bits & Gates & to C & Beyond*, 2nd edition. McGraw-Hill, 2003. [ch1/pdf | amazon | publisher]
- A. McEwen and H. Cassimally. **Chapter 1: The Internet of Things: An Overview.** *Designing the Internet of Things*. Wiley, 2012. [ch1/pdf | amazon | publisher]
- A. Grau. **Can You Trust Your Fridge?** *IEEE Spectrum*, Mar 2015. [pdf | link]



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IoT Design Project Overview

Each IoT design project will involve building an IoT system comprised of an IoT input device, IoT cloud, IoT output device, and IoT dashboard. The IoT input devices will have various input modules attached that can sense what is going on in the environment (e.g., light, temperature, moisture, motion) and be able to upload data into the cloud. We will be using Particle as our IoT cloud service. Each IoT output device will be able to download data from the cloud and will have various output modules attached to display data (e.g., LEDs, numeric display, piezo buzzer). An IoT dashboard enables users to interact with the IoT system through the IoT cloud. We will be using Ubitdots as our IoT dashboard service. The following diagram illustrates the overall approach we will be using in our IoT systems.

The IoT design projects will be centered around one of several themes: smart home, early disaster warning, wearable health monitoring, and digital agriculture. Each project is described in more detail below.

IoT Design Project: Smart Home

There has been quite a bit of excitement lately about smart homes that integrate sensors into everyday objects around the home including thermostats, appliances, doors/windows, and lights. These sensors can automatically learn about our behavior and autonomously interact with the cloud to improve our standard of living.

In this project, scholars will build a simple smart home system that is capable of monitoring temperature, humidity, light, and/or motion and then display status information. For example, a group might start by building an IoT input device with an ultrasound range finder input module to monitor motion for security purposes

Design Project Summary

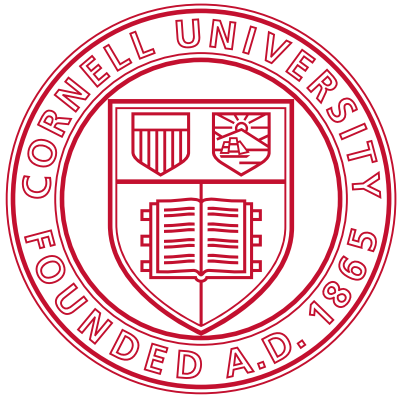
- Lab 1: Computer Engineering from the Hardware Perspective
- Lab 2: Computer Engineering from the Software Perspective
- Projects involve designing, implementing, and testing a simple IoT system inspired by real-world applications of IoT

Goal: Introduce CURIE scholars broadly to the practice of engineering and more specifically to computer engineering

CURIE Design Project Sponsors

Funding partially provided by the National Science Foundation through NSF SHF Award #2008471

An equipment donation including Argon Internet-of-Thing devices was provided by Particle Industries



Funding and logistics partially provided by the Diversity Programs in Engineering Office