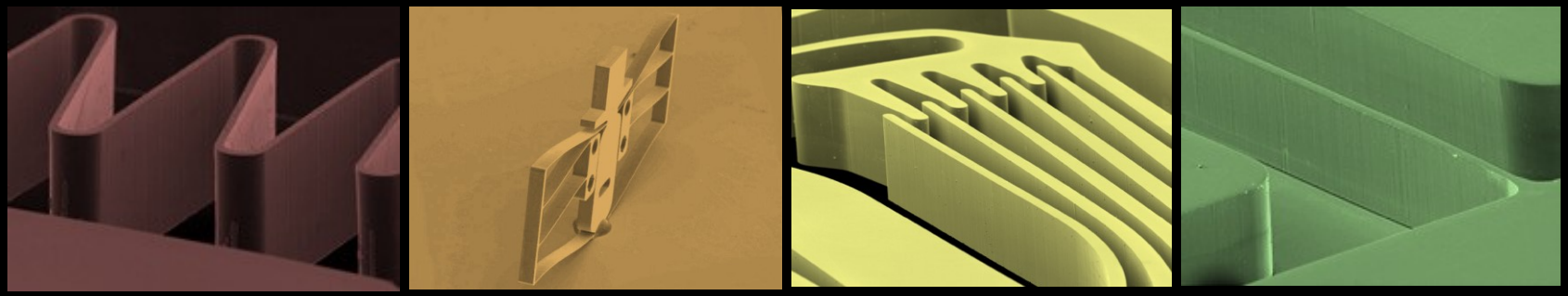
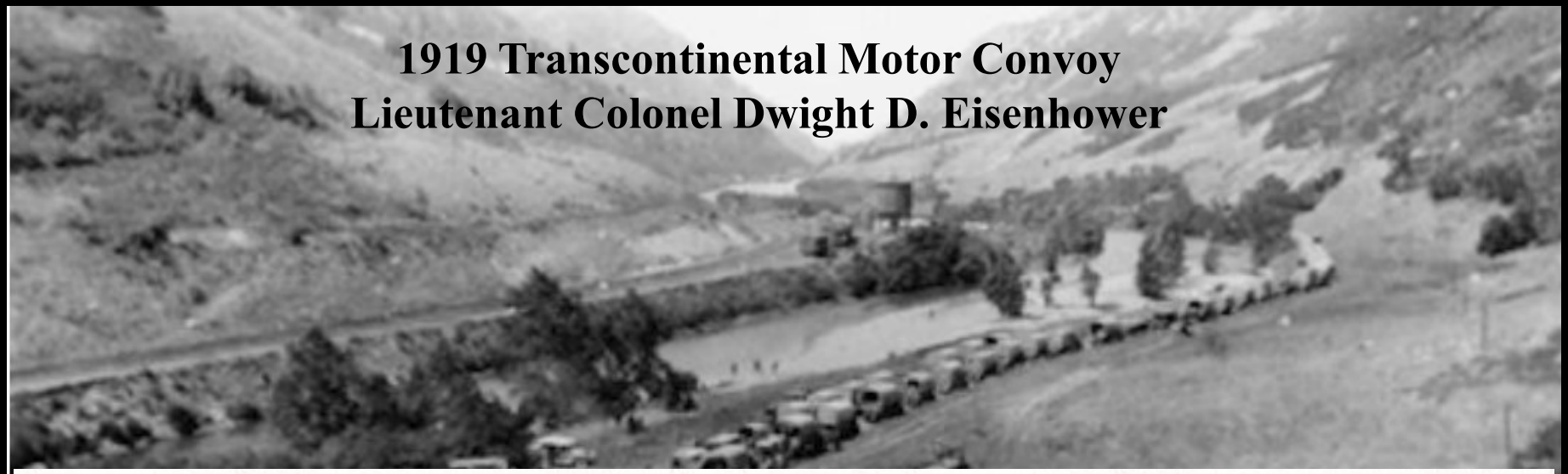


Micro-Nano and the Emerging Sensor Based Economy

Todd Christenson, Ph.D.
President, MANCEF
CTO, co-Founder, Chairman-Emeritus, HT MicroAnalytical, Inc.

23 July 2019

100 years ago…

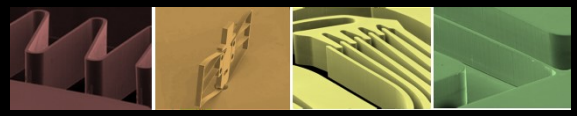


1919 Transcontinental Motor Convoy
Lieutenant Colonel Dwight D. Eisenhower

The route the convoy would take was mostly along the Lincoln Highway, the first major transcontinental motor route. The more than 80 vehicles carried 24 officers and 258 enlisted men, and they left D.C. at 1 p.m., on **July 7, 1919.** It took the convoy the rest of the day to reach Frederick, Maryland, where Eisenhower joined the group. In seven and a half hours, they had traveled 46 miles, a drive that today would take just about an hour. **with traffic?!**

100 years ago…

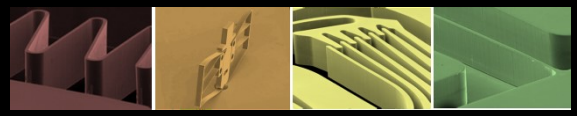
Introduction



Data Analytics is central to
nearly all emerging technology applications today,
and in nearly all markets including:

Transportation
Agriculture
Healthcare
Energy
Environment
Manufacturing
and Education!

Introduction



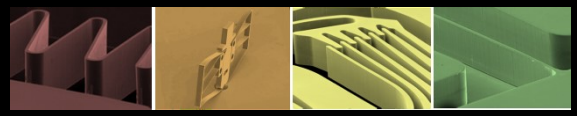
… data which is substantially provided by

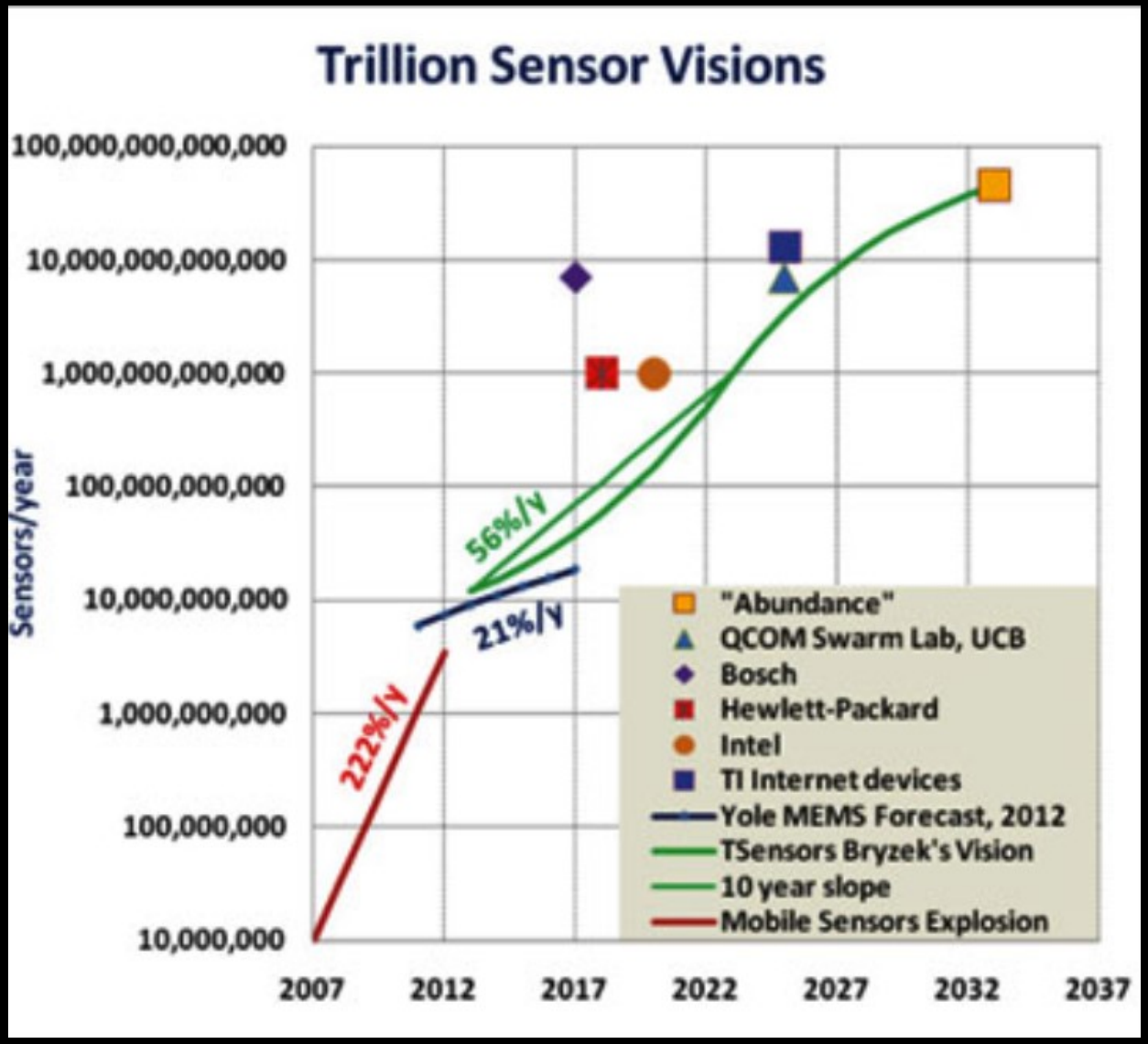
sensors

that are in turn enabled by

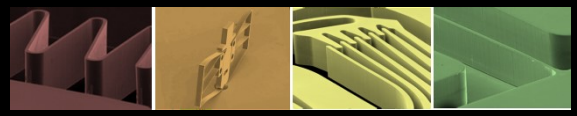
micro-nano

Data Analytics





Data Analytics



in ~ < 5 years:

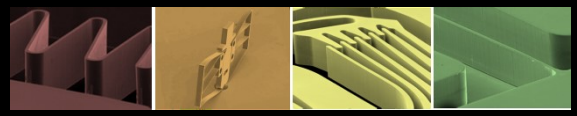
~ 1 Yottabyte of data / year

(10^{24}) (avg ~ 4MB/s/person)

Ultimately (2035?): Abundance?

(10^{27}) BRONTOBYTE

Data Analytics

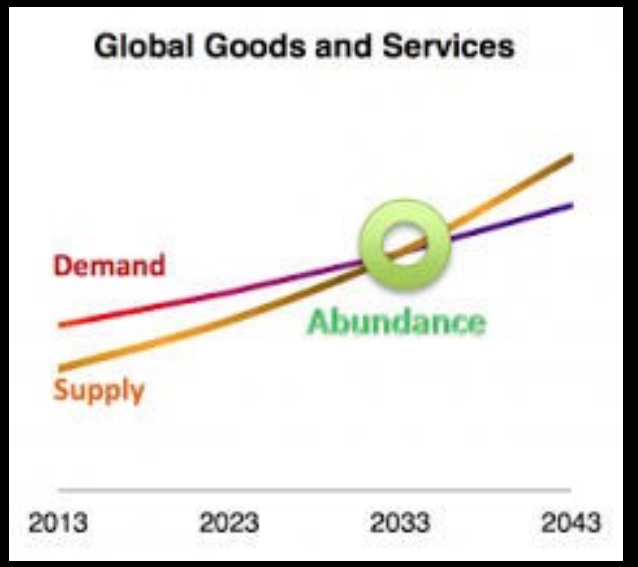


in ~ 15 years:

50-80% of worlds GDP

(i.e. ~> $60 – 90 Trillion)

Data Analytics

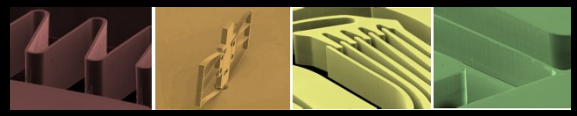


in ~ < 20 years:

Abundance estimated:
45 Trillion connected nodes

(most of which end in a sensor)

Overview - Highlights



Sensor Market Impact

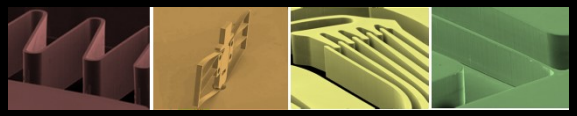
Human – Machine Interface

‘Printed’ Sensors / Electronics

Sensor Enabled Software Startups

Job / Skillset Impact

The Sensor-Based Economy



FreedomLab

NEWS | SOCIETY AND CULTURE | TECHNOLOGY AND INNOVATION | THE MACROSCOPE

The rise o
based

Sensor economy opening expanding services and opportunities for individuals, industry

by Sandra Zistl, Siemens

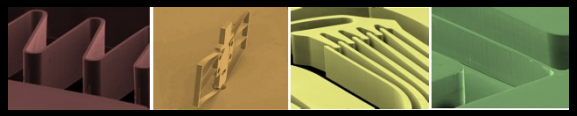
The Trillion Sensor Economy is Coming. Are You Ready?

"In many ways we a
says Bob Brumley, r
Holdings, a tech de

g equipment to pro…

y monitor the

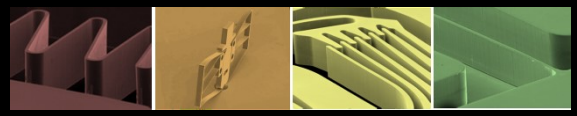
Transportation



electrification of mobility (and the earth)

- autonomous — sensor enabled
- drones — sensor enabled
- V2V — sensor enabled
- emergency response — sensor enabled
- power management — sensor enabled
- higher efficiency motors — sensor enabled

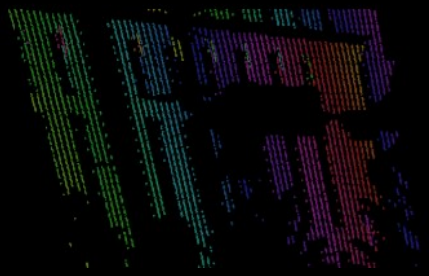
Transportation



100s of startups for ‘smart mobility’

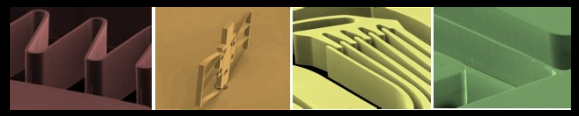
65 Global Startups Set to Share Mobility Innovations at 2019 AutoMobili-D

LUMINAR



METAWAVE

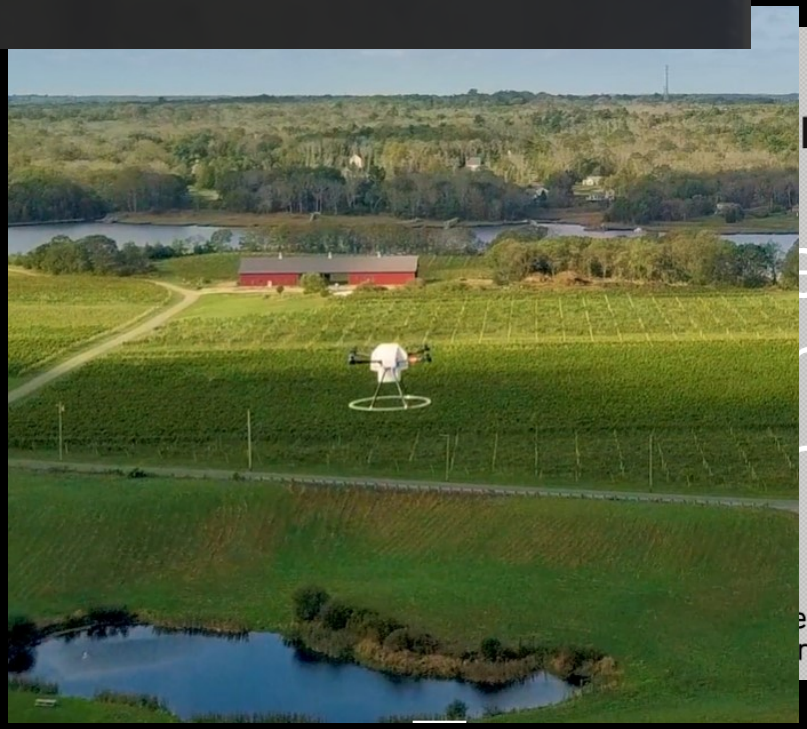
Agriculture



sensor based smart agriculture

UNDERSTORY

AMERICAN ROBOTICS



ESENSE

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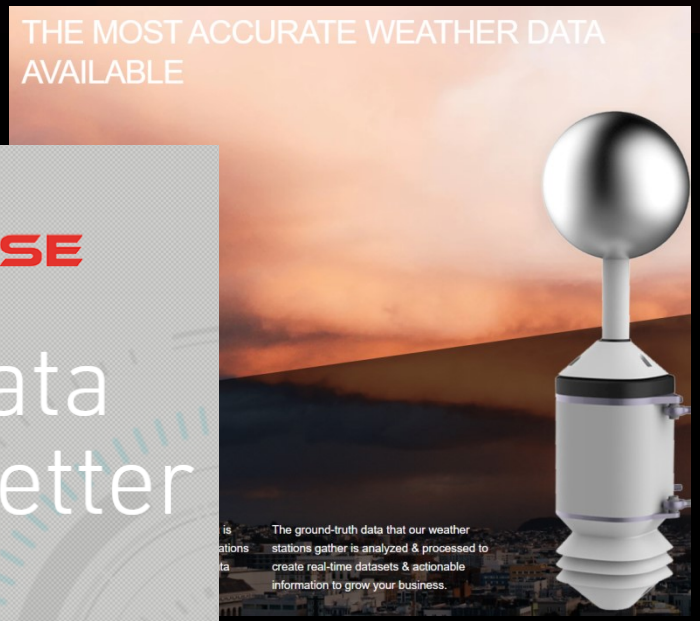
n.

ess Grain Monitoring and

n a Cloud-Based App

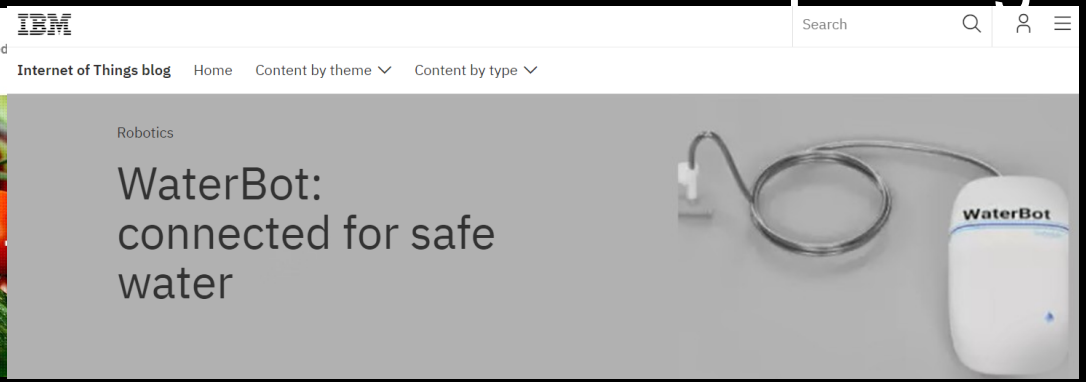


Agriculture

livestock tracking and health monitoring

food freshness, food & water safety

Paper based gas sensors replacing



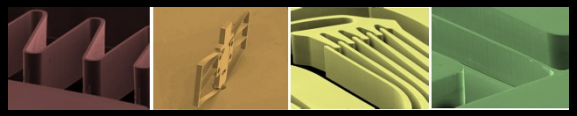
internet of water

Agriculture

farm & crop management

seeds with built in sensors

Agriculture



AgriFood tech funding: $16.9B, 1450 investments

AgriFood Tech Category Definitions

Ag Biotechnology
On-farm inputs for crop & animal ag including genetics, microbiome, breeding, animal health.

Agribusiness Marketplaces
Commodities trading platforms, online input procurement, equipment leasing.

Bioenergy & Biomaterials
Non-food extraction & processing, feedstock technology, cannabis pharmaceuticals.

Farm Management Software, Sensing & IoT
Ag data capturing devices, decision support software, big data analytics.

Farm Robotics, Mechanization & Equipment
On-farm machinery, automation, drone manufacturers, grow equipment.

Midstream Technologies
Food safety & traceability tech, logistics & transport, processing tech.

Novel Farming Systems
Indoor farms, aquaculture, insect, & algae production.

Innovative Food
Cultured meat, novel ingredients, plant-based proteins.

In-Store Retail & Restaurant Tech
Shelf-stacking robots, 3D food printers, POS systems, food waste monitoring IoT.

Restaurant Marketplaces
Online tech platforms delivering food from a wide range of vendors.

eGrocery
Online stores and marketplaces for sale & delivery of processed & un-processed ag products to consumer.

Home & Cooking Tech
Smart kitchen appliances, nutrition technologies, food testing devices.

Online Restaurants and Meal Kits
Startups offering culinary meals and sending pre-portioned ingredients to cook at home.

Miscellaneous
e.g. fintech for farmers

Upstream
Downstream
Upstream+Downstream

Crunchbase, March 28. 2019

Agriculture

Economy

"Great" profits from smart agriculture

11:34 September 14, 2015

While many localities in the country still struggle with 50 million VND / ha fields, at the farm of the family of Mrs. Nguyen Thi Hue, Phuoc Thanh residential group, Ward 7, Da Lat City (Lam Dong), each hectare Agricultural land here has yielded up to 5 billion VND / year.

Đưa chúng tôi tham quan vùng sản xuất nông ng
vì sao gia đình bà lại phát triển kinh tế theo quy t
nước có nền nông nghiệp tiên tiến trên thế giới đ
nghiệp hiện nay cần phải đầu tư theo chiều sâu,
and sustainable development. In order to achiev
compulsory condition is to apply scientific and te
technology, post-harvest preservation technolog
and management. of the agricultural sector to increase productivity and product quality.

biết để có 1.000m2 đất sản xuất loại nông
ing bao gồm nhập khẩu toàn bộ các trang
kính đúng kỹ thuật đảm bảo cho cây sinh
vegetables, tubers and fruits are grown on
Products include sugar beets, carrots,
onths old, harvested with different colors
cularly for tomatoes, there are dozens of
different types from thumbs to tomatoes for fruits weighing up to 1kg with different colors, different shapes.

Tiny vegetables are grown on "two-tier beds" of planting material, coconut fiber and nutritional fertilizer.

Tomato beds are wrong.

Rau củ tí hon được trồng trên những "chiếc giường hai tầng" chất liệu trồng là xơ dừa và phân dinh dưỡng.

Những luống cà chua sai trĩu quả.

Healthcare

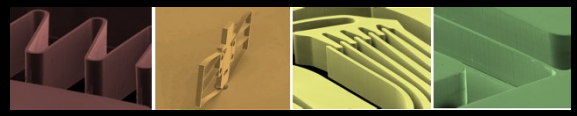
COMMENTARY • MOBILE HEALTH

Ex-Apple CEO John Sculley: Why Sensors Are the Future of Health Care Tech

By John Sculley July 17, 2019

The new Apple Watch is capable of taking an FDA-approved electrocardiogram. Apple, Amazon, Google, and Microsoft can use evolving mobile health care technology to help better treat patients, writes former Apple CEO John Sculley.
Karl Mondon—Digital First Media/The Mercury News via Getty Images

Healthcare



proteus
DIGITAL HEALTH

Pills that tell your doctor when you've taken them — and how much exe you're getting

Proteus' digital pills work by way of a tiny sensor roughly the size
Proteus Digital Health

Proteus' digital pills work by way of a tiny sensor ro
a period. The sensor can either be stamped into a pi

proteus
DIGITAL HEALTH

Ingestion Sensor – Tiny, Sa

Powered by minute quantities

Composition	Common Re
Copper: 0.0077 mg Magnesium: 0.0098 mg	2 mg in Centru 50 mg in Centr

Only 2 materials detected within range of rep
Drug Substances (2008)

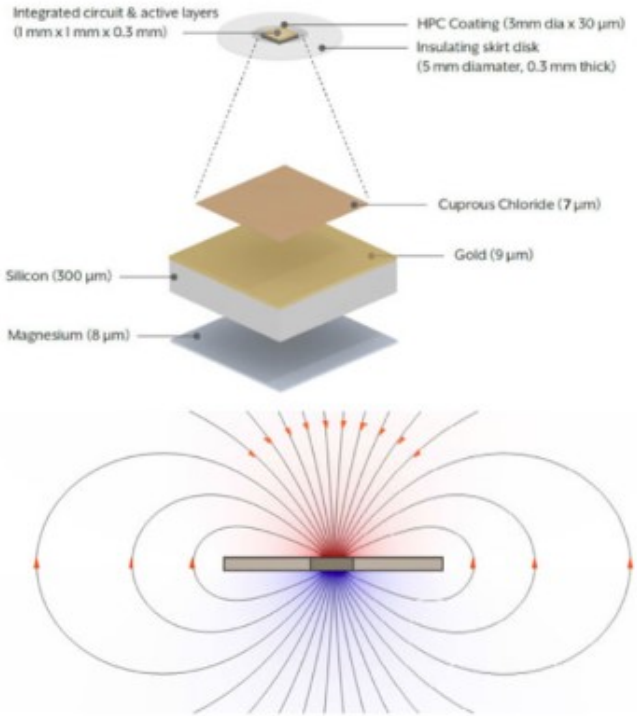
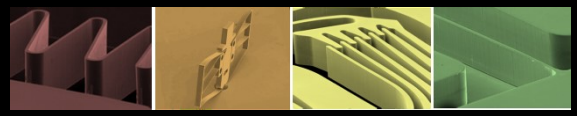


Fig. 2 Photograph and schematic of the ingestible sensor and cross-section showing electric potential and current flow (arrows) around the sensor.

Healthcare



Helius Home: Stable Patient

helius

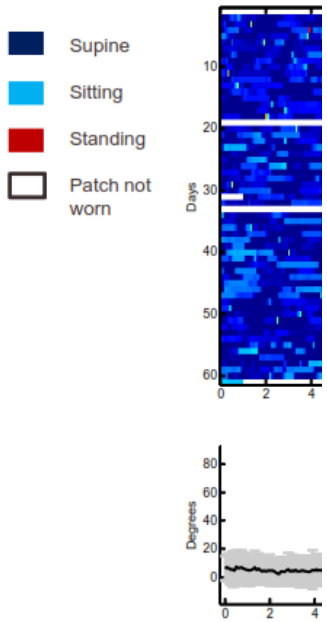
Helius Home: Unstable Patient

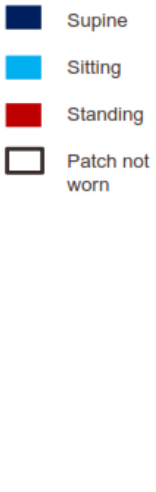
helius

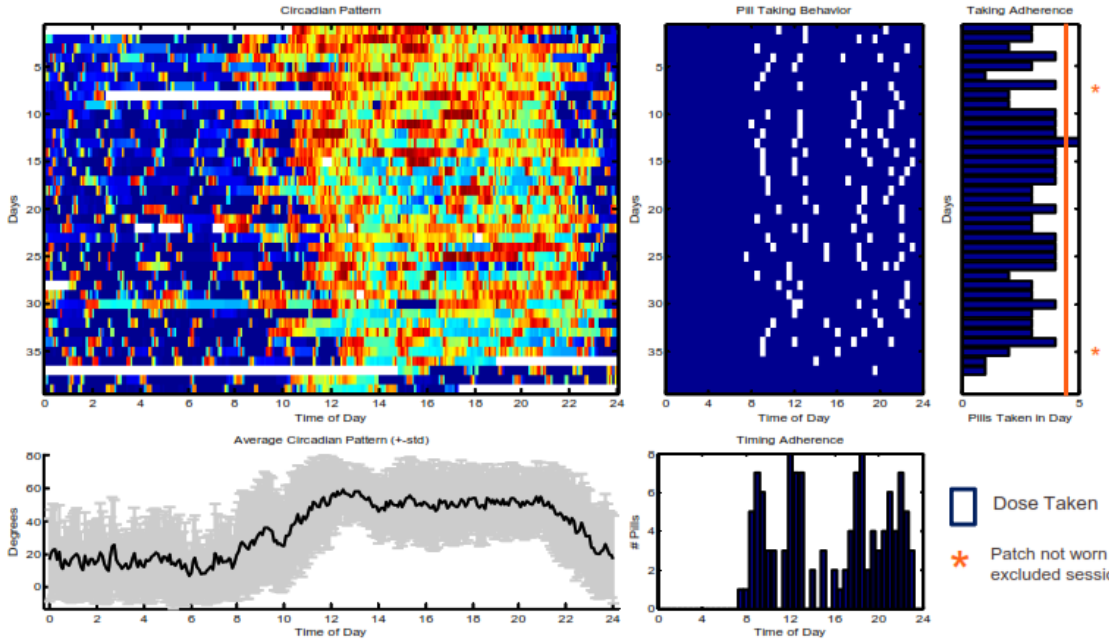
Data for 90-Year Old with Mild Dementia
Reveals Unstable Activity and Medication Patterns
Son Follows Up Frequently to Make Sure His Dad is Doing Okay

Circadian Pattern Based on Posture

Medication Taking Behavior

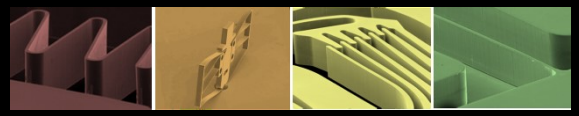






proteus DIGITAL HEALTH

Healthcare



The Healthcare Internet of Things (IoT) Market Map

Clinical Efficiency

AUGMEDIX
TeleTracking
fruit street
AdhereTech
Obaa
simplifeye
PRISTINE
VOLUNTIS
Connected Therapeutics
awarepoint
Location as a Service
evermind

Infant Monitoring

Sproutling
BABYBE
mimo
Owlet
Rest Assured.

Sleep Monitoring

beddit
NovaSom
hello

Clinical-Grade Biometric Sensors

QUANTTUS
vitalconnect
mc10
Senseonics
BL Healthcare
connectedhealth
Sotera
WIRELESS
iRhythm
proteus
DIGITAL HEALTH
EarlySense
Monica
Healthcare
EYENETRA
SilentAlert

Created By

CB INSIGHTS

Fitness Wearables

sensoria
LUMO
OMsignal
lark
motiv
ATHOS
ATLAS
MOOV
JAWBONE
Withings
Inspire health
MISFIT

Consumer / Home Monitoring

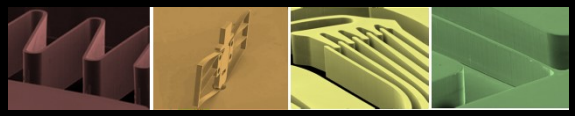
sano
GlucoVista
aira
QARDIO
WHOOP
CHRONO THERAPEUTICS
BIOSERENITY
SUNSPRITE
kinsa
TURINGSENSE
INFOBIONIC
SCANADU
cue
AliveCor
THALMICLABS
ANGEL SENSOR
3rings

Brain Sensors / Neurotechnology

NEUROVIGIL
JAN Medical
Thync
How good feels
muse
ybrain
NeuroSky
halo
neuroscience

www.cbinsights.com

Healthcare

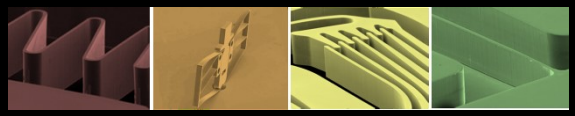


SleepMed

Home sleep testing made easy

ARES™ provides a comprehensive analysis of sleep health from the comfort of home.

Healthcare

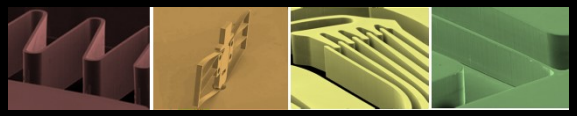


EXO IMAGING

Medical Imaging For Everyone

We will change the imaging and therapeutic markets by reducing cost and increasing access and immediacy. EXO's 3D broadband ultrasound platform will proliferate into numerous new applications ranging from tomography, endoscopy, ultrasound patches, tissue ablation, precision surgery, targeted drug delivery and pain management.

Healthcare – HMIs



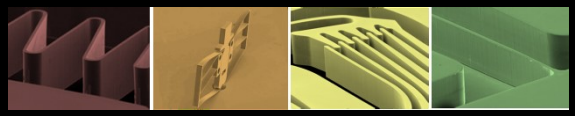
The Human Machine Interface

The technology feeding development is:

Micro – Nano!

Success forms basis for mHealth

Healthcare – HMIs



E-textiles Wearables Functional Fabrics

Flexible – Stretchable - Conformal

affoa Advanced Functional Fabrics of America

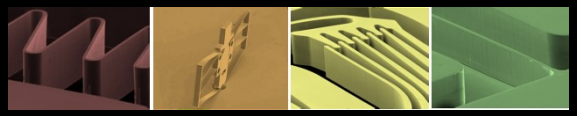
NEXTFLEX®

mc10®

nextinput

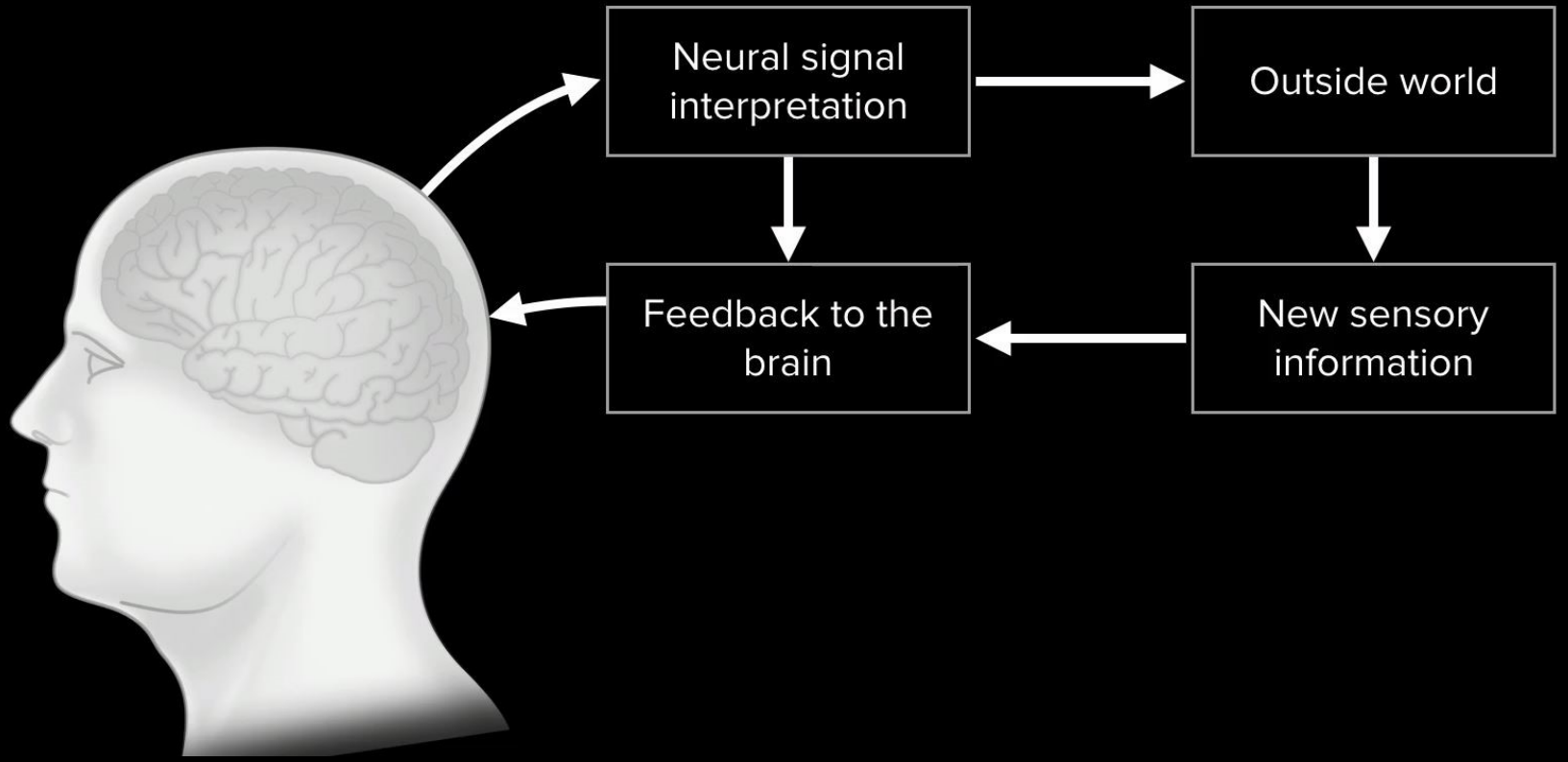
HEXOSKIN
HEALTH SENSORS & AI

Healthcare - HMIs

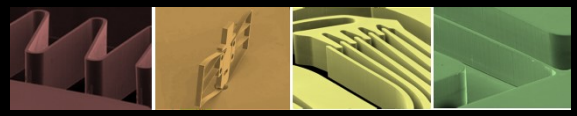


NEURALINK

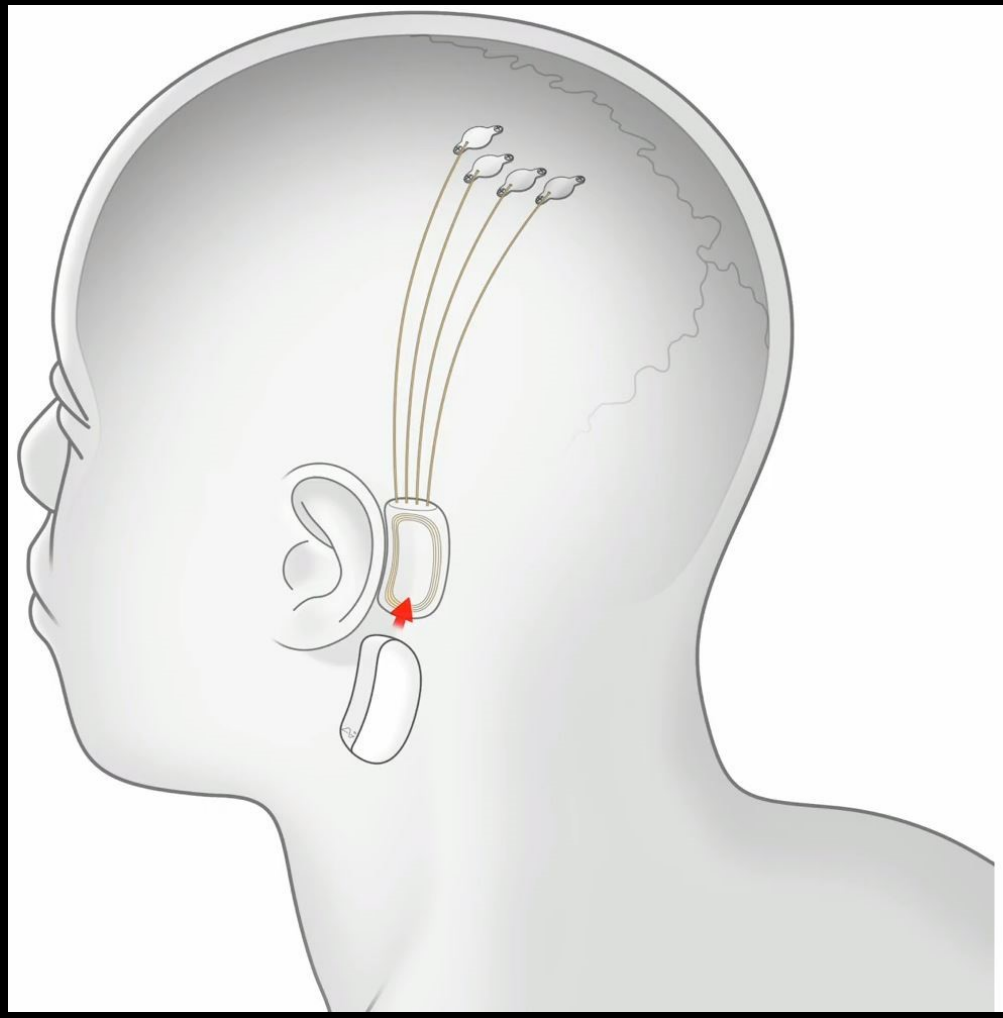
BRAIN-MACHINE INTERFACES

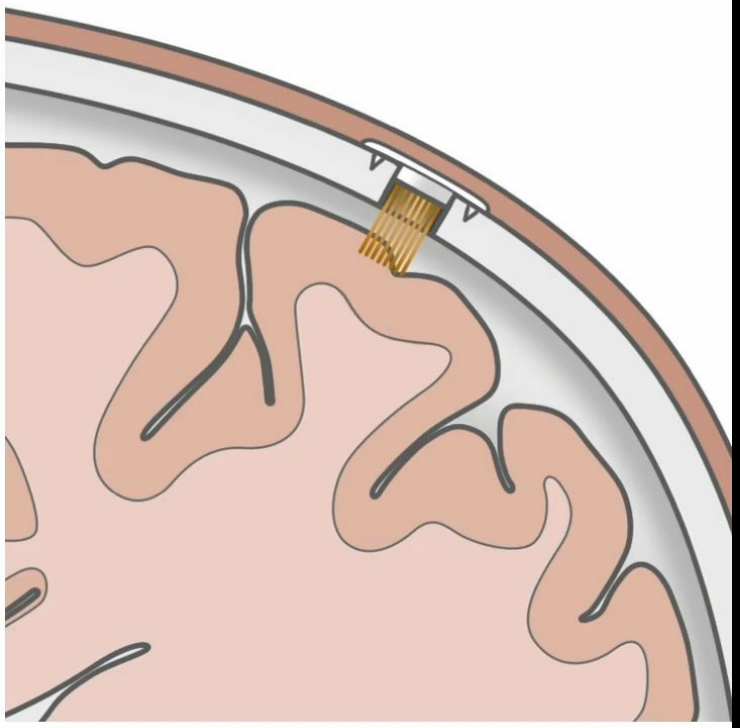


Healthcare - HMIs

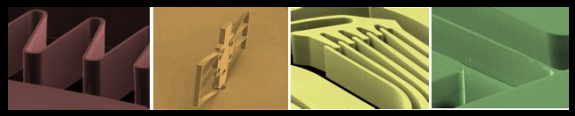


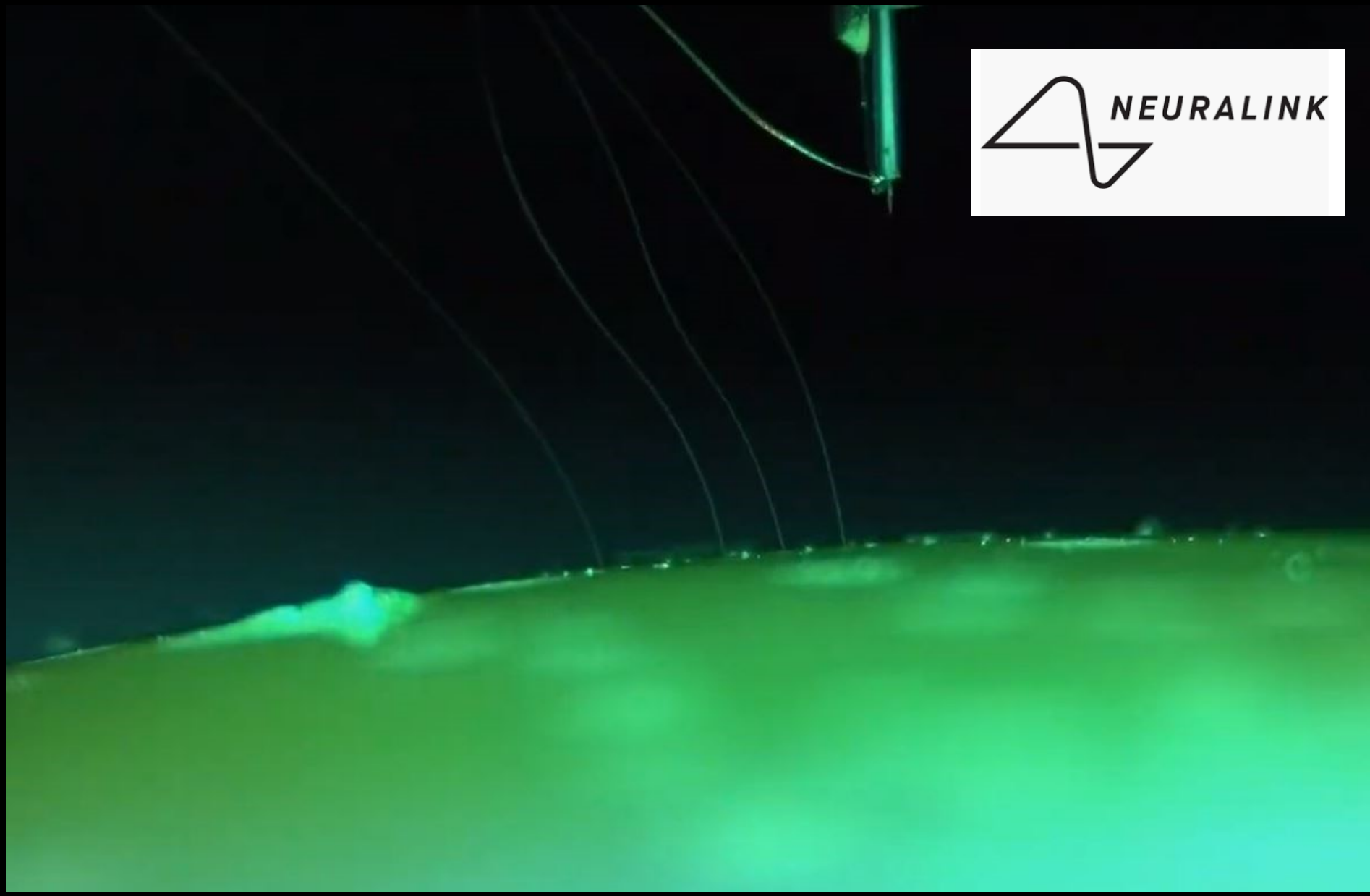
NEURALINK



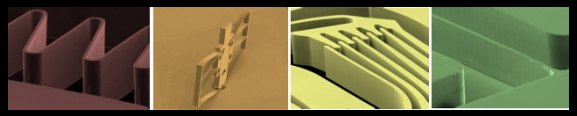


Healthcare - HMIs





Healthcare - HMIs



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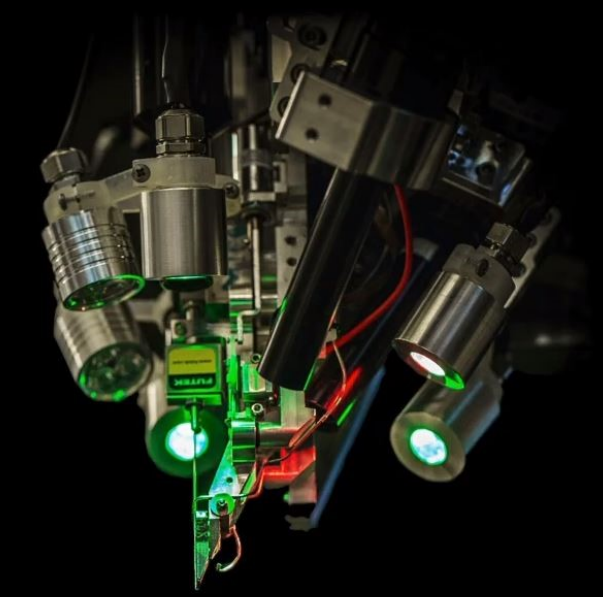
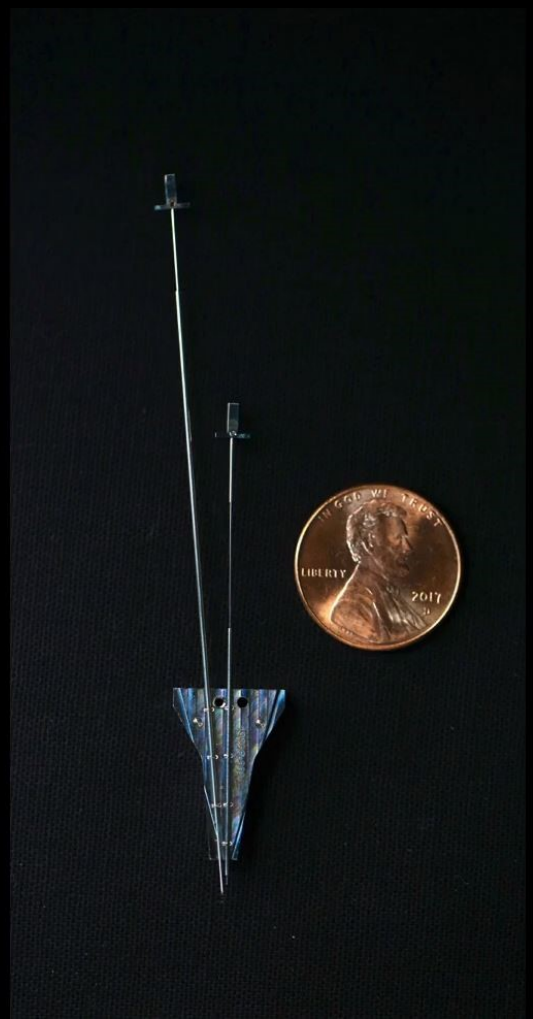
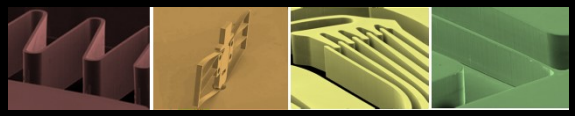
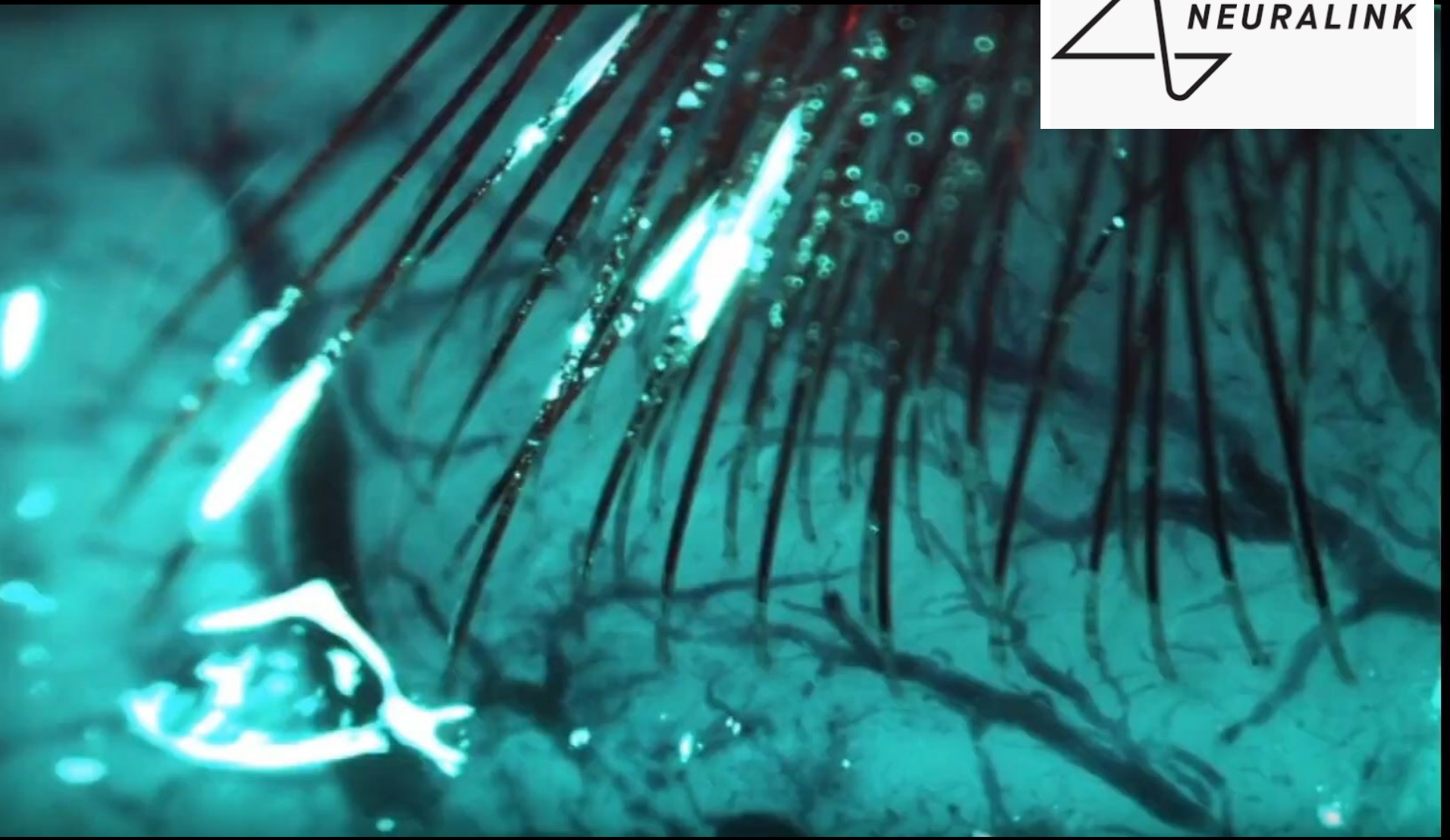




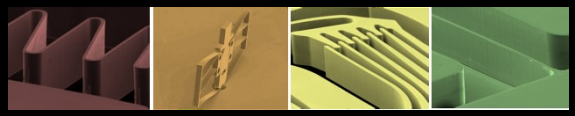
Healthcare - HMIs



NEURALINK



Healthcare - HMIs



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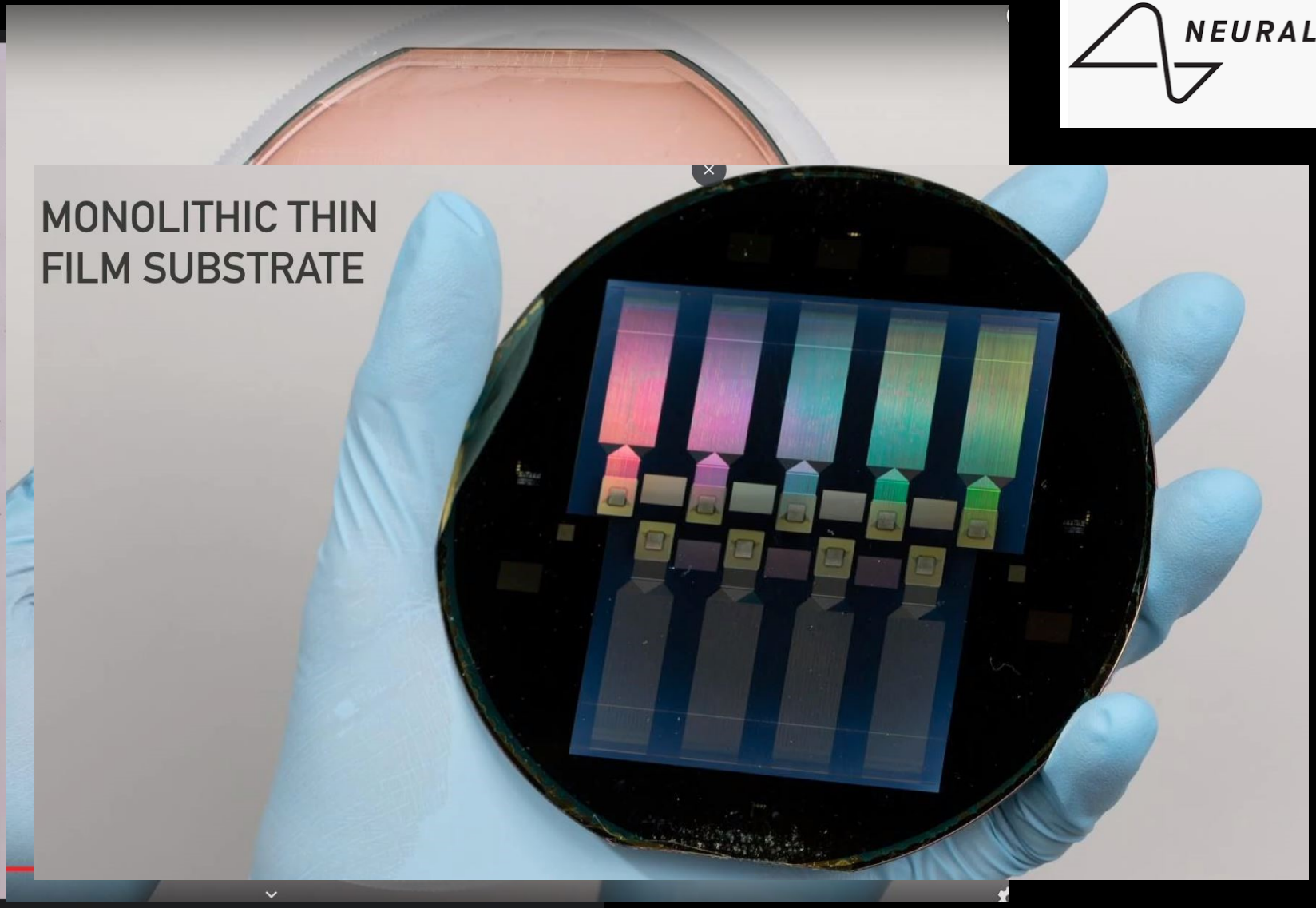
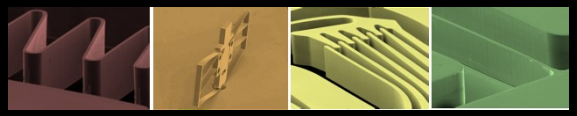
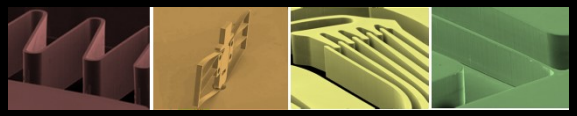


Healthcare - HMIs



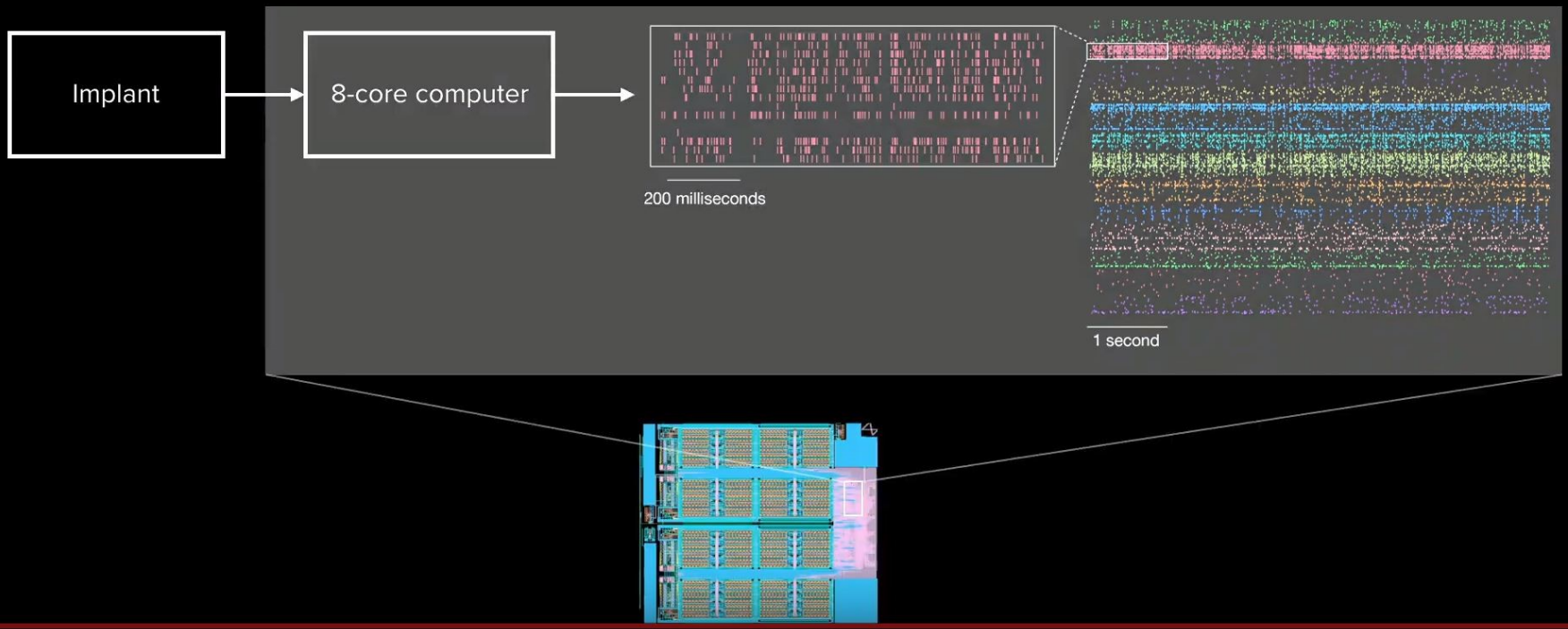
NEURALINK

Healthcare - HMIs



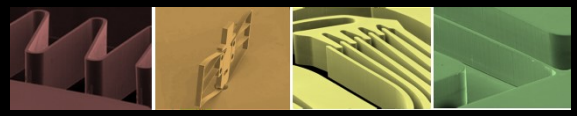
NEURALINK

ON-CHIP SPIKE DETECTION



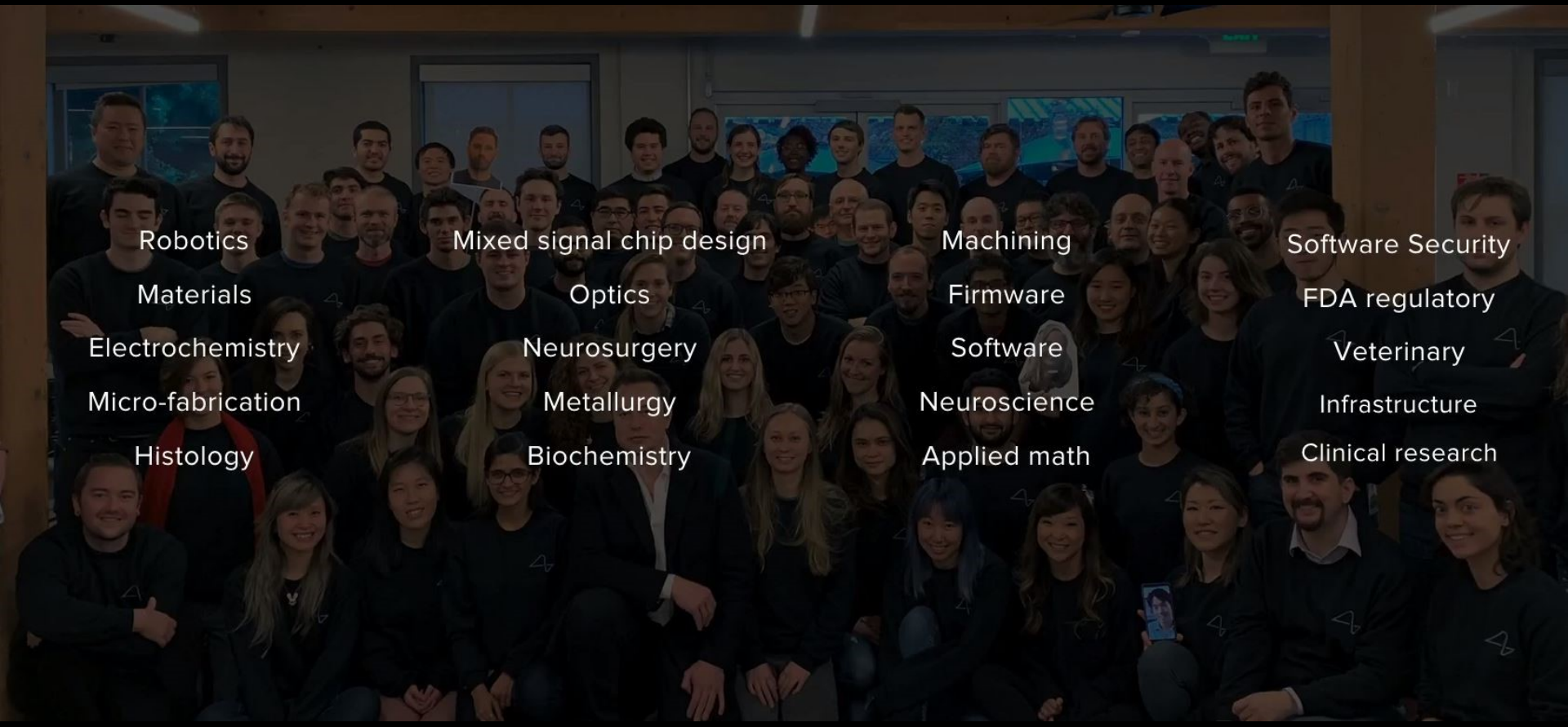
LIVE

Healthcare - HMIs

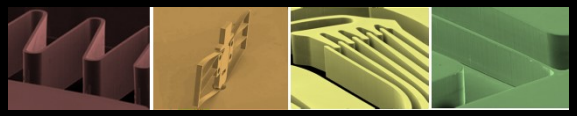


Now Recruiting

NEURALINK



Energy

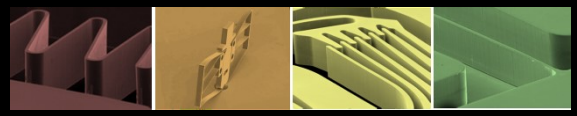


breezi the fitness tracker for HVAC systems

qlair

Building health

Environment



Deteriorating Infrastructure

Smart Municipalities

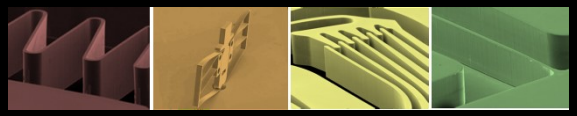
Internet of Water

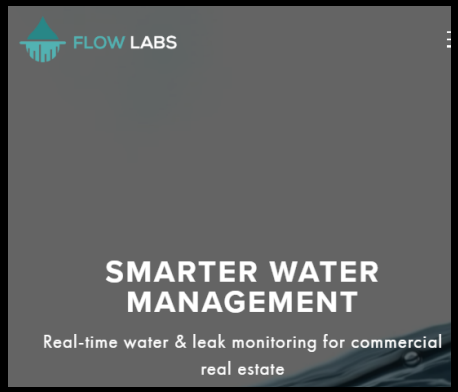
Disaster Resilience (Hitachi – 1.4T sensors)

Wellness sensing

eWallpaper – T sensors in B m^2

Environment

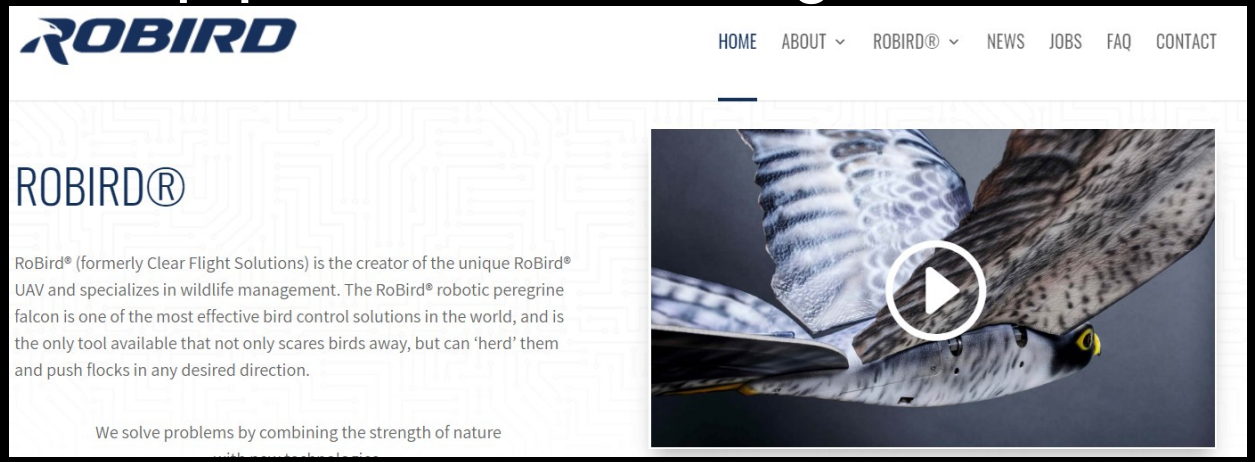




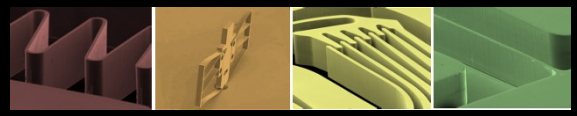
OtoSense

drone as a service: pipeline monitoring, bird on runways, …

CLEAR FLIGHT SOLUTIONS



Manufacturing



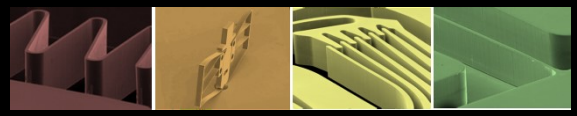
Industry IoT – Industry 4.0

Extreme customization

Printed sensors / electronics

No more wafers? FPD based microfabrication

Manufacturing - Industry 4.0



Micro / Nano crosscuts through all!

explosion of data / ectivity

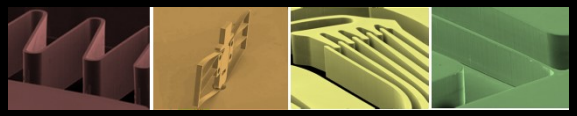
analytics / intelliger

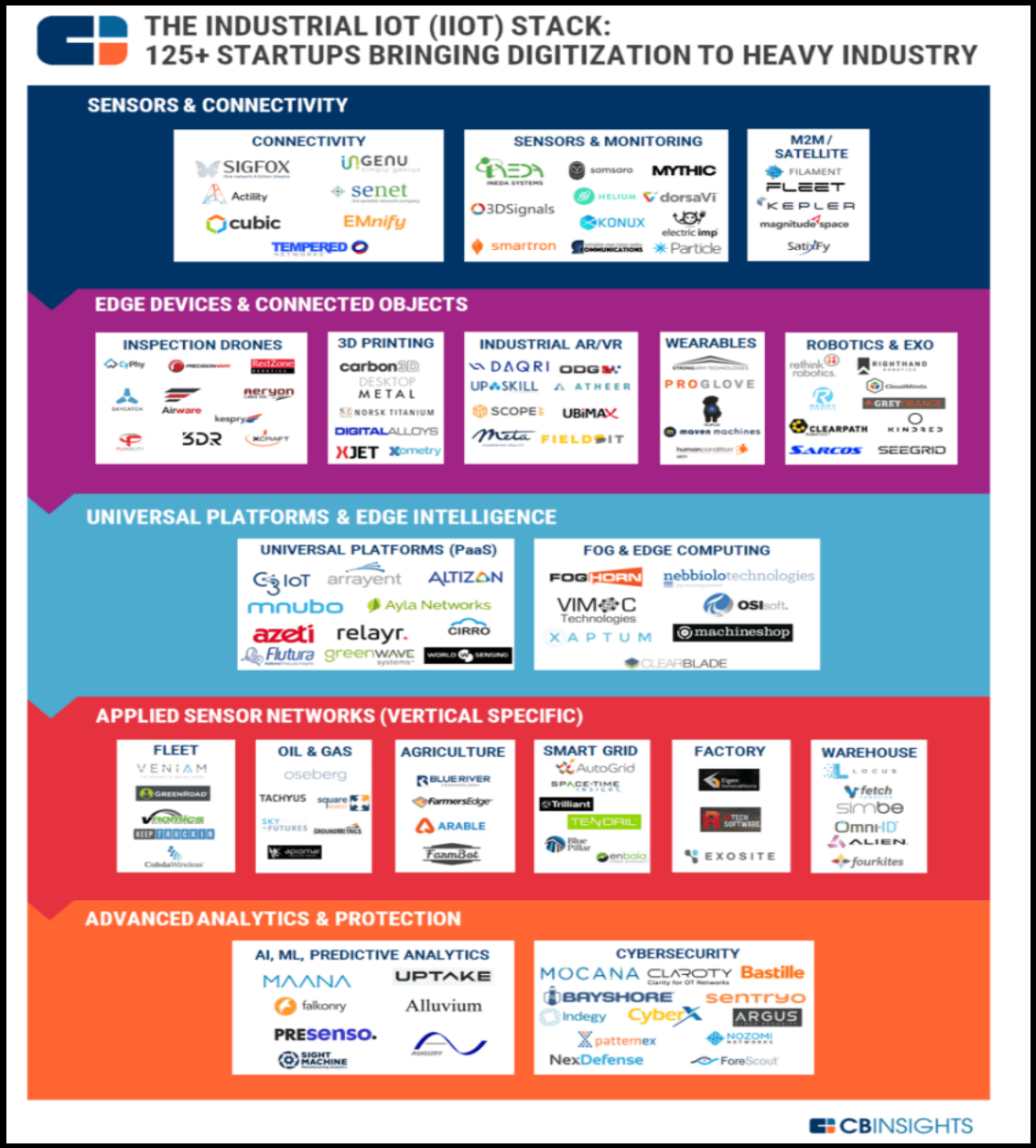
advanced robotics ots

additive manufactur

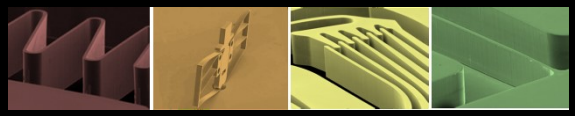
shorter and shorter product cycles

Manufacturing - Industry 4.0





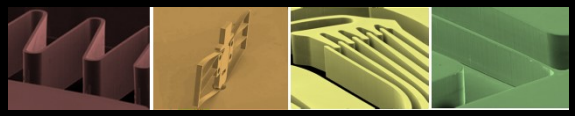
Manufacturing - Customization



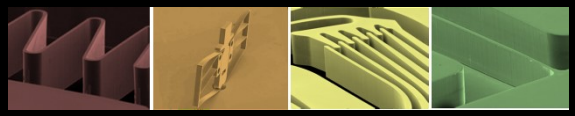
“ everyone is a ‘maker’ ”

Extreme customization –
no product like any other

Manufacturing - Printed



Manufacturing - Printed



Printed electronics

Exponential technology on verge of disruption

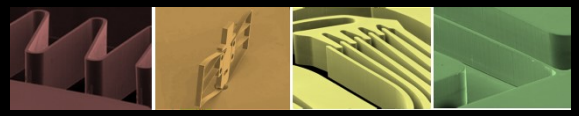
AsahiKASEI

min CD < 250nm

NANODIMENSION
Electrifying Additive Manufacturing®

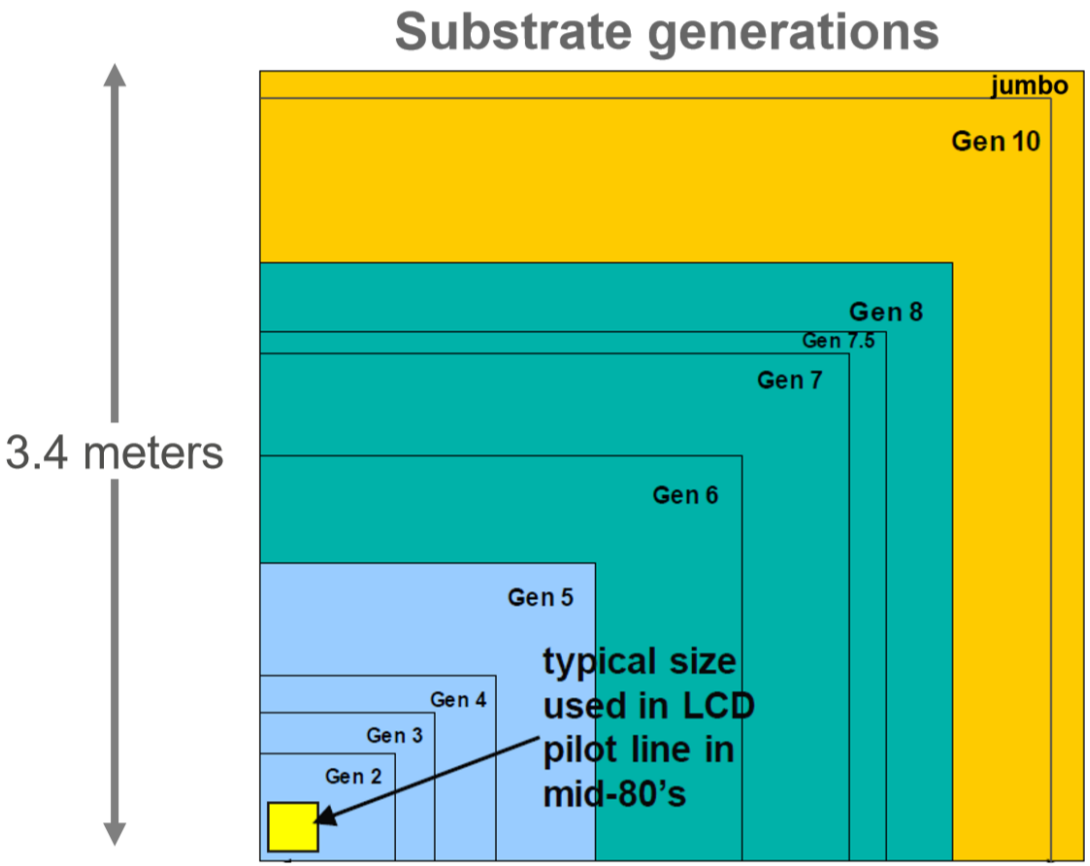
OPTOMEC

Manufacturing – Large Area



Dr. Robert Andosca, AEI

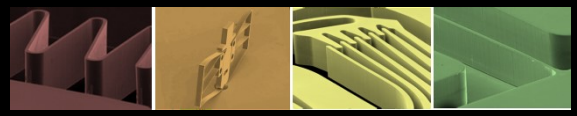
SUBSTRATE SIZE INCREASING FOR MANUFACTURING ECONOMICS



Large area manufacturing uses similar techniques as IC processing

- ✓ 1X and stepper photolithography
  - Spinless resist coating
  - Down to 1.2 μm linewidths
- ✓ DC and RF magnetron sputtering and PECVD deposition
  - High uniformity
- ✓ RF plasma etch
  - High uniformity

Manufacturing – Large Area



Dr. Robert Andosca, AEI

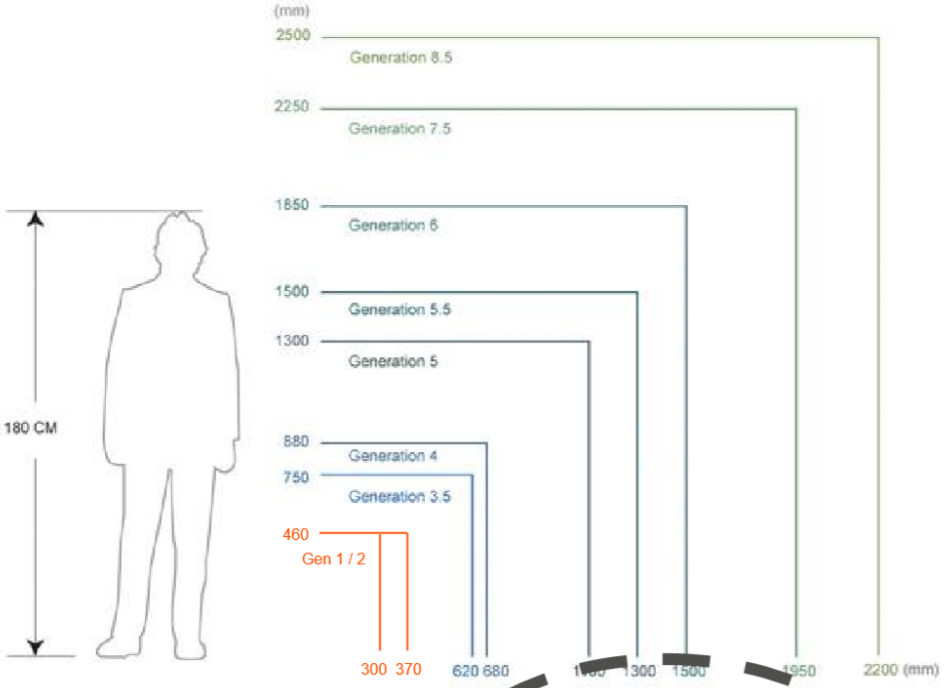
ECONOMIES OF SCALE – FABRICATE MEMS USING LARGE AREA TECHNIQUES

A single ***Gen 2 substrate*** area equivalency –

✓ **6.5 wafers @ 200 mm diameter**

A single ***Gen 4 substrate*** area equivalency –

✓ **22 wafers @ 200 mm diameter**



GEN	Chip size + 200 μm scribe	Chips / substrate	Est. chip cost low volume 6-masks, 90% yield	Est. chip cost high volume 6-masks, 90% yield
2.0	1 x 1 cm^2	1406	**$3.80 chip only | $8.00 WLP**	**$0.38 chip | $0.80 WLP**
4.0	1 x 1 cm^2	4945	**$1.46 chip only | $3.00 WLP**	**$0.15 chip | $0.30 WLP**

Manufacturing – Large Area

Dr. Robert Andosca, AEI

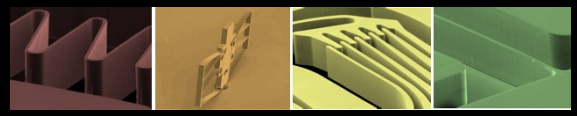
dpiX GEN 4.5 FPD FOUNDRY – **NOW ONLY LARGE AREA MEMS FOUNDRY IN WORLD**

- **World class cleanroom facility**
  - Location: Colorado Springs, CO, USA
  - Building: 260,000 ft^2
  - Cleanroom: 65,000 ft^2
  - Substrate size: single G4.5 plate = (39) 6” wafers
  - Single lot: (20) G4.5 plates = (780) 6” wafers
- **Volumes**
  - Prototyping
  - Pilot production
  - Mass production
- **Customer Benefits**
  - Provide customers a **secure IP environment** for technology and product development
  - Extensive design engineering expertise
- **Open for business → MEMS April 2019 !**

X-ray photo detector arrays for medical imaging on **Gen 4.5 glass**

X-ray photo detector arrays for medical imaging on **Gen 4.5 flexible substrate**

Job Impact



Robotics forecast to eliminate 50% of current US jobs within next 10 years

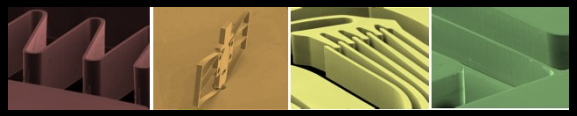
Autonomous transportation will eliminate millions of jobs

40% of large companies disappear along with ~100M jobs replaced with exponential tech companies

During the same time ~ 300M new jobs worldwide due to IoE, IoT (~100M in U.S.)

… Massive Global Retraining required

Supporting Skillsets



Coding / Algorithm Development / Debugging

Materials (mechanics of matl's, elect, thermal, biomed, optical)

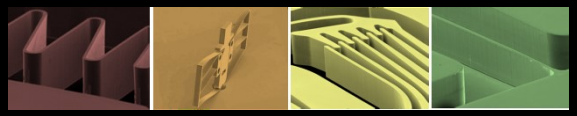
Estimation (order of magnitude)

Meaurement Science - Units / Tolerancing

Quality Management

Documentation

Other Developing Educational Trends



accelerated / more efficient learning

Online - ASU

Chronotype adapted

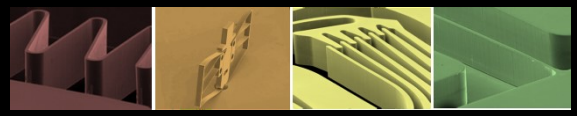
Gamification – sensor enabled!

Learn by doing – AR – Immersion learning

- sensor enabled!

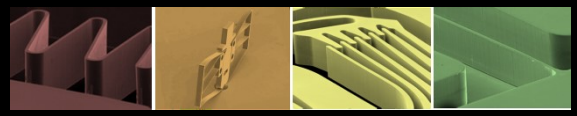
Peace Engineering

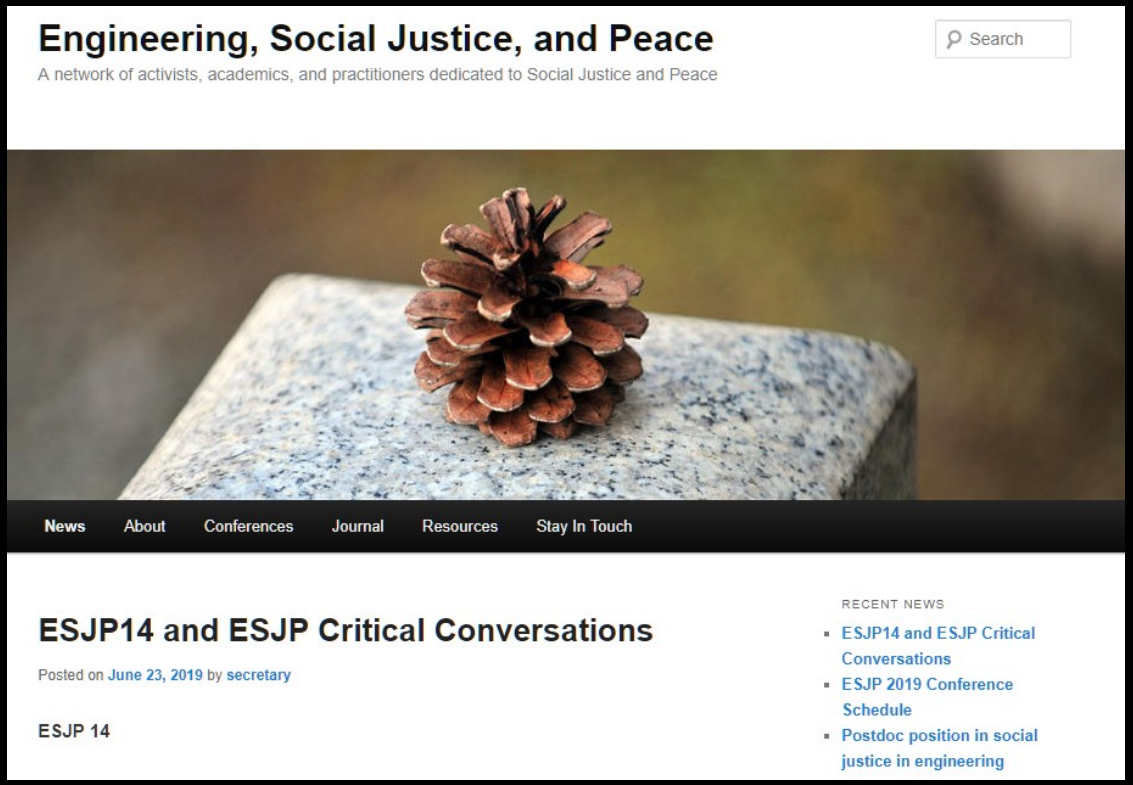
Peace Engineering



"positive, sustainable
engineering and innovation
based solutions to world problems"

Peace Engineering

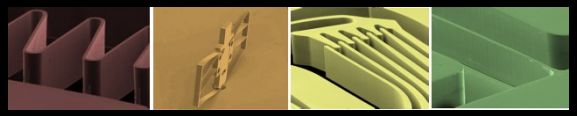




seeks to better understand the progressive potential of engineering. Th

reviewed, and the peer-review process is designed accommodate scho

Peace Engineering



PEACE INNOVATION LAB
STANFORD

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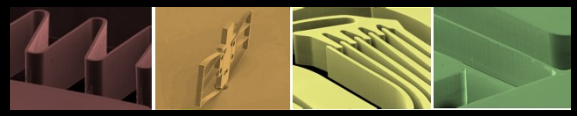
- What is Peace Engineering?
- Mark Nelson Introduces Concept of Peace Data at Intertrust Conference
- Addressing Gender Bias in the Workplace: A New Approach
- Peace in Our Lifetime?
- Culture is the New Care
- Social Entrepreneurship Inside of Hard Places
- Innovation for/with Refugees: Next Steps
- Let's Talk About Sex

What is Peace Engineering?

by Admin

Co-Directors Mark Nelson and Margarita Quihuis of the Peace Innovation Lab at Stanford define peace engineering and peace innovation and why it is important to reimagine the future of engineering. Join them November 12 through 16, 2018 at the WEEF-GEDC Conference – https://weef-gedc2018.org.

Peace Engineering



DREXEL UNIVERSITY College of Engineering

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PEACE ENGINEERING

MS IN PEACE ENGINEERING | RESEARCH | URBAN TECHNICAL EXTENSION | PEACETECH LAB | APPLY NOW

Home > Academics > Areas of Study & Programs > Peace Engineering

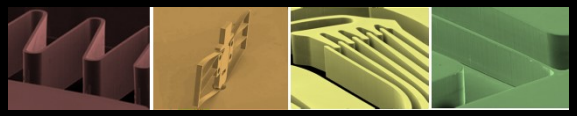
Peace Engineering is the nation's first program dedicated to preventing and reducing violent conflict through education and research that integrates innovative technologies, approaches, and policies with the studies and practices of peacebuilders. This new program was created in collaboration with PeaceTech Lab, an NGO headquartered in Washington, D.C.

MS in Peace Engineering

NEW IN FALL 2018

The 48 credit **MS Degree in Peace Engineering** is open to students from STEM backgrounds and combines case-based courses with experiential learning internships and research development efforts that are driven by the needs of the peacebuilding community.

Peace Engineering

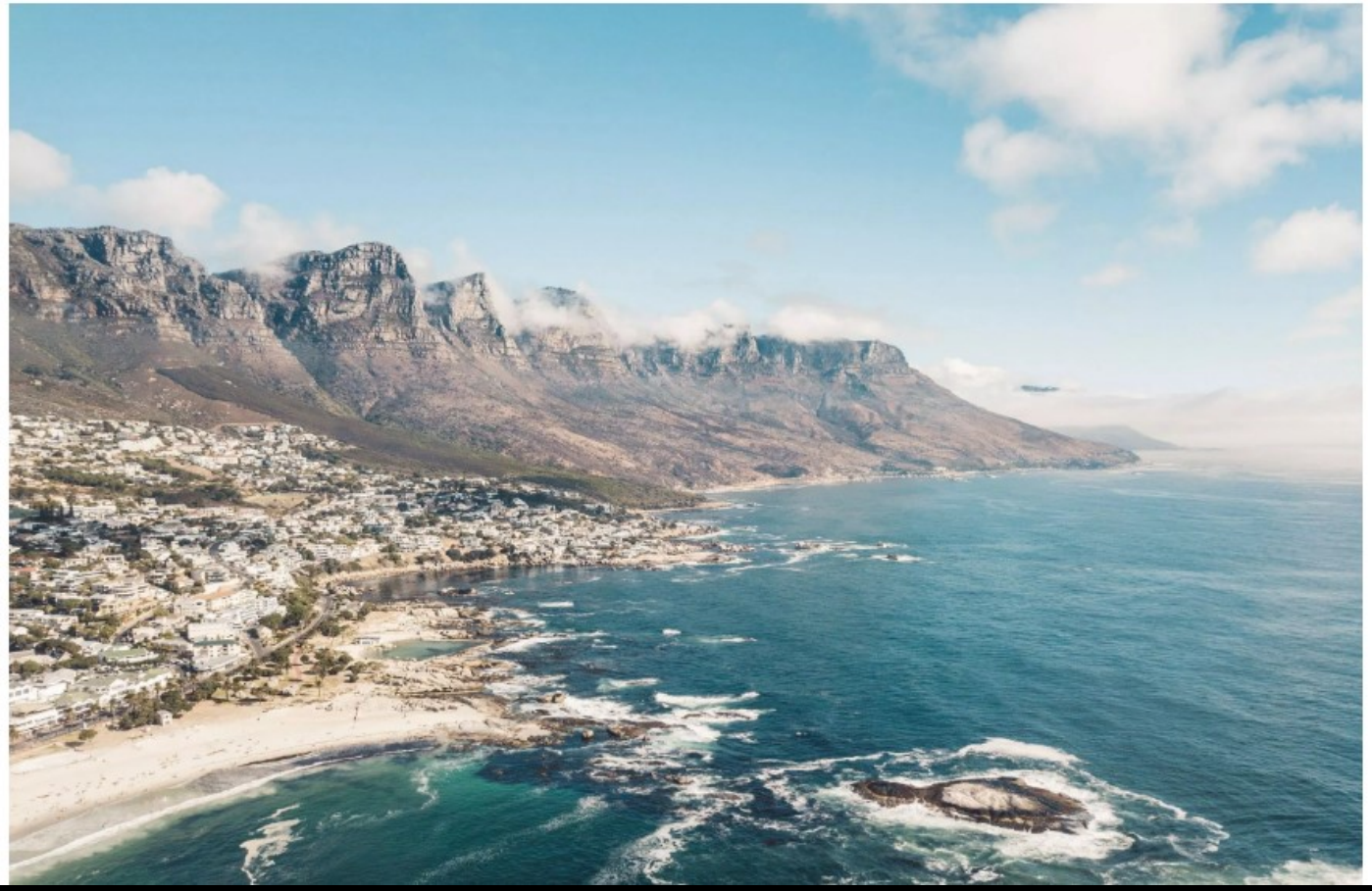


Peace Engineering

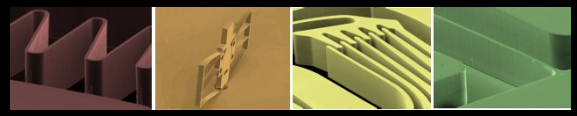
WEEF-GEDC 2020 Cape Town

November 15, 2020 - November 20, 2020

« 17th International Association for Continuing Engineering Education World Conference (IACEE)



Summary



A sensor based economy boom. Large and microfabricated components and nano materials will fuel much of it

Emerging skill set needs have emphasis on interfaces

Data Analytics will continue to play an increasingly larger role in the economy and education

What will a transcon ‘convoy’ be in July 2119 ?

www.mancef.org