The TerraSwarm Research Center (TSRC)

David Blaauw
Prabal Dutta
Kevin Fu
Carlos Guestrin
Roozbeh Jafari
Doug Jones
John Kubiatowicz
Vijay Kumar
Edward Lee
Richard Murray
George Pappas
Jan Rabaey
Anthony Rowe
Alberto Sangiovanni-Vincentelli
Carl M Sechen
Sanjit A. Seshia
Tajana Simunic Rosing
Ben Taskar
John Wawrzynek
David Wessel

Presented by:

Edward A. Lee
EECS, UC Berkeley

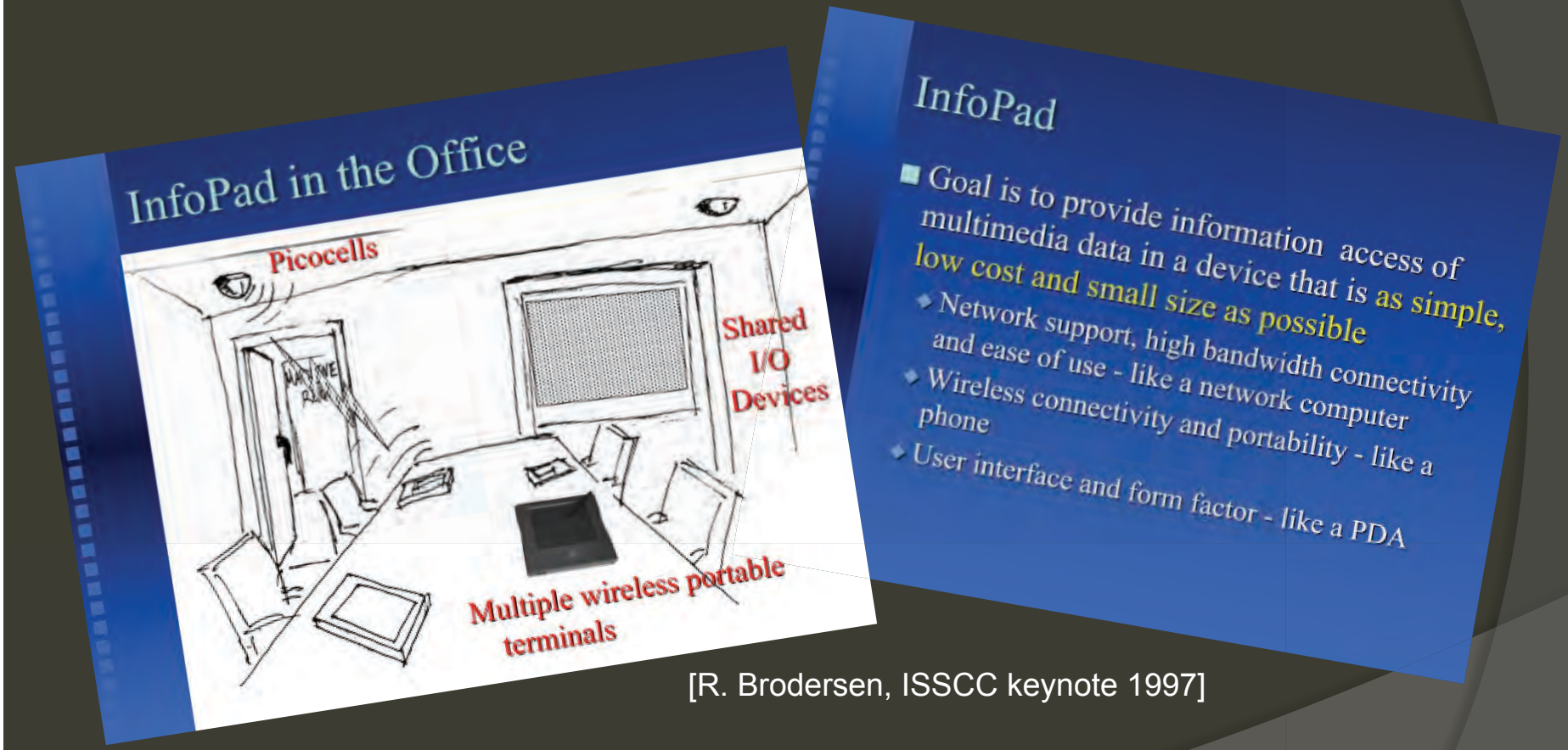
SwarmLab Seminar, Nov. 1, 2012

The Backdrop:
Information Technology

The Cloud

Value from Data Aggregation

Today's Big Thing: The 20 year overnight revolution of wireless handheld devices



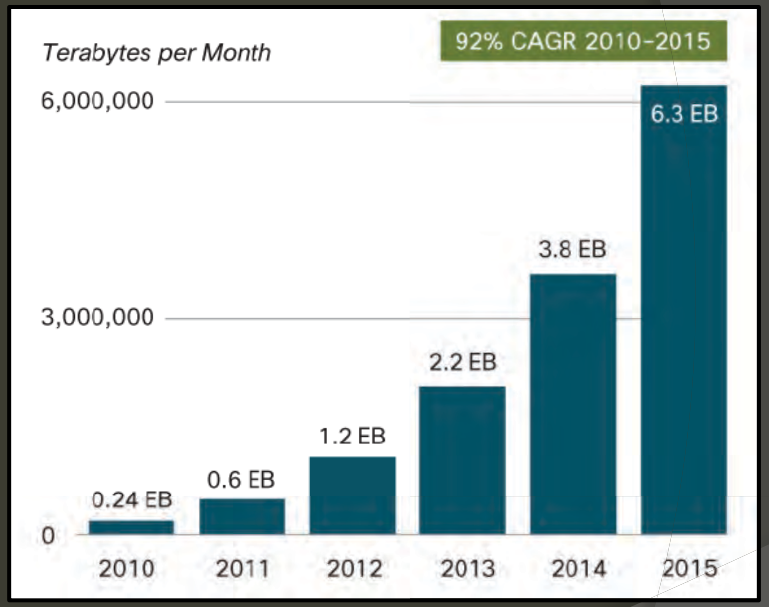
[R. Brodersen, ISSCC keynote 1997]

The Birth of the Wireless Tablet

The UCB Infopad Project (1992-1996)

The IT Platform of Today: Mobiles at the Edge of the Cloud

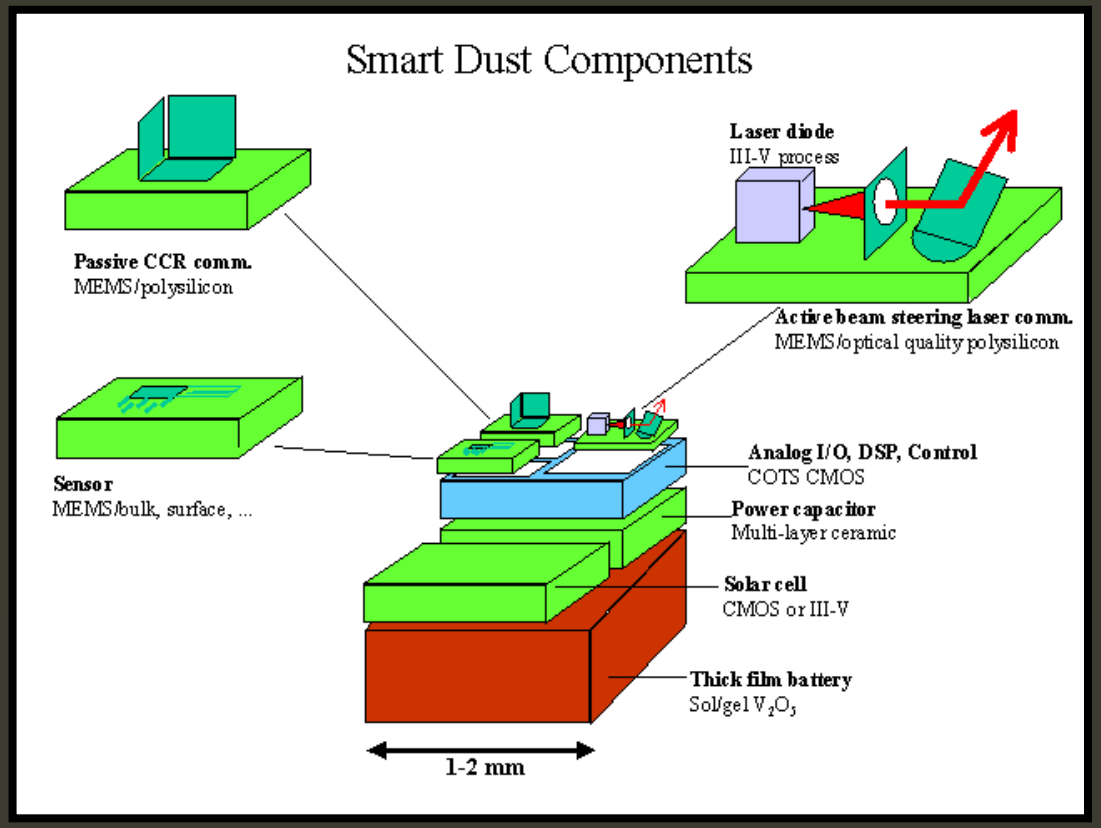
Mobile data growth
[Source: Cisco VNI Mobile, 2011]



Mobile traffic grew 2.6x in 2010 (nearly tripling for 3rd year)
Driven by Tablets

[J. Rabaey, ASPDAC'08]

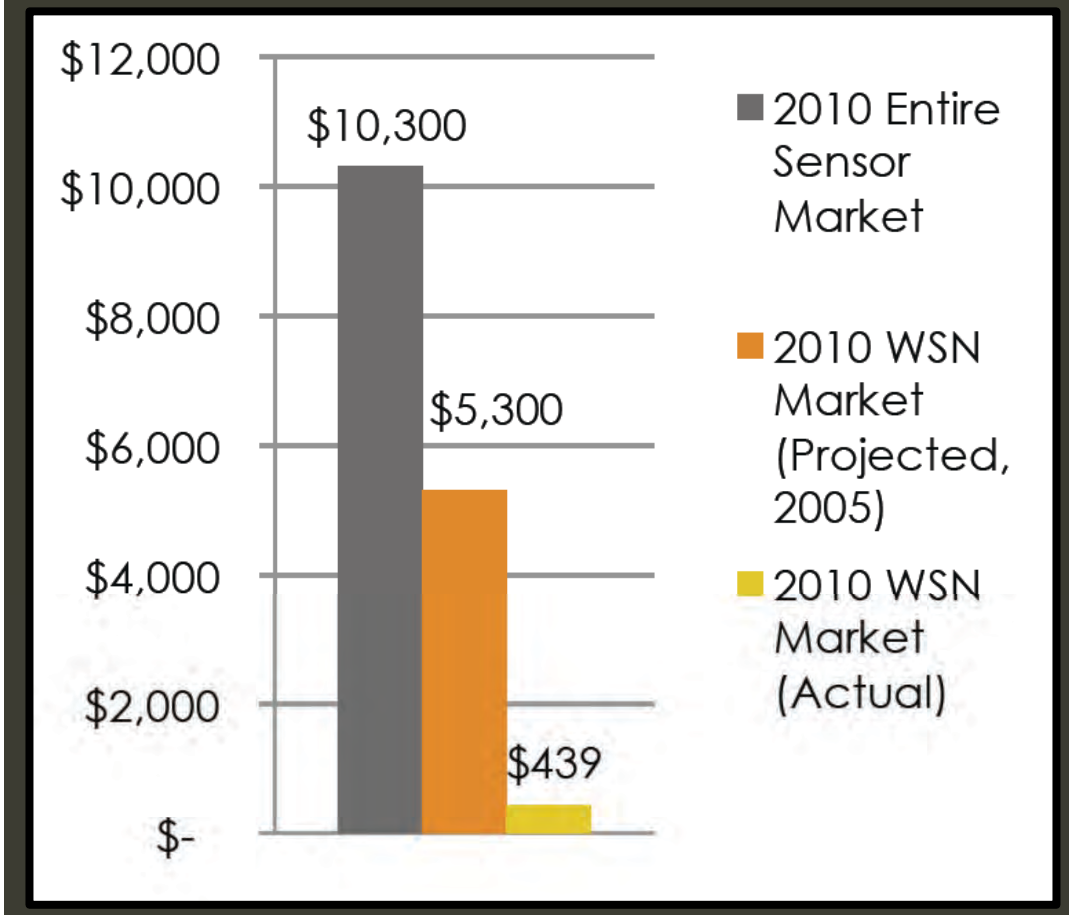
1995 Question: What happens if sensors become tiny, wireless, and self-contained?



… Wireless Sensor Networks

[Courtesy: K. Pister, UC Berkeley]

2010 Outcome: The Unfulfilled Promise of Wireless Sensor Nets



Source: On World

What slowed them down?

(Source: On World)

- Cost savings not yet disruptive
- Reliability
- Energy (battery life)
- Ease of use

[J. Rabaey, VLSI keynote 2011]

Wireless Sensor Nets

What REALLY slows them down:

NO Economy of Scale

Stovepipes, Fragmentation, Non-interoperability, Lack of Virtualization

Industrial automation, smart buildings, renewable energy, data centers, …

TinyOS, eCOS, LiteOS, Contiki, Arch Rock

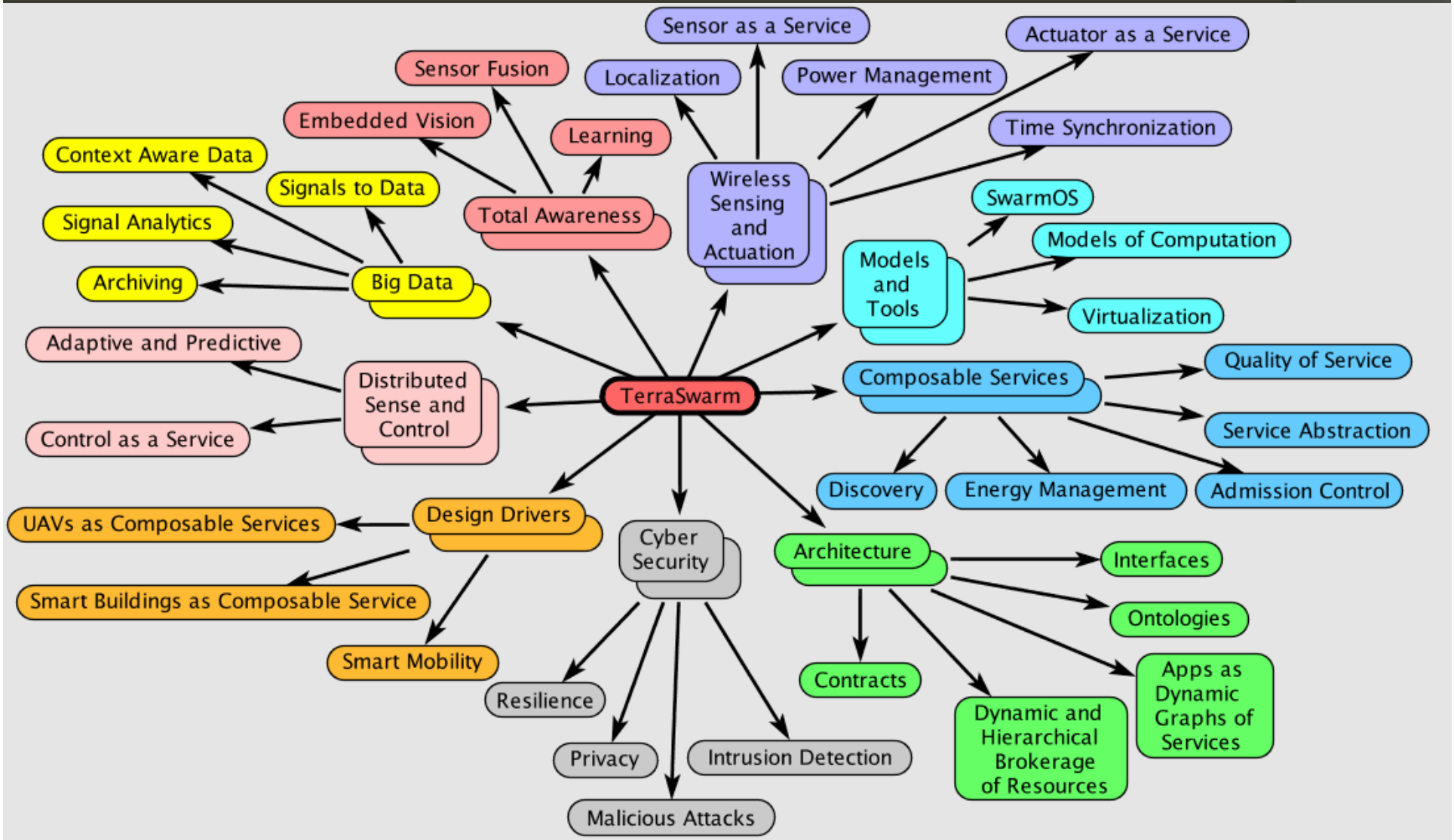
802.11x (WiFi), 802.15.4x (Zigbee), 802.15.1 (Bluetooth(LE)), 802.15.6 (WPANs), NFC, …

[J. Rabaey, VLSI keynote 2011]

The Swarm at The Edge of the Cloud

[J. Rabaey, ASPDAC'08]

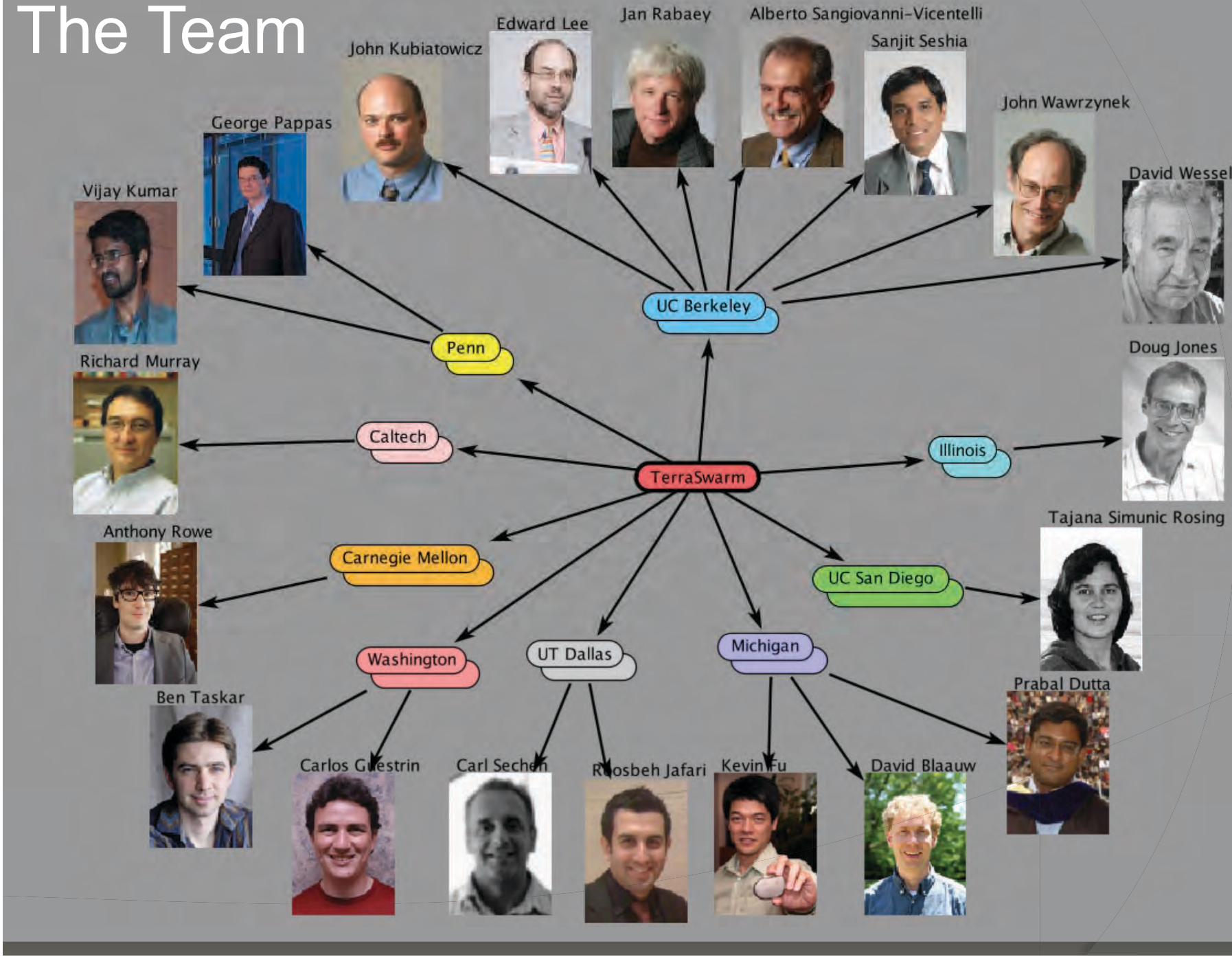
The Problem Space



Challenges

- Data collection and storage
- Data integrity
- Safety of physical interactions
- Design of complex systems
- Design of self-adaptive systems
- Security and privacy
- Energy efficiency

The Team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UC San Diego
Washington
UT Dallas
Michigan
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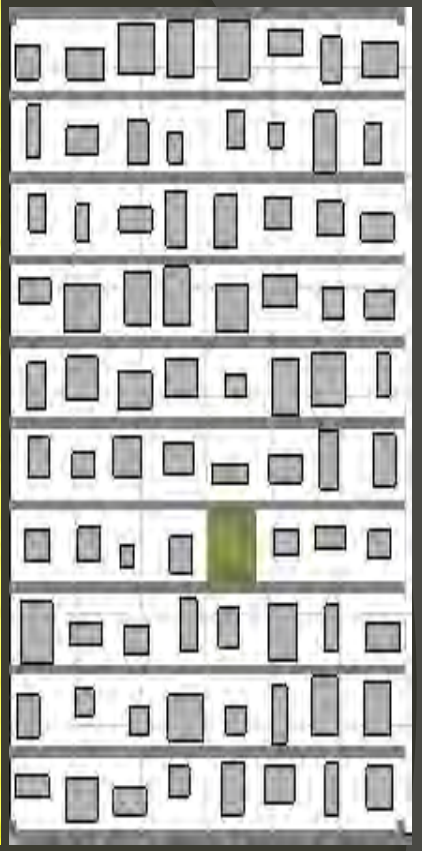
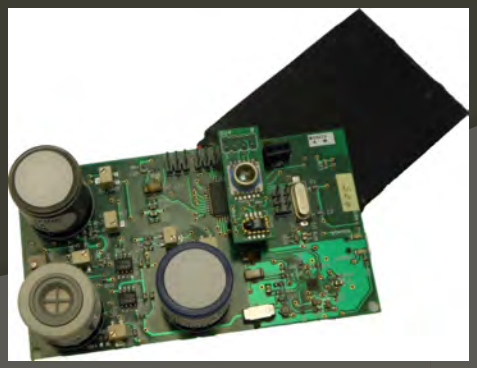
Bringing to the table:

CitiSense

A UC San Diego Testbed covering a 690 x 1120m area usese a sensor board and mobile devices to collect and aggregate environmental data.

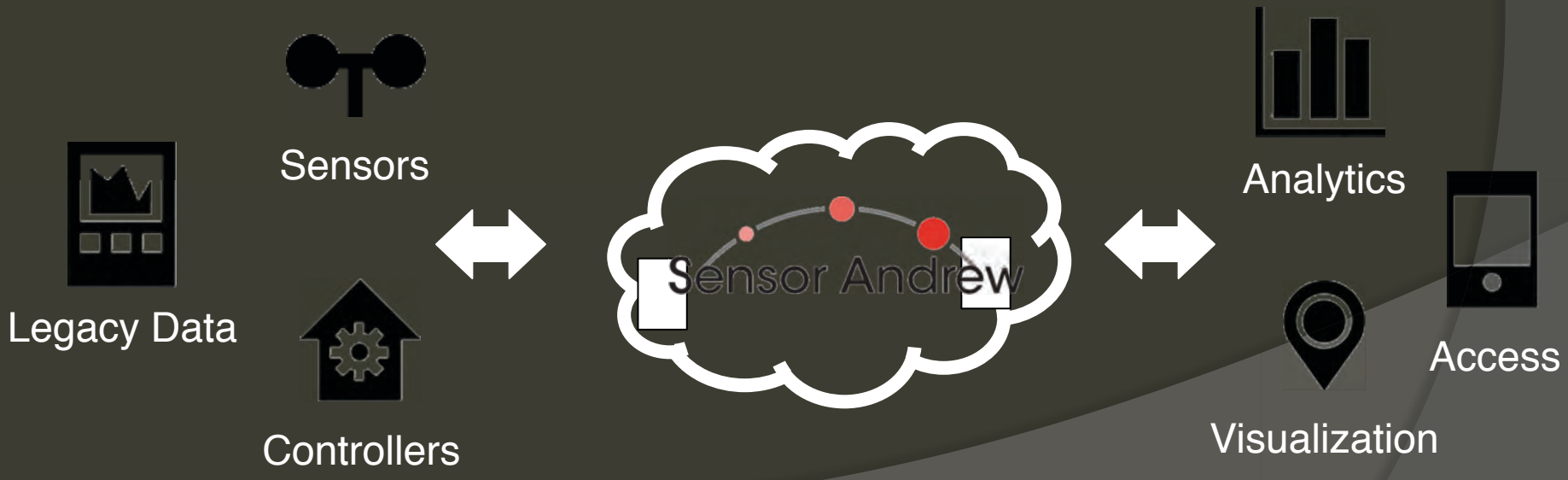




Bringing to the table:

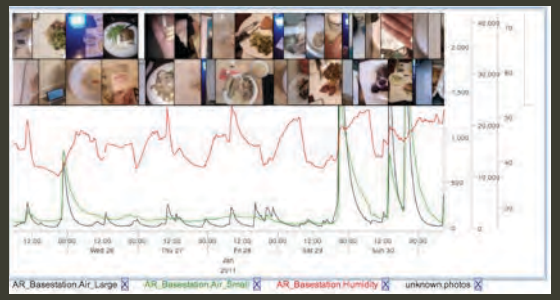
Sensor Andrew

A CMU Infrastructure to help connect the *virtual* and *physical worlds.* It provides a framework and open API (based on XMPP) to access, store, control, describe and search sensor data while maintaining security and privacy.



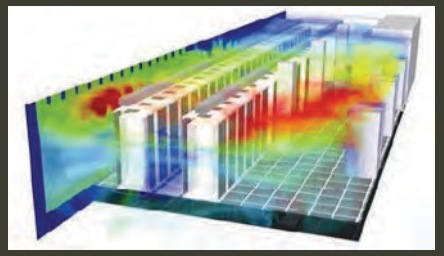
Sensor Andrew Projects

Smart Home



Body Track

Water Quality Monitoring



Data Center Energy

Wireless Protocols

People Tracking

Building Automation Systems

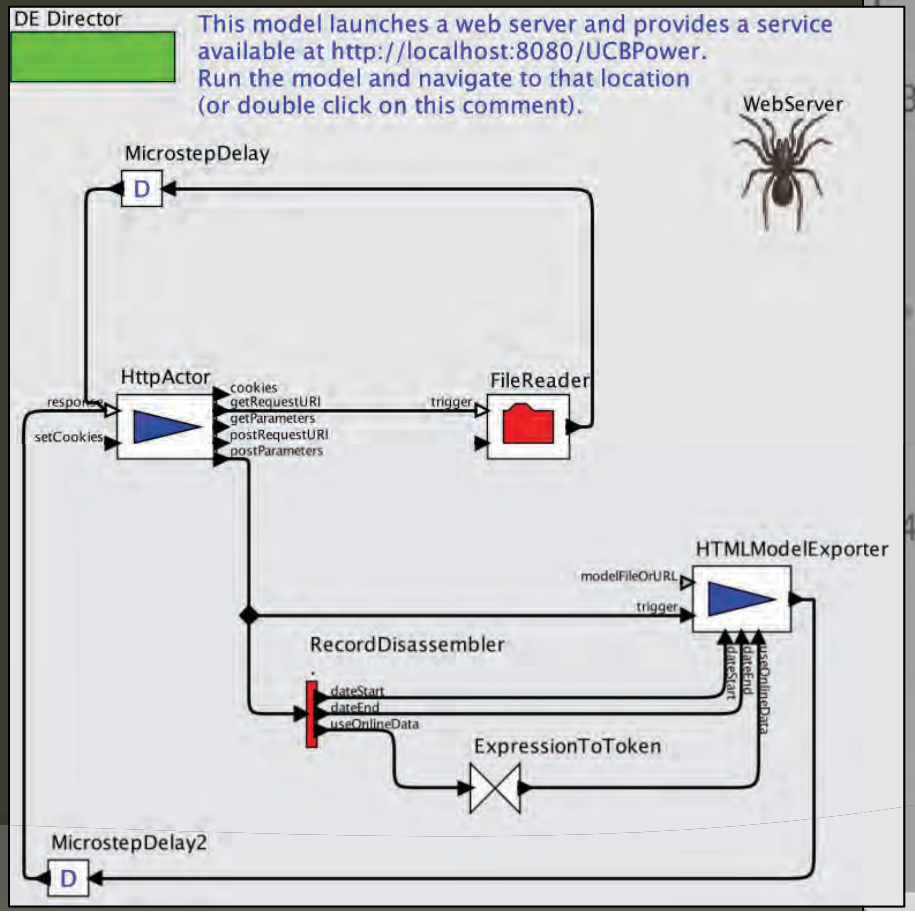
Campus Facilities

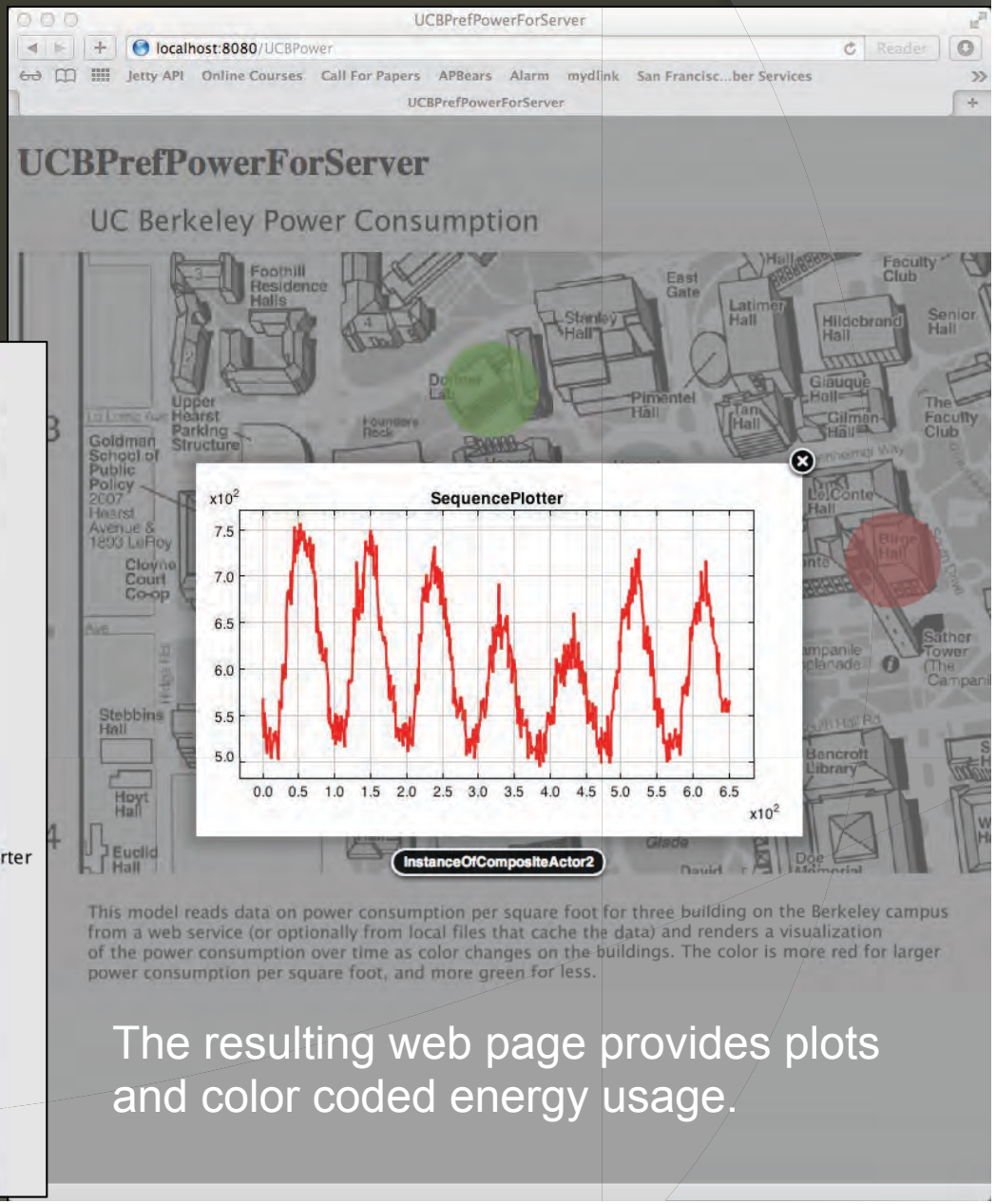
Air Quality Tracking

Bringing to the table:

OpenBMS (LoCal)

Berkeley infrastructure provides access to a campus instrumented for energy data. The Ptango project provides rapid prototyping of services.



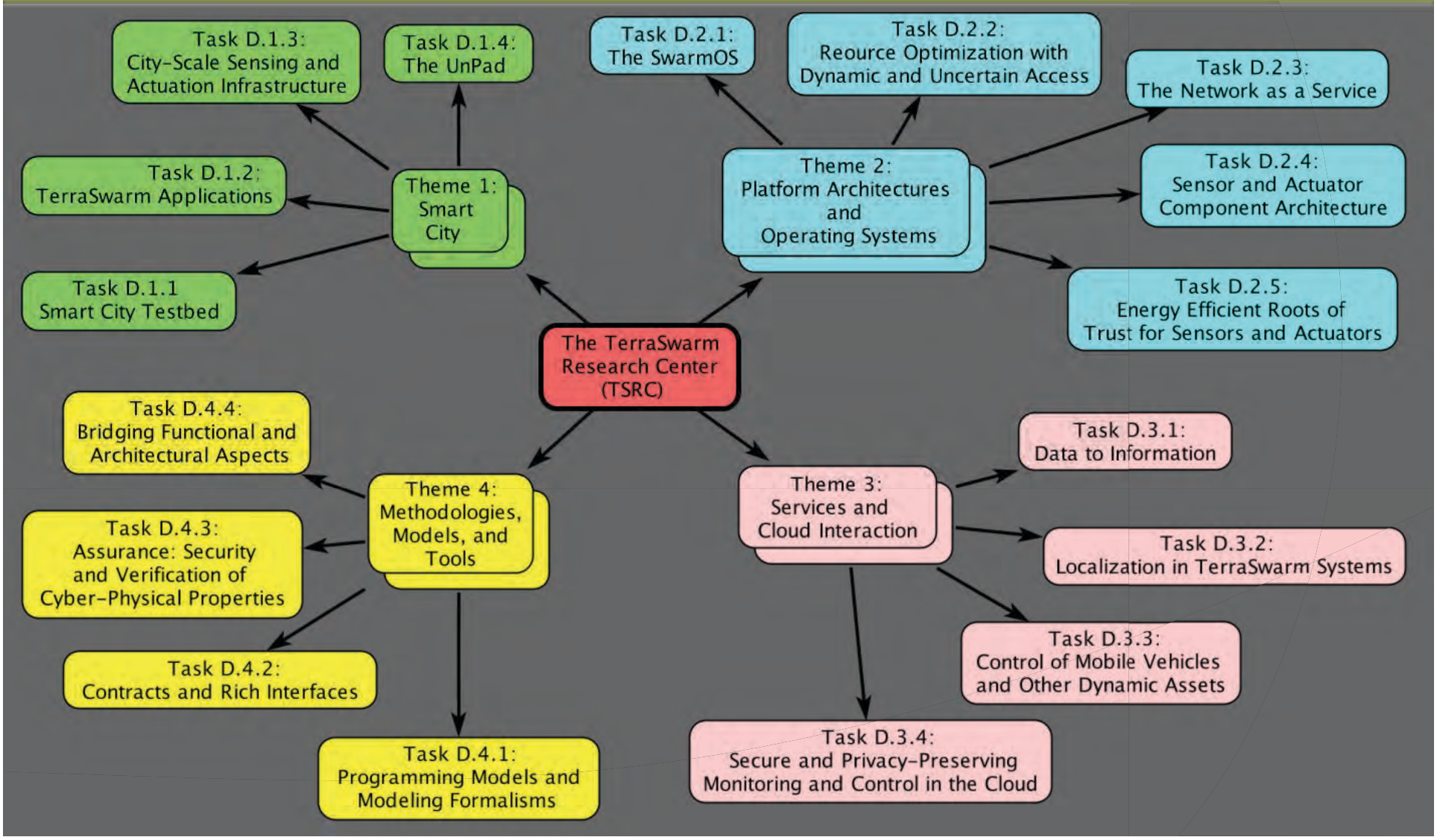


The resulting web page provides plots and color coded energy usage.

Additional Background

- GraphLab [Guestrin]
- Open Sound Control [Wessel]
- Low-energy sensors [Blaauw, Dutta]
- Wearable sensors [Jafari]
- Modeling tools [Lee, Sangiovanni]
- Analysis tools [Seshia]
- Tesselation [Kubiatowicz]
- UAV testbed [Kumar, Pappas]
- …

Center Themes



A Tale of Two Cities

Atlantic City, October 28, 2012

Atlantic City, October 30, 2012

Security and Privacy

Open architectures with dynamically recruitable sensors open enormous security and privacy concerns. But recent innovations show that data aggregation and networking can be used to *enhance* security and privacy.

E.g., Differential privacy [Dwork et al., 2006] provides a framework for removing side-channel information that can be derived by cross-correlating data sets.

In another example, tighter coupling of time bases in distributed systems (time synchronization) provides a framework for detecting and countering denial of service attacks.

Safety in Numbers

Large Numbers and Reliability

Humans

- **10-15% of terrestrial animal biomass**
- **10^9 Neurons/"node"**
- **Since 10^5 years ago**

Ants

- **10-15% of terrestrial animal biomass**
- **10^5 Neurons/"node"**
- **Since 10^8 years ago**

Easier to make ants than humans

"Small, simple, swarm"

[D. Petrovic, UCB – Atheros]

[J. Rabaey, VLSI '11]

IBM Smarter Planet Initiative: Something profound is happening… CYBER PHYSICAL SYSTEMS!

INSTRUMENTED

We now have the ability to measure, sense and see the exact condition of practically everything.

INTERCONNECTED

People, systems and objects can communicate and interact with each other in entirely new ways.

INTELLIGENT

We can respond to changes quickly and accurately, and get better results by predicting and optimizing for future events.

[Sangiovanni-Vincentelli, TTM 2012]

Intelligent systems that gather, synthesize and apply information will change the way entire industries operate.

Smart water

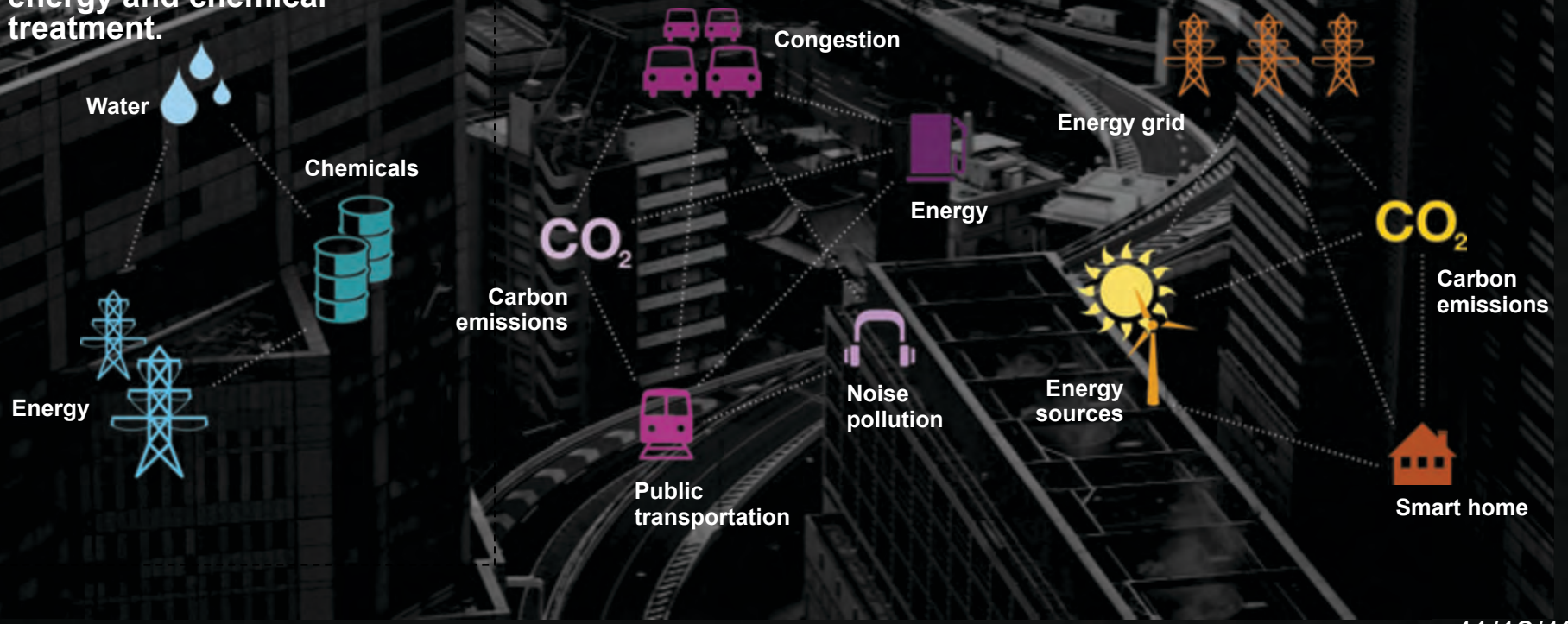
Apply monitoring and management technologies to help optimize the availability, delivery, use, and quality of water as well as related systems including energy and chemical treatment.

Smart traffic

Use real-time traffic prediction and dynamic tolling to reduce congestion and its byproducts while positively influencing related systems.

Smart energy

Analyze customer usage and provide customized products and services that help to boost efficiency from the source through the grid to the end user.



[Sangiovanni-Vincentelli, TTM 2012]

11/12/12

Bridging the Cyber with the Physical

- Computation is discrete
- The physical world is not
- Naïve bridges between the two fall short

The Age of the “UnPad” (or $\overline{\text{Pad}}$) *

Computers and mobiles to completely disappear!

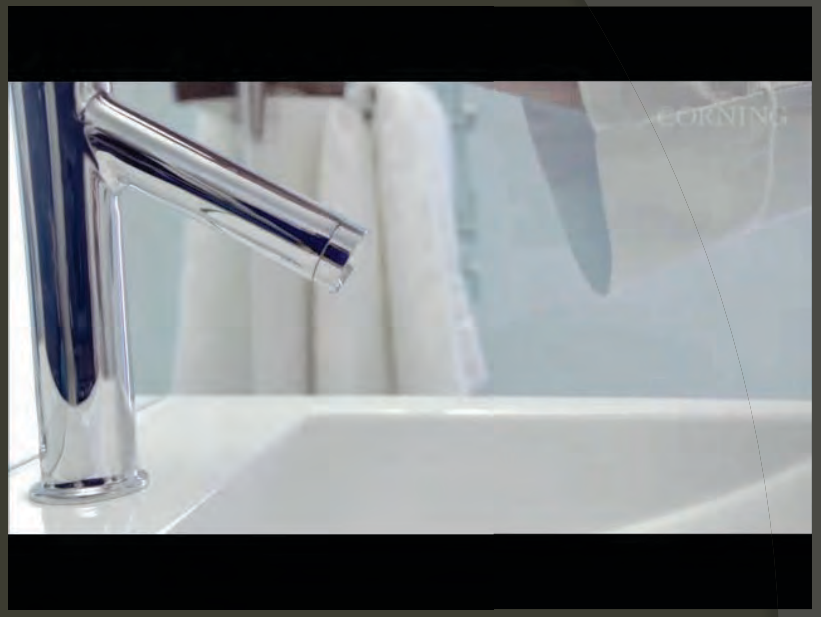
The Immersed Human

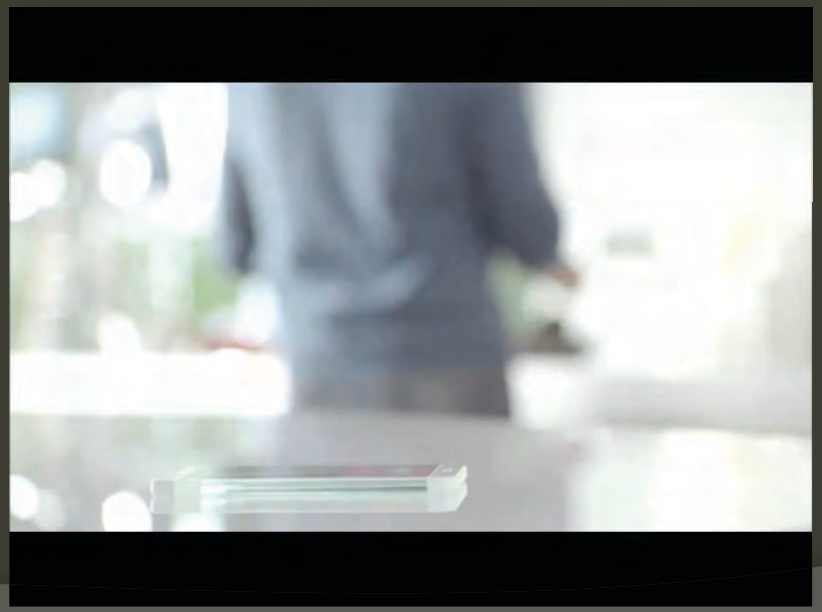
Real-life interaction between humans and cyberspace, enabled by enriched input and output devices on and in the body and in the surrounding environment

* Term originally coined by BWRC Directors

A Glimpse at the “Unpad”

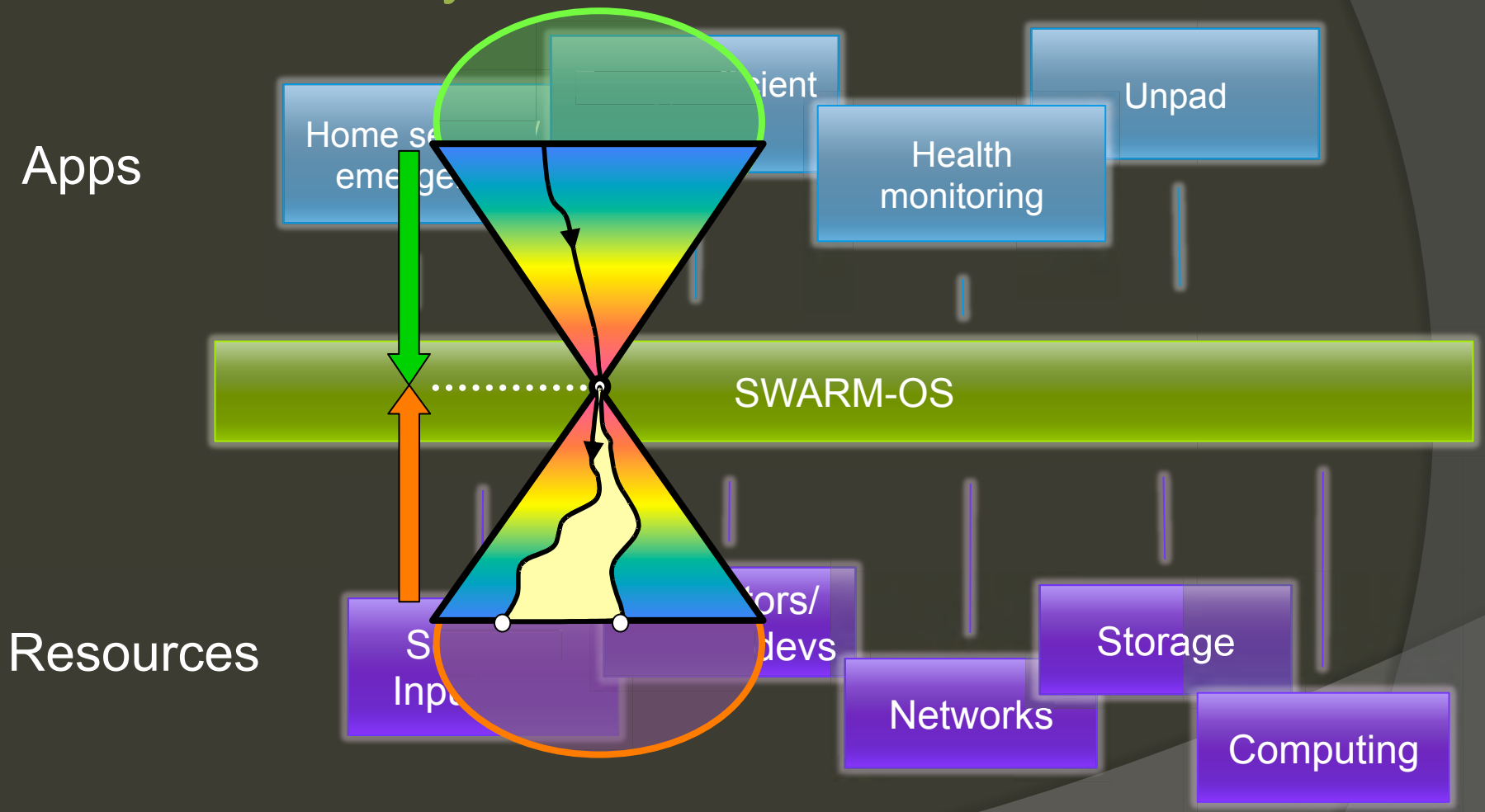
Courtesy: Corning Glass
“A World Made of Glass”
(http://www.youtube.com/watch?v=iY1Q0bNwXuI)





The Swarm as a Platform

A mediation layer



Presenting a uniform API to Apps Developers (similar to trends in the Cloud)

[J. Rabaey, VLSI '11]

Wireless Less Reliable Than Wired?

Wired

Point-to-point
(wire as single point of failure)

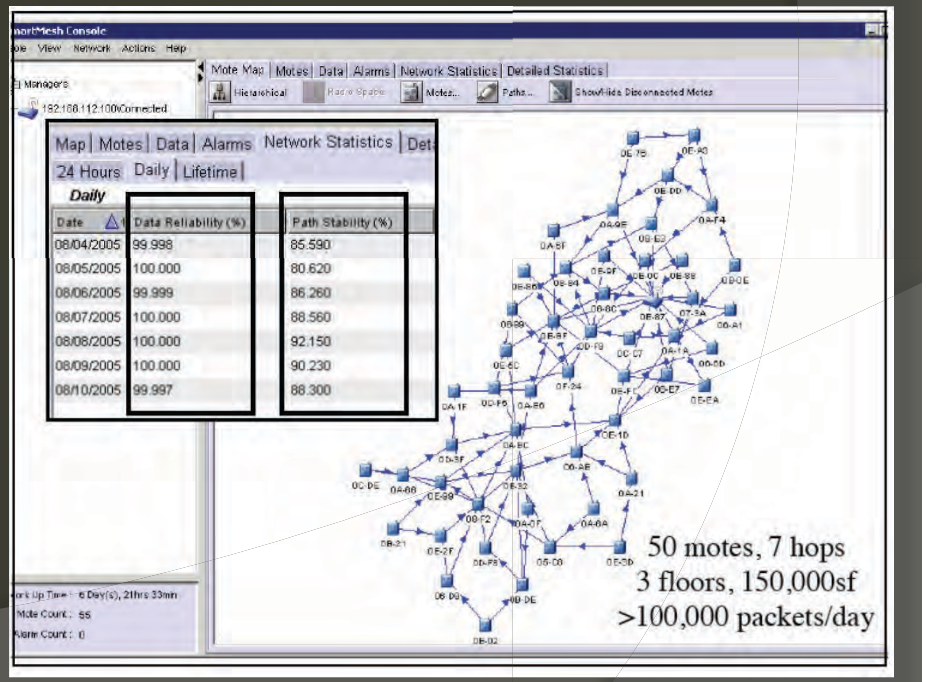
Wireless

Broadcast
(redundancy & interference)

Wireless reliability with many 9's

- Exploit spatial diversity
- Exploit time diversity
- Exploit frequency diversity
- **Exploit redundancy**

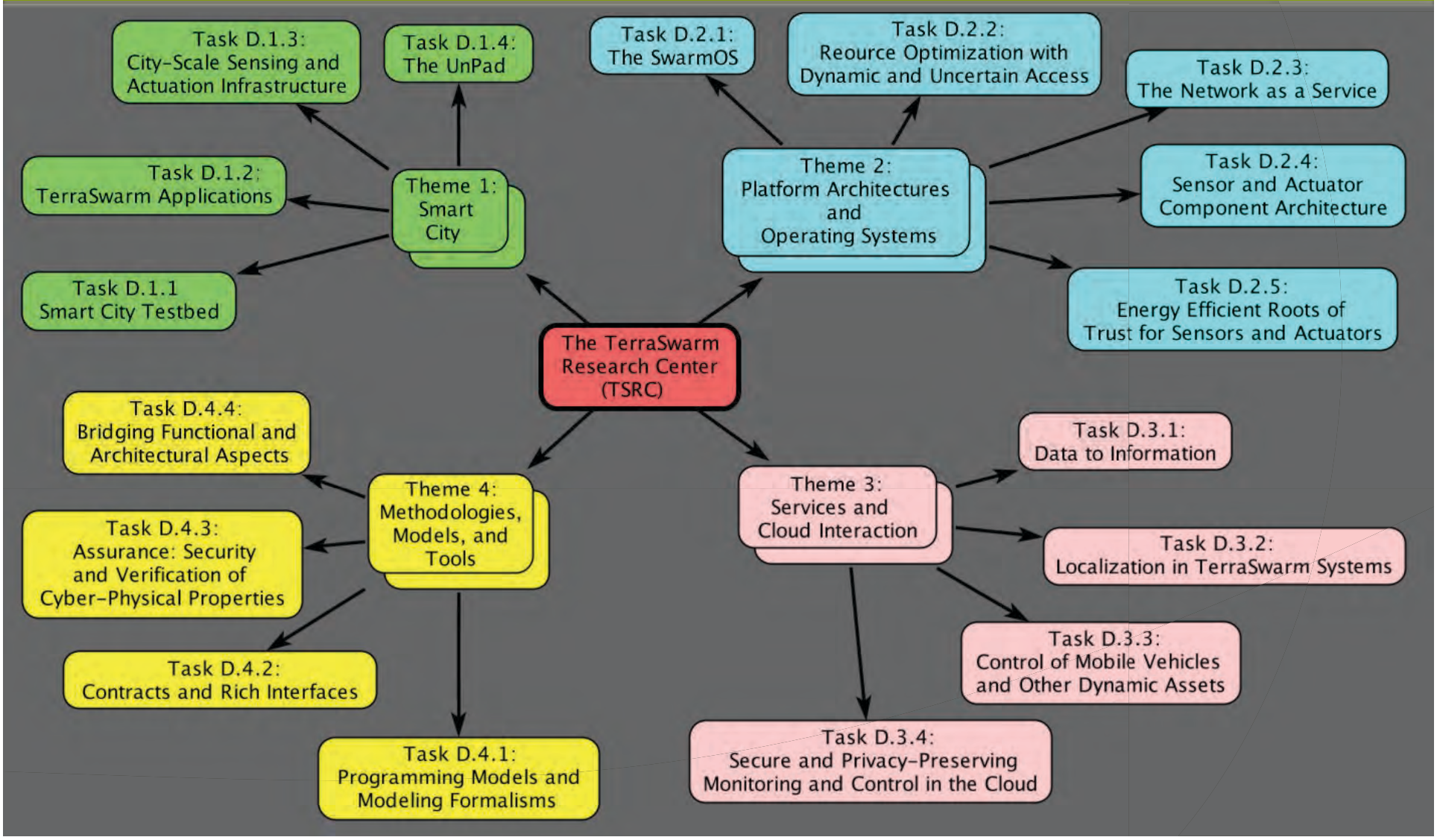
When properly managed!



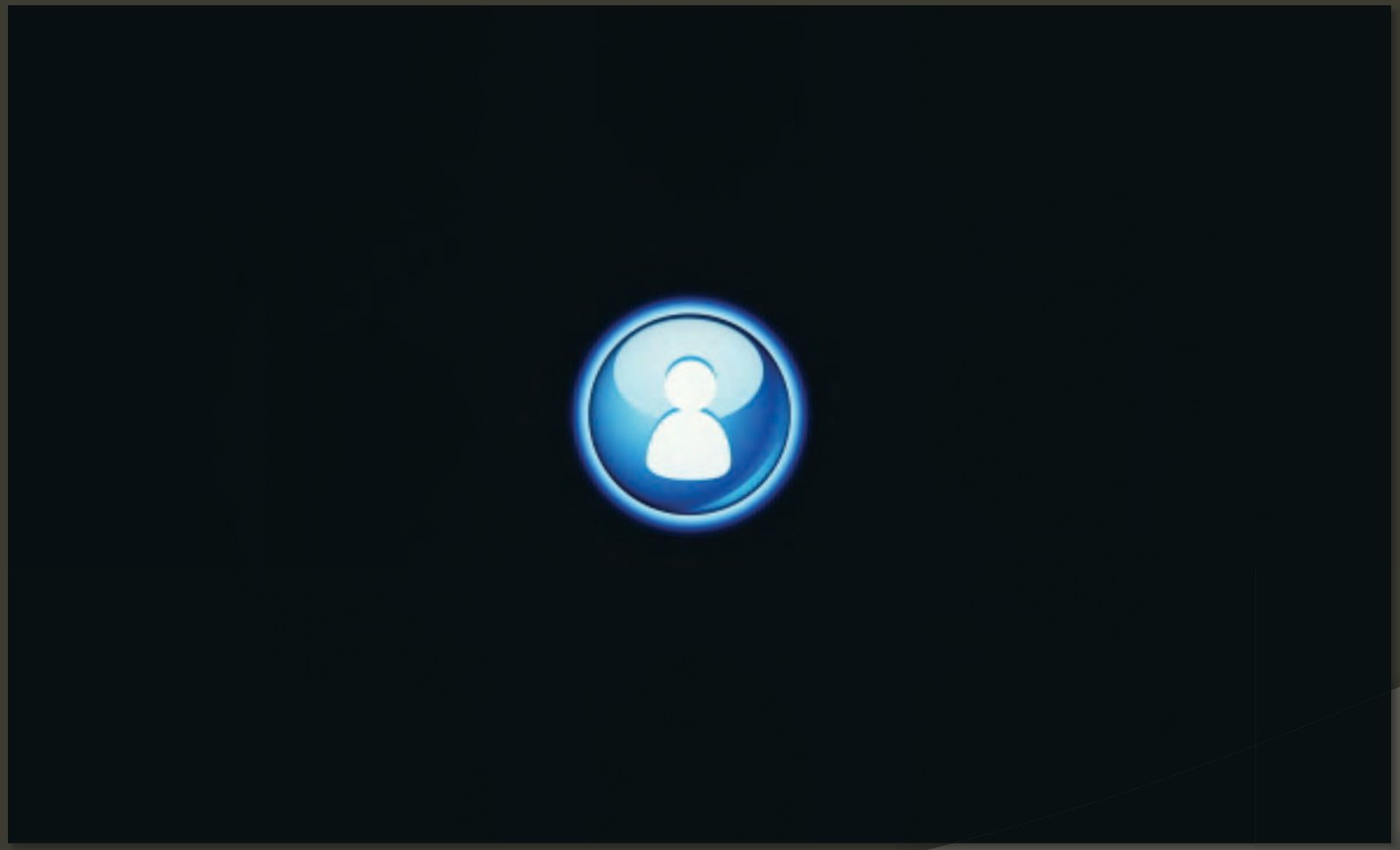
[Courtesy, Dust Networks]

[J. Rabaey, VLSI '11]

Center Themes



Let’s get to work…



http://terraswarm.org