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reliability designed, reliability delivered

Wearables that Work: Getting it Right the First Time

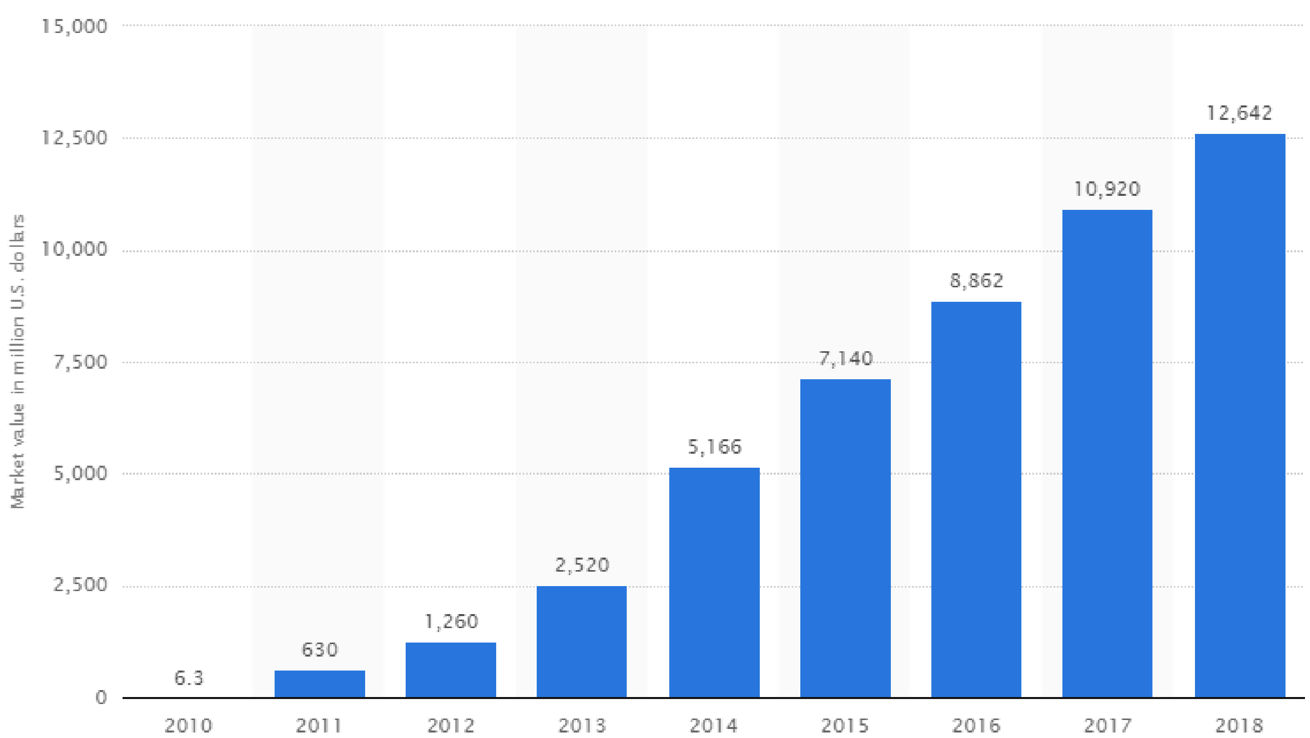
Greg Caswell

SMTA San Jose, CA June 25, 2015

Wearables Market is Hot, Hot, Hot!

Wearable device market value from 2010 to 2018 (in million U.S. dollars)

This statistic provides a forecast for the market value of the wearable device market from 2010 to 2018. Wearable technology in the future is expected to include products such as Google Glass and the iWatch as well as other medical technology. By 2018, it is estimated that this market will be worth some 12.6 billion U.S. dollars.



http://www.statista.com/statistics/259372/wearable-device-market-value/

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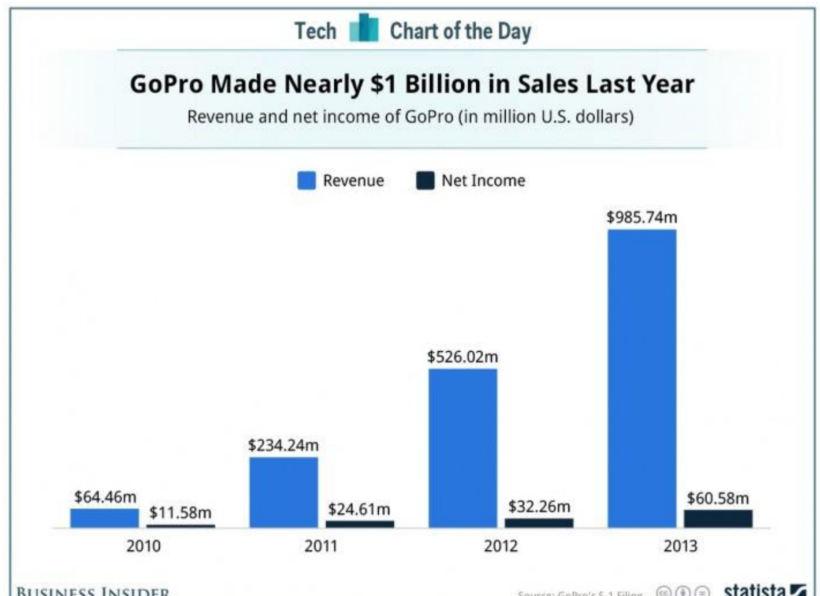
FitBit and GoPro (Fitness Tracker, Internet Video)

Fitbit's and GoPro's success? Focused application, strong commitment to quality, <u>seamless wireless engagement</u>



An Explosion of New Applications

NeuroOn: World's First Sleep Mask for Polyphasic Sleep

FreeWavz: Smart Earphones With Built-In Fitness Monitoring

runScribe: Wearable for the Data-Driven Athlete

Carry Less, Adventure More: Survival Belt

...Including This...

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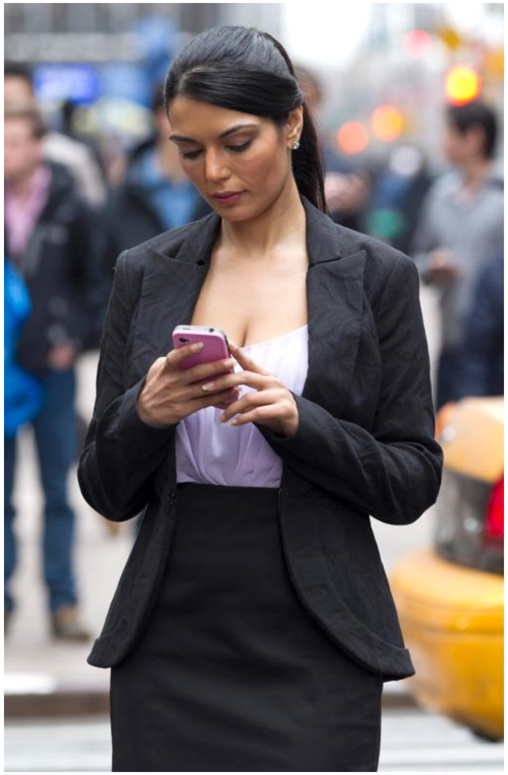
...and now here!!! - Apple Watch



Expects to sell 20 million units in 2015 at $350 each because the typical iPhone user looks at his/her phone 110 times a day

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We Have a Problem: Wearables Are Not Workable

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Wearable Technology is Not Working

- 24%: Wearables are too complicated to use
- 22%: Wearables did not set up properly
- 21%: Wearables did not work as advertised

There are strong indications that wireless reliability is a key player in this failure of wearable technology

Sourced: http://www.accenture.com/SiteCollectionDocuments/us-en/engaging-digital-consumer-new-connected-world.pdf

Think Wireless is Easy? Already Solved?

specific problem symptoms grouped into eight major vehicle categories.

The top two problems reported by owners are Bluetooth pairing/connectivity and built-in voice recognition systems misinterpreting commands. These are also the most frequent problems reported by owners at 90 days, according to the J.D. Power 2014 U.S. Initial Quality Study.SM

"As we've seen in our Initial Quality Study, owners view in-vehicle technology issues as significant problems, and they typically don't go away after the ownership honeymoon period is over," said Renee Stephens, vice president of U.S. automotive at J.D. Power. "Furthermore, early indications from our upcoming 2015 U.S. Tech Choice Study show that vehicle owner expectations of advanced technology capabilities are growing. Owners clearly want the latest technology in their vehicles, and they don't hesitate to express their disapproval when it doesn't work. Their definition of dependability is increasingly influenced by usability."

Because issues with technology impact overall dependability, they also impact repurchase intent. The study finds that 56 percent of owners who report no problems with their vehicle say they "definitely will" purchase the same brand next time, compared with 43 percent of those who report three or more problems. Together with the fact that 15 percent of new-vehicle buyers indicate they avoided a model because it lacked the latest technological features—up from just 4 percent in 2014[2]—technology clearly plays a key role in affecting future purchase decisions.

Key Study Findings

- Among owners who experienced a Bluetooth pairing/connectivity problem, 55 percent say that their vehicle would not recognize their phone, and 31 percent say the phone would not automatically connect when entering their vehicle.

The top two problems reported by owners are Bluetooth pairing/connectivity and built-in voice recognition systems misinterpreting commands. These are also the most frequent problems reported by owners at 90 days, according to the J.D. Power 2014 U.S. Initial Quality Study.SM

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Reliability is Letting Wearable Tech Down

- “Another month, another bad experience with regard to reliability of wearable tech – this time with the Fitbit Flex. When the silicone<sic> wristband was only about a month old, it started coming apart…..”

- “Did you try turning it off, and then on again? How about charging it?”

- “After the first time you go through that dance, you realize it will never ever work. The failure mode is 100% catastrophic from the point of view of the user.”

http://wearabletechwatch.net/2013/09/06/reliability-is-letting-wearable-tech-down/

http://forums.jawbone.com/t5/SUGGESTIONS/Is-the-UP24-Reliable-now/td-p/79393

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Terrible Wearables: Hall of Shame

- "In taking blood pressure readings, the Withings blood pressure monitor failed every time (but one), all at the same point"

http://wearabletechwatch.net

- Contacts rubbing skin raw
  - Heat & sweat
    - http://www.n3rdabl3.co.uk/2014/07/lg-g-watch-charging-points-cause-injury-users/

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Terrible Wearables: Hall of Shame (cont.)

- "Sunscreen melted my Nook"
  - A tiny warning on the can reads it can damage some fabrics materials or surfaces.

http://bcove.me/hh5yfn26

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I got a few smart watches and they worked <u>so poorly</u> that I just said, 'UGH', I did not really want this. It was <u>not a good experience</u>

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How Do We Make Wearables Workable?

Define Wearable Electronics

Wikipedia:

"…miniature electronic devices that are worn by the bearer under, with or on top of clothing."

That's It?!

https://en.wikipedia.org/wiki/Wearable_computer

Apps | Abaqus Blogging | Scratch Project ... | FutureAdvisor | Outlook Web A... | Online Time Tra...

Create account Log in

WIKIPEDIA
The Free Encyclopedia

Main page
Contents
Featured content
Current events
Random article
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Wearable computer

From Wikipedia, the free encyclopedia
(Redirected from Wearables)

The **lead section of this article may need to be rewritten.** Please discuss this issue on the talk page and read the layout guide to make sure the section will be inclusive of all essential details. *(February 2015)*

Wearable computers, also known as **body-borne computers** or **wearables** are miniature electronic devices that are worn by the bearer under, with or on top of clothing.[1] This class of wearable technology has been developed for general or special purpose information technologies and media development. Wearable computers are especially useful for applications that require more complex computational support than just hardware coded logics.

If one is asked to give a simple, yet modern, example for wearable technology, that will be the Nike+ system which allows you to track your time, distance, pace and calories via a sensor in the shoe. Another example can be Google Glass, which combine innovative displays with some novel gestural movements for interaction.

The WIMM One, an Android powered wearable computer.

One of the main features of a wearable computer is consistency. There is a constant interaction between the computer and user, i.e. there is no need to turn the device on or off. Another feature is the ability to multi-task. It is not necessary to stop what you are doing to use the device; it is augmented into all other actions. These devices can be incorporated by the user to act like a prosthetic. It can therefore be an extension of the user's mind and/or body.

Many issues are common to the wearables as with mobile computing, ambient intelligence and ubiquitous computing research communities, including power management and heat dissipation, software architectures, wireless and personal area networks.

Contents [hide]

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Alternative Definition of Wearables

An 'always-available' technology

attached to the human body or clothing

that allows the wearer to

monitor, engage with, and control

devices, themselves, or their social network

always-available means it must be always-workable!

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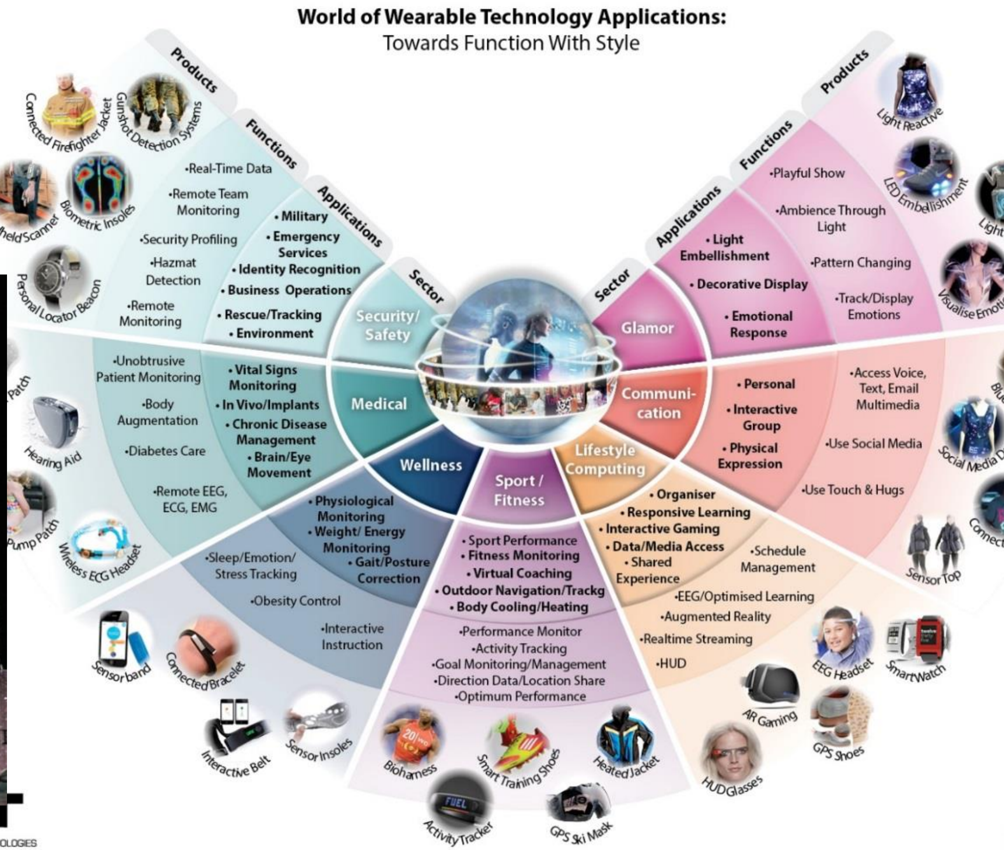
Wearables (Consumer, Medical)



WEARABLE TECHNOLOGIES

Beecham Research

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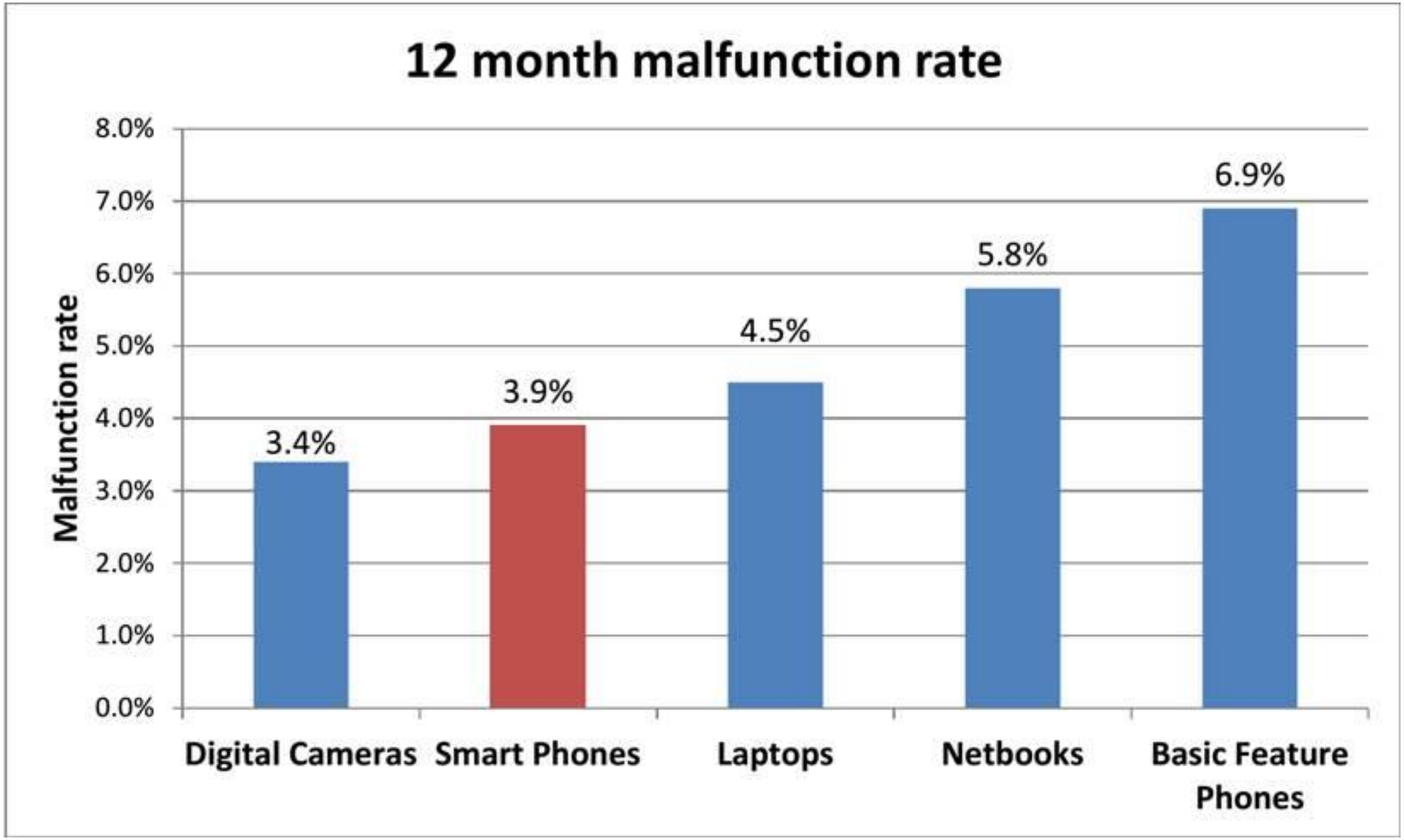
Is Your Wearable A Consumer Device…



Square Trade

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...or a Medical Device?

Family	Cumulative Failures	Duration (yrs)	Lifetime (yrs)	Units	Therapy Comprised	Therapy Uncomprised	Probability Device-Year (Hazard)
SecuraDR	0.0%	1	10	14000	0	0	0.00%
SecuraVR	0.0%	1	10	6000	0	0	0.00%
Maximo DR	0.1%	6	8	37000	8	26	0.02%
VirtuosoDR	0.1%	4	10	71000	19	15	0.03%
GEM III VR	0.3%	10	10	17000	9	27	0.03%
Intrinsic	0.2%	6	10	31000	7	36	0.03%
Maximo VR	0.2%	6	10	43000	12	33	0.03%
VirtuosoVR	0.1%	3	10	32000	9	4	0.03%
GEM III DR	0.3%	7	7	20000	11	27	0.04%
Marquis VR	0.4%	7	10	19000	15	27	0.06%
EntrustDR	0.3%	5	10	28000	6	37	0.06%
EntrustVR	0.3%	5	10	14000	5	21	0.06%
Marquis DR	0.8%	7	7	48000	100	79	0.11%
Onyx	0.5%	5	10	1000	1	3	0.10%
GEM	1.0%	10	10	22000	N/A	N/A	0.10%
GEM DR	1.2%	10	10	15000	N/A	N/A	0.12%
EntrustDR	2.8%	5	10	500	1	6	0.56%
VirtuosoDR (advisory)	28.3%	4	10	4000	2	490	7.08%

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Why is Reliability a Challenge?

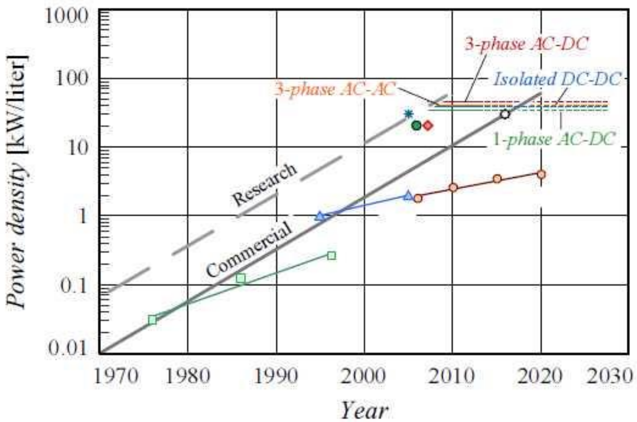
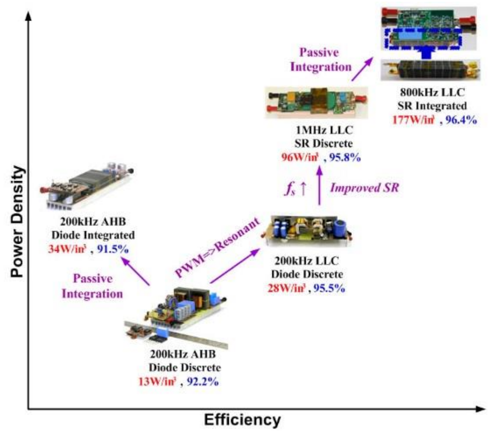


Figure 2. Power density trends of commercial and research systems and the Power Density Barriers.

Everything is Hot



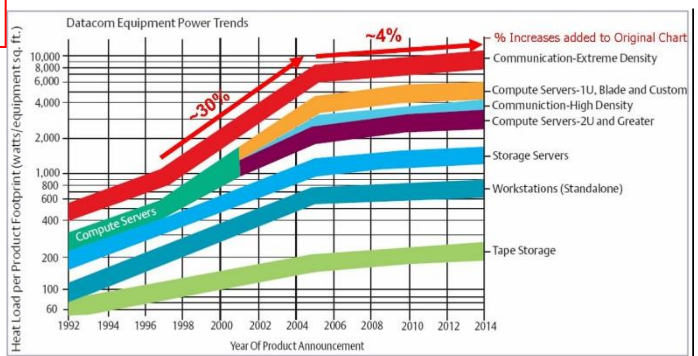


Figure 1. Equipment densities are rising even faster than once predicted.
© 2005 ASHRAE TC 9.9 Datacom Equipment Power Trends & Cooling Applications

Everything is Mobile

Everything is Everywhere

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How Long Does a Wearable Need to Last?

- IMPORTANT: Not the same as a Warranty (marketing)

- Rough equivalents:
  - Clothes: ??
  - Running Shoes: 3 months to 5 years (600 miles)
  - Watches: 3 to 20 years
  - Glasses: 2 to 5 years
  - Cell phones: 12 to 36 months

- With a new technology, there is an opportunity to influence expectations

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How Are Wearables Used?

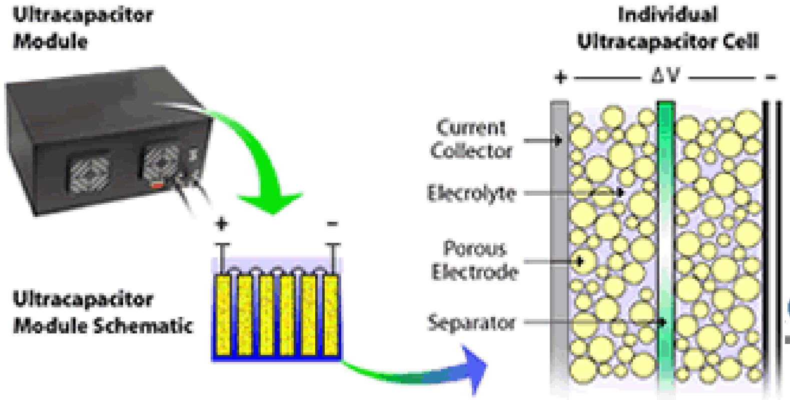
The Use Case for Wearables Has Not Been Defined!

A Critical Action for the Wearable Tech Community

Where will they use it? How often?

Examples of Next Gen Technologies in Wearables

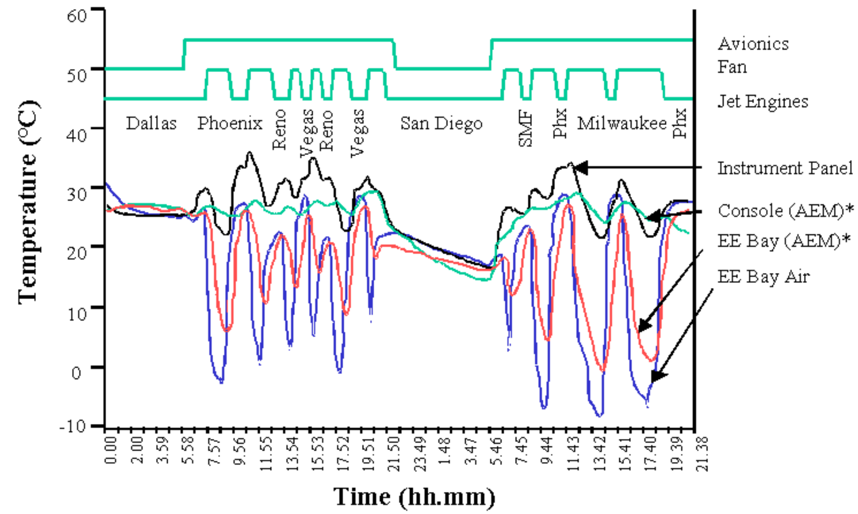
- Embedded components
- Ultra-small components (i.e., 01005 capacitors)
- New substrate materials
  - Polyethersulfone, polyethylene terephthalate (PET), polyethylene napthalate (PEN)
  - Polyimide is not a next gen technology
- Printed connections
  - Silver inks, copper inks, nanosolders, conductive polymers
- Organic displays
- Power Via Supercapacitors

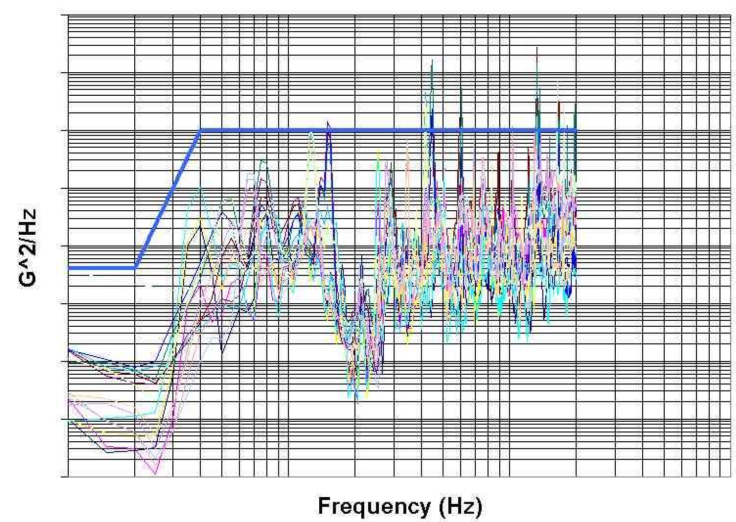


Waiting on the Use Case: Define Failure Inducing Loads

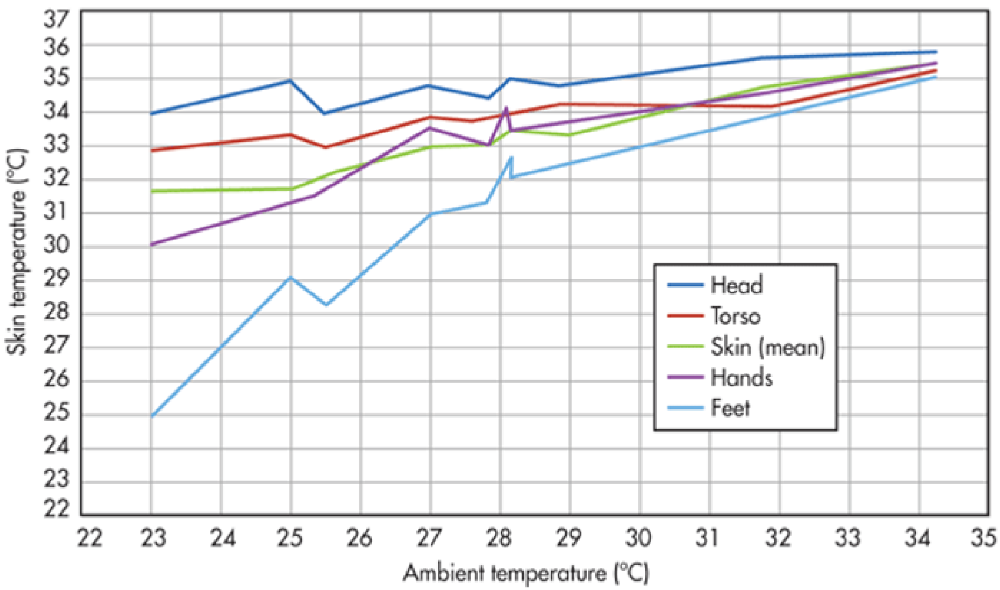
- Temperature Cycling
  - Tmax, Tmin, dwell, ramp times
- Sustained Temperature
  - T and exposure time
- Humidity
  - Controlled, condensation
- Corrosion
  - Salt, corrosive gases (ie Cl
- Power cycling
  - Duty cycles, p
- Electrical Lo
  - V ent density
  - ient, electrical noise
- M ending (Static and Cyclic)
  - ard-level strain
- Random Vibration
  - PSD, exposure time, kurtosis
- Harmonic Vibration
  - G and frequency
- Mechanical shock
  - G, wave form, # of events

And now we have to think about wear and wireless!





Field Environment: Body & Outdoor Temperatures



- Maximum temperatures likely not a significant concern
- Typically far below ratings

- However, very cold temperatures (below -20C) could be a challenge
  - Especially in combination with a mechanical load

Temperature	Avg. U.S. CLIM Data	Avg. U.S. Weighted by Registration (Source: Confidential)	Phoenix (hrs/yr)	U.S. Worst Case (hrs/yr)
95F (35C)	0.375%	0.650%	11% (948)	13% (1,140)
105F (40.46C)	0.087%	0.050%	2.3% (198)	3.8% (331)
115F (46.11C)	0.008%	0.001%	0.02% (1.4)	0.1% (9)

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Field Environment: Mechanical

- Vibration
  - Not typically affiliated with human body, but outliers can occur (especially with tools, transportation)
  - Examples: Jackhammer, reciprocating saw
  - Have induced failures in rigid medical devices

- Mechanical Shock
  - Drop loads can reach 1500g for mobile phone (some OEMs evaluate up to 10,000g)
  - Likely to be lower for lighter wearables, but could be repeated (i.e., affiliated with shoes)

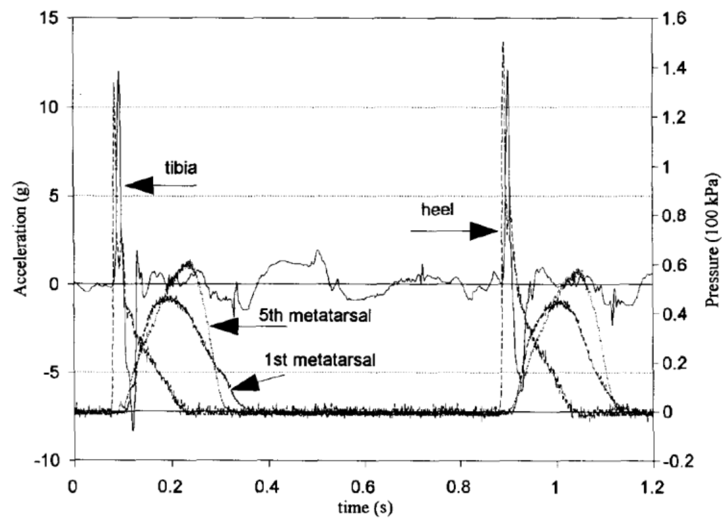

Fig. 7. Typical acceleration and pressure patterns recorded while subject was running.

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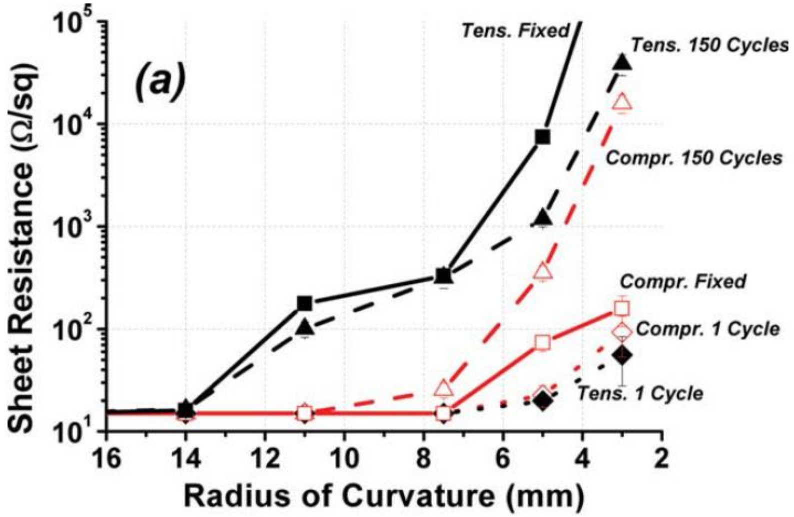
Field Environment: Mechanical (cont.)

- Bending (Cyclic / Overstress)
  - Often considered one of the biggest risks in regards to wearables
  - Certain human movements that induce bending (flexing of the knee) can occur over 1,000/day

- Case Study
  - There is indication that next-gen substrate materials experience a change in electrical properties after exposure to bending
  - Can be exacerbated by elevated temperature



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Corrosion: Handling / Sweat

- Composition of dissolved salts in water
  - Can include other biological molecules.
- Main constituents, after the solvent (water),
  - Chloride, sodium, potassium, calcium, magnesium, lactate, and urea.
- Chloride and sodium dominate.
  - To a lesser but highly variable extent, iron, copper, urocanate (and the parent molecule histidine), and other metals, proteins, and enzymes are also present.
- Different constituents of sweat can attack different elements of the wearable technology (contacts, windows, straps, etc.)

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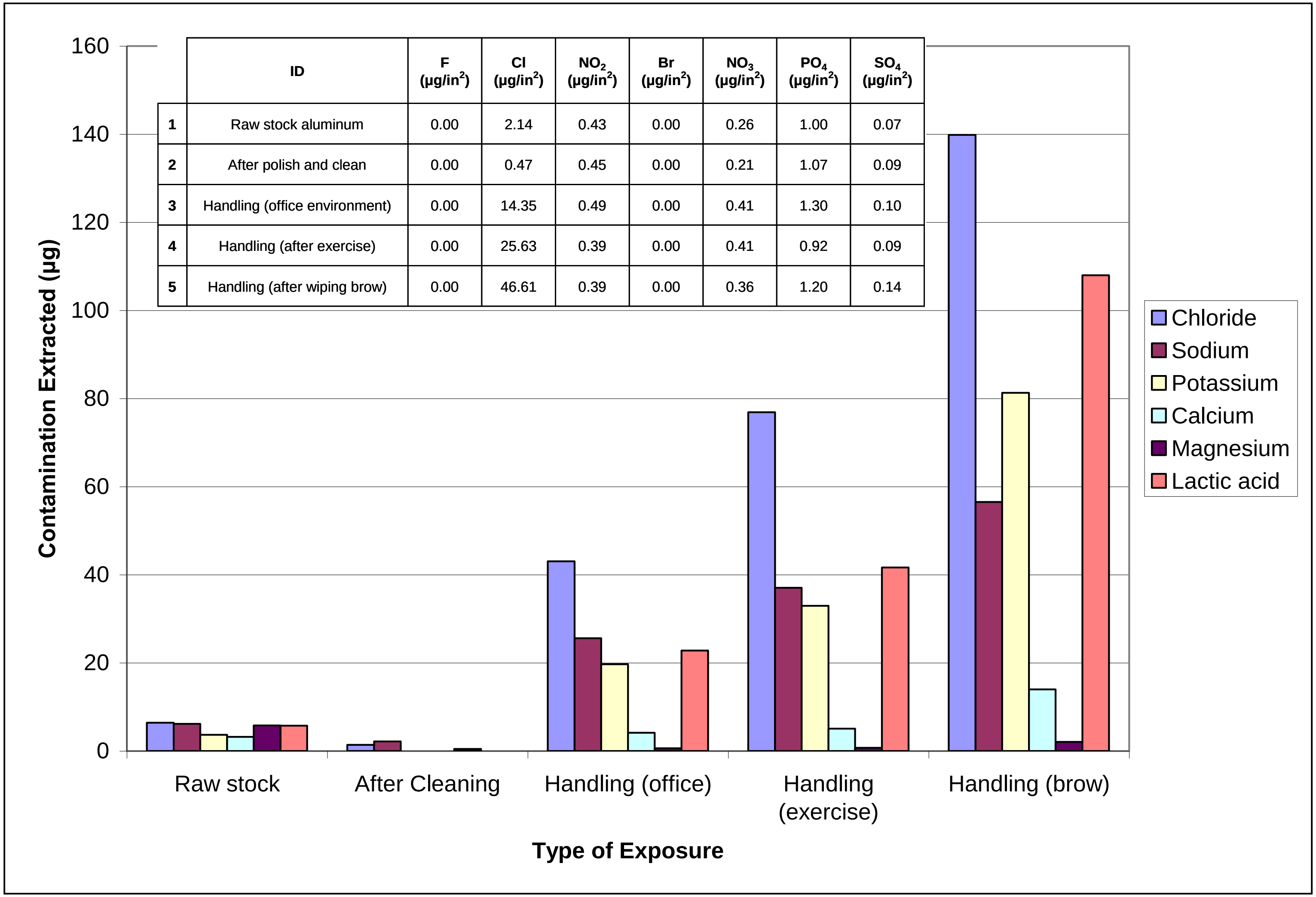
Handling / Sweat (cont.)

	ID	F (µg/in²)	Cl (µg/in²)	NO_2 (µg/in²)	Br (µg/in²)	NO_3 (µg/in²)	PO_4 (µg/in²)	SO_4 (µg/in²)
1	Raw stock aluminum	0.00	2.14	0.43	0.00	0.26	1.00	0.07
2	After polish and clean	0.00	0.47	0.45	0.00	0.21	1.07	0.09
3	Handling (office environment)	0.00	14.35	0.49	0.00	0.41	1.30	0.10
4	Handling (after exercise)	0.00	25.63	0.39	0.00	0.41	0.92	0.09
5	Handling (after wiping brow)	0.00	46.61	0.39	0.00	0.36	1.20	0.14



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Examples of Sweat Formulation

- Defined by EN 1811 comprises 0.5% NaCl, 0.1% urea, 0.1% lactic acid and the pH adjusted to 6.6 with NH_4OH.
- ISO standard ISO 3160-2 comprises 20 g/l NaCl, 17.5 g/l NH_4Cl, 5 g/l acetic acid and 15 g/l d,l lactic acid with the pH adjusted to 4.7 by Na[illegible]H.
- Another mixture comprising 7.5 g/l NaCl, 1.2 [illegible] ml/l lactic acid, pH = 4.57.
- Another one use[illegible] KCl, 0.3 g/l Na_2SO_4, 0.4 g/l N[illegible]
- Other mixt[illegible] NaCl, 0.1% Na_2SO_4, 0.2% urea and 0.2% lactic acid, pH ad[illegible] to 4.5.
- Japanese mixture 1 is 19.9 g/l NaCl, 1.7 g/l urea, 1.7 g/l lactic acid, 0.8 g/l Na_2S, and 0.2 g/l NH_4Cl
- Japanese mixture 2 is 17g NaCl, 1500 ml CH_3OH, 1 g urea, 4 g lactic acid made up to 1 liter by water.

Never Go Below pH of 4.5
Does Not Exist in the Real World

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Rain & Water Immersion Challenges

- Issue of exposure to water & rain must be addressed for wearable electronics to survive

- Some cell phone manufacturers coat the product with either a conformal coating or a superhydrophobic coating to protect the electronics

P2i perform protect improve

Semblant™

ACULON Performance Surface Solutions

H2O PROTECTION

LIQUIPEL WATERSAFE™ TECHNOLOGY

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Corrosion: UV Exposure

- Exposure to ultraviolet (UV) is typically not sufficient to induce degradation in electronic materials

- However, a combination of temperature, moisture, and UV can break polymeric chains
  - Exact combination, and specific portion of the UV spectrum, is not always well characterized

- It has been documented that stress corrosion cracking has been caused by sunscreen lotion

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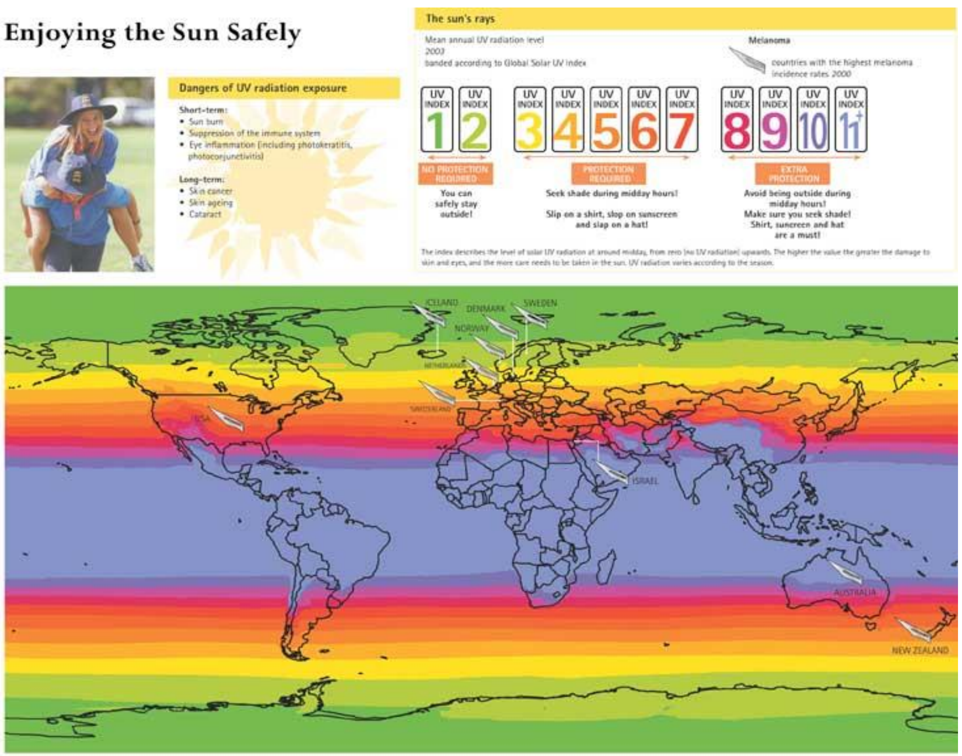
UV Exposure

Annual UV Intensity – Global Picture



http://www.drb-mattech.co.uk/uv%20map.html

Annual UV Energy Calculations by City			
City	Latitude	Average Total Energy at 340nm (W*hr/m^2/nm)	Average Annual Total Radiant Dose at 340nm (kJ/m^2/nm)
Singapore	1	426	1532
Paris, France	48	499	1796
Sao Paulo, Brazil	22	553	1991
Tokyo, Japan	35	570	2053
Guatemala	14	648	2334
Miami, FL	25	661	2380
New York NY	40	661	2381
Barcelona, Spain	41	662	2382
Brasilia, Brazil	15	662	2383
Melbourne, Australia	37	708	2549
Buenos Aires, Argentina	34	727	2618
Baghdad, Iraq	33	732	2634
Minneapolis, MN	44	735	2647
Townsville, Australia	19	743	2673
Madrid, Spain	40	748	2694
LA, CA	34	767	2761
Phoenix, AZ	33	869	3129

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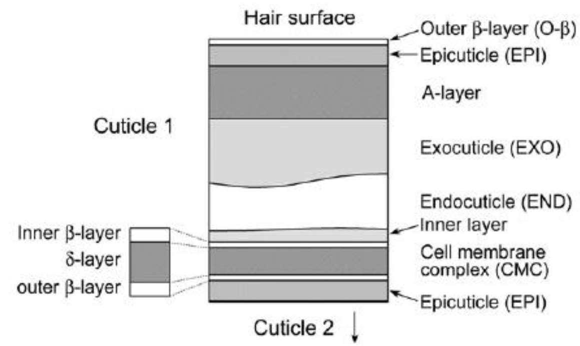
Wear

Hardness of Skin and Hair Can Vary Widely (Ethnicity, Sex, Dryness)

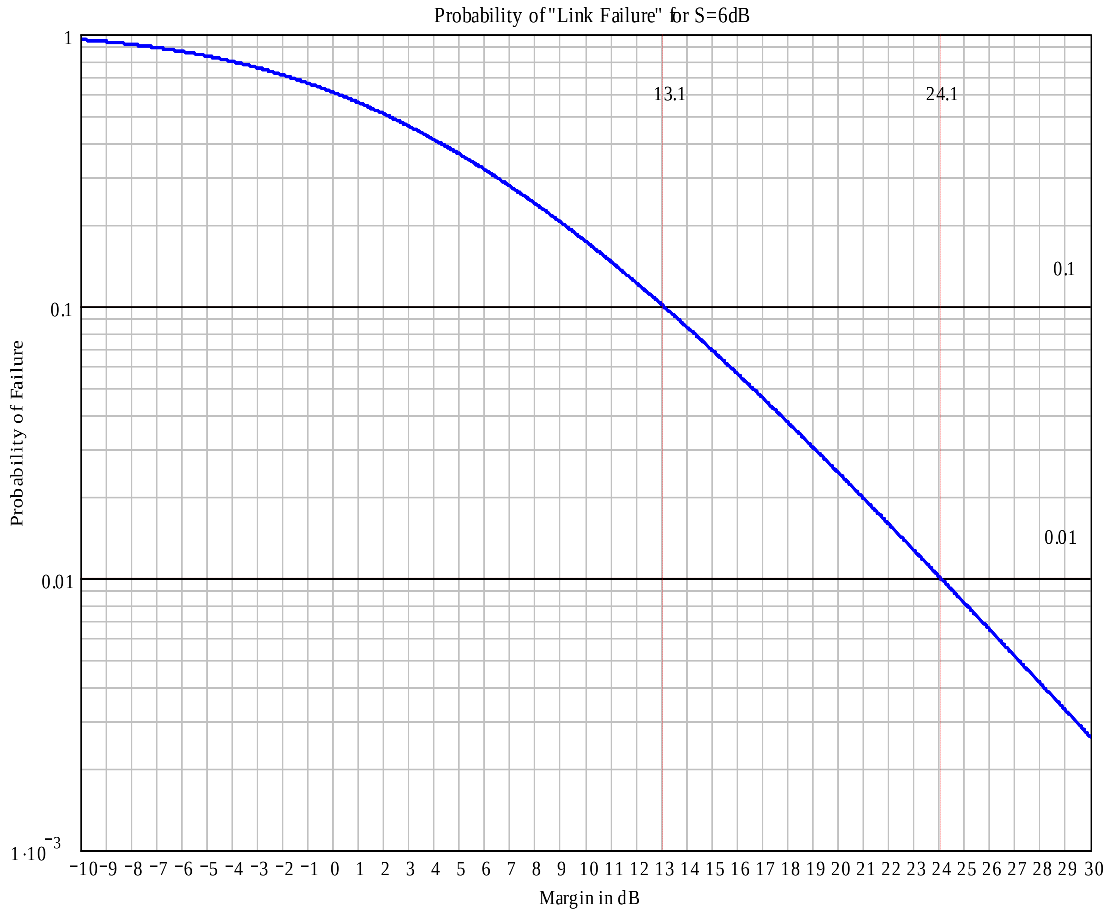
Schematic of the sublamellar structure of the human hair cuticle



	Hardness (GPa)			Elastic modulus (GPa)		
	Cuticle[a]	Cortex[b]	Medulla[b]	Cuticle[a]	Cortex[b]	Medulla[b]
Caucasian	0.32 ± 0.04	0.27 ± 0.02	~ 0.19	6.0 ± 0.4	6.5 ± 0.5	~ 5.5
Asian	0.39 ± 0.06	0.30 ± 0.02	~ 0.18	7.5 ± 0.8	6.7 ± 0.3	~ 5.8
African	0.24 ± 0.05	0.23 ± 0.06	~ 0.16	4.8 ± 0.6	5.8 ± 0.7	~ 5.0

Wireless

- How have we traditionally met reliability goals in wireless?
  - Margin, Margin, Margin
  - Testing, Testing, Testing



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Reliability = Margin = Power

- Relationship between transmitted and received power
  - $$P_r = P_t \times G_t \times G_r \times \left(\frac{1}{4\pi \times f}\right)^2 \times \left(\frac{1}{d}\right)^n$$
    - G is gain, f is frequency, d is distance, and n is the path loss exponent (location dependent)

- Need greater reliability?
  - Higher power, Better antenna, Higher antenna
    - This is key for wearables! Google Glass (head) has better transmission than Nike (foot)

Location	n	σn
Retail Store	2.2	8.7
Home	3	7
Office	2.6	14.1
Factory	3.3	6.8
What About Wearables?		

http://www.digikey.com/en/articles/techzone/2011/aug/comparing-low-power-wireless-technologies

The Path to Margin is Paved With Problems…

…Lower Battery Life, Higher Cost, Larger Design, FCC Violations, Slower Data Rates, etc.

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Wireless – It is Not All About the Test

- Higher Reliability Applications (Military/Industrial) Rely on Lots and Lots and Lots of Field Testing
  - Is this Practical for Wearables?

- Everyone Else Relies on Standards (Compliance). But…
  - Compliance Is NOT Reliability
  - Wearables need to be more reliable than traditional Bluetooth/ Wi-Fi/RFID (always available)
  - Cell Phones Buy Spectrum (no interference)

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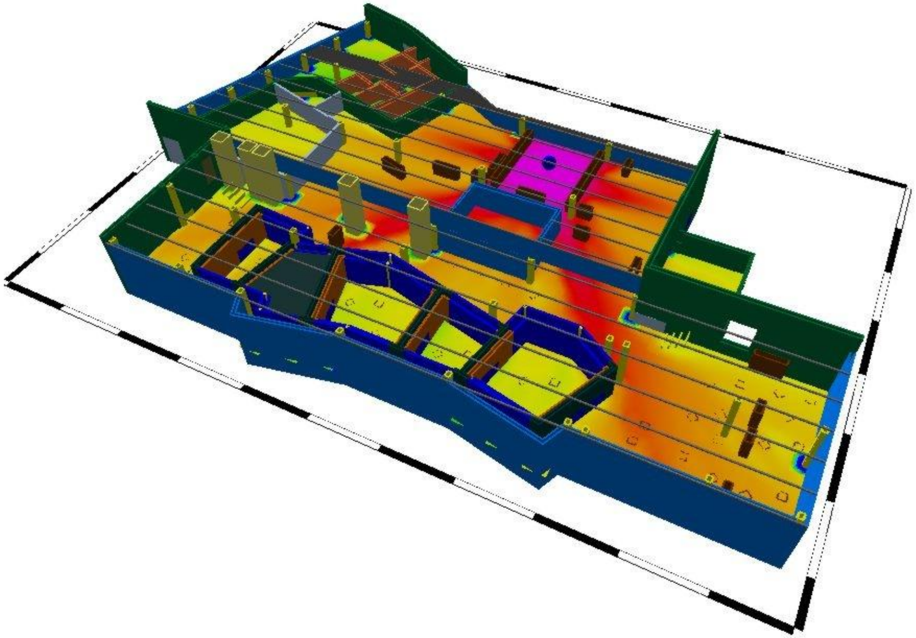
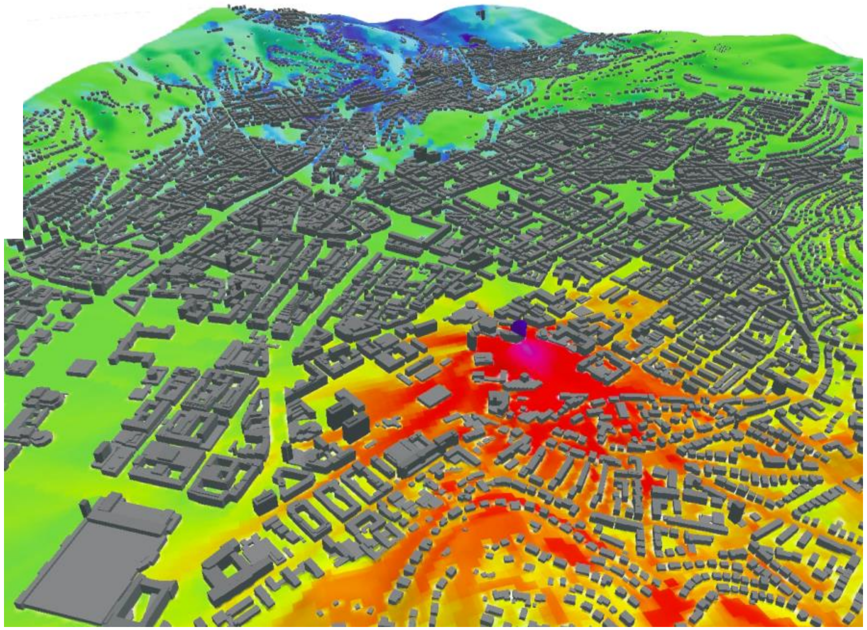
Simulate, Simulate, Simulate





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Other Challenging Environments for Wearables

- Washer / Dryer
- Cleaning fluids
- Mud / Dust / Water

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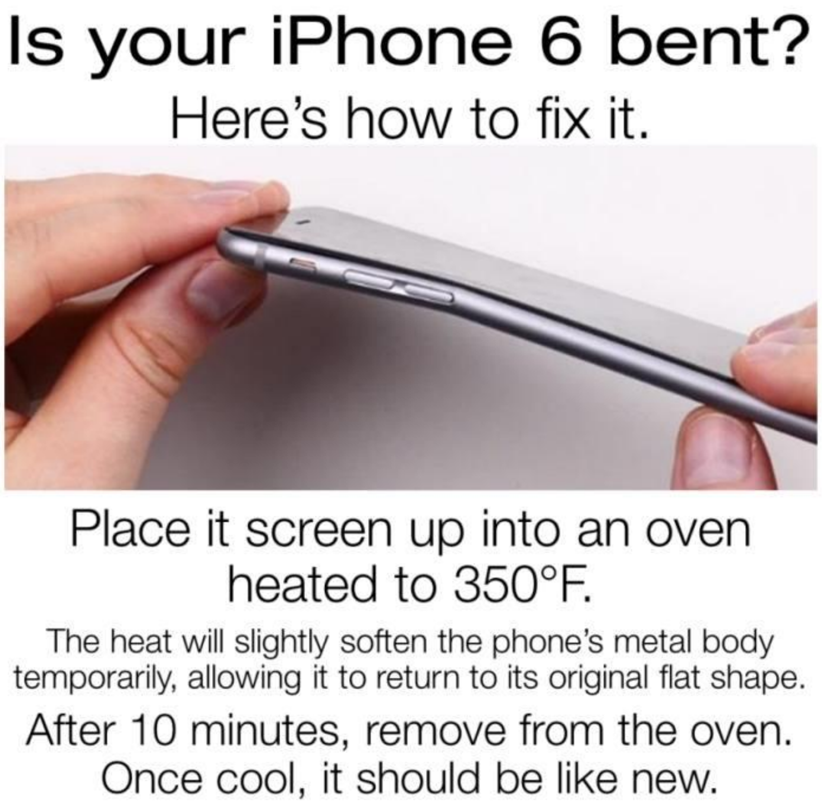
If You Don't Understand the Use Environment…



Bringing it All Together

Reliability Expectations

+

Use Environment

=

Appropriate Material and Technology Selection

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Conclusions

- Wearables and IoT are an Exciting Revolution!

- There are Clear Risks
  - Wearables use new technology that hasn't been fully characterized
  - They'll be placed in environments not fully defined

- Do Not Rely on 'What Has Everyone Else Done' or 'Agile Development' (Code Name: Customers as Guinea Pigs)
  - Bring Knowledge and Simulation into the Design Process

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