

# InvenSense®

*Sensing Everything*



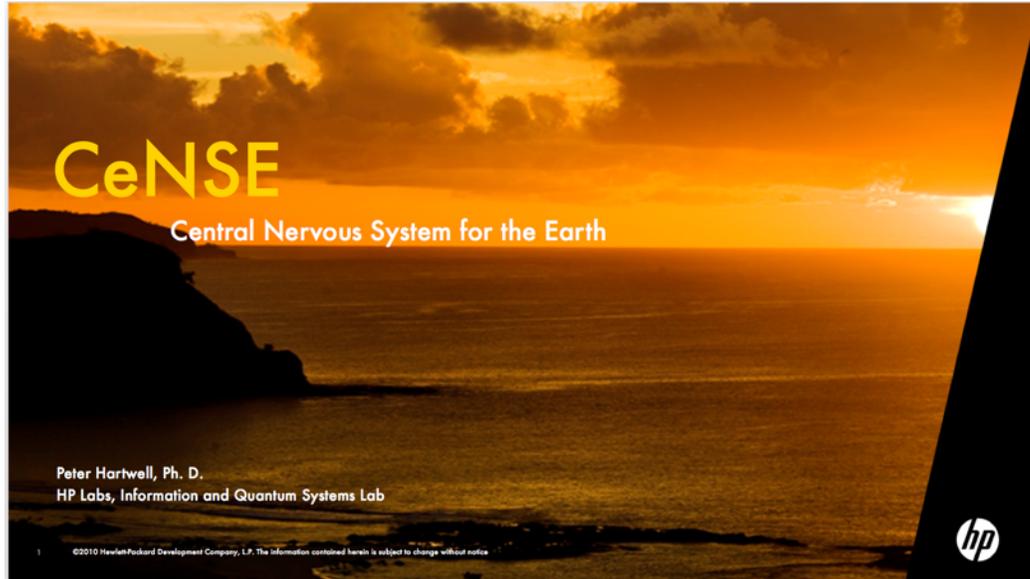
*Mobile | Wearables | Smart Home | Industrial | Automotive*

## Internet of Sens`ors

*Peter Hartwell – Jan 11, 2016*

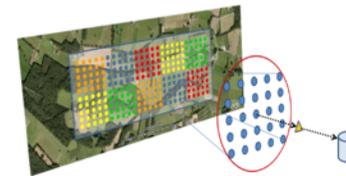
# A few slides to look back

- What did I say, where did it go?

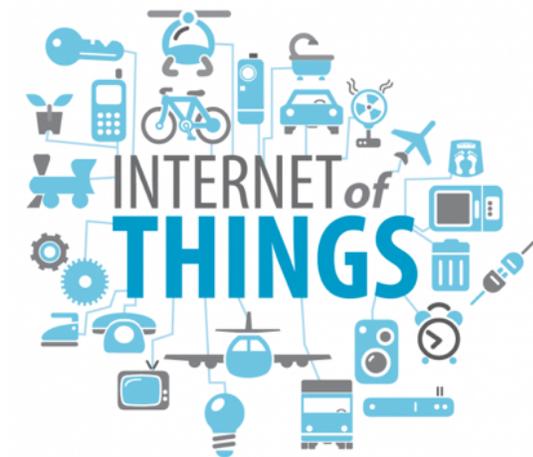


## Sensing Vision

A voice for the planet



2 Peter Hartwell, Hewlett-Packard Labs, May 2010



Jan 11, 2011



# A few slides to look back

## CeNSE – Central Nervous System for the Earth

Revolutionize human interaction with the earth as profoundly as the internet has revolutionized personal and business interactions



One trillion nanoscale sensors and actuators will need the equivalent of 1000 internets: the next huge demand for computing!

**Sensing systems:**  
\$70 B global market by 2013  
Source: Frost & Sullivan

**Value Added Sensing Services:**  
\$290B global market by 2013  
Source: Harbour Research

### Why HP?

- Only company with the technical breadth and depth
- Uniquely positioned core competencies: hardware and IT
- Pull through for computing
- New information services



5 Peter Hartwell, Hewlett-Packard Labs, May 2010

Jan 11, 2011

## • 1 Trillion Sensors

## • Then: focused on

- Arrays
- Big data
- Analytics

## • Now:

- Industrial Internet (4.0)

- Consumer: There is an app for that

- Remote monitoring
- Remote control
- Notifications



# A few slides to look back



Senses as state variables

Vibration	Tilt	Air Flow	Light
Biological	Rotation	Navigation	Temperature
Chemical	Humidity	Sound	Pressure



Moore's Law for sensors =  
One node type



- Multi-sensor node
- Not as small – yet!



16 Peter Hamwell, Hewlett-Packard Labs, May 2010

Jan 11, 2011



<p><b>AIR QUALITY</b> Go beyond CO<sub>2</sub>, learn about real indoor pollution based on VOC levels. Aerate smarter.</p>	<p><b>TEMPERATURE</b> Save money and be healthier with the right temperature for every room and every season.</p>	<p><b>HUMIDITY</b> Keep mold, flu, viruses and bugs away from your home.</p>	<p><b>NOISE</b> Reduce stress, sleep better, work smarter and be a more responsible neighbor.</p>
<p><b>LIGHT</b> Know when it's too dark to work or too bright to sleep.</p>	<p><b>PRESSURE</b> Predict weather changes and see if the headache you're having is weather related.</p>	<p><b>SHAKE</b> Know when somebody moves your Cubes. Shake the Cube to check your current status.</p>	<p><b>GLOW</b> Colorful glows reflect your indoor health.</p>

- T(trillion)Sensors
- Worldwide meetings



[Join Our Email List](#)

The **TSensors Summits** are being organized as a forum for the world's sensor visionaries to present their views on which sensor applications (**TApps**), sensor types and sensor manufacturing platforms have the potential to fuel sensor market growth to the trillions within a decade. Such forecasted explosion will be a continuation of consumer sensor growth from 10 million units in 2007 (iPhone introduction) to almost 10 billion devices in 2013.

### Upcoming Events



**December 9 & 10, 2015**  
Celebration, Florida  
[More Information](#)

2 days, 44 talks, 300 people



TSensors Summit	Speakers
UC Berkeley, April 2013	14
Stanford University, October 2013	47
Tokyo, February 2014	18
Munich, September 2014	36
UC San Diego, November 2014	33
Tokyo, December 2014	36
Celebration, FL, December 2015	44
<b>Total</b>	<b>228</b>

- ▶ ~180 speakers presented the visions for ~500 variables to be sensed, expected to reach ultrahigh volumes.
- ▶ ~50 speakers presented the visions for emerging infrastructure (energy harvesting, wireless communication, networks, etc.)

J. Bryzek, TSensors Summit, 2015

## Sensor Studded Mobile Devices

**T SENSORS SUMMIT™**

**MEMS & Sensors Industry Group®**  
A MEMS & Sensors Industry Group® Enterprise

4 Microphones  
Tri-Accel  
Tri-Gyro  
Tri-Mag  
Pressure  
Light  
Proximity  
32 SAW  
Image stabilization  
Fingerprint  
2 Cameras



Microphone  
Tri-Accel  
Tri-Gyro  
Quad-Pulse



J. Bryzek, TSensors Summit, 2015

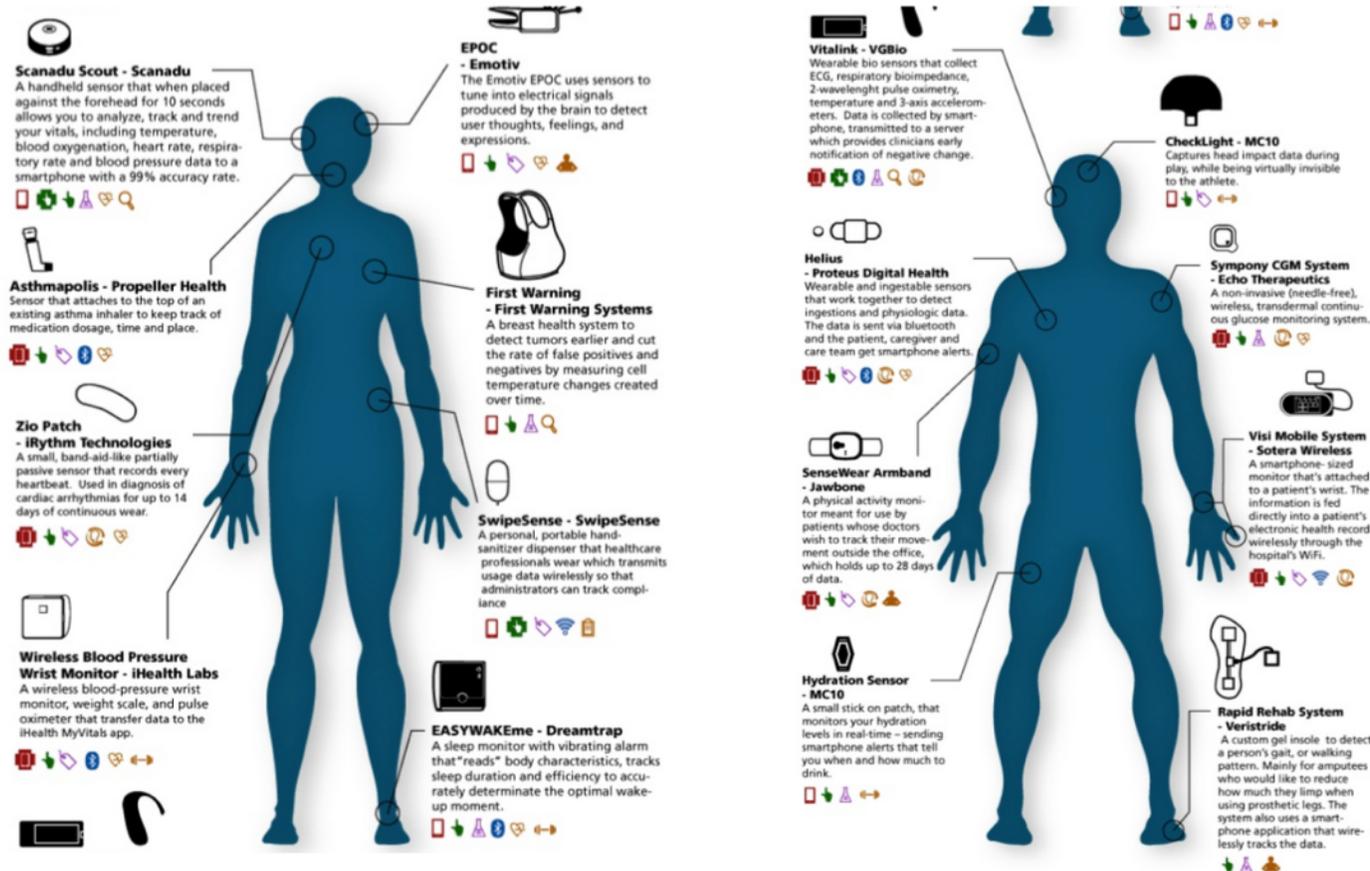
42



## Wearable Sensors Galore

**T SENSORS SUMMIT™**

**MEMS & Sensors Industry Group®**  
A MEMS & Sensors Industry Group® Enterprise



<http://www.mhealthnews.com/news/sensors-stake-their-claim-mhealths-future>



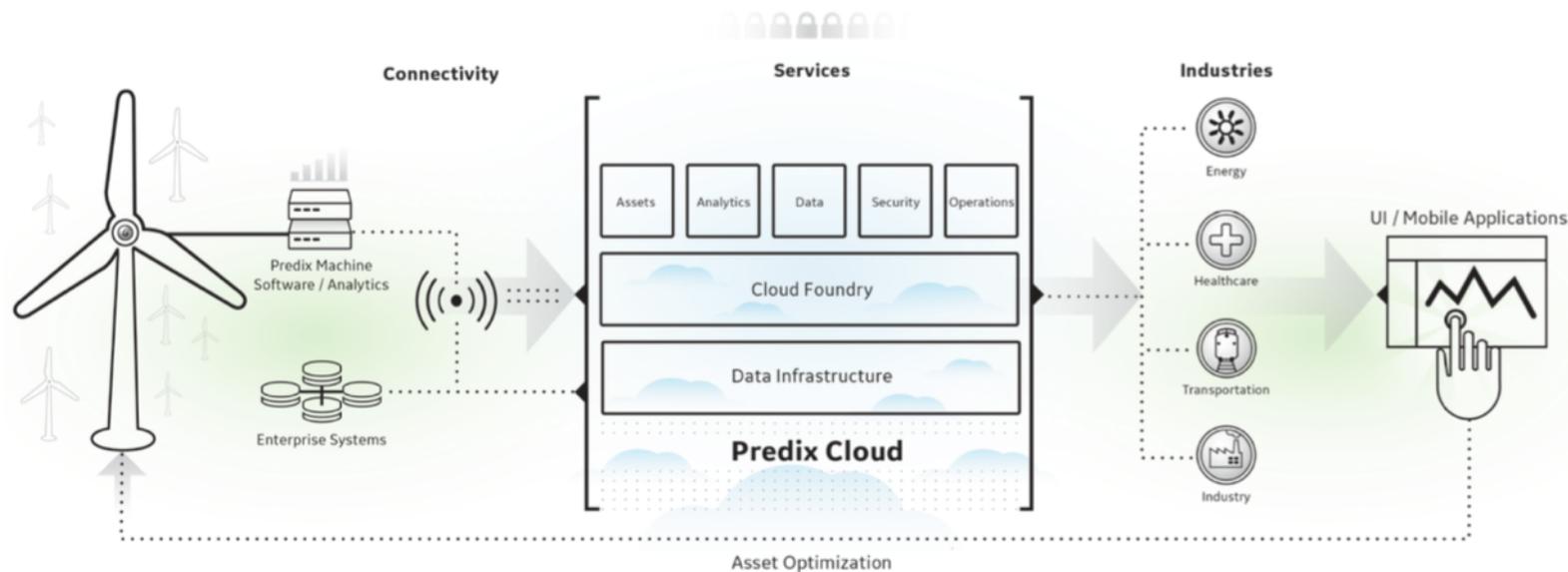
## Moving All IoT Data to Cloud: GE Predix

**T SENSORS SUMMIT**



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- Industry first effort to capture, visualize and process all IoT sensor data.
- The platform enables processing massive sensor data in the Cloud and apply AI based algorithms to predict future event based on sensor data.



<https://www.predix.io/>



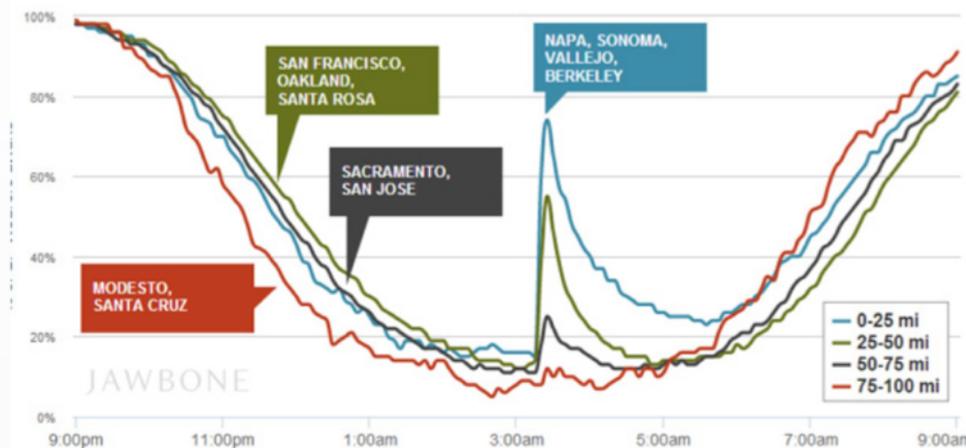
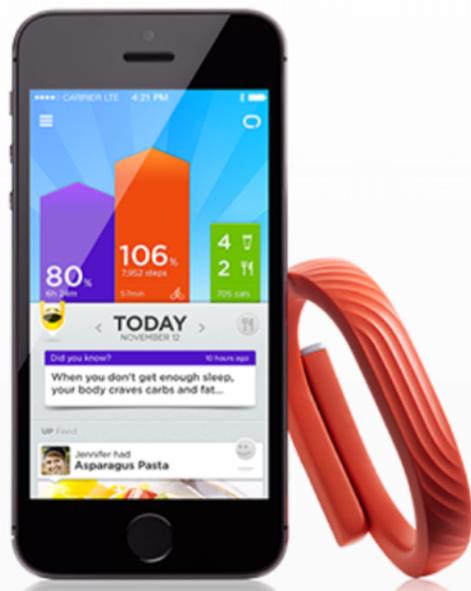
## The Power of Big Data

**T SENSORS SUMMIT**



A MEMS & Sensors Industry Group Enterprise

# Jawbone



Big Data: 8/24/14 earthquake in Napa, CA, based on Jawbone users' data.

<https://jawbone.com/up>

The wristband tracks in the background your movement and sleep. The app displays your data, lets you add things like meals and mood, and delivers insights that keep you moving forward.



# IoT Application “Tornado”



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67



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WWF Global español

Home » what we do » Priority Places » Arctic » Arctic wildlife » Polar Bear » Polar bear tracker

- What We Do
- Priority Places
- Arctic
- Arctic wildlife
- Polar Bear**
- Polar bear tracker**
- Safeguarding polar bears
- Diet
- Reproduction
- Status & Population
- Habitat
- Threats
- Conflict with people
- Our solutions
- News and resources
- Donate to polar bears

## Polar bear tracker

[Like](#) 179 [Tweet](#) 20 [Email](#) 13 [ShareThis](#) 7464

Follow polar bears as we track them across the vast white desert of the Arctic ocean.

With the help of polar bear researchers, WWF is following the bears' travels in the Arctic.

Their positions are beamed from collars on the bears' necks, via satellite to scientists, and then to this site. It allows us to get regular updates about how the polar bears behave in their arctic environment and how they may be affected by climate change.

### SUBSCRIBE AND SHARE

Stay informed with WWF's monthly Arctic newsletter.

And visit us on: [Twitter](#) | [Youtube](#)

[Like](#) 179 [Tweet](#)

### FIELD NOTES

#### The strange case of Green Bear

Around the world, polar bear researchers use satellite collars to track where bears go, and how ...

07 Jul 2015

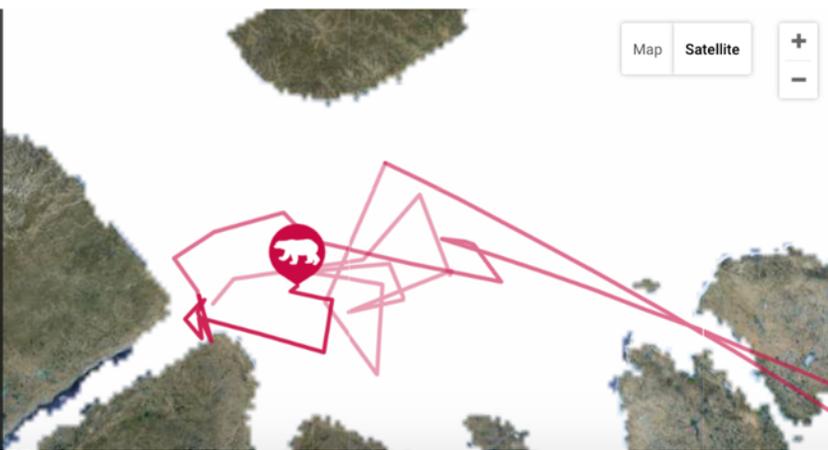
#### Walk 3,700 km with a polar bear

### WWF SPECIES TRACKER

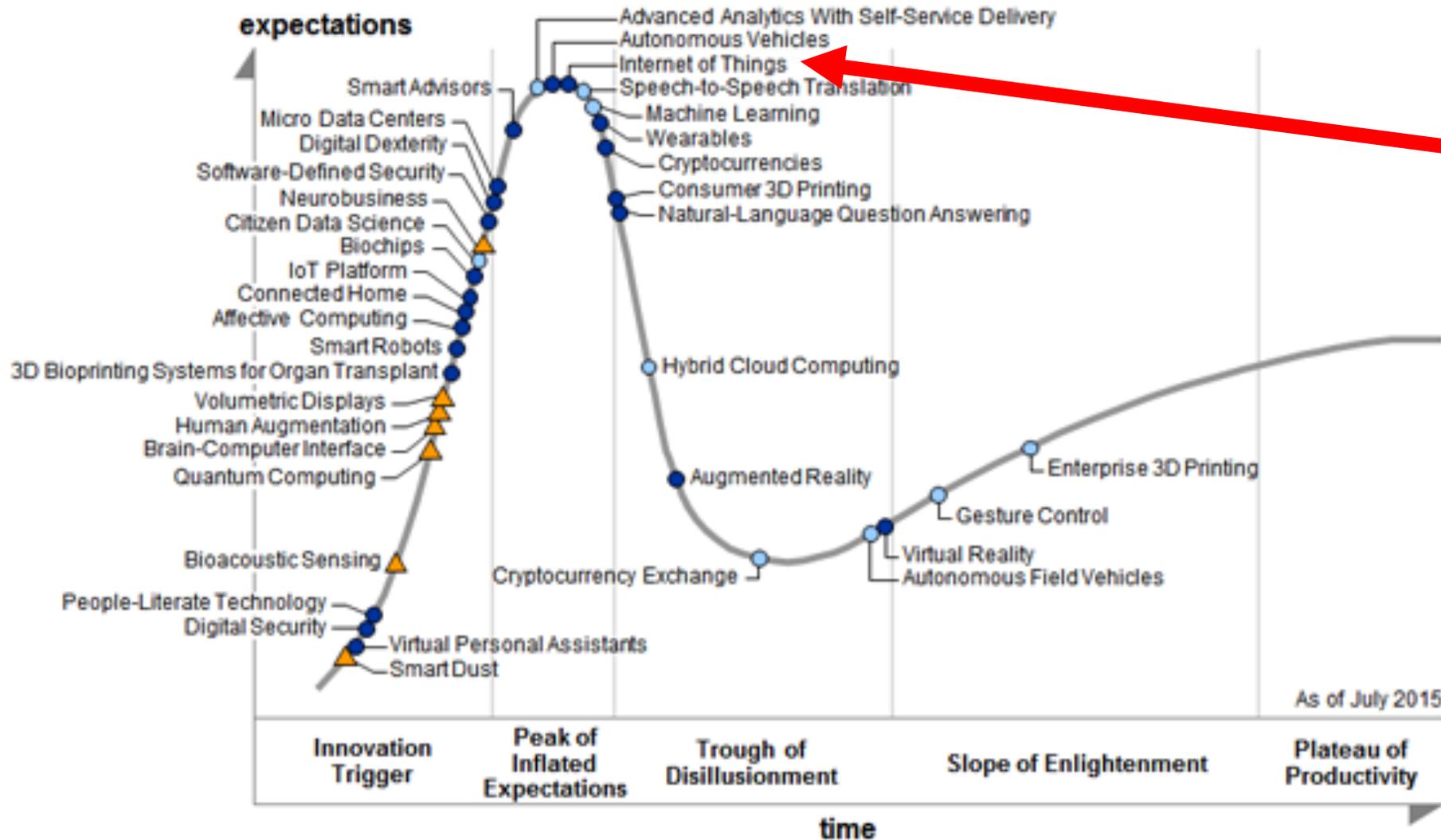
**15725**  
Estimated travel: 1560 km  
Polar bear 15725 was captured north of Prince of Wales Strait, May 1, 2014. She was accompanied by two new cubs - one ma...[Read more](#)

IN THIS REGION (SEE ALL)

- 32840
- 15725
- 15738
- 15814



# Gartner Hype Cycle



IoT

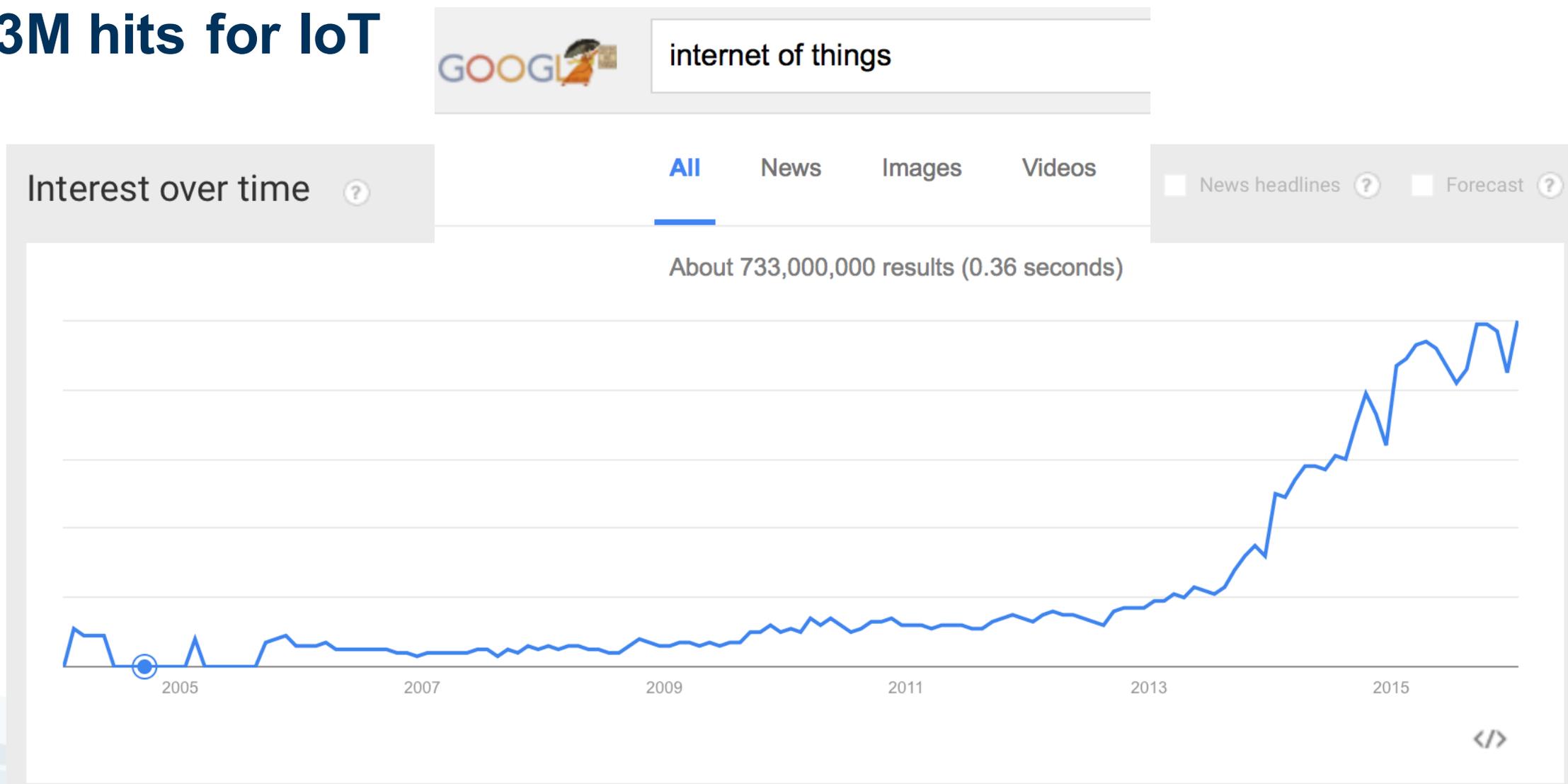
**Plateau will be reached in:**

○ less than 2 years    ● 2 to 5 years    ● 5 to 10 years    ▲ more than 10 years    ⊗ obsolete before plateau



# Google search trends (since 2004)

- 733M hits for IoT



Jan 10, 2016

- **Internet of (every)Thing - its really happening**
  - Everything connected to your phone
- **2000+ vendors in 500k sf of floor space**



## What to See at Tech West

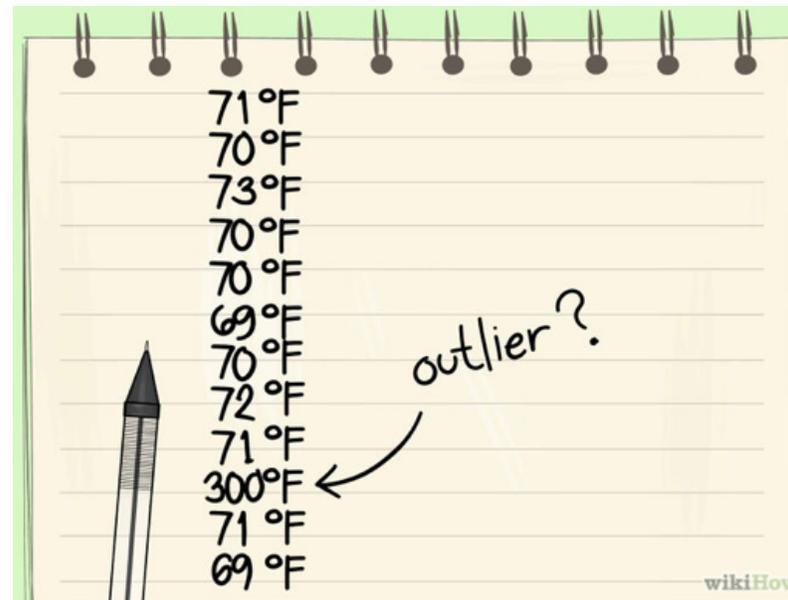
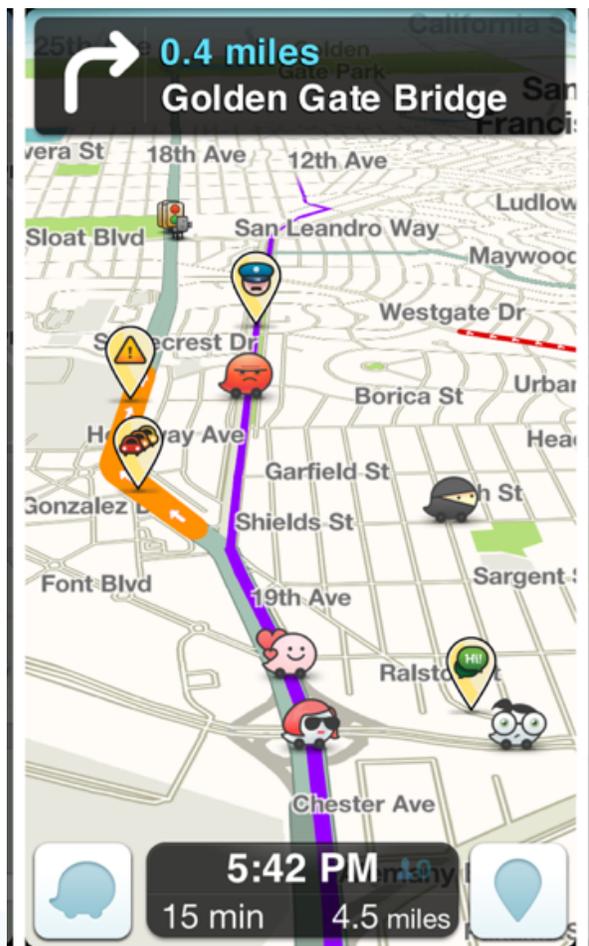
Featuring the innovative power behind the industry's emerging technology, Tech West encompasses revolutions in fitness and health, the Internet of things, smart home and other high-growth technologies changing the way we live, work and play. You'll discover the titans of tech, promising startups and everything in between.



- **2 big hardware problems with IoT**
  - Locating the sensors
  - Keeping the sensors powered
- **I want your data and I pay you for it with “features”**
- **If features are compelling, you keep the batteries charged**
- **Where people are (so so where their devices are) is interesting**



- Outlier removal, increased SNR



- More sources, more accuracy
- Rejection of outliers
- Errant or malicious data



Waze for IoT

- Poor quality location data but LOTS of it shows paths accurately

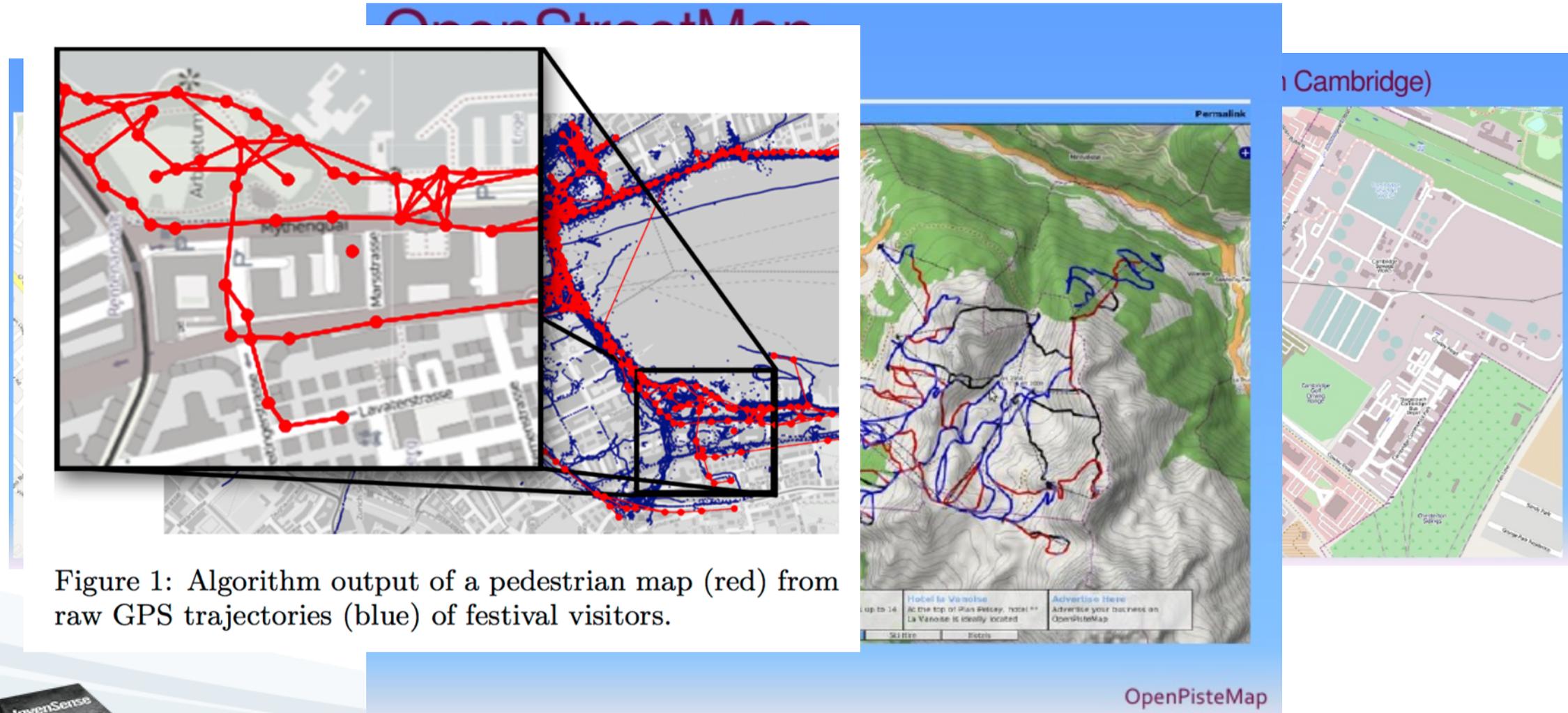


Figure 1: Algorithm output of a pedestrian map (red) from raw GPS trajectories (blue) of festival visitors.



# But where are we, really?

- Colin McAnlis of Google – ArmTech 2015
  - <https://www.youtube.com/watch?v=GulyESNLACo>
  - *Bella and the Internet of Things*
- Google
  - Brillo – operating system – android based security features
  - Weave – communications protocol
  - Thread – wireless mesh network standard

## Secure by default

Brillo's built-in security features limit exposure to attacks, the update service allows you to recover compromised devices quickly, and all data can be easily secured by hardware and software-backed encryption.



# Privacy but trusted data

- I want your temperature, but don't care who you are
- Need to trust data
- Impact of hacking



**autoblog** NEW CARS ▾ FOR SALE ▾ NEWS & REVIEWS ▾ OWNERSHIP ▾

VIDEO Dec 8th 2015 at 10:43AM 99

## Car turns in its own driver for hit-and-run

it - until her car called the police.

Cathy Bernstein, 57, attempted to drive off after hitting a truck and a van in Port St Lucie in Florida.

But her Ford vehicle's 911 Assist system Sync thwarted her escape, by passing on her location and details to police and connecting her in-car telephone system to local officers.

**"During a conversation with police she denied that she had been in a car accident, but the police operator appeared to be sceptical."**

The system automatically calls police when the car's airbag is deployed.

During a conversation with police she denied that she had been in a car accident, but the police operator appeared to be sceptical.

Sky News

A woman in Florida may have escaped prosecution for the accidents she caused last week if only her [Ford](#) hadn't called the cops on her.

Last Monday a woman from Port St. Lucie, FL, reported that a driver rear-ended her and then drove off. Around the same time Port St. Lucie police also received an automated call from a Ford vehicle. In

g+



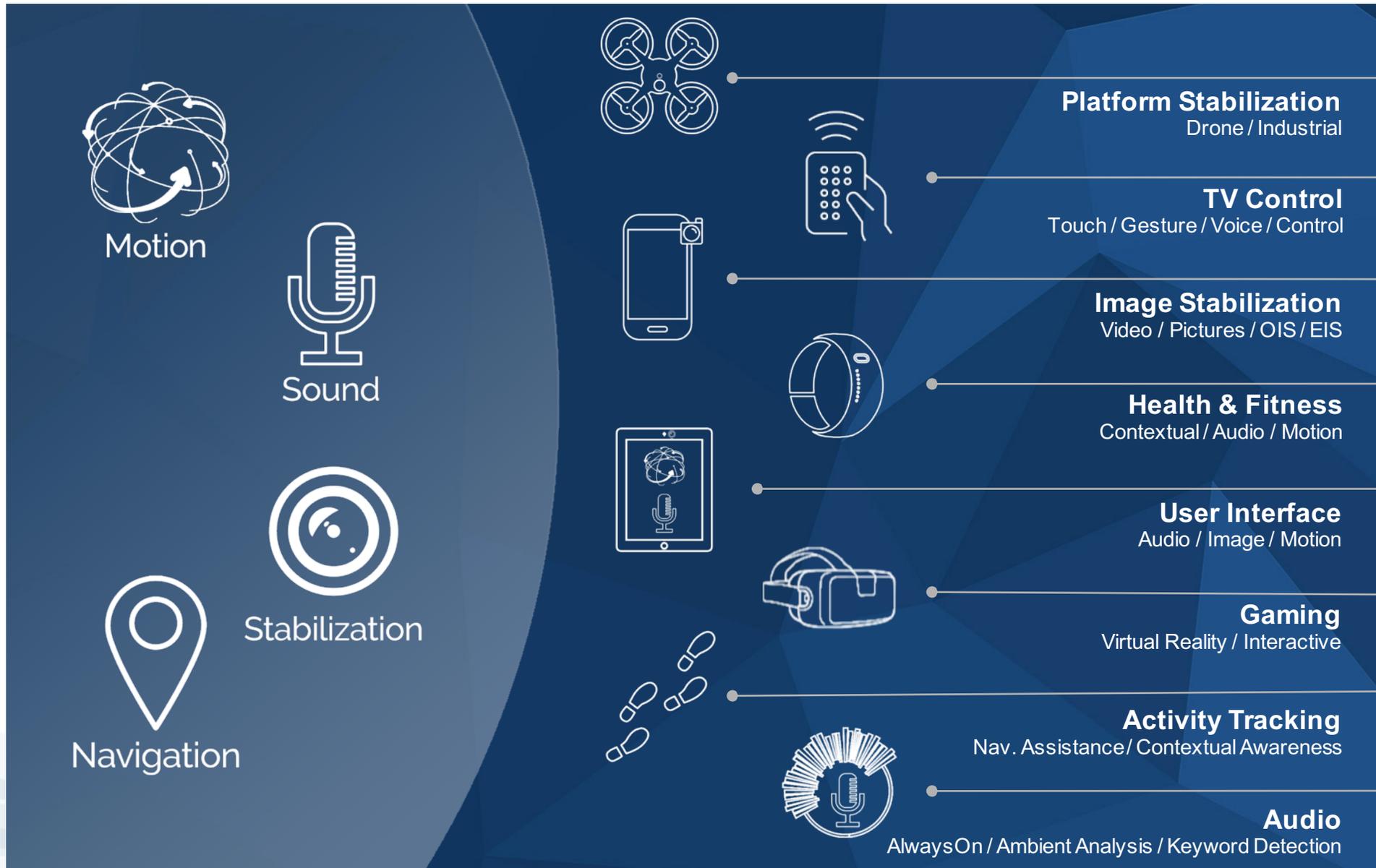
# 7 out of 10 fear security implications of Internet of Things

The Internet of Things is oft-discussed among network managers and security is still the top concern.

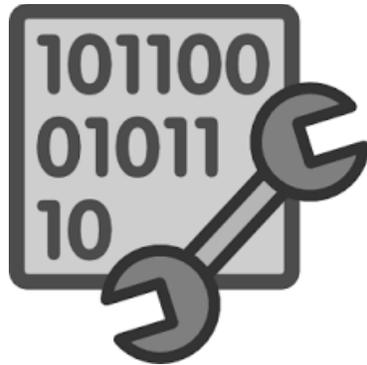
By Frank Ohlhorst | August 20, 2014, 9:41 AM PST

The resulting report, "[Internet of Things: Connected Home](#)," was produced in partnership with GMI, a division of Lightspeed Research. More than 1,800 consumers between the ages of 20 and 50 who claim to be tech savvy participated in the survey, which was administered in 11 countries around the world, including the United States, Australia, China, Germany, India, and the United Kingdom.





## Adding value with expanded skill set



Sensor  
understanding



System  
Knowledge

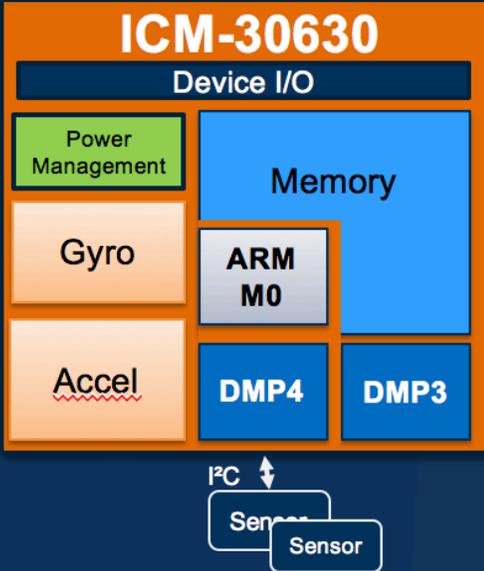


Big Data  
Expertise



- Major players
  - AP/SoC
  - Radio
  - Power Mgt.
  - Sensing
- One chip to rule them all
- Single chip IoT

 **Firefly: Embedded Hub w/ Framework** InvenSense



The diagram shows the internal architecture of the ICM-30630 chip. At the top is the Device I/O interface. Below it are several functional blocks: Power Management, Gyro, Accel, ARM M0, Memory, DMP4, and DMP3. The ARM M0 core is connected to the DMP4 and DMP3 blocks. The chip is connected to external sensors via an I2C interface.

**World's Lowest Power Embedded Context Sensor Hub**

**Complete Sensor Hub with SW**

- Rapid integration of developer code
- Turnkey Android Lollipop solution
- Supports 3<sup>rd</sup> party sensors
  - ALS, Proximity, Mag, HRM, Pressure

**ICM-30630: Sampling Now**

- Sensors: Gyroscope + Accelerometer
- Cores: DMP3, DMP4,
- ARM Cortex-M0 CPU up to 64MHz
- Total Memory: 64KB SRAM, 64KB Flash
- Size: 3x3x1mm LGA

**Open Tri-Core Platform**

- Optimized for fixed point processing
- Offloads math intensive operations
- Open ARM Core for Fast Innovation
- Power-Optimized Extensible Framework
- M0 & DMP → lower power and higher performance than M4



Does big data have to be big?

Sending 0's  
Collecting data or information

How do you spend your power?

Power to analyze  
vs.  
Power to transmit

What about the raw data?

- Sending only information good for control loops
- Need to archive for proof nothing happened





Valid data



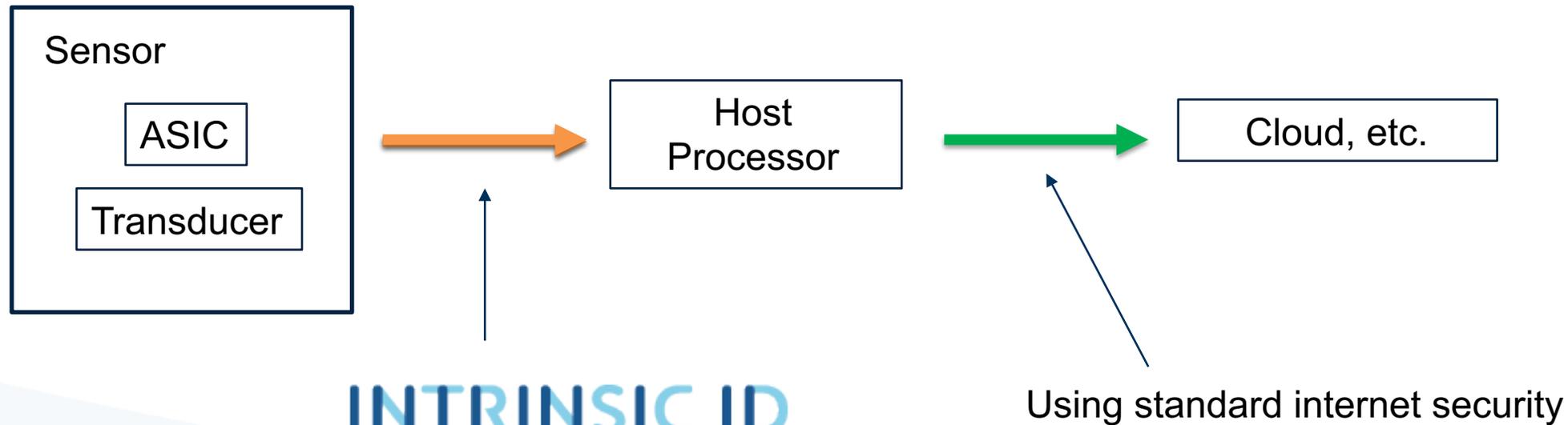
Errant data



Privacy



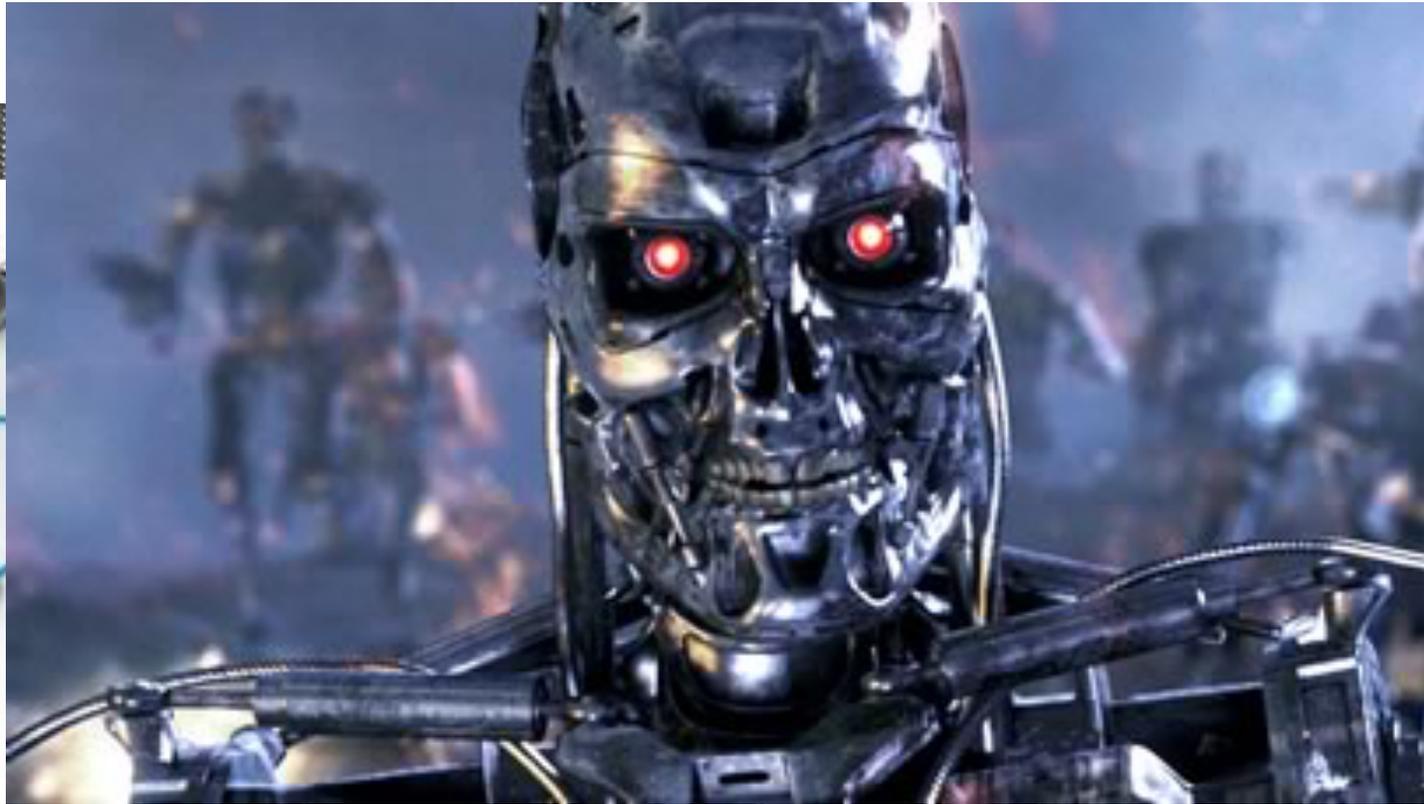
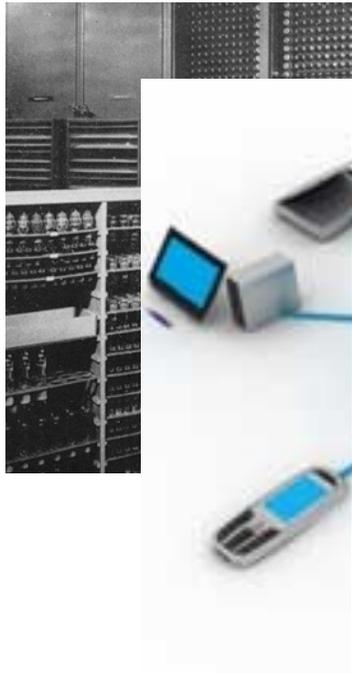
- Our transducer is secure to its ASIC – CSP
  - some aren't (wire bonds)
- Create PUF (physically uncloneable feature) from on-board memory
- Secure link to host



**INTRINSIC ID**  
secure your digital life™



# Whats next? Actuators.



Door magnet sensor  
Wireless IR detector  
TV set  
Home Server  
3.5" Master panel

Man Generated Data  
Sensor network collecting data  
Actuators to act upon data

Computer -> Internet -> Sensors -> Actuators -> Skynet

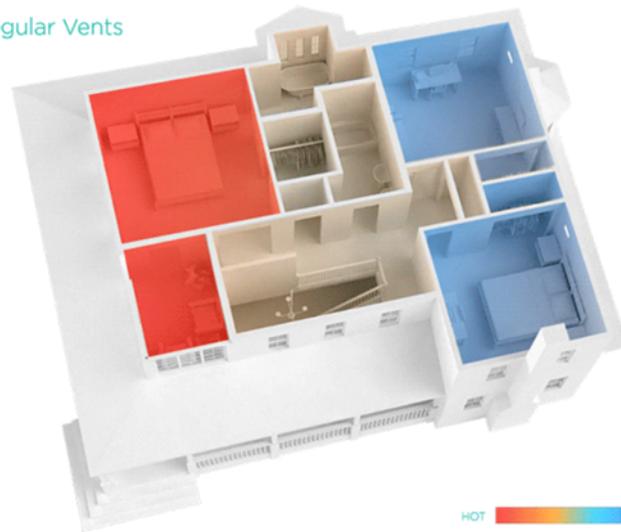


## Smart Vent Technology

Smart Vents connect to the Internet and to each other. Control how much air reaches each room of your house to balance energy usage and comfort.

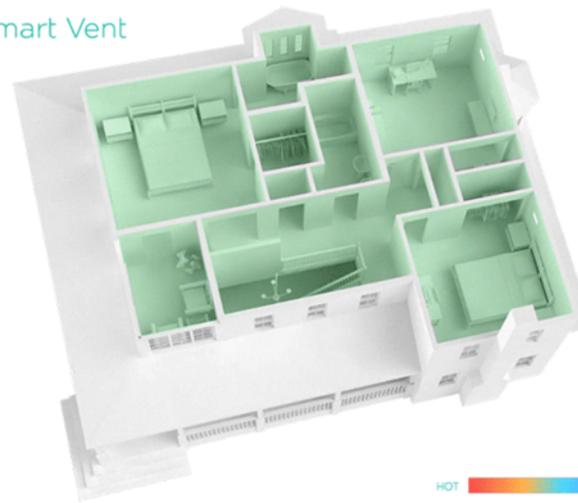


Regular Vents



HOT COLD

Smart Vent



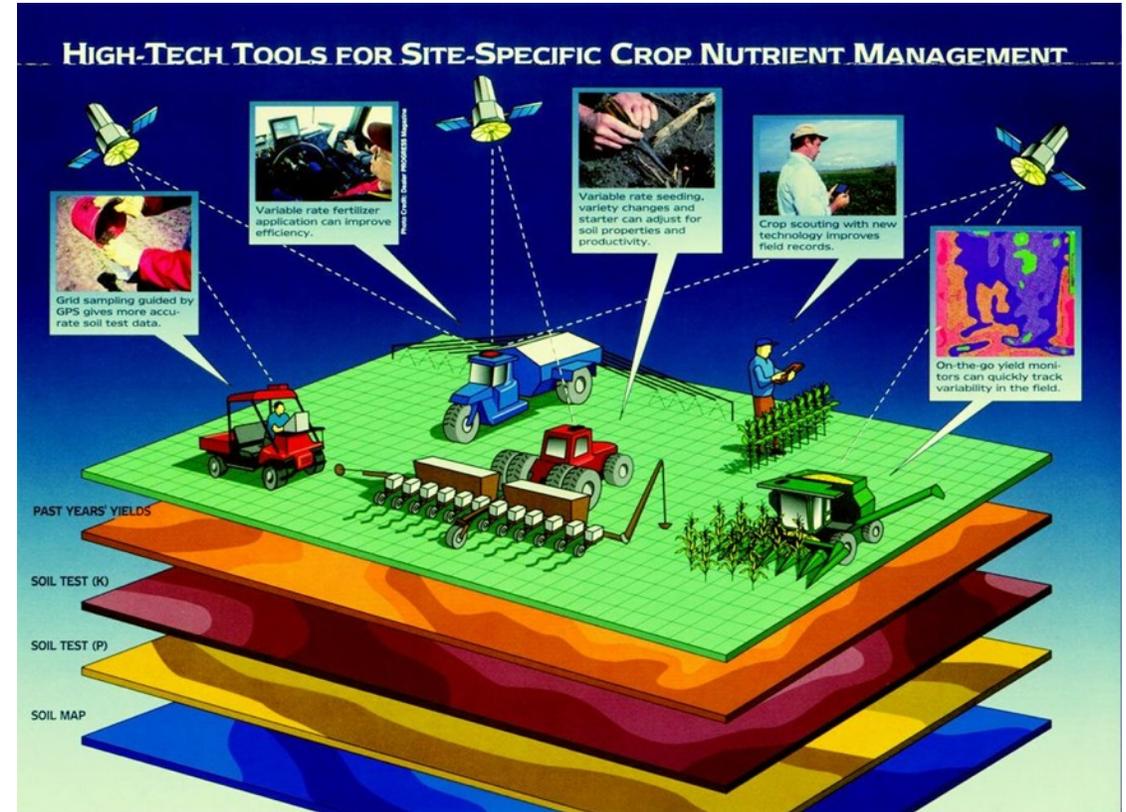
HOT COLD



- Sensor platform big time



Autonomous Car



Precision Agriculture



- **It happened -> the IoT is upon us**
- **Sensors improve our lives**
- **I barely touched the quantified self**
  - **Bio and health examples abound and it's a whole different thing**
  - **There is some control here because the FDA is involved**
- **Security and privacy is at least being discussed**



- **If its really about understanding our impact on the planet**
- **And making changes to reduce impact**
- **Then we have to do it AND it has to work**
- **And if we screw it up early, it will be a huge setback that will be hard to over come**



# *InvenSense*<sup>®</sup>

*Sensing Everything*

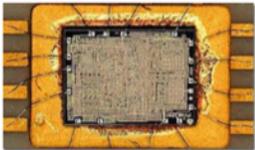


# Path to making T Sensors

- plastic substrates and printed electronics -> good enough

## 1971: Intel 4004

First Si  $\mu$ Proc.  
10  $\mu$ m  
4 bit  
pMOS  
-15VVdd  
2300 TOR  
108 KHz



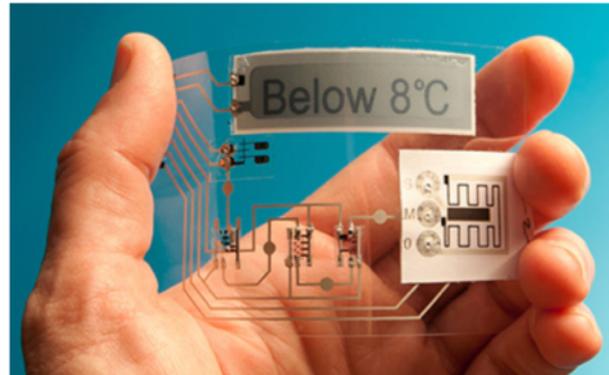
## 2011: imec & Holst

First plastic  $\mu$ Proc.  
5  $\mu$ m  
8 bit  
pMOS, dualVt  
-10VVdd  
2000 TOR  
6 Hz



## 2015

ThinFilm prints 5  $\mu$ m transistors and sensors, with down to \$0.05/tag.



J. Bryzek, TSensors Summit, 2015



- More cellphones than toothbrushes in 2011
- There are 6.8 billion people on the planet. 5.1 billion of them own a cell phone, but only 4.2 billion own a toothbrush. (Source: Mobile Marketing Association Asia)



## Grush: The Gaming Toothbrush

### Grush & Smile

Grush transforms the brushing chore into a fun and interactive game. An advanced Bluetooth motion sensing toothbrush, coupled with interactive and instructive mobile games, guide kids' brushing and lets parents track the results.

