Microsoft

Battery-free, RF-powered cameras

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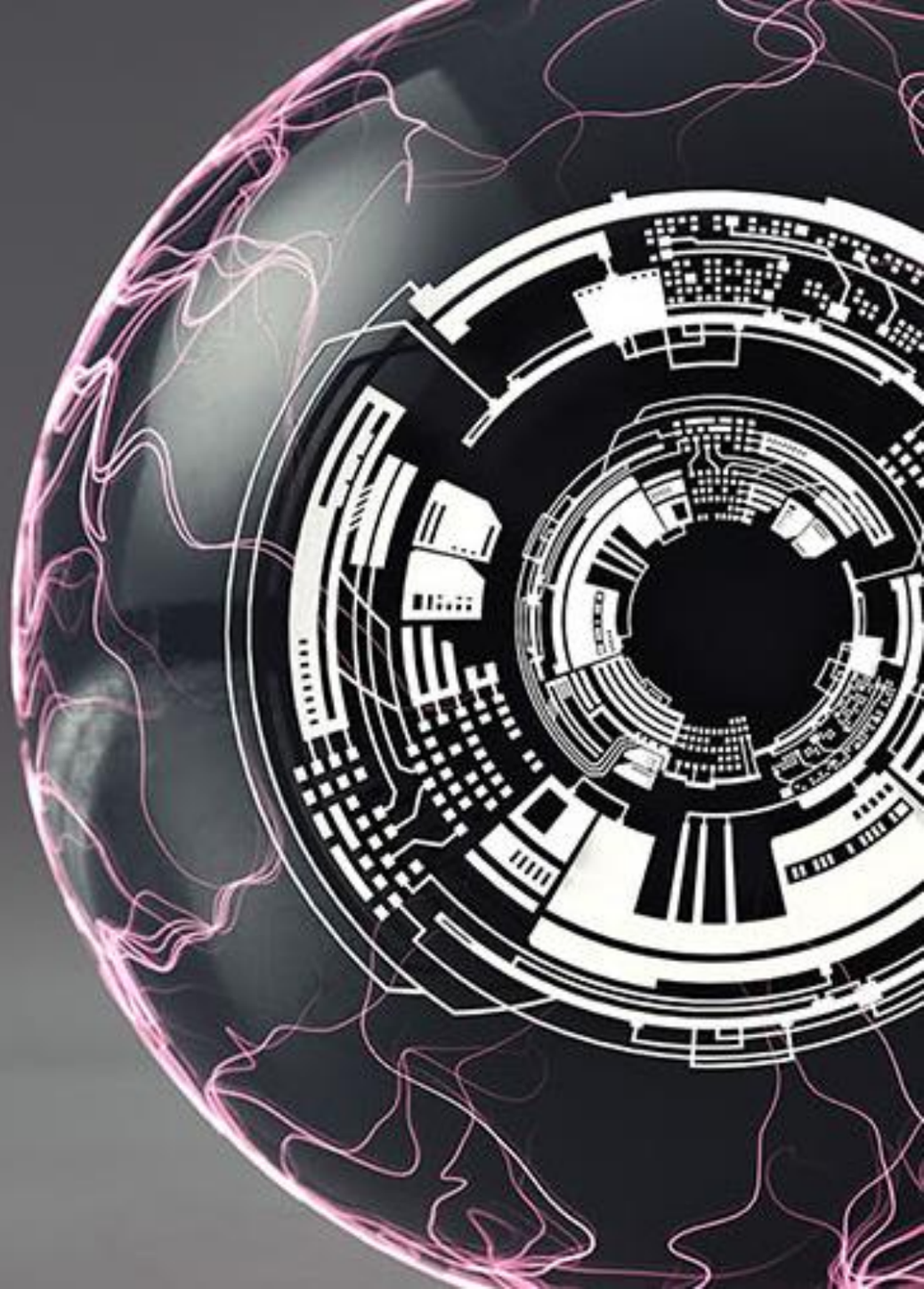


WISP: Wireless Identification and Sensing Platform

First UHF-powered accelerometer

Battery-Free Wireless Identification and Sensing, M.Philipose, J.R. Smith, B. Jiang, K. Sundara-Rajan, A. Mamishev, S. Roy. IEEE Pervasive Comp., V4 N1, 2005
A wirelessly powered platform for sensing and computation, J.R. Smith, A. Sample, P. Powledge, A. Mamishev, S. Roy. *Ubicomp 2006*
RFID Sensor Networks with the Intel WISP *Best Demo, Sensys,* M. Buettner, B. Greenstein, R. Prasad, A. Sample, J.R. Smith, D. Yeager, D. Wetherall, 2008

Sensor Systems Lab Students

Saman Naderiparizi

Zerina Kapetanovic

Vaishnavi Ranganathan

Yi “Eve” Zhao

Microsoft Interns this summer!

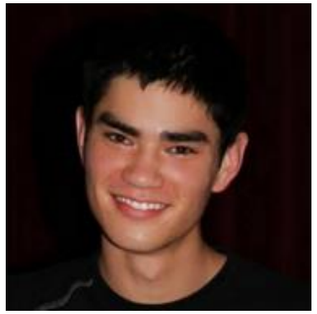
Xingyi Shi

Gregory Moore

Aaron Parks

Brody Mahony

Jim Youngquist



Patrick Lancaster

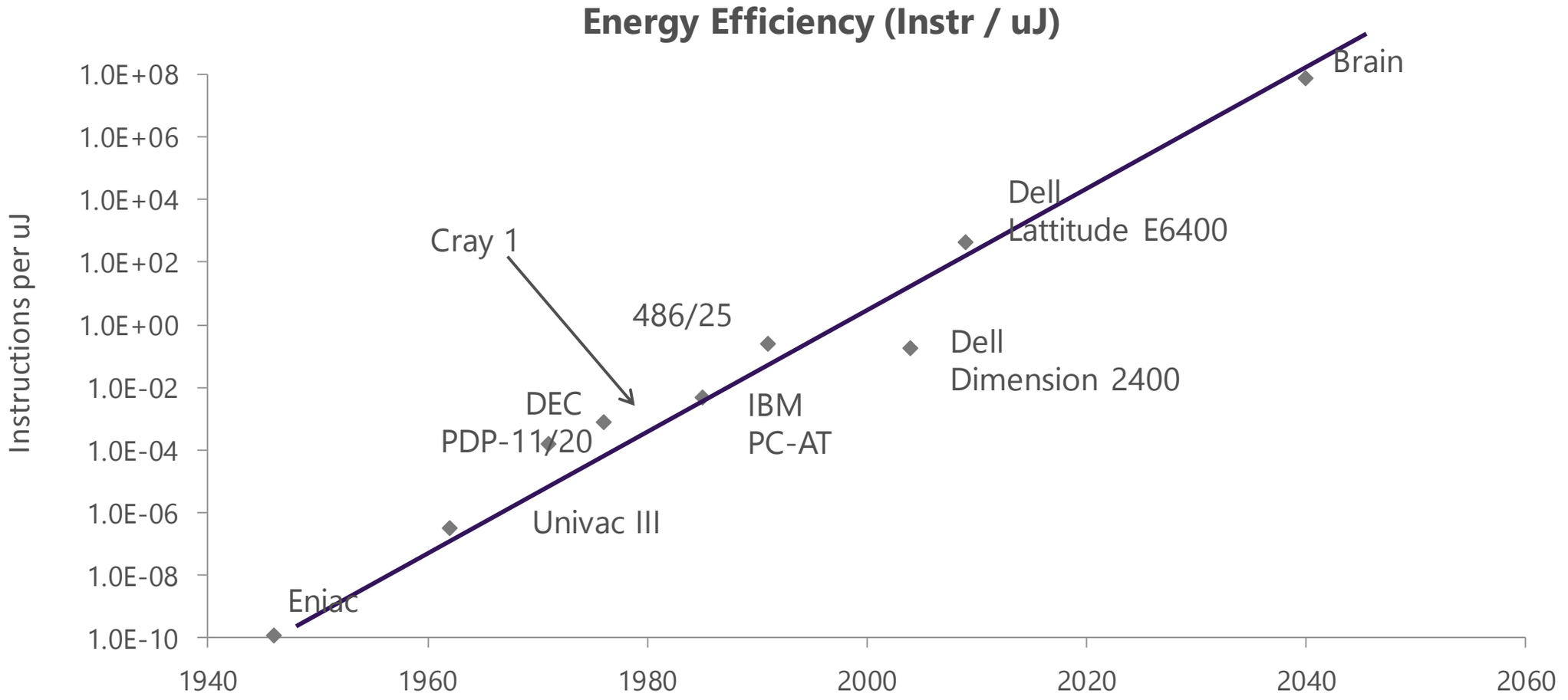
Vamsi Talla

Ben Waters, EE

PhD alums

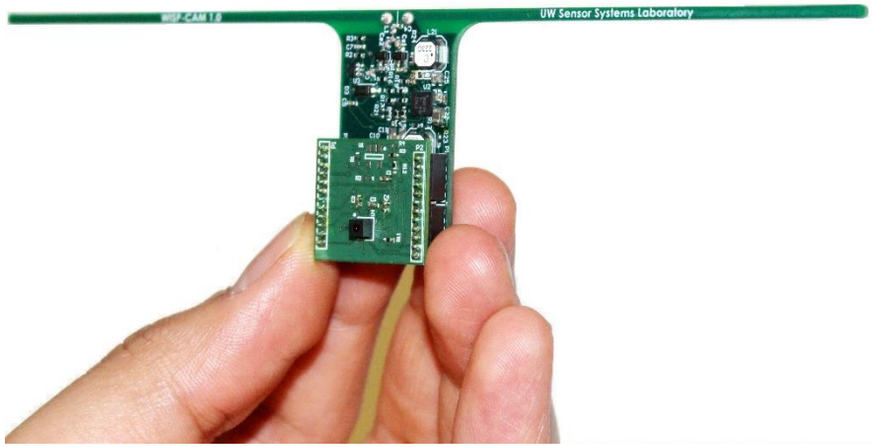
Enabling trend

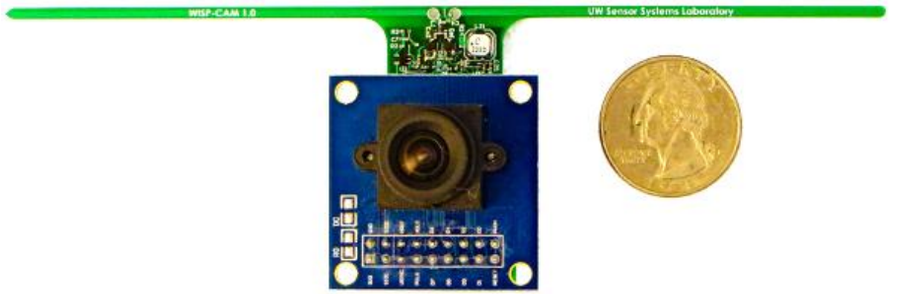
Energy Efficiency Scaling



Data: ***Implications of Historical Trends in the Electrical Efficiency of Computing***
Koomey, Berard, Sanchez et al, IEEE Annals of the History of Computing, 2011

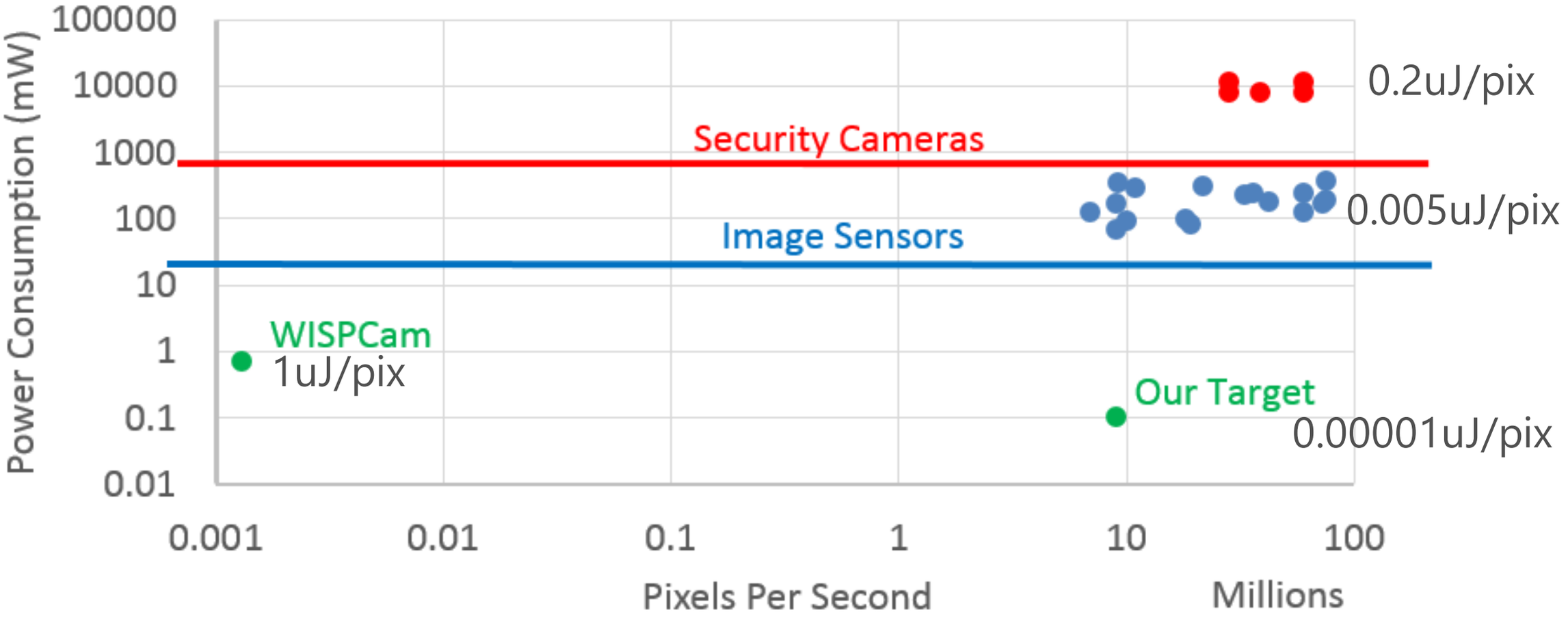
WISPCam: A Battery-Free RFID Camera





Saman Naderiparizi, A. N. Parks, Z. Kapetanovic, Y. Zhao, J. Youngquist, B. Ransford and J. R. Smith,
IEEE RFID 2015, ACM Ubicomp 2015, GetMobile Magazine 2016

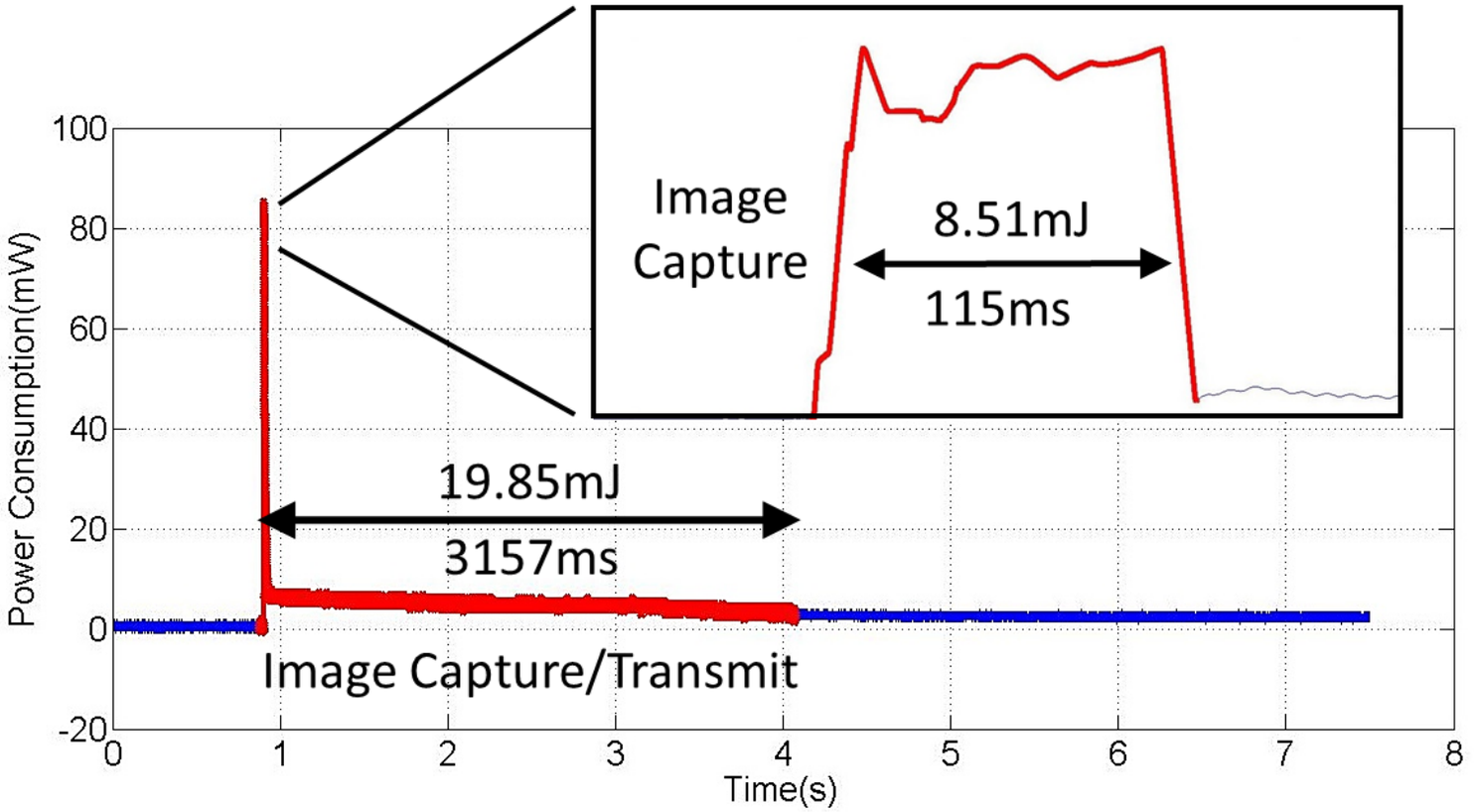
Camera power-performance scaling



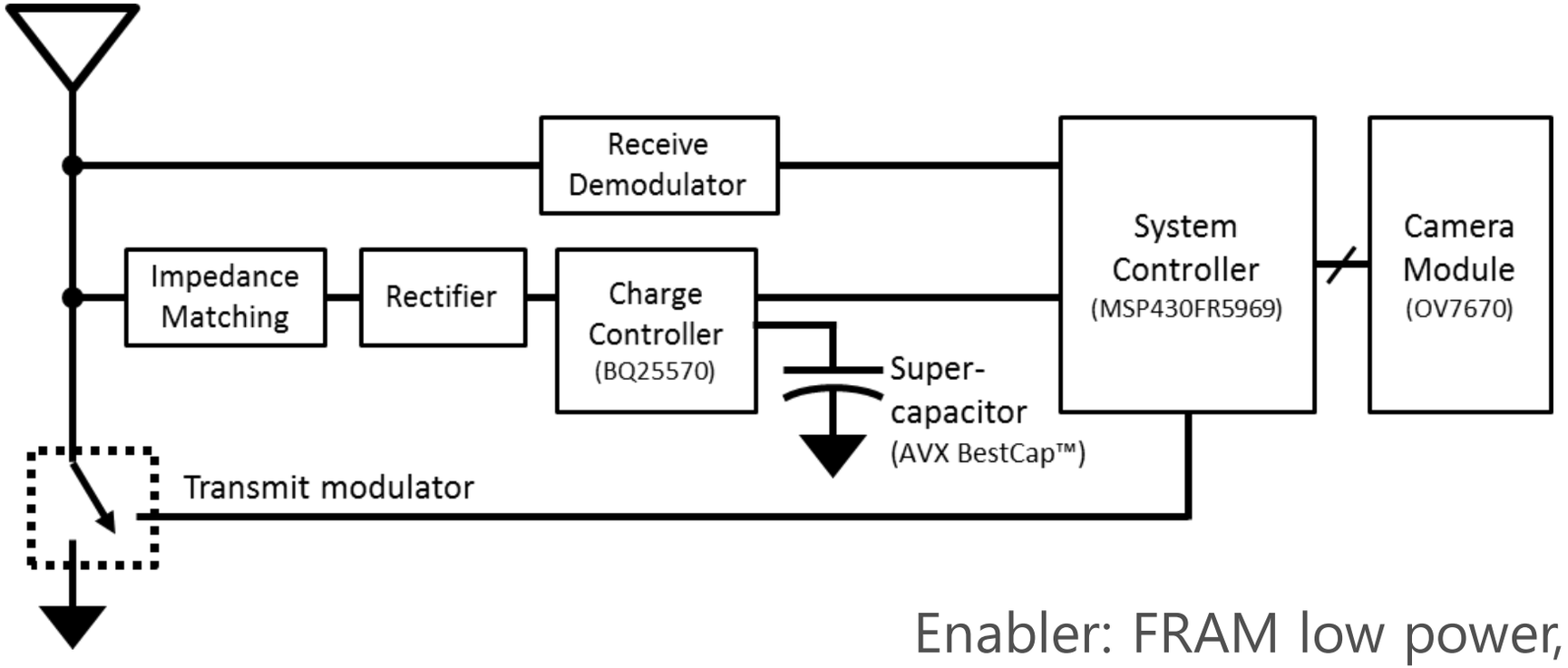
Battery-free sensing overview

We have previously shown battery-free sensing using simple sensors such as temperature, acceleration, …

WISPCam Energy Consumption

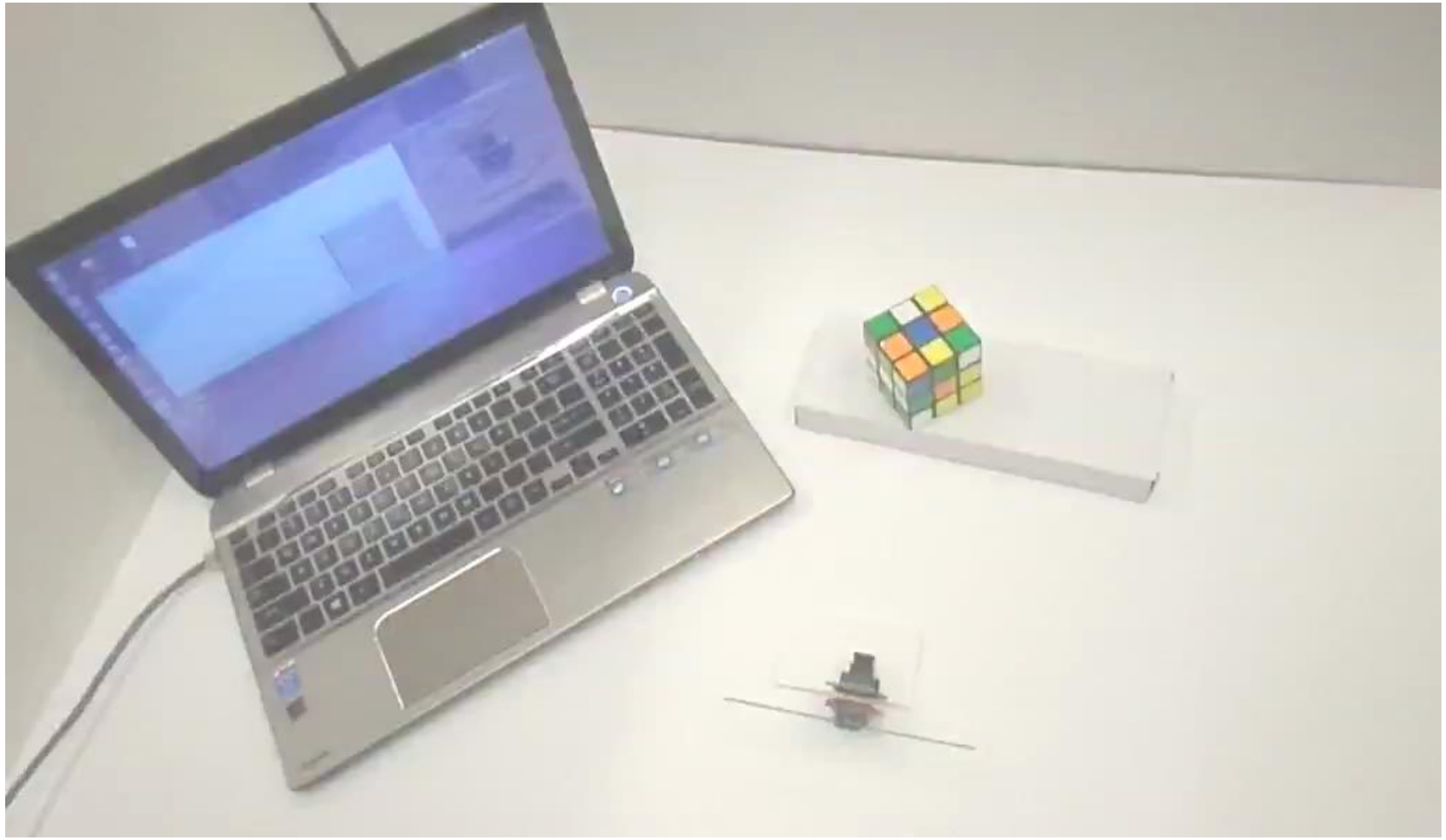


WISPCam System Overview



Enabler: FRAM low power, non-volatile storage of image

WISPCam demo video



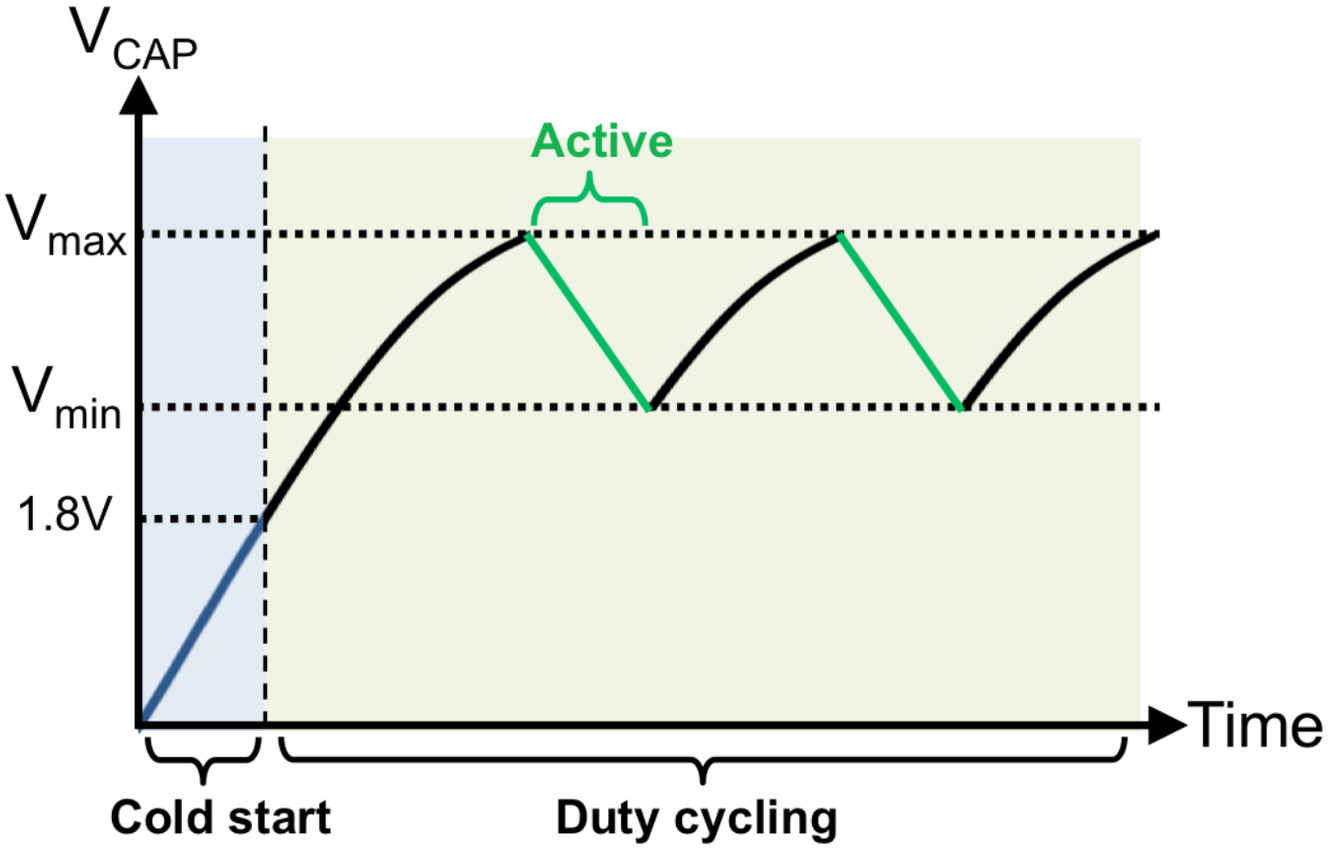
Enabling a battery-free camera

Efficient on-board large energy storage.

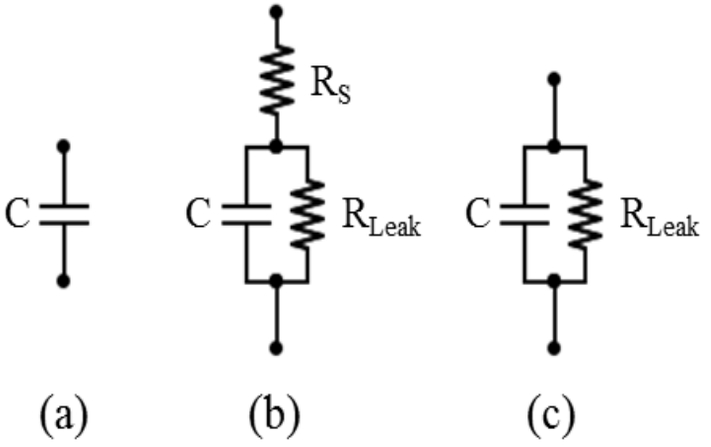
Large data storage and transmission on an energy-constrained system

Efficient Charge Storage

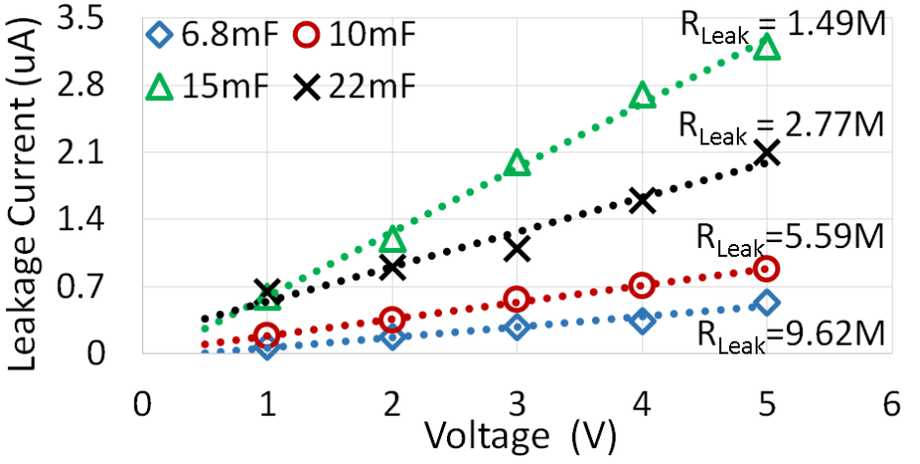
$\frac{1}{2} C(V_{max}^2 - V_{min}^2)$



Leakage



Super capacitor electrical model



Leakage of various super capacitors

Generally the higher the C the higher the leakage current

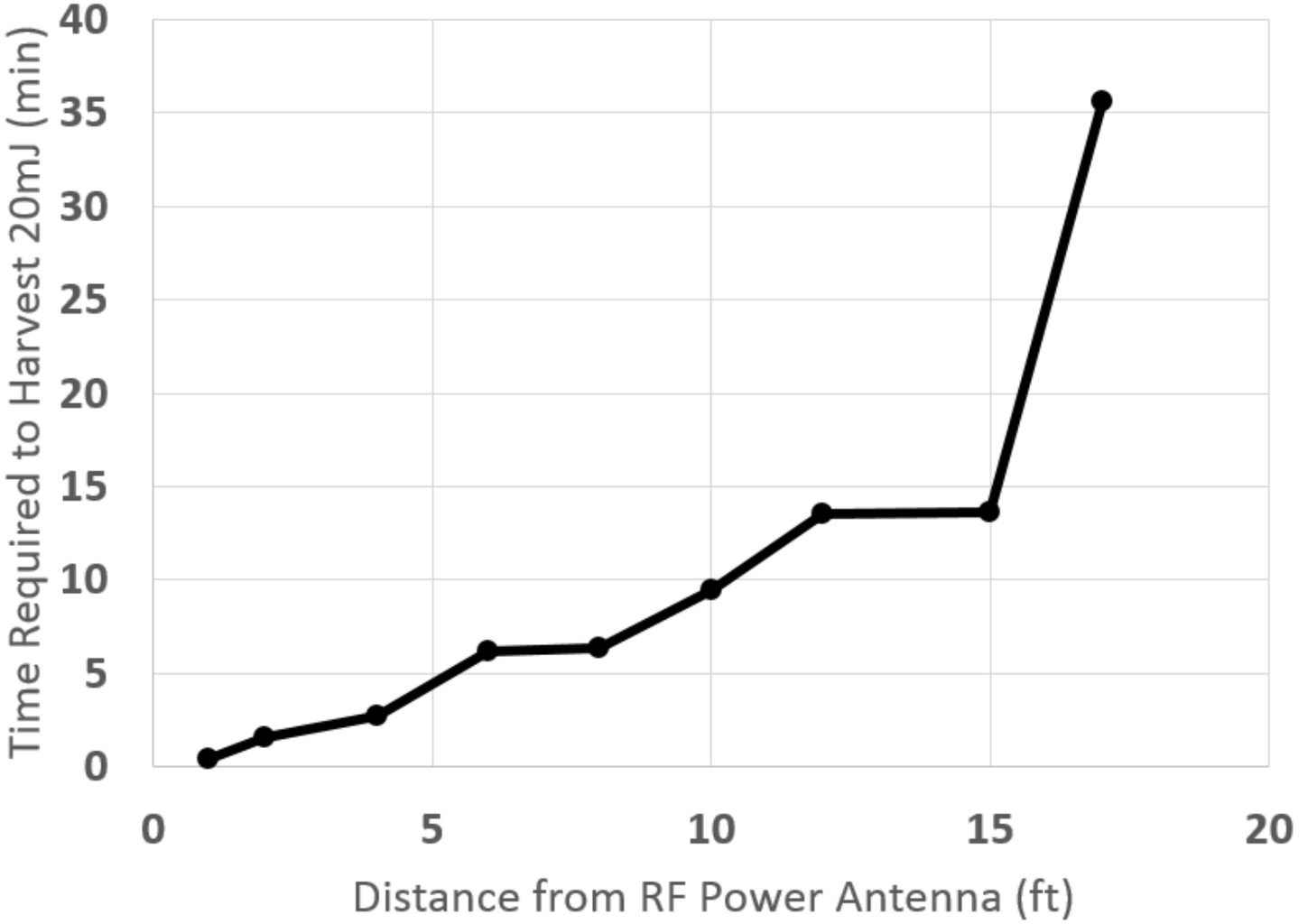
Usable Power While Charging

Required Energy
Minimum voltage threshold
Leakage resistance
Charging power

Usable Power

Input Power	6.08mF	11.24mF	21.98mF	17.45mF
10uW	8.8uW	8.3uW	6.8uW	3.9uW
100uW	99uW	98uW	97uW	95uW

WISPCam Update Rate



WISPCam Applications

Inaccessible / difficult to access locations

Gauge/meter monitoring

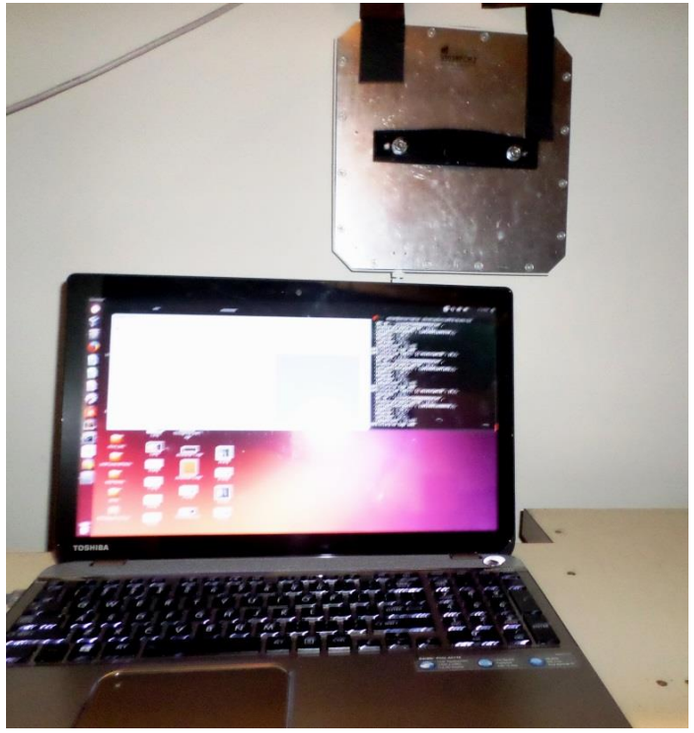
Security

…

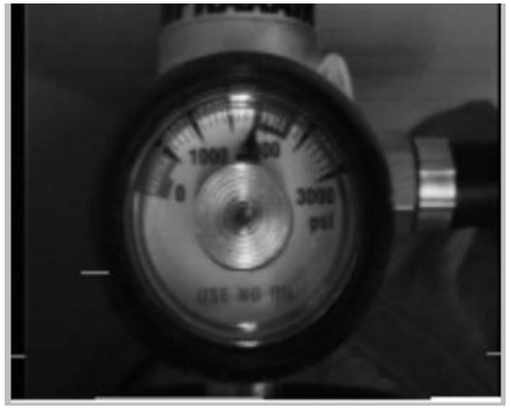
Through-Wall Imaging

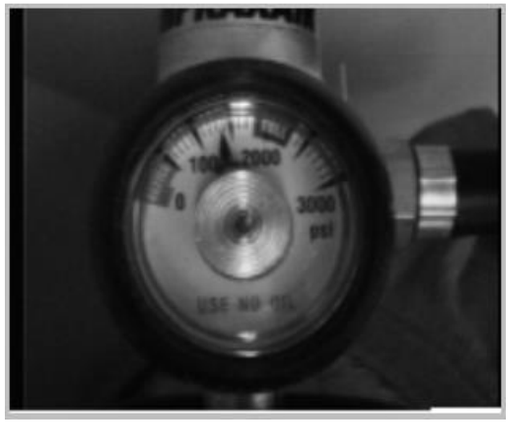
Scene

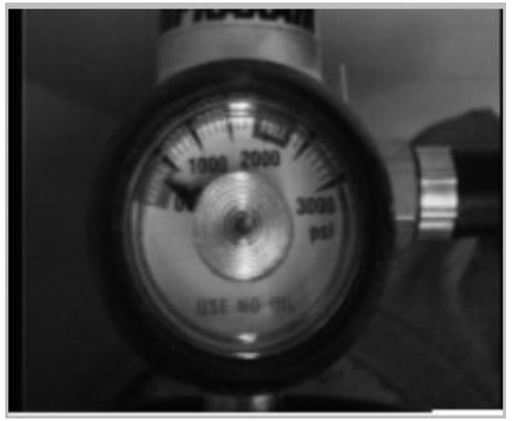
Interface software



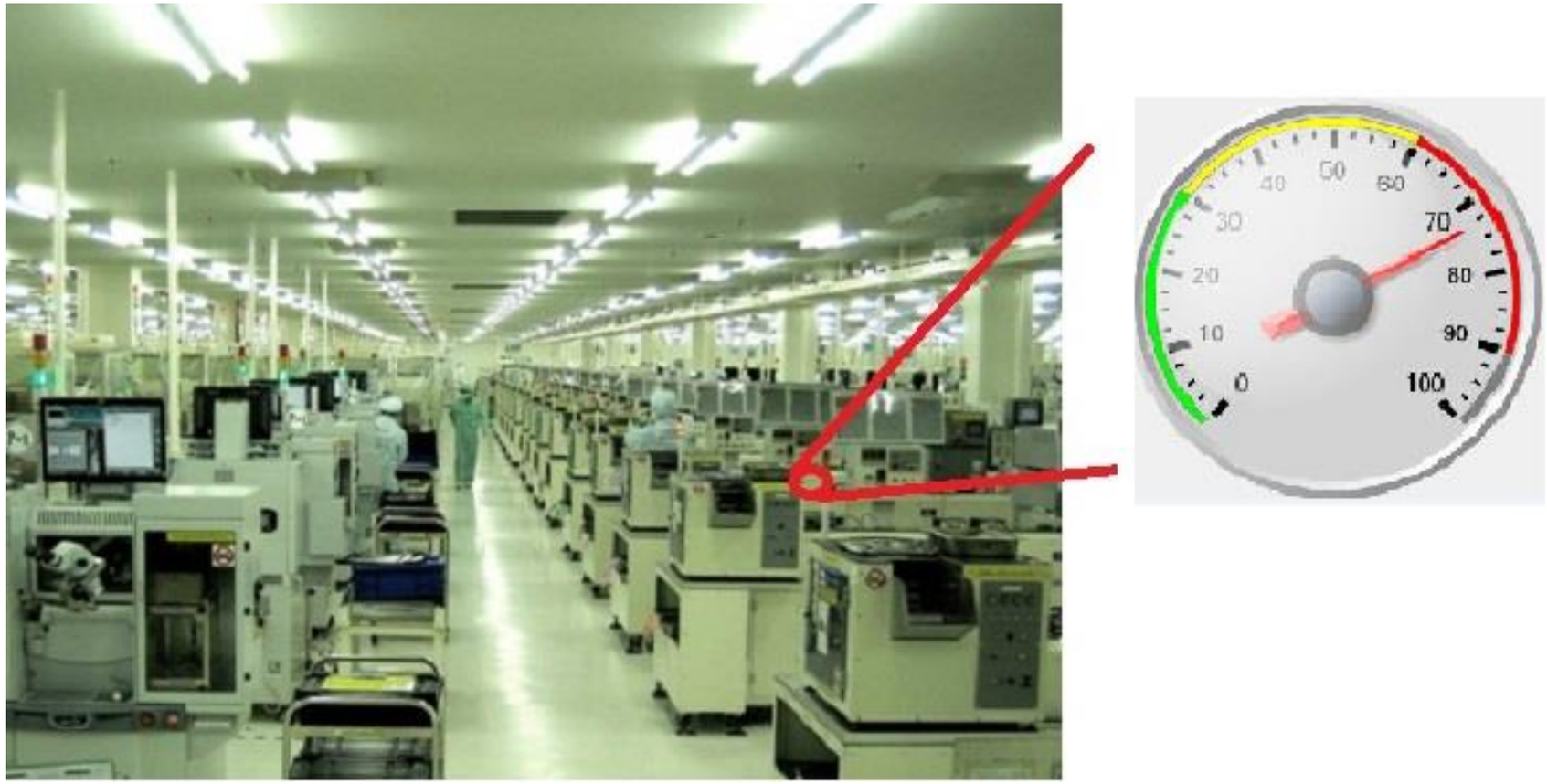
Gas Pressure Gauge







Metering Application Example



Motion Triggered Camera

Computation in WISPCam

WISPCam Limitations:

- Communication Speed
- Computational Capabilities
- Memory

How to do more than just image capture?

Smart Task Categories

Computationally light

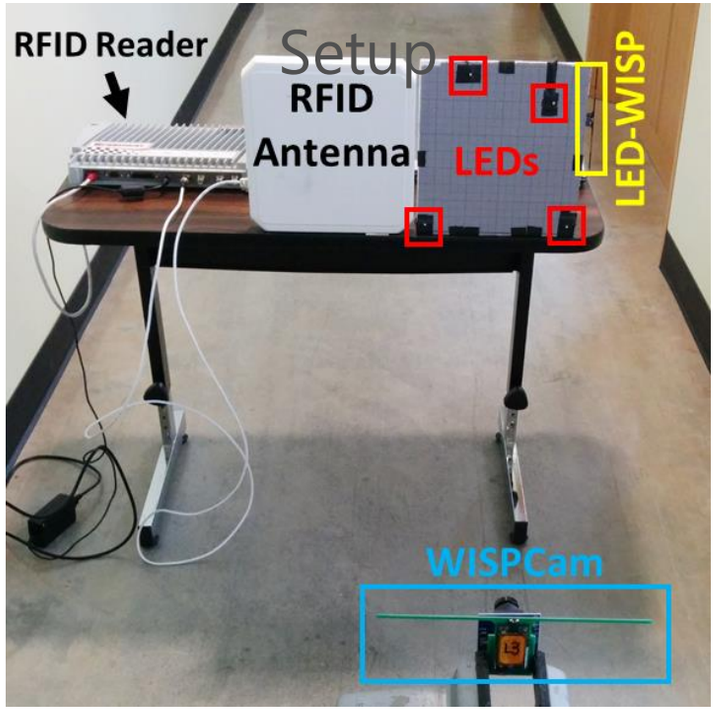
- Image subtraction

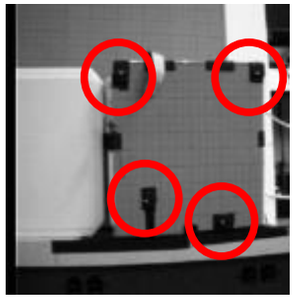
Computationally Demanding

- Face Detection

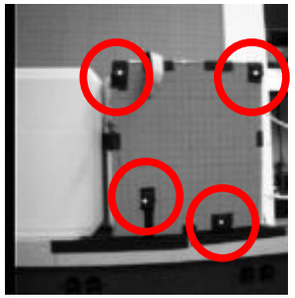
Computationally Light Tasks

Optical localization

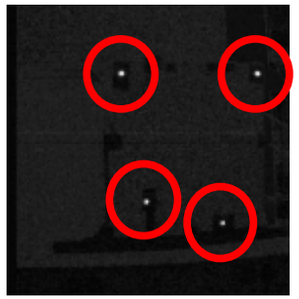




Background

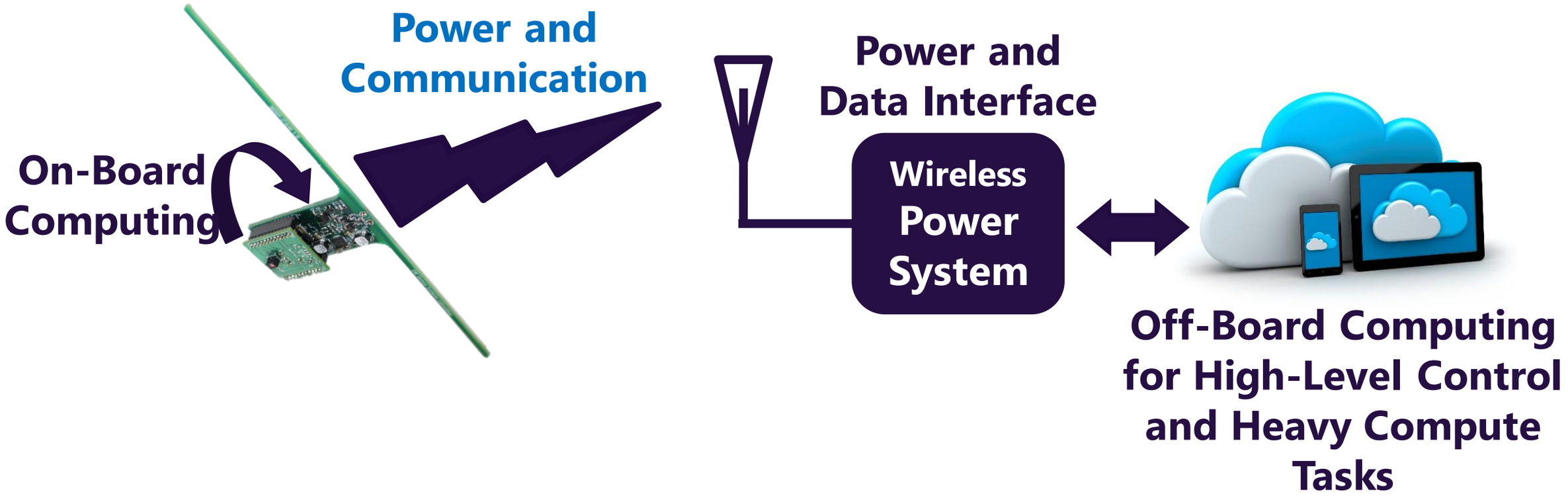


Foreground



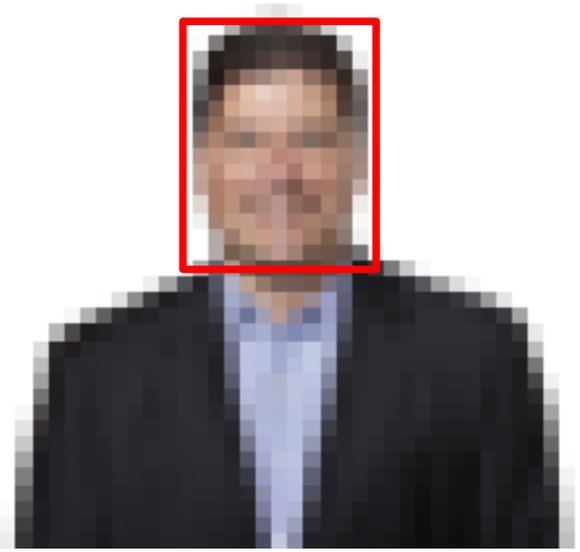
Subtracted

Computationally Demanding Tasks



Face Detection/Recognition Example

Impossible

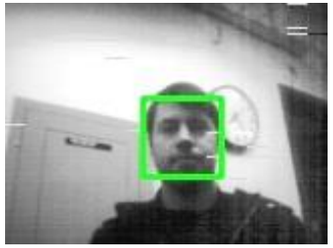


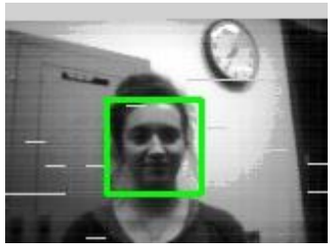
Possible

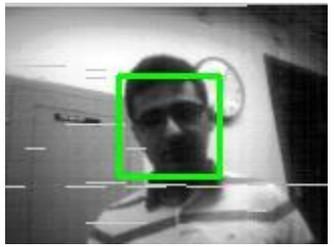
Possible

Face Recognition on a Battery-Free Camera

Low resolution Window





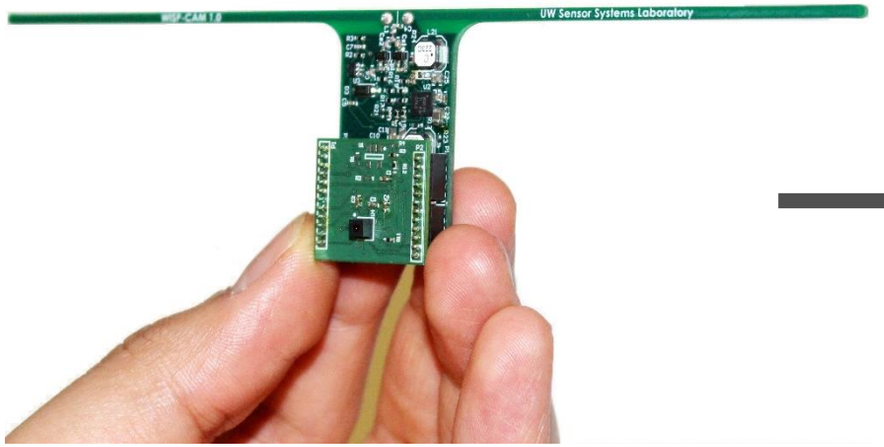


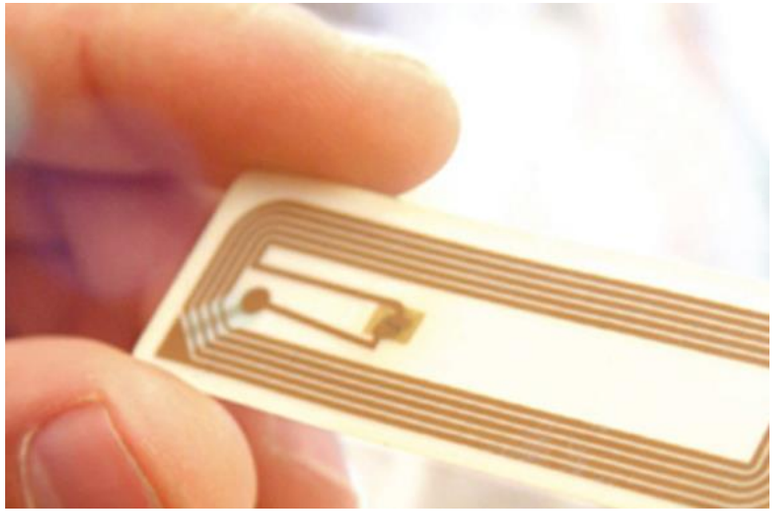
Low resolution Faces

High resolution Faces

Specific-face triggered image capture?

Implications





Cameras can evolve to sticker form factor, with no wires or batteries

Sticker cameras can have substantial computation…trigger on person, event,…

Can deploy them much more widely than would be possible today

Inside walls, containers, gutters, trash cans, …

Will create new privacy “gray areas”…making it easy to see things that in principle are public, but in practice are hard to view

NSF Engineering Research Center on Sensorimotor Neural Engineering (CSNE)

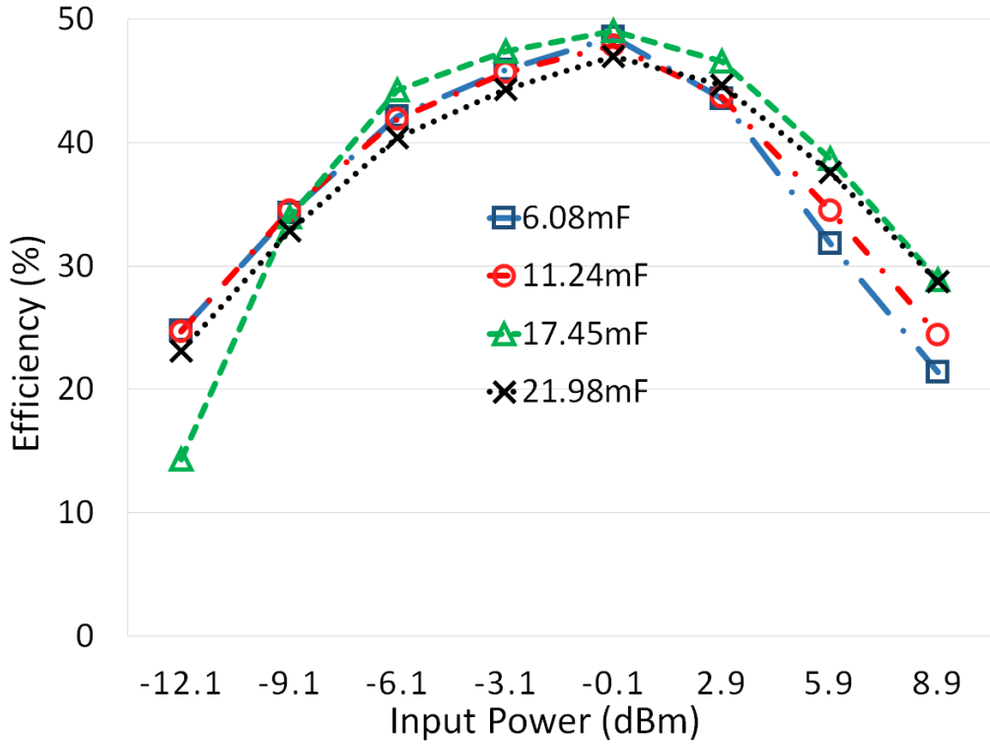
Intel Science and Technology Center for Pervasive Computing (ISTC-PC)

Thank you

WISPCam Harvester Efficiency

WISPCam power harvester efficiency past cold-start

For 17.45mF, efficiency drops faster at lower power levels



How Many Security Cameras are Out There?

- 44ZB data generation per year by 2020
- 50B internet connected devices
- 1.1ZB is security cameras
  - 2.5% of all data ！
  - **245M active security cameras in 2014**

Security Camera Limitations

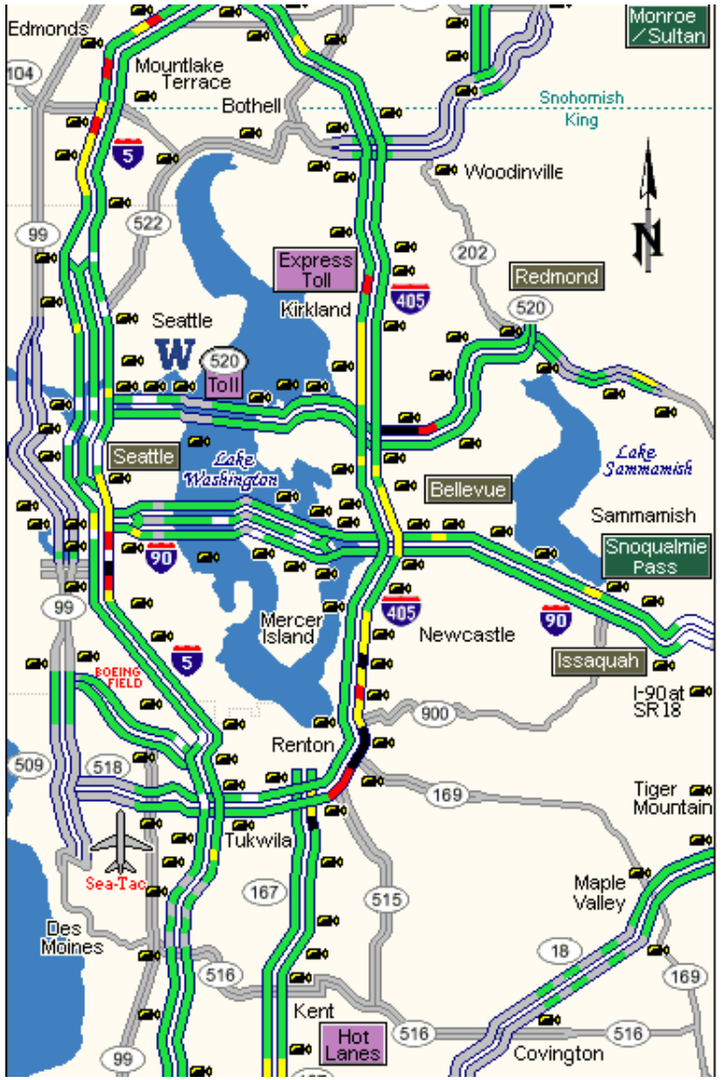
Severe power problem:

- Image Sensor @4K and 15fps (~200mW)
- Video Compression Module and off-chip Image Processor (~1500mW)
- Wireless Communication (~1100mW)

Total about 2800mW.

- Need to be plugged-in.
- Thus limited location usage.

Despite the Limitations …



Security cameras are deployed widely

Eliminating all wires---power and data---will make security cameras even more widespread and enable new applications