Handling and Delivering Healthcare Data
In an Age of Ever-Evolving, Unimaginable Technologies

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www.medicalmems.net
MEMS ≡ MicroElectronic Mechanical Systems

https://www.mems-exchange.org/MEMS/what-is.html
We are entering an age of *incessant*, endlessly streaming real time data – for the most part unformatted, non-standardized, non-interoperable, insecure, varying degrees of HIPPA compliance, and frequently proprietary – much of it sitting on private vendor servers.
The Microtechnology Tidal Wave

MEMS & Microtechnology

Healthcare Industry

MEMS ?

SURVIVAL ISLAND
By the end of 2015, 500 million smartphone users across the globe will be using a healthcare app.

By 2018, half of the more than 3.4 billion smartphone and tablet users will have downloaded mobile health applications.

Margaret A. Hamburg, MD
Commissioner of Food and Drugs
mHealth Summit
Gaylord National Convention Center, National Harbor, MD
December 11, 2013
There are more cellphones on the globe than there are people, toothbrushes and toilets

45 trillion networked sensors are projected to be in use in 20 years

- Wearable
- Implantable
- Digestible
- Lab-on-a-Chip
An Exploding Market

• Sales of remote monitoring devices grew from $3.9B in 2007 to $10B in 2012

• Wearable devices market is projected to grow to $75 Billion by 2025 *

• 3 Billion Wearable Sensors will be in use in 2025 – 1/3 of which will have capabilities that we cannot yet imagine or predict **

• Over 600,000 of 2.5 million implanted devices in use (such as pacemakers) are linked to home networks for remote monitoring

• 500,000,000 people are using mobile health apps in 2015

• Apple app store offered 12,000 health related apps in 2013


** Wearable Sensors 2015-2025: Market Forecasts, Technologies, Players, Mr James Hayward and Dr Guillaume Chansin, Wearable Technology Report
THE PROBLEM WITH POSITIONING FOR THE FUTURE IN MICRO & NANO TECHNOLOGIES IS THAT A TECHNOLOGY WILL EXIST IN 6 MONTHS THAT IS ENTIRELY UNIMAGINABLE TODAY”
Trillion Sensors (TSensors) Visions

- Mobile sensor market for volumes *not envisioned* by leading market research organizations in 2007, grew exponentially 212%/y between 2007 and 2012.
- Several organizations created visions for a continued growth to trillion(s).
  - Market research companies don’t yet see it.
  - Explosion to trillion(s) is likely to be driven by new applications *not yet envisioned* by leading market research organization.
- Forecasting thus needs visionaries!
DATA WATERBOARDING

24/7 Data

- EHRs
  - Clinical Decision Support
  - Guideline & Protocols
  - Clinical Alerts
  - Genetic Diagnostic & Treatment Profiles
- Micro & Nano Devices – from the unwell and the healthy populations
  - Wearables
  - Implantables
  - Digestibles
  - Extrinsic
  - Lab-on-a-Chip
- Real Time Remote Video Monitoring & Auditing
- Coding

Clinician circa 2018
Thoughtflow® – The Core of Clinical Practice

Thoughtflow®
How Clinicians Obtain, Process, Prioritize & Act Upon Data

© Samuel R. Bierstock, MD, BSEE
Conventional EHRs Remain stuck in this concept of “Workflow”
Thoughtflow ® in the Electronic World

DATA ARRIVES AS QUICKLY AS IT IS GENERATED

- Accurate Voice Recognition
- Maturing Language Processing
- Vocabulary Standards
- Maturing Clinical Decision Support
- Accurate Automated Coding
- Accepted Protocols, Guidelines, Treatment Plans and Order Sets

The concept of ‘Workflow” is over as a driving force. We are entering the age of “Thoughtflow ®”
Body Area Network: New Trend

Products
- High-Performance MEMS
  Accelerometers, Gyros
  Pressure Sensors, uPhone
  Strain Gauge
- RF Transceivers
- Analog precision human
  interface, eg: ECG
- Low power uC/MCU
- Power Mgmt, Signal
  condition, Thin Film Battery

Benefits of MEMS-based Solutions:
- Accuracy of Sensors
- Non-Invasive Technique
- Low Cost for Public
  Healthcare Service
- 24h Monitoring
Wearable Sensors Galore

Scanadu Scout - Scanadu
A handheld sensor that when placed against the forehead for 10 seconds allows you to analyze, track, and trend your vitals, including temperature, blood oxygenation, heart rate, respiratory rate and blood pressure data to a smartphone with a 99% accuracy rate.

Astmapolis - Propeller Health
Sensor that attaches to the top of an existing asthma inhaler to keep track of medication dosage, time, and place.

Zio Patch - iRhythm Technologies
A small, band-aid-like partially passive sensor that records every heartbeat. Used in diagnosis of cardiac arrhythmias for up to 14 days of continuous wear.

Wireless Blood Pressure Wrist Monitor - iHealth Labs
A wireless blood-pressure wrist monitor, weight scale, and pulse oximeter that transfer data to the iHealth MyVitals app.

EPOC - Emotiv
The Emotiv EPOC uses sensors to tune into electrical signals produced by the brain to detect user thoughts, feelings, and expressions.

First Warning - First Warning Systems
A breath health system to detect tumors earlier and cut the rate of false positives and negatives by measuring cell temperature changes created over time.

Helius - Proteus Digital Health
Wearable and ingestible sensors that work together to detect ingestions and physiologic data. The data is sent via Bluetooth and the patient, caregiver and care team get smartphone alerts.

SenseWear Armband - Jawbone
A personal, portable hand-sanitizer dispenser that healthcare professionals wear which transmits usage data wirelessly so that administrators can track compliance.

EASYWAKEme - Dreamtrap
A sleep monitor with vibrating alarm that "reads" body characteristics, tracks sleep duration and efficiency to accurately determine the optimal wake-up moment.

Hydration Sensor - MC10
A small stick on patch, that monitors your hydration levels in real-time – sending smartphone alerts that tell you when and how much to drink.

Vitalink - VG8io
Wearable bio sensors that collect ECG, respiratory biometrics, 2-wavelength pulse oximetry, temperature and 3-axis accelerometers. Data is collected by smartphone, transmitted to a server which provides clinicians early notification of negative change.

Checklight - MC10
Captures head impact data during play, while being virtually invisible to the athlete.

Sympo CGM System - Echo Therapeutics
A non-invasive (needle-free), wireless, transdermal continuous glucose monitoring system.

Visi Mobile System - Sotera Wireless
A smartphone-sized monitor that’s attached to a patient’s wrist. The information is fed directly into a patient’s electronic health record wirelessly through the hospital’s WiFi.

Rapid Rehab System - Veristride
A custom gel insole to detect a person’s gait, or walking pattern. Mainly for amputees who would like to reduce how much they limp when using prosthetic legs. The system also uses a smartphone application that wirelessly tracks the data.

Welcome to the Future

An Invitation to:

A Ride Through The Future
That You May Not Know You Are Already In
Sensor Studded Mobile Devices

Microsoft's $199 Fitness Band Packs in 10 Sensors, Works with Windows Phone, iOS, and Android

http://www.dailytech.com/Microsofts+199+Fitness+Band+Packs+in+10+Sensors+Works+with+Windows+Phone+iOS+and+Android/article36803c.htm#sthash.2wDoqYux.dpuf
Cellphone Diagnostic Testing Apps

**ECG monitor from AliveCor**
http://www.alivecor.com/home

**ECG monitor from Quardio**
https://www.getqardio.com/qardiocore/

**Preventice’s smart bandage constantly tracks cardiac ECG and rhythm monitoring**
http://www.preventice.com/bodyguardian/howitworks/

**Uchek** (MIT) detects 25 diseases, such as diabetes, urinary tract infections, pre-eclampsia, glucose, proteins, ketones, and more.

**Fraunhofer’s glucose, lactate and cholesterol sensors, pulse oximeter, and a fluorescence sensor for detecting biomarkers**

**Lapka can detect radiation and organicity of food.**
https://mylapka.com/pem
First Open Wearable Platform from Samsung

- **Simband**: modular wristband enabling multiple plugged-in sensors.

- First sensors developed by Imec:
  - **PPG** sensors that measure blood flow, heart rate, blood pressure, and other vital signs.
  - **ECG** sensor to measure the rate and regularity of a heartbeat.
  - Body temperature.
  - Galvanic skin response.
  - Bioimpedance sensor to monitor everything from blood flow to body fat.

- Samsung Architecture Multimodal Interactions (S.A.M.I.) is a data broker that enables wearable devices to upload information to the cloud.

[Link to Samsung innovation areas](http://www.samsung.com/us/globalinnovation/innovation_areas/)
Wearable Tattooed Sensors

UC San Diego

MC10
Wearable Sensor based Clothing

Bio-sensing clothing for everyday life

- Designed to be worn all-day, every day
- Continuously reads your biometrics and emotional state
- Improves your life without getting in the way
- Seamlessly connects to your mobile devices

Features

- Heart rate: Taken from sensors directly organs your vein, (oxygen is the most accurate measure of your heart rate per minute
- Breathing: Measures your heart rate accurately and breathing rate using your respiration
- Activity: Tracks your daily steps and get irregularities to be more active
- Calories: Tracks your daily steps and get irregularities to be more active
- Emotive State
- Moments
- Smart Apparel
- Analytics

Washable T-shirt that can read a patient’s heart rate, blood pressure, cardiac irregularities

http://www.omsignal.com/

NTT Docomo and Toray announced Hitoe (Japanese for "one layer") cloth with coated nanofibers and a square patch that does the sensing, measuring heartbeat and even offering metrics resembling a cardiogram.

http://www.engadget.com/2014/01/30/ntt-docomo-toray-smart-cloth/

http://www.timesofisrael.com/israeli-ecg-t-shirt-monitors-hearts-saves-lives/#ixzz3ATObYkF2
Wearable Jewelry

Wellograph Wellness Watch
9DOF + Heart monitor

Netatmo’s June bracelet
with UV sensor

Intel unveiled 3G snakeskin smart bracelet

Wearable Smart Shoes

Nike’s smart shoe insert with 8 sensors measures jump height, speed, performance.

Fall-Prevention Motorized Shoe for elderly people based on pressure sensors detecting loss of balance.

http://nocamels.com/2014/05/israeli-fall-prevention-motorized-shoe-is-a-step-in-the-right-direction/
Wearable Diagnostics

SensiVest™

A non-invasive lung fluid status monitor. Patients measure their lung fluid content daily in the comfort of their home. The simple measurement takes only 90 seconds to complete.

Measurement results may be automatically uploaded to the secure cloud application for a healthcare provider to review and act upon based on his discretion.

http://sensible-medical.com/
Wearable belts with position sensors and accelerometers that detect position and impending fall and deploy air bags to protect the hip.

Active Protective
http://www.activeprotective.com

Hip Hope
http://www.hip-hope.com

Hip-Hope unique Custom made sensors System logic and Algorithm make it finally possible to distinguish between real falls and misleading fall-like events.

Learn how it works
Wearing Your Computer

University of Pittsburgh Swanson School of Engineering

- Responsive hybrid material
- Fueled by an oscillatory chemical reaction and can perform computations based on changes in the environment or movement, and potentially even respond to human vital signs
- Self-oscillating polymer gels and piezoelectric micro-electric-mechanical systems creating a new reactive material system capable of performing computations without external energy inputs, amplification or computer mediation
- Different oscillatory patterns form a type of “memory”, allowing the material to be used for computation.

Wearable Smart Bra...

Smart Bra concept is aimed at helping people ward off emotional eating (Image: Microsoft) using ECG and EDA, an electrodermal activity sensor measuring skin conductance (moisture) and movement (respiration rate).

http://www.telegraph.co.uk/technology/microsoft/10499811/Microsoft-developing-smart-bra.html

Bra with autolock. When True Love is detected, the bra unhooks automatically from the front. The bra contains a heart-rate sensor. The app calculates the "true love rate," comparing the readings to activities like shopping, watching a horror movie, flirting, jogging, or receiving a surprise gift.

http://news.cnet.com/8301-17938_105-57617747-1/bust-lock-down-bra-only-unhooks-for-love-true-love/

The sensor finds cancer by detecting tiny metabolic temperature changes caused by cancerous cells in a tumor. The temperature readings are sent to a global library where they're run through a proprietary algorithm. Then the results are sent back to a user’s phone.


Fancy lingerie brand Victoria’s Secret is now selling a sports bra for around $75 with built in electrodes that hook up to a heart rate monitor.

Breast Health Exams

Glove Tricorder with pressure feedback loops, temperature sensors, accelerometers and later ultrasound pads to the tips of the glove, allowing doctors to see inside the breast to diagnose breast cancer and enlarged kidneys and other sub-dermal issues.

Breast lumps self-exams sensor (mammogram replacement)


http://medsensation.com/
Wearables for Babies

Smart diapers monitors urinary tract infection, prolonged dehydration, kidney problems.
https://www.indiegogo.com/projects/pixie-scientific-smart-diapers

Teddy bear measures child’s temperature, heart rate, and oxygen levels through his ‘smart paws’. Bear’s LED heart beats at the same rate as child’s, creating a bond between child and bear.
http://blogs.plos.org/globalhealth/2014/05/wiredhealth/

Smart sock from Owlet Baby Care monitors infant’s quality of sleep, blood oxygenation levels, and skin temperature
https://www.owletcare.com/

The Mimo baby monitor has respiration sensors, temperature sensors, the Mimo Kimono monitors baby movements and body position. Clinically validated sleep algorithms, you can know when your baby falls asleep, when they wake and how well they are sleeping.
http://mimobaby.com/

SmartOne infant monitor measures temperature, baby orientation and breathing
http://mysensiblebaby.com/
Smart Sporting Balls

Connected smart basketball for iOS and Android to help improve shooting and ball handling skills – fast. Tracks makes and misses and learns and adapts to any player’s skill level.

http://www.94fifty.com/

http://micoach.adidas.com/us/smartball/
Detecting Players’ Brain Injury

A green, yellow and red lights indicate moderate, medium and severe impacts, respectively, measured by acceleration sensors. The system also logs the total number of impacts.

S3 itself is a wireless helmet-mounted impact logger that transmits data to the Eurotech Everyware Cloud where it can be used to provide immediate information on the impact levels experienced by an athlete to coaches, doctors, and parents.

http://www.mc10inc.com/

http://www.sensuss.com/news
Helping in Daily Life

The first sonic connected toothbrush provides daily feedback on the quality of brushing and helps all the family to improve brushing habits.

http://www.kolibree.com/en/

Personal asthma wheeze monitor measures WheezeRATE™, or the percentage of breathing time a person spends wheezing, as a result of their airways narrowing, using Acoustic Respiratory Monitoring. It enables measurement of the response allergens and medications.

http://isonea.com/

Shake stabilized spoon for Parkinson disease patients eliminates 70% of the tremor.

http://www.liftlabsdesign.com/

The first sonic connected toothbrush provides daily feedback on the quality of brushing and helps all the family to improve brushing habits.

The app analyses data and provides key feedback to improve over time through a new and fun experience.

http://www.kolibree.com/en/
Monitoring Sleep

Sense system includes:
- Sense, a device that sits on nightstand monitoring the conditions in your bedroom and disturbances at night.
- Sleep Pill, sleep tracking sensor that clips invisibly to your pillow
- Mobile applications that bring it all together

The app tells you how well you slept, or didn't, by giving you a unique **Sleep Score** each night.

https://www.kickstarter.com/projects/hello/sense-know-more-sleep-better

Beddit is an ultra-thin film sensor that you place in your bed, under the bed sheet.
All you have to do is to sleep on it. Beddit connects wirelessly to your smartphone for a **sleep analysis**.

http://www.beddit.com/
Paying with Your Hand

Biyo senses the unique vein patterns in your palm to create the most secure and convenient password that you never have to remember.

http://biyowallet.com/
Brainwaves Driven Smart Toys

Brainwaves driven ears and tail from Necomimi ($69) express your emotional state before you start talking.

http://www.necomimi.com/
Sensing the Brain

Wireless neuroheadset based on 16 sensors detects:

- Thoughts
- Feelings
- Expressions
- Subconscious emotional states
- Facial expressions
- User-trained mental commands which can control existing and custom applications and games as if by magic.

ElMindA’s Brain Network Activation Analysis System uses dozens sensors that measure and analyze neural activity during specific brain processes, measuring it against a database of over 7,000 brain functions to see how a patient’s condition stacks up, to spot problems early, such as like Alzheimer’s, Parkinson’s and ADHD.

http://www.emotiv.com/epoc/

Sotera Wireless’ non-invasive measures continuous blood pressure, along with pulse rate, skin temperature, electrocardiogram, blood oxygenation and respiration rate and temperature. FDA approved

Cnoga’s device spectrometrically measures noninvasively blood pressure, blood oxygen, and pulse.

HealthStats watch measures blood pressure using applanation tonometry.
Noninvasive Glucose Monitoring

Integrity Applications’ employs a combination of ultrasound, electromagnetic, and thermal technologies to obtain blood glucose readings.

http://www.integrity-app.com/

Minimally-invasive continuous glucose monitoring system based on skin permeation

http://www.echotx.com/symphony-cgm-system.shtml

Biosensors’ approach is based on electromagnetic impedance spectroscopy (EIS) and electromagnetic impedance tomography (EIT).

http://www.biosensors-tech.com/#

Sensing glucose, heartbeat, skin resistance, quality of skin collagen, skin health and identifies nervous people based on color change of RGB lights passing through skin.

http://www.globes.co.il/en/article-1000877563

C8 MediSensors developed Raman spectroscopy based glucose sensor, raised $120M ($43M in 2012) and closed in 2013 after finding measurement instability. Apple hired several of former employees.
Personal Glucose Monitors

Contact lens embedded glucose monitor in tears being developed at Google, wirelessly communicates with mobile devices. Google partnered with Novartis to bring it to market.

http://www.nytimes.com/2014/07/16/business/international/novartis-joins-with-google-to-develop-contact-lens-to-monitor-blood-sugar.html?_r=0

Toilet embedded sensors measure blood glucose and albumin, free protein, urea, bilirubin, and others, for tracking health condition for type 2 and pre-diabetes, based on mid-IR spectroscopy

http://www.pyreos.com/
Intelligent Pill Bottles

GlowCap® – Remembering so you don’t have to.

GlowCap® fits most prescription bottles and uses light and sound reminders to signal when it is time to take your medications. Inside the cap, a chip monitors when the pill bottle is opened and wirelessly relays alerts, through the AT&T Mobile Broadband Network, to you or your caregiver. A push button at the base of the lid makes refills easier than ever.

http://www.glowcaps.com/
Intelligent Pills

Digital Medicines

Tiny, Safe Ingestible Sensor
Grain-of-sand sized sensor made from dietary minerals, manufactured in drugs

Medicines Signal When Ingested
Unique, pill-specific signal inside body with no battery, radio or antenna

Monitor Therapy & Outcomes
Wearable patch measures ingestions & full panel of physiologic response metrics

Deliver Mobile User Experience
Applications translate data into knowledge, incentives and collaboration

©2012 Proteus
Implantable Devices

Intraocular lens with Batteryless Pressure Sensor for measuring Intraocular Pressure after Cataract Surgery

http://www.launchpnt.com/portfolio/biomedical/intraocular-pressure-sensor/

Wireless sensors that transmit cardiac output, blood pressure

Extendible bands to enable wireless transmission of an indication of the intraluminal characteristic

Antennas in Stents to transmit pressure, flow etc.
Contact Lens with Intraocular Pressure Sensor

http://www.slideshare.net/MikePinelisPhD/140804-25-most-interesting-medical-mems-sensors
Spectrometric Food Quality Measurement

SCIO scanner enables scanning food to get calorie counts, scanning pills to see what chemical compounds they’re made of, and scanning your household plants and flowers to see if they need more water.

Tellspec food quality monitor based on spectrometer processing sensor data in the Cloud.

‘Star Trek’–style Tricorder

1. Exponential Future

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http://www.thetechgets.com/2014/05/scio-handheld-spectrometer-kickstarter.html


http://www.foxnews.com/tech/2015/04/02/how-your-smartphone-could-become-star-trekstyle-tricorder/
Breath Diagnostics

• Dogs are trained to detect medical problems based on breath due to their extreme smell sensitivity:
  • Low sugar level in diabetics or cancer.

• What can be smelled with chemical sensors:
  • Cancer
  • Cholesterol
  • Asthma
  • Lipid peroxidation
  • Metabolism
  • Neonatal jaundice, intestinal distress
  • Cystic fibrosis/bronchitis
  • Periodontal disease
  • Infectious disease (flu)
  • Etc.

• Stony Brook University in New York have developed a breath analyzer (right)
  • Technology utilizes single crystal nanowires that are created by electrospinning.
  • Configuration of metal and oxygen atoms in the nanowires defines which molecules are captured by the chip.

Source: Dr. J. Stetter, SRI
Blood Testing based on Lab on Chip

- Stanford startup Theranos rolled out in 2014 the blood testing system after 10 year/$100M+ funding:
  - 1000x reduced blood volume for about 1000 blood tests.
    - Lab on Chip with fluorescent tags?
  - Providing results in 4 hours
  - With increased accuracy.
  - At a fraction of the lab cost.

- Focus: detecting the onset of disease in time for therapy to be effective

https://theranos.com/
Increasing Imaging Sophistication Level...

World’s first cellphone based ultrasound imager.

World’s first portable X-ray imager.
25lbs, MODIS™ 810 from Tribogenics is the world’s smallest self-contained imaging system. Battery powered and solar rechargeable. Unfolds in seconds to provide rapid imaging anywhere in the world for both diagnostic and industrial needs.
Holographic Ultrasound Imaging

Ambulance Drone

- Ambulance Drone can deliver defibrillation to any patient in a 12 km² area within 1 minute.
- At that speed, survival rates can be as high as 80%.

http://alecmomont.com/projects/dronesforgood
Personal iPad-Size DNA Sensor

• Disruptive DNA-sequencing technology based on GENIUS™ electronic technology enabling fast, accurate, and low cost genetic testing.
  • **Gene-Electronic-Nano-Integrated-Ultra-Sensitive**

• Provides orders of magnitude improvement across all dimensions of cost:
  • Cost of instrument (few $k, as opposed to current $1M)
  • Cost per test ($10, as opposed to current $1000)
  • Cost of labor
  • Cost of informatics

• Enables the democratization of sequencing in a way never before possible.

[http://genapsys.com/](http://genapsys.com/)
Single-Crystalline Silicone Nanoribbon Skin

- Seoul National University developed a skin that can stretch over the entire prosthesis (or robots).

- Includes sensors and actuators:
  - Pressure
  - Temperature arrays
  - Humidity
  - Strain
  - Electroresistive heaters, and more.

- Stretchable sensors and actuators facilitate highly localized mechanical and thermal skin-like perception in response to external stimuli.

The greatest challenge to our healthcare system as we move toward the end of the second decade of this century will be the effective delivery of data to clinicians, care-givers, decision makers, and analysts, in an age when we have no idea of what new technologies will even exists six months from the present 

*in a pertinent, useful, actionable manner*
A Plug for our Aging Veterans

Please visit www.beforeyougo.us to see and hear our tribute to our aging veterans of World War II, Korea and Vietnam – and send it to every veteran that you know and their families.

It’s FREE and they deserve to hear our thanks.
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