

Micro-Nano and the Emerging Sensor Based Economy

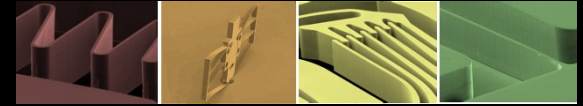
Todd Christenson, Ph.D.

President, MANCEF

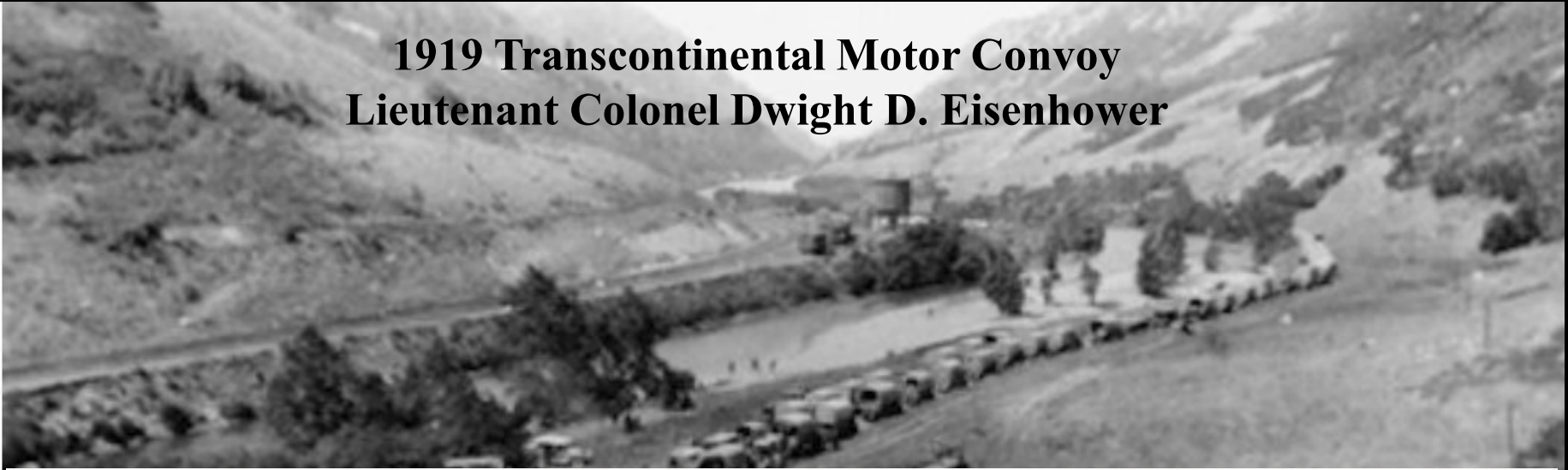
CTO, co-Founder, Chairman-Emeritus, HT MicroAnalytical, Inc.

23 July 2019

100 years ago...



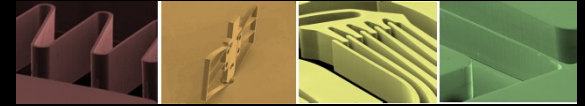
1919 Transcontinental Motor Convoy Lieutenant Colonel Dwight D. Eisenhower



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?!**

The whole convoy, with

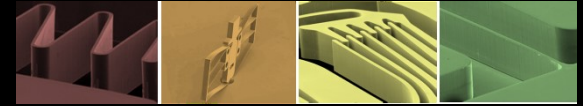
100 years ago...



**Washington D.C. – San Francisco
in 62 days**



Introduction



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

Transportation

Agriculture

and Education!

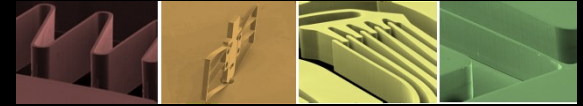
Healthcare

Energy

Environment

Manufacturing

Introduction



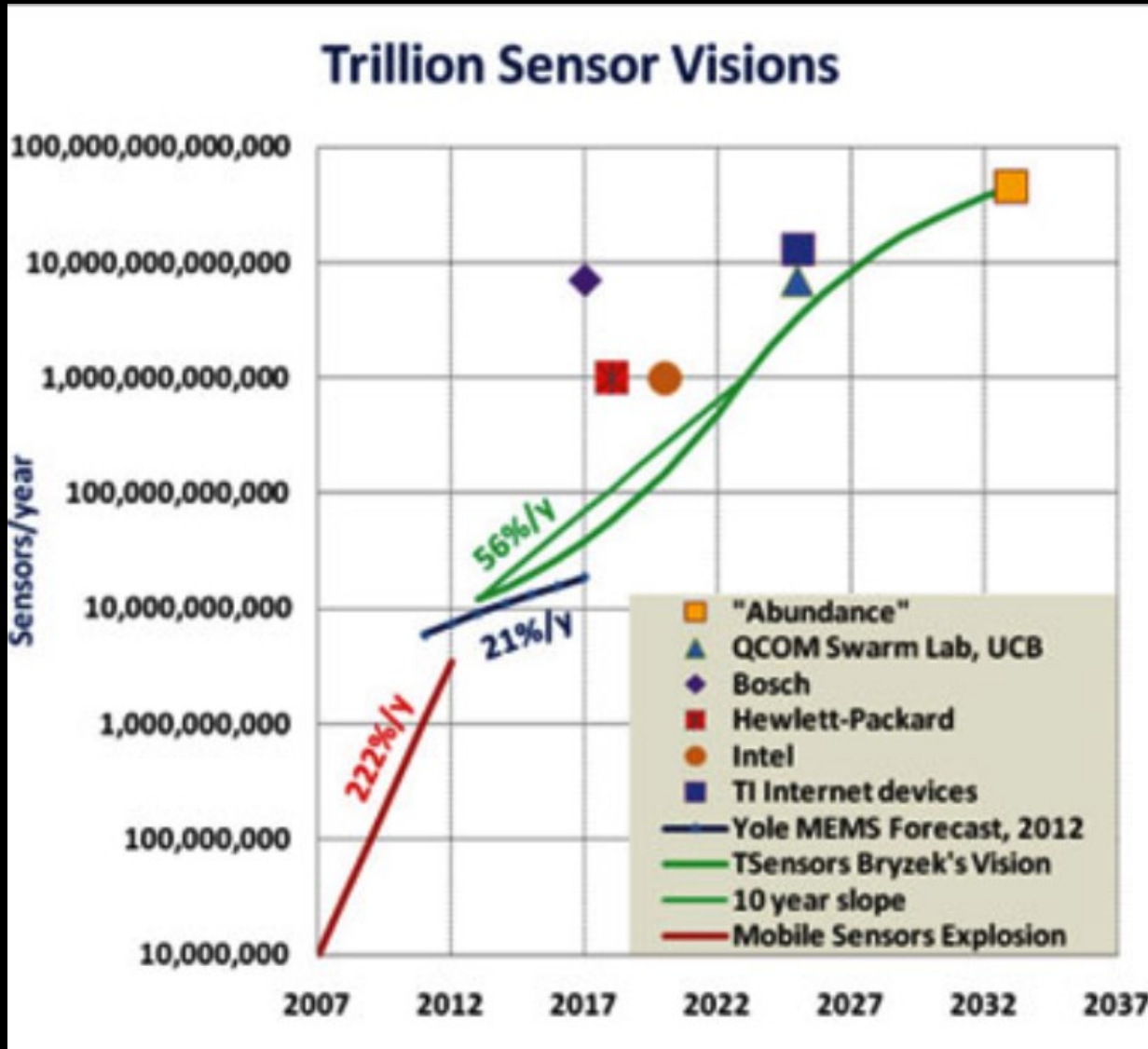
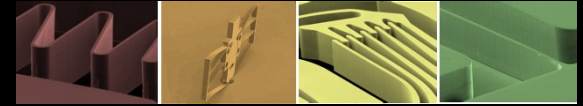
... data which is substantially provided by

sensors

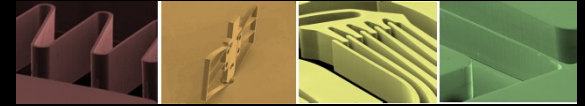
that are in turn enabled by

micro-nano

Data Analytics



Data Analytics



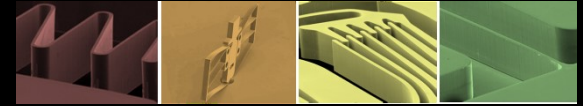
in ~ < 5 years:

~ 1 Yottabyte of data / year

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

Ultimately (2035?): Abundance?

(10^{27}) BRONTOBYTE

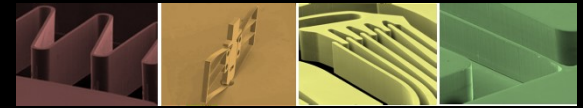


in ~ 15 years:

50-80% of worlds GDP

(i.e. $\sim >$ \$60 – 90 Trillion)

Data Analytics

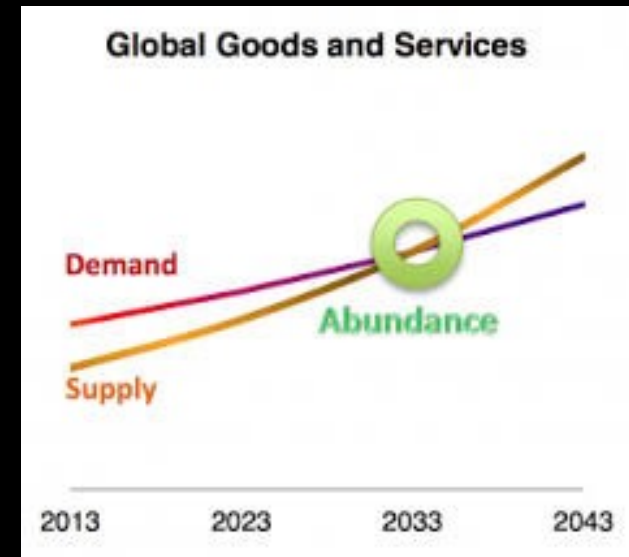


in ~ < 20 years:

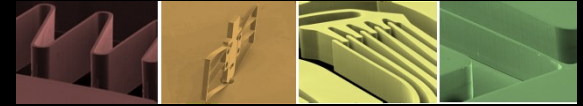
Abundance estimated:

45 Trillion connected nodes

(most of which end in a sensor)



Overview - Highlights



Sensor Market Impact

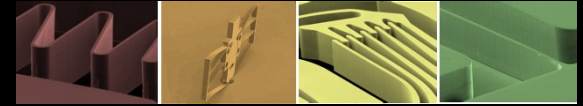
Human – Machine Interface

‘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 of sensor-based

Sensor economy opening expanding services and opportunities for individuals, industry

by Sandra Zistl, Siemens



The Trillion Sensor Economy is Coming. Are You Ready?

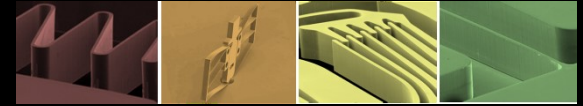
“In many ways we are...
says Bob Brumley, CEO of...
Holdings, a tech de...

ing 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

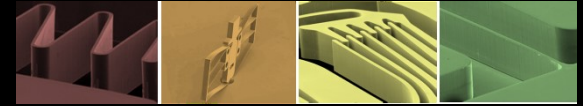
power management

sensor enabled

higher efficiency motors

sensor enabled

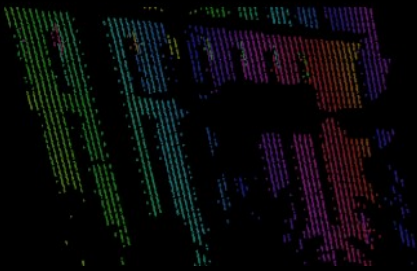
Transportation



100s of startups for 'smart mobility'

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

LUMINAR

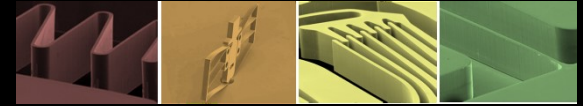


TOPOSENS



METAWAVE

Agriculture



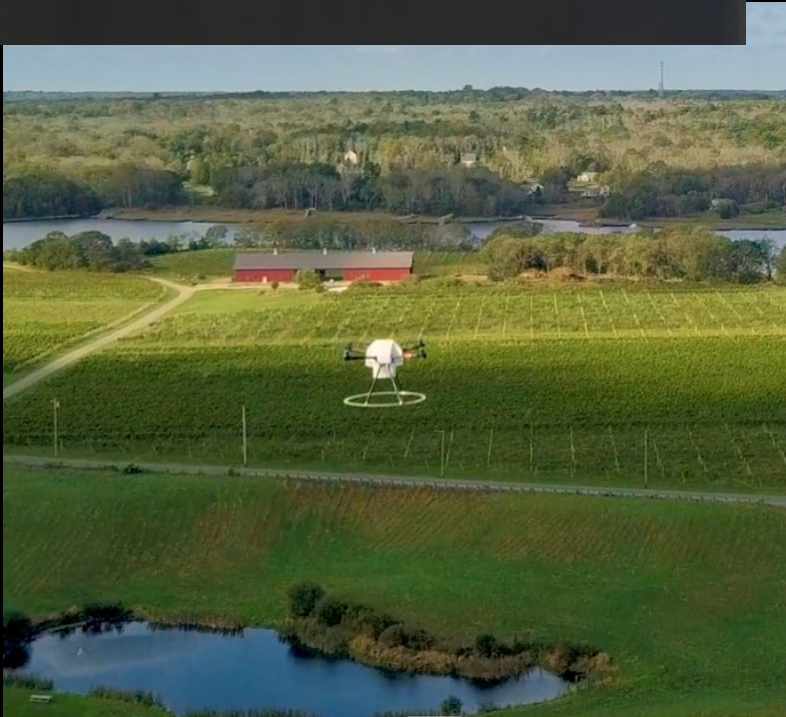
sensor based smart agriculture



AR AMERICAN ROBOTICS



THE MOST ACCURATE WEATHER DATA
AVAILABLE



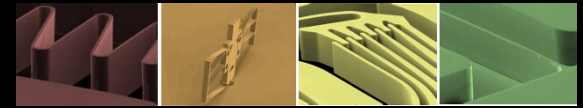
ESENSE

er Data
ns Better
n.

ess Grain Monitoring and
n a Cloud-Based App



Agriculture



livestock tracking
and health
monitoring



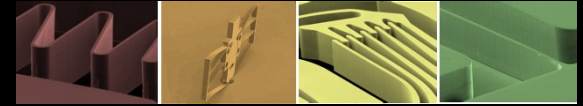
food freshness,
food & water safety

Paper based gas
sensors replacing

The screenshot shows a website layout. On the left is the 'telspec' logo with the tagline 'Keep your health up'. The main navigation includes 'Home', 'Technology', 'About', 'Tellspecopedia', and 'Med'. The IBM logo is on the right, with a search bar and user profile icon. Below the navigation is a sub-navigation for 'Internet of Things blog' with options for 'Home', 'Content by theme', and 'Content by type'. The main content area features a large image of hands holding fresh vegetables with the text 'BUILDING FOOD Real-time, Portable Analysis for'. To the right is a featured article titled 'WaterBot: connected for safe water' under the category 'Robotics', accompanied by an image of the WaterBot device.

internet of water

Agriculture

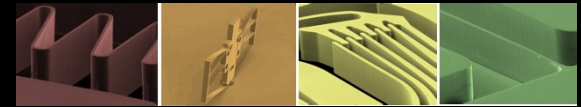


farm & crop management












seeds with built in sensors

Agriculture



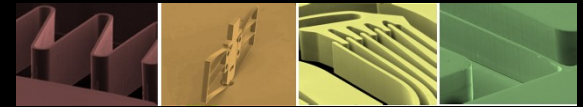
AgriFood tech funding: \$16.9B, 1450 investments

AgriFood Tech Category Definitions

 Ag Biotechnology On-farm inputs for crop & animal ag including genetics, microbiome, breeding, animal health.	 Innovative Food Cultured meat, novel ingredients, plant-based proteins.
 Agribusiness Marketplaces Commodities trading platforms, online input procurement, equipment leasing.	 In-Store Retail & Restaurant Tech Shelf-stacking robots, 3D food printers, POS systems, food waste monitoring IoT.
 Bioenergy & Biomaterials Non-food extraction & processing, feedstock technology, cannabis pharmaceuticals.	 Restaurant Marketplaces Online tech platforms delivering food from a wide range of vendors.
 Farm Management Software, Sensing & IoT Ag data capturing devices, decision support software, big data analytics.	 eGrocery Online stores and marketplaces for sale & delivery of processed & un-processed ag products to consumer.
 Farm Robotics, Mechanization & Equipment On-farm machinery, automation, drone manufacturers, grow equipment.	 Home & Cooking Tech Smart kitchen appliances, nutrition technologies, food testing devices.
 Midstream Technologies Food safety & traceability tech, logistics & transport, processing tech.	 Online Restaurants and Meal Kits Startups offering culinary meals and sending pre-portioned ingredients to cook at home.
 Novel Farming Systems Indoor farms, aquaculture, insect, & algae production.	 Miscellaneous e.g. fintech for farmers

Upstream
Downstream
Upstream+Downstream

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.

different types from thumbs to tomatoes for fruits weighing up to 1kg with different colors, different shapes.

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

biết để có 1.000m2 đất sản xuất loại nông nghiệp 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, months old, harvested with different colors regularly for tomatoes, there are dozens of



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

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

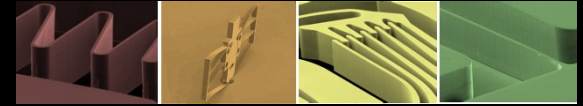


Tomato beds are wrong.



Những luống cà chua sai trĩu quả.

Healthcare



COMMENTARY • MOBILE HEALTH

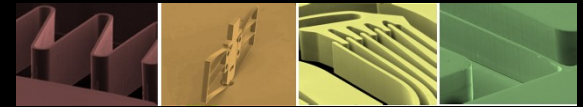
Ex-Apple CEO John Sculley: Why Sensors Are the Future of Health Care Tech

By [John Sculley](#) July 17, 2019

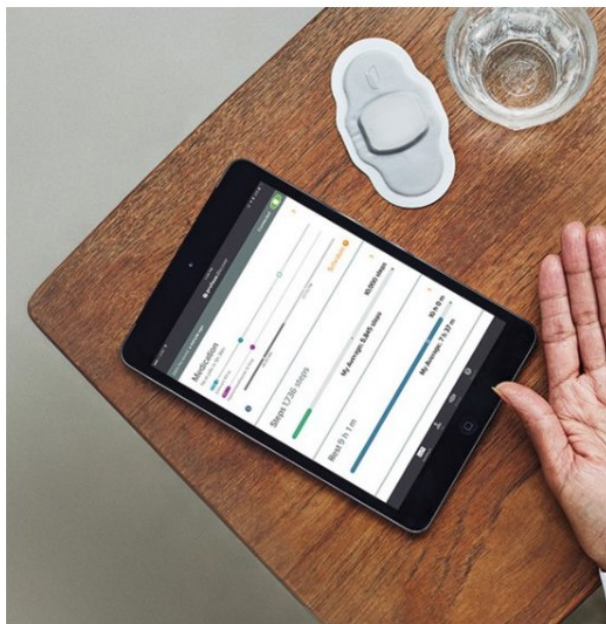


The new Apple Watch is capable of taking an FDA-approved electrocardiogram. Apple, Amazon, Google, and Microsoft can use evolving mobile health care technology to help better treat patients, writes former Apple CEO John Sculley.
Karl Mondon—Digital First Media/The Mercury News via Getty Images

Healthcare



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



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



Powered by minute quantities:

Composition	Common Reference
Copper: 0.0077 mg	2 mg in Centrum
Magnesium: 0.0098 mg	50 mg in Centrum

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

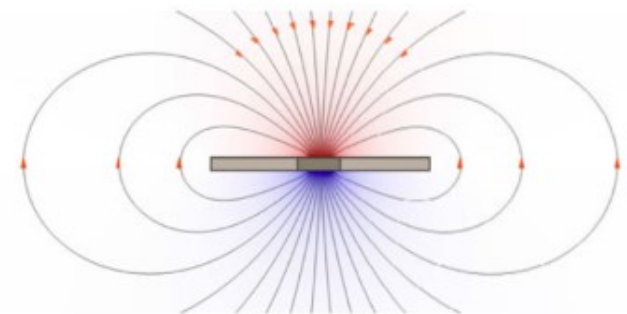
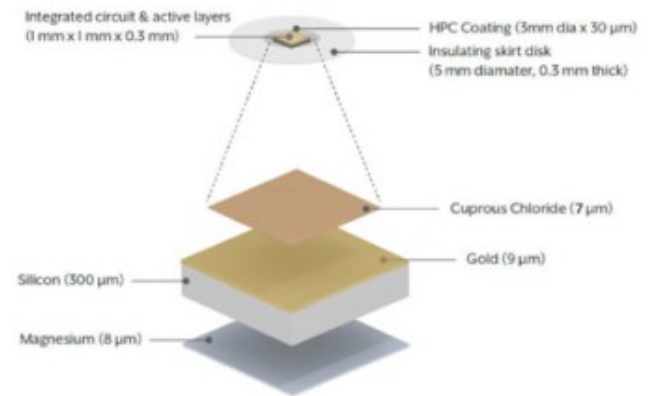
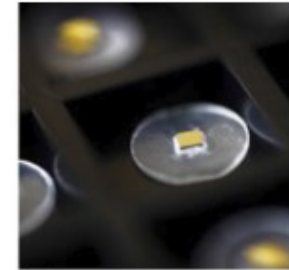
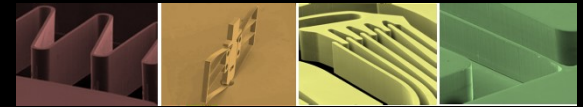


Fig. 2 Photograph and schematic of the ingestible sensor and cross-section showing electric potential and current flow (arrows) around the sensor.

Proteus' digital pills work by way of a tiny sensor roughly the size of a grain of salt. The sensor can either be stamped into a pill or inserted into a pill.



Healthcare



Helius Home: Stable Patient

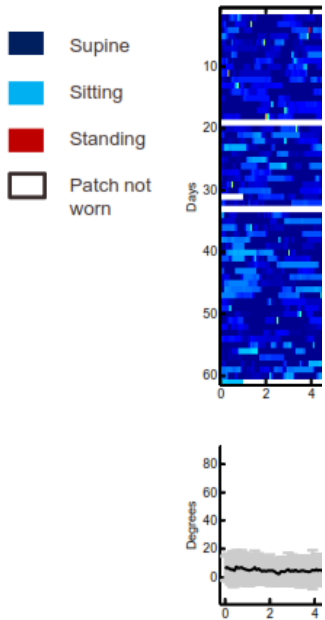
helius

Helius Home: Unstable Patient

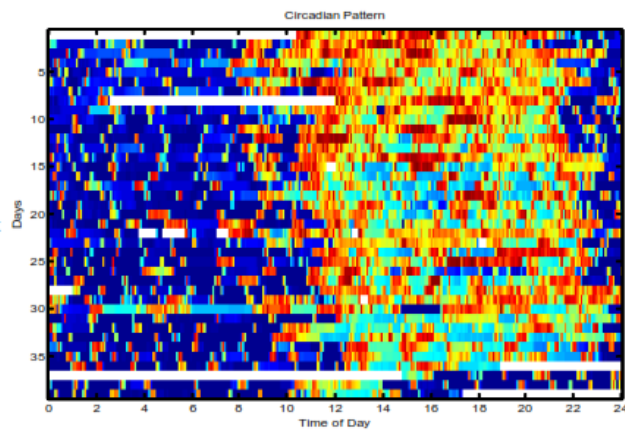
helius

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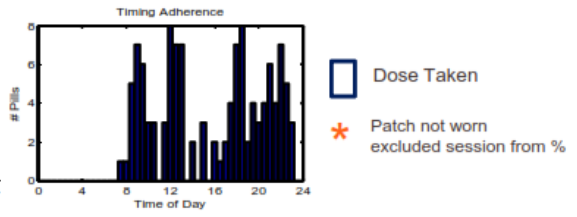
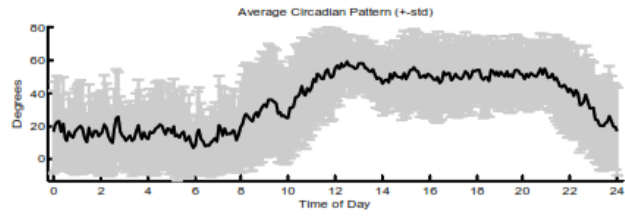
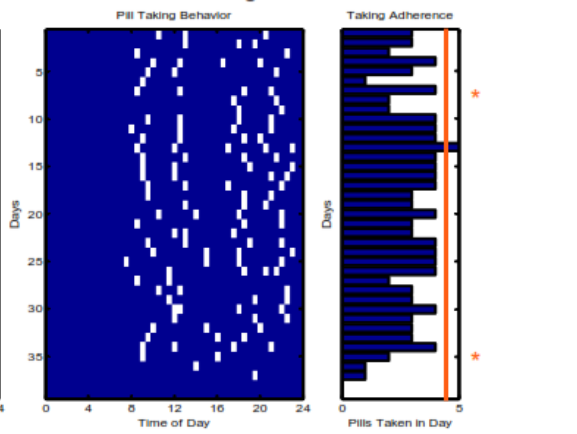
Data for 90-Year Old with Mild Dementia
Reveals Unstable Activity and Medication Patterns
Son Follows Up Frequently to Make Sure His Dad is Doing Okay



Circadian Pattern Based on Posture



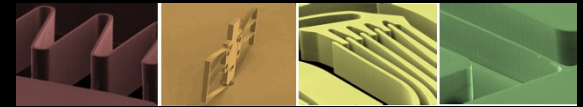
Medication Taking Behavior



proteus
DIGITAL HEALTH

proteus
DIGITAL HEALTH

Healthcare



The Healthcare Internet of Things (IoT) Market Map

Clinical Efficiency



Clinical-Grade Biometric Sensors



Consumer / Home Monitoring



Infant Monitoring



Sleep Monitoring



Fitness Wearables



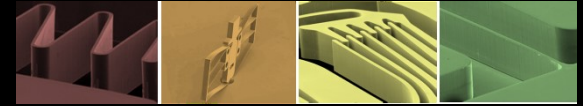
Brain Sensors / Neurotechnology



Created By

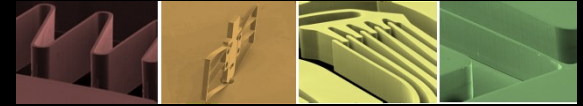


Healthcare



**Home sleep testing
made easy**

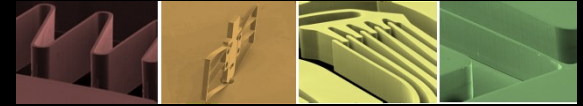
ARES™ provides a comprehensive analysis
of sleep health from the comfort of home.



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.



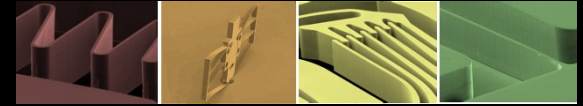
The Human Machine Interface

The technology feeding development is:

Micro – Nano!

Success forms basis for mHealth

Healthcare – HMIs



E-textiles Wearables Functional Fabrics

Flexible – Stretchable - Conformal

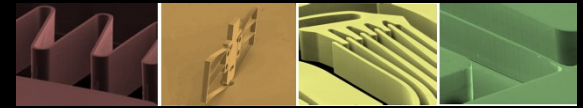


Advanced Functional Fabrics of America

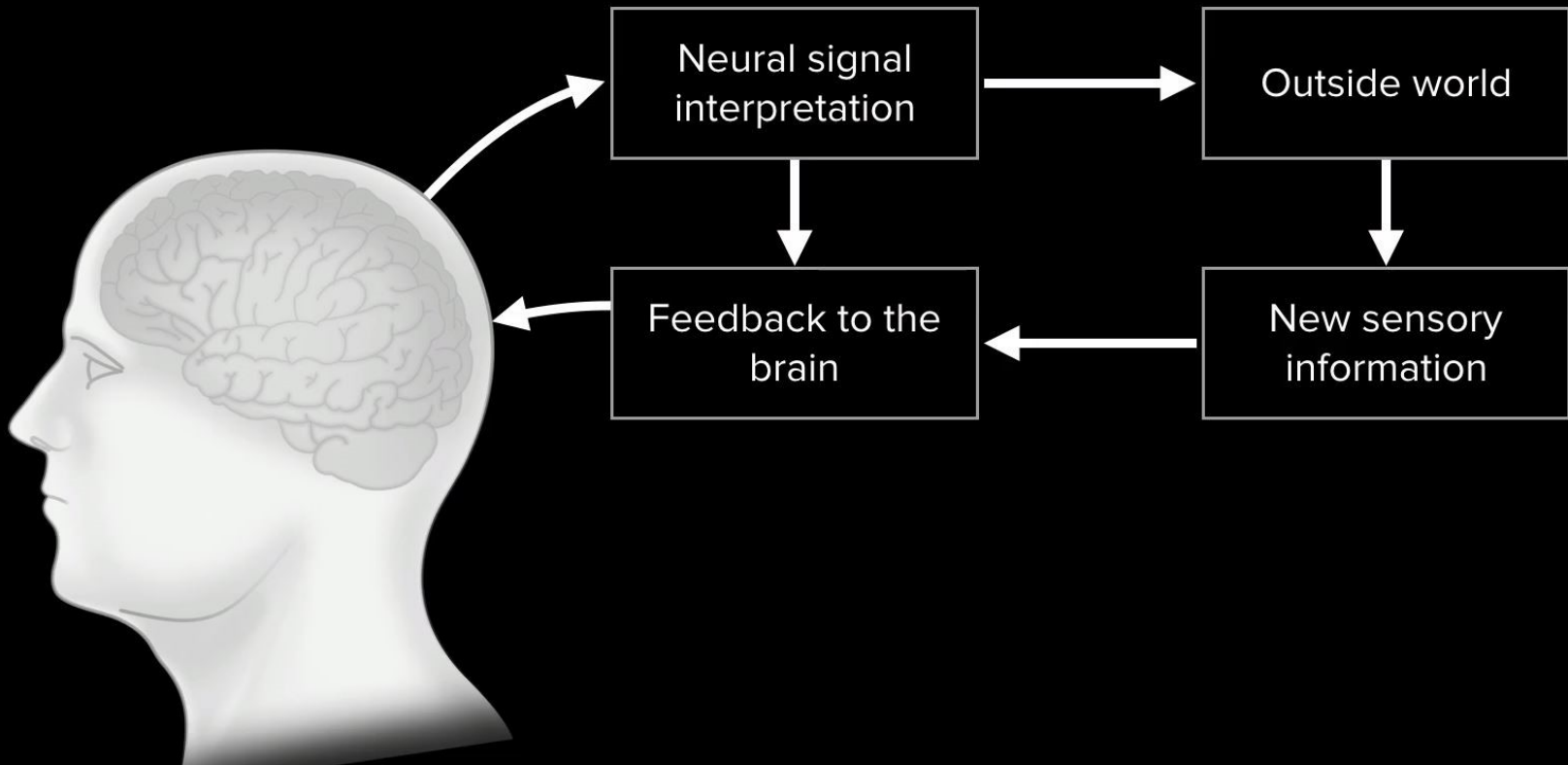


HEXOSKIN
HEALTH SENSORS & AI

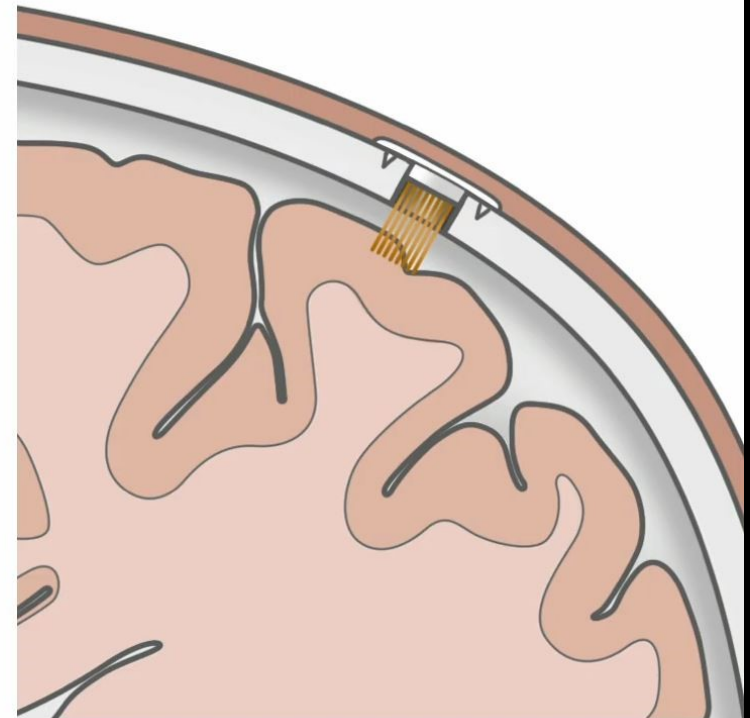
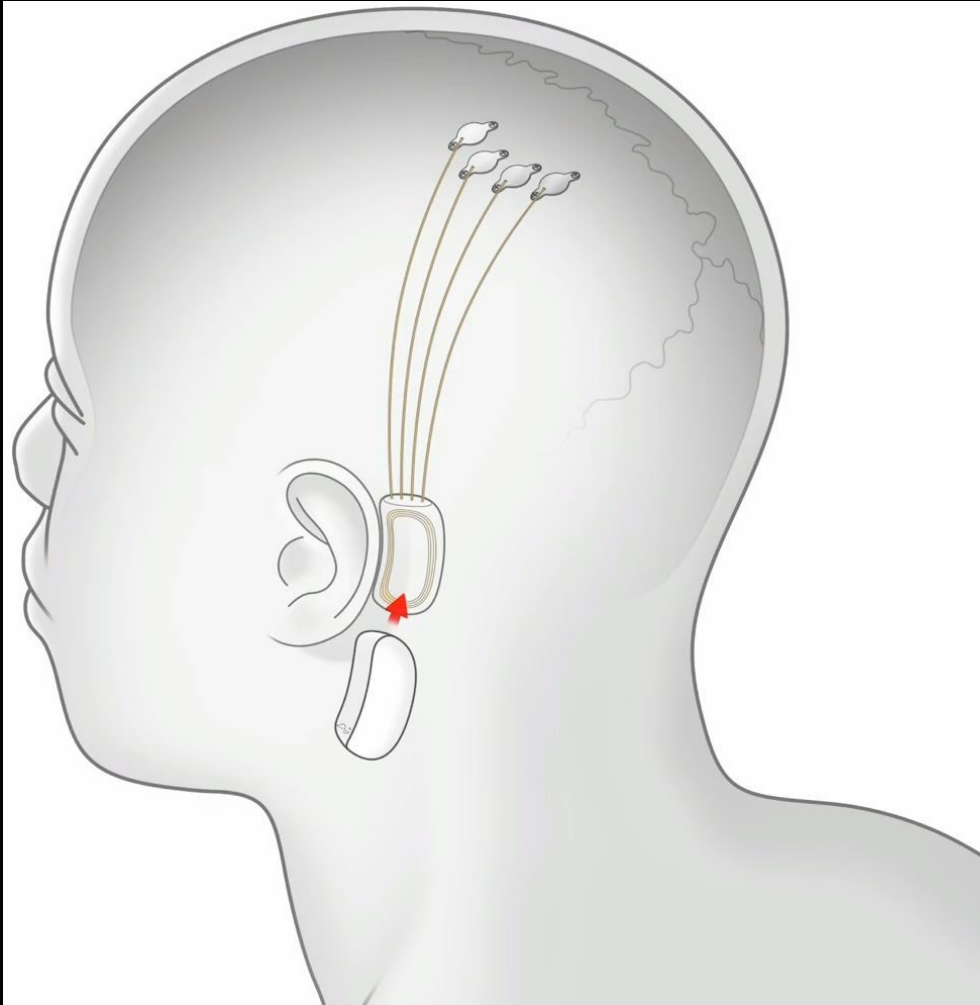
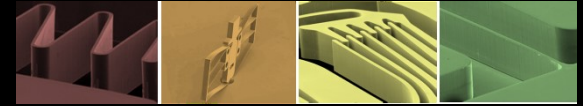
Healthcare - HMIs



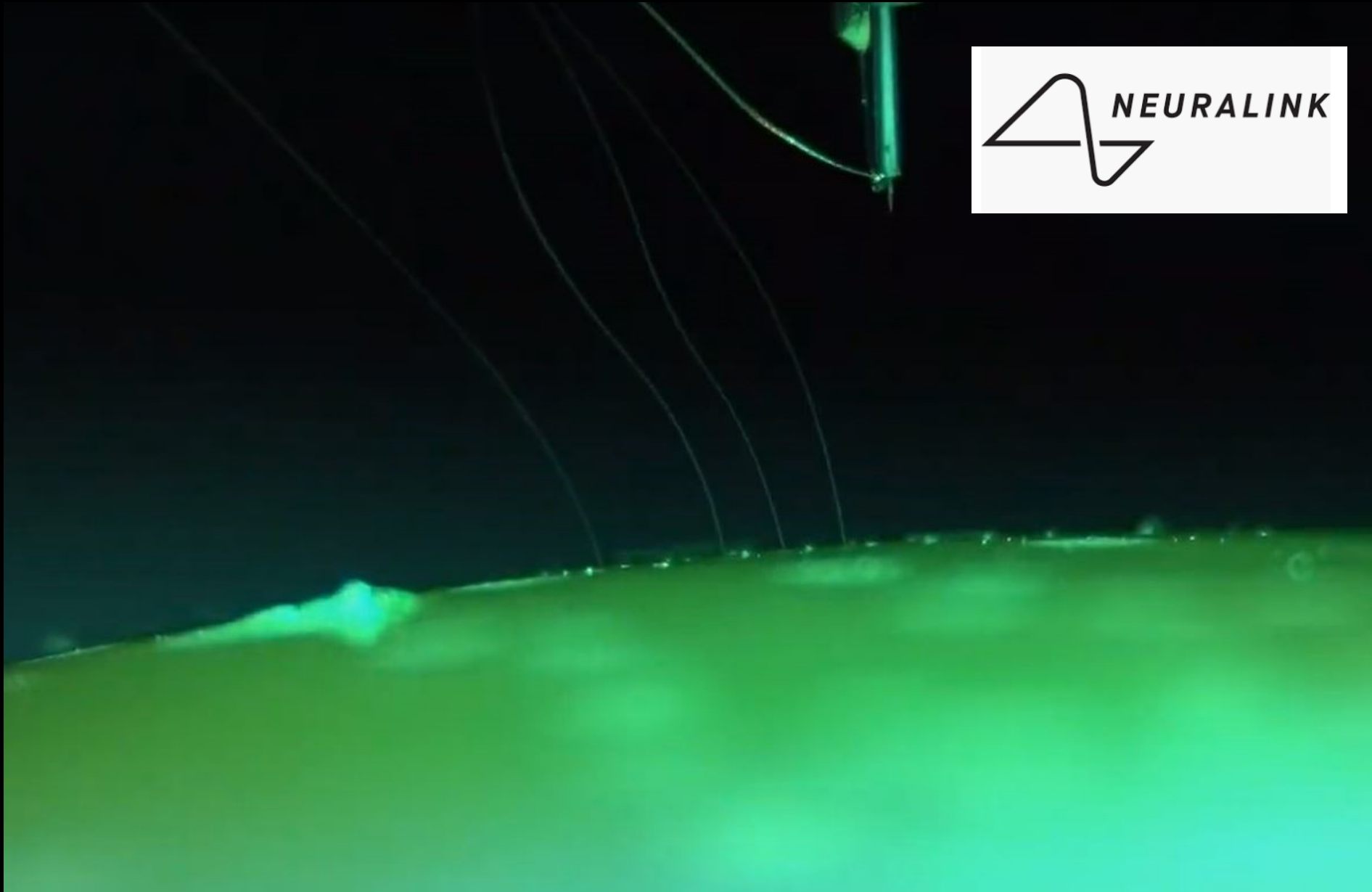
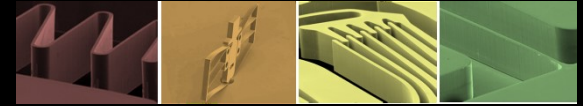
BRAIN-MACHINE INTERFACES



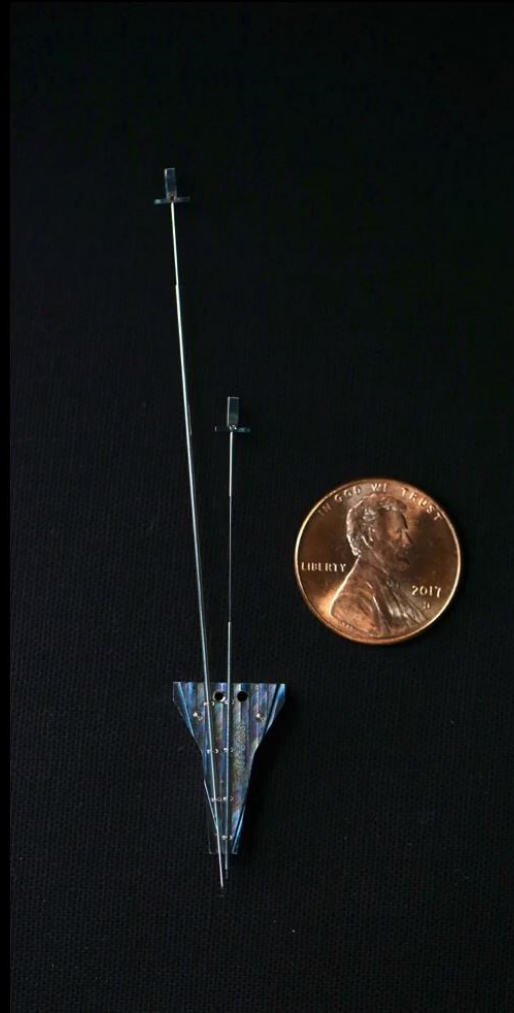
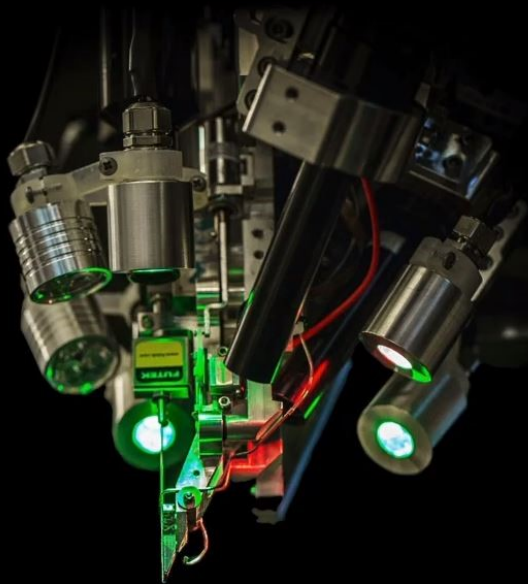
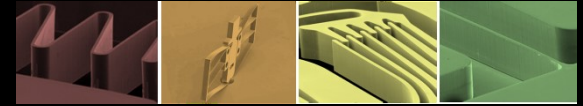
Healthcare - HMIs



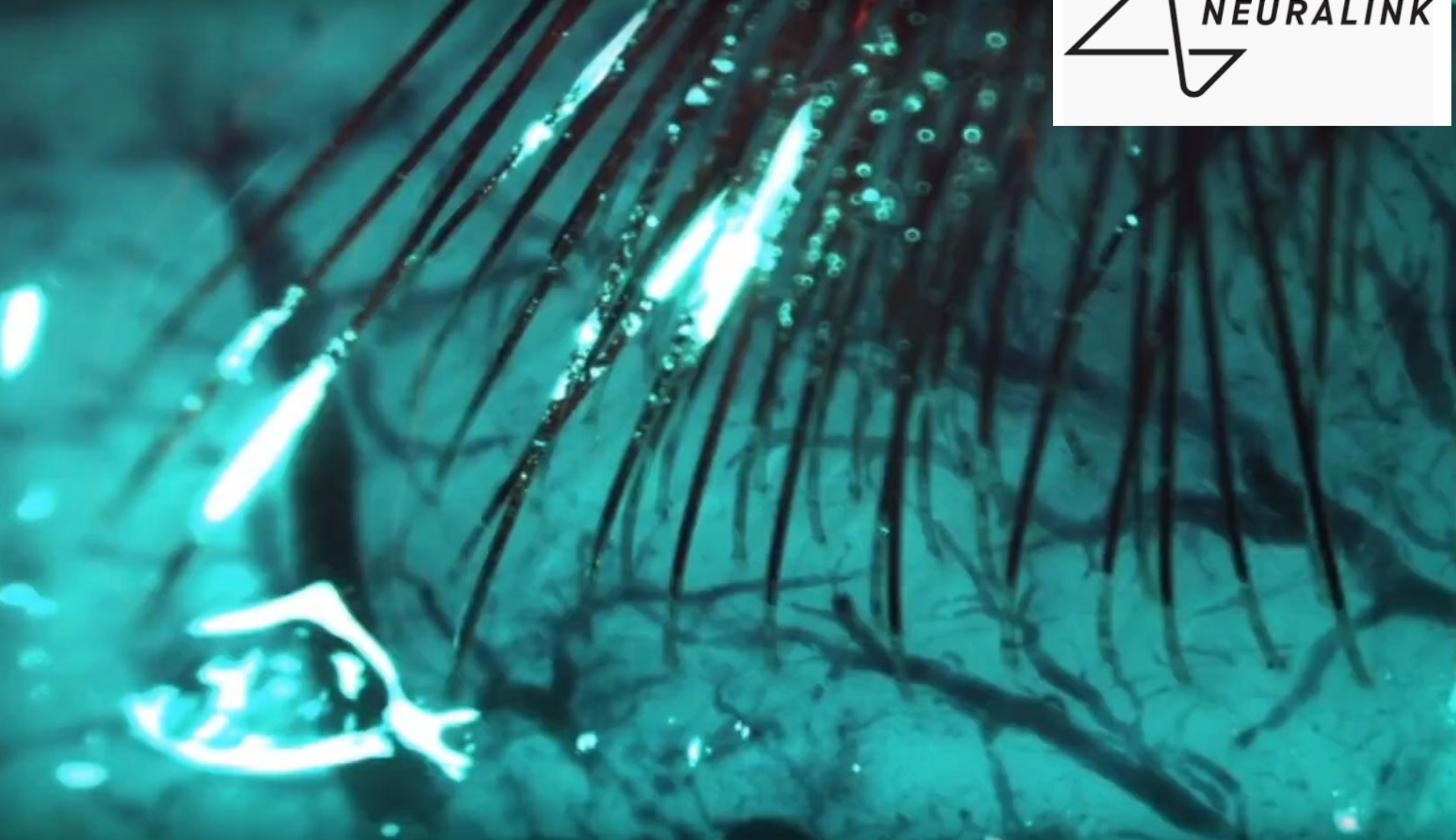
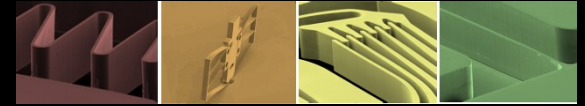
Healthcare - HMIs



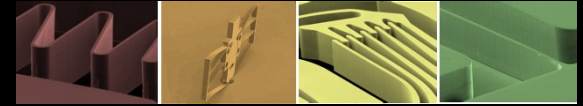
Healthcare - HMIs



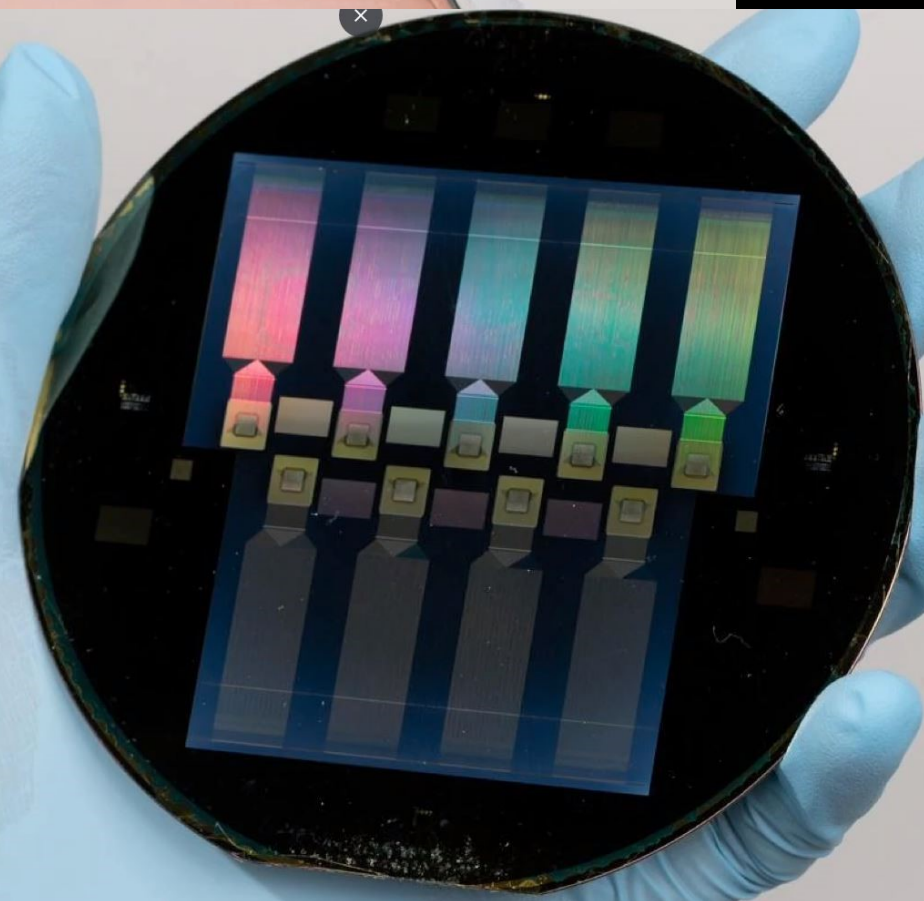
Healthcare - HMIs



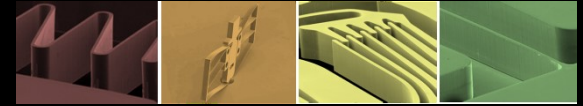
Healthcare - HMIs



MONOLITHIC THIN
FILM SUBSTRATE



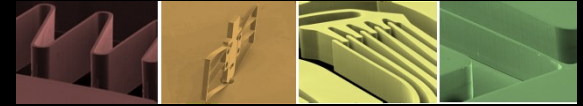
Healthcare - HMIs



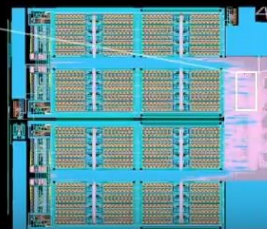
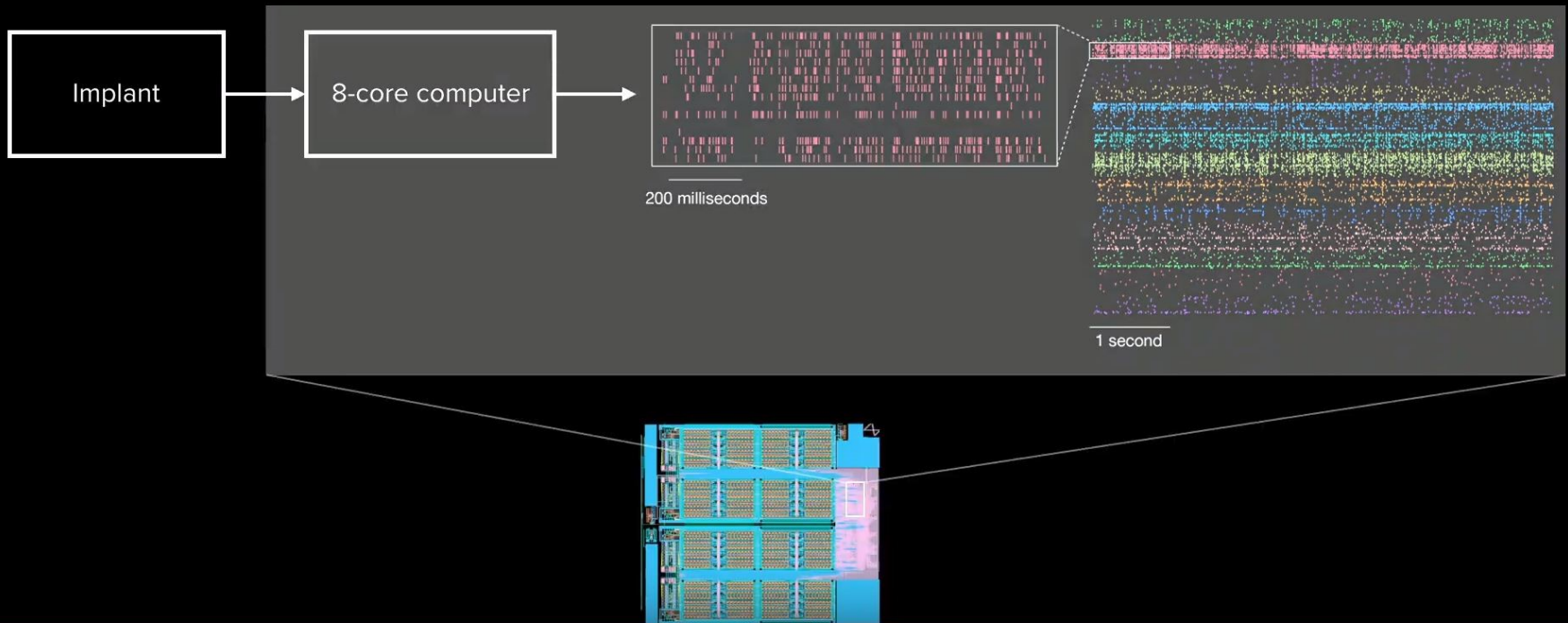
Neuralink Livestream



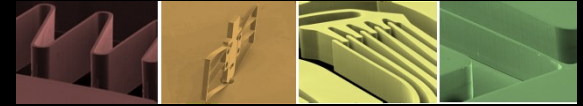
Healthcare - HMIs



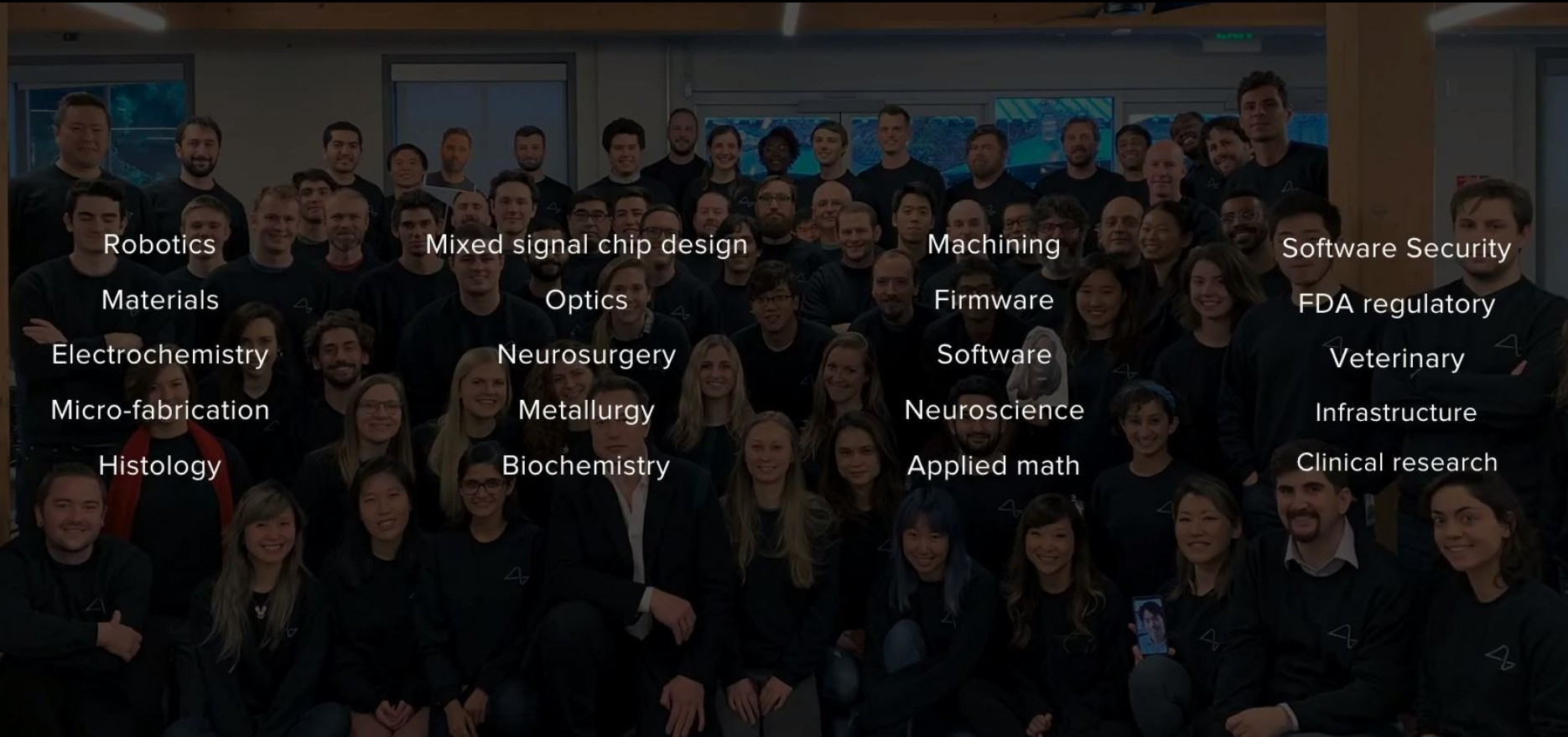
ON-CHIP SPIKE DETECTION



Healthcare - HMIs



Now Recruiting



Robotics

Mixed signal chip design

Machining

Software Security

Materials

Optics

Firmware

FDA regulatory

Electrochemistry

Neurosurgery

Software

Veterinary

Micro-fabrication

Metallurgy

Neuroscience

Infrastructure

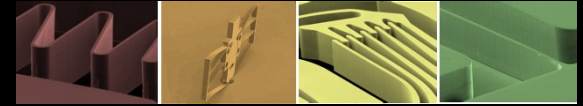
Histology

Biochemistry

Applied math

Clinical research

Energy



breezi the fitness tracker for HVAC systems

qlair



Pipers® Team

Self-serve
in-line inspection
for oil and gas.
Zero downtime.

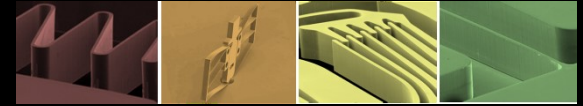


Building health



CONSTRUCTIS
We Build Smart Energy

Environment



Deteriorating Infrastructure

Smart Municipalities

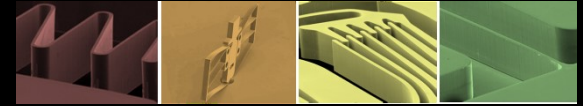
Internet of Water

Disaster Resilience (Hitachi – 1.4T sensors)

Wellness sensing

eWallpaper – T sensors in B m²

Environment



SKYX∞

Purpose-built Aerial Systems

Operating Temperature Range
-20°C – 40°C
-11°F – 100°F

Optimal Speed
65 kph – 120 kph
40 mph – 75 mph

Endurance
Up to 1.5 hours

Sensors
High-Resolution RGB, Infrared Camera and a High-Definition Video Camera

Operational Range (Per Segment)
100 km
65 miles

Ceiling Height
Up to 3,200 m
Up to 10,500 ft

Batteries
Redundant Industrial Lithium-ion Power System

Communication
Cellular, Long-Range RF and SATCOM

FLOW LABS

SMARTER WATER MANAGEMENT

Real-time water & leak monitoring for commercial real estate



OtoSense

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

CLEAR FLIGHT SOLUTIONS

ROBIRD

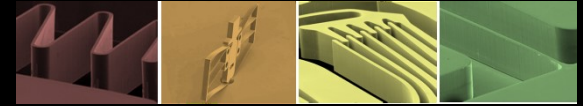
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ROBIRD®

RoBird® (formerly Clear Flight Solutions) is the creator of the unique RoBird® UAV and specializes in wildlife management. The RoBird® robotic peregrine falcon is one of the most effective bird control solutions in the world, and is the only tool available that not only scares birds away, but can 'herd' them and push flocks in any desired direction.

We solve problems by combining the strength of nature with smart technology.

Manufacturing



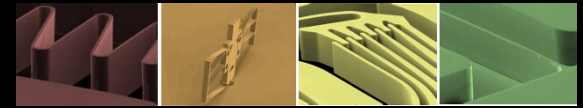
Industry IoT – Industry 4.0

Extreme customization

Printed sensors / electronics

No more wafers? FPD based microfabrication

Manufacturing - Industry 4.0



Micro / Nano crosscuts through all!

explosion of data / activity

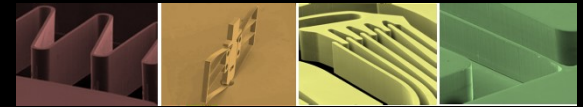
analytics / intelligence

advanced robotics / automation

additive manufacturing

shorter and shorter product cycles

Manufacturing - Industry 4.0



THE INDUSTRIAL IOT (IIOT) STACK: 125+ STARTUPS BRINGING DIGITIZATION TO HEAVY INDUSTRY

SENSORS & CONNECTIVITY

CONNECTIVITY	SENSORS & MONITORING	M2M / SATELLITE
SIGFOX Actility cubic TEMPERED	INGENU senet EMnify 3DSignals smartron HELIUM KONUX dorsaVI electric imp Particle	FILAMENT FLEET KEPLER magnitude space Satify

EDGE DEVICES & CONNECTED OBJECTS

INSPECTION DRONES	3D PRINTING	INDUSTRIAL AR/VR	WEARABLES	ROBOTICS & EXO
CyPhy RedZone SAVATON Airware kespry 3DR XORRAFT	carbon3D DESKTOP METAL NORSK TITANIUM DIGITAL ALLOYS XJET xometry	DAQRI UPASKILL SCOPE Meta ODG ATHEER UBIMAX FIELDBIT	PROGLOVE maven machines humancraft	rethink robotics RIGHTHAND CLEARPATH SARCOS KINDRED SEEGRID

UNIVERSAL PLATFORMS & EDGE INTELLIGENCE

UNIVERSAL PLATFORMS (PaaS)	FOG & EDGE COMPUTING
C3 IoT arrayent ALTIZON mnubo Ayla Networks azeti Flutura relayr. greenwave systems CIRRO WORLD SENSING	FOG HORN nebbiolotechnologies VIMC Technologies XAPTUM OSI Soft machineshop CLEARBLADE

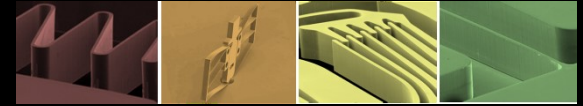
APPLIED SENSOR NETWORKS (VERTICAL SPECIFIC)

FLEET	OIL & GAS	AGRICULTURE	SMART GRID	FACTORY	WAREHOUSE
VENIAM GREENROAD VIAVIA KEEP TRACKING CobandInnovator	oseberg TACHYUS square SKY-FUTURES V-ABSTRACT square square square square square	BLUE RIVER FarmersEdge ARABLE FarmDot	AutoGrid SPACE TIME Trilliant TEACORIL Blue Pillar enbata	EXOSITE	LOCUS fetch simbe OmniID ALIEN fourkites

ADVANCED ANALYTICS & PROTECTION

AI, ML, PREDICTIVE ANALYTICS	CYBERSECURITY
MAANA falkony PREsenso. SIGHT MACHINE UPTAKE Alluvium AMBIUS	MOCANA CLAROTY Bastille BAYSHORE Indegy CyberX ARGUS patternex NexDefense NOZOMI ForeScout

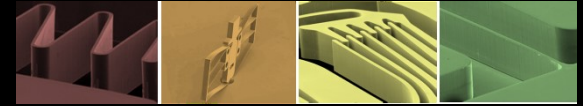
Manufacturing - Customization



“ everyone is a ‘maker’ ”

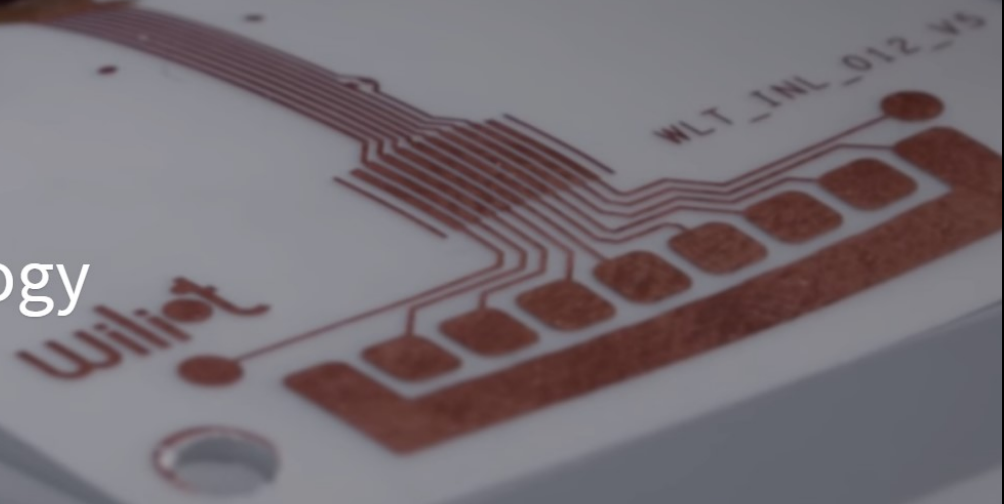
Extreme customization –
no product like any other

Manufacturing - Printed

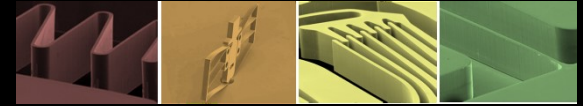


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Battery-Free
Bluetooth[®] Technology
- Connecting People
with Products



Manufacturing - Printed



Printed electronics

Exponential technology on verge of disruption

AsahiKASEI

min CD < 250nm

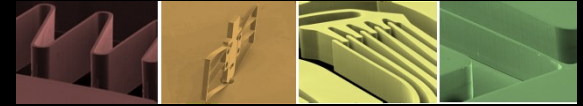


NANODIMENSION

Electrifying Additive Manufacturing®

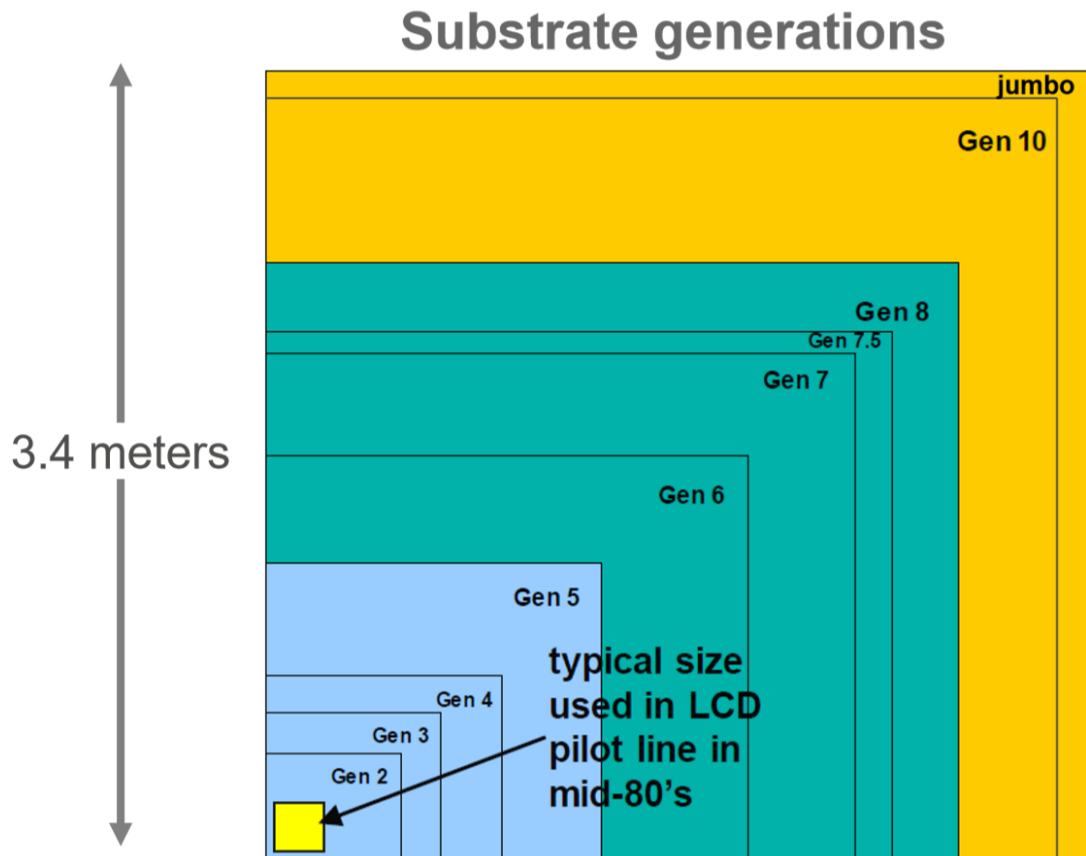
OPTOMECC

Manufacturing – Large Area



Dr. Robert Andosca, AEI

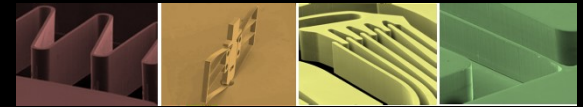
SUBSTRATE SIZE INCREASING FOR MANUFACTURING ECONOMICS



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

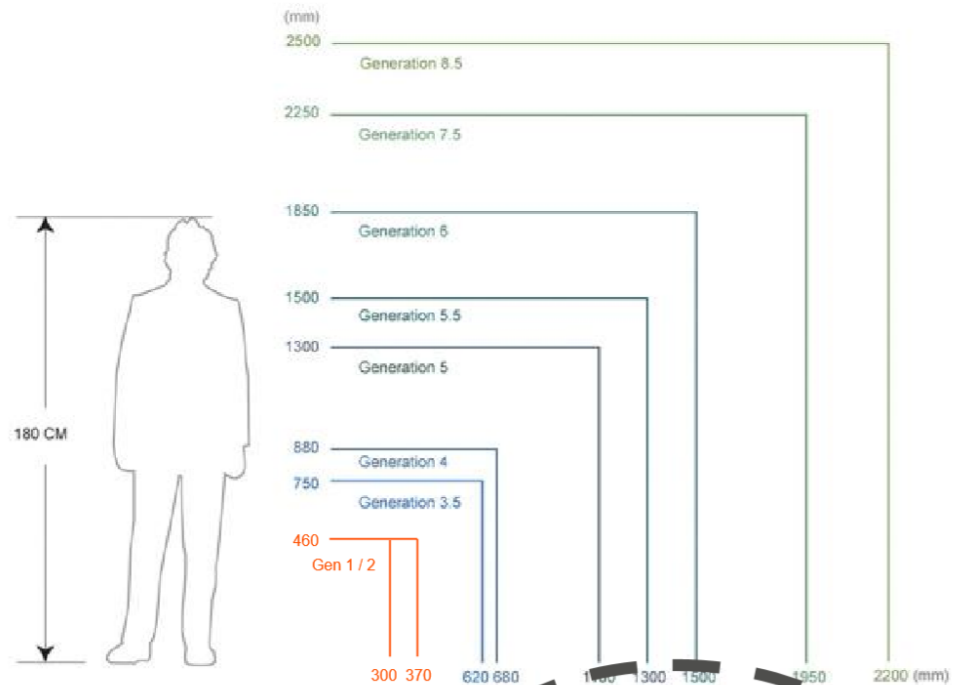
ECONOMIES OF SCALE – FABRICATE MEMS USING LARGE AREA TECHNIQUES

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

✓ **6.5 wafers @ 200 mm diameter**

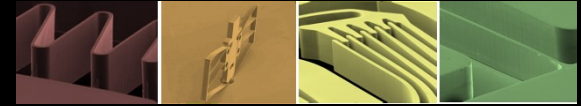
A single **Gen 4 substrate** area equivalency –

✓ **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 ft²
 - **Cleanroom:** 65,000 ft²
 - **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 !**

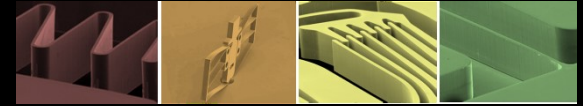


X-ray photo detector arrays
for medical imaging on
Gen 4.5 glass



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

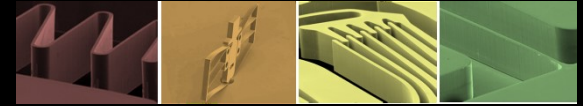
Autonomous transportation will eliminate millions of jobs

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)

Measurement Science - Units / Tolerancing

Quality Management

Documentation

Sensors Startups

\$4.6M AVERAGE VALUATION

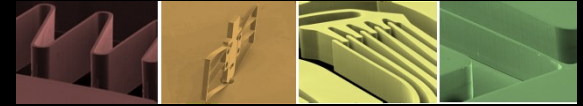


376 COMPANIES

3,196 INVESTORS

269 JOBS

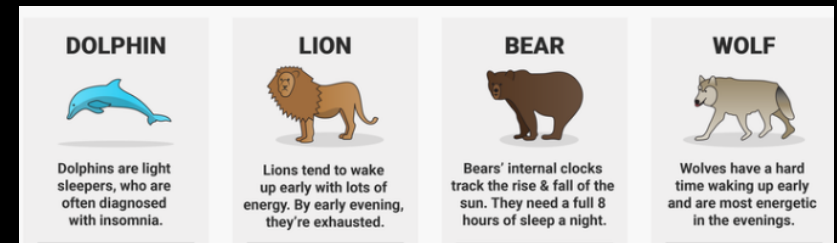
Other Developing Educational Trends



accelerated / more efficient learning

Online - ASU

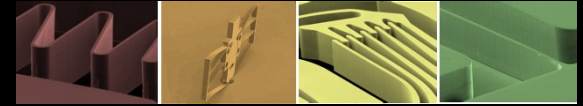
Chronotype adapted



Gamification – sensor enabled!

Learn by doing – AR – Immersion learning
- sensor enabled!

Peace Engineering



WEFF - GEDC
2018
New Mexico.USA

PEACE ENGINEERING

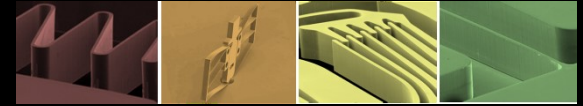
Transforming Engineers for a Sustainable Global Future

Imagine. Design. Create.

Building a better world through peace engineering

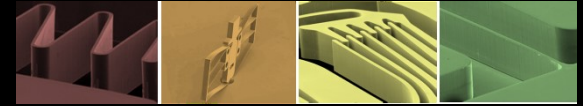
November 12-16, 2018
Albuquerque, NM, USA

Peace Engineering



“positive, sustainable
engineering and innovation
based solutions to world problems”

Peace Engineering



Engineering, Social Justice, and Peace

A network of activists, academics, and practitioners dedicated to Social Justice and Peace



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ESJP14 and ESJP Critical Conversations

Posted on [June 23, 2019](#) by [secretary](#)

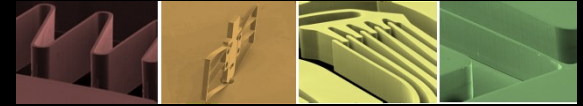
[ESJP 14](#)

RECENT NEWS

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- [ESJP 2019 Conference Schedule](#)
- [Postdoc position in social justice in engineering](#)

journal for practicing engineers, engineering educators, and others seeks to better understand the progressive potential of engineering. The 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

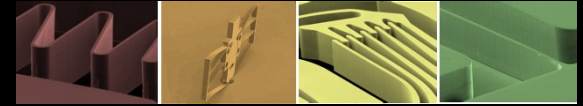
What is Peace Engineering?

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

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PEACE ENGINEERING

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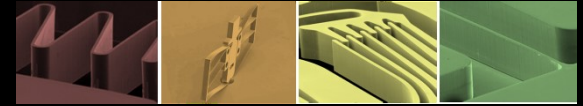
Peace Engineering is the nation's first program dedicated to preventing and reducing violent conflict through education and research that integrates innovative technologies, approaches, and policies with the studies and practices of peacebuilders. This new program was created in collaboration with PeaceTech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

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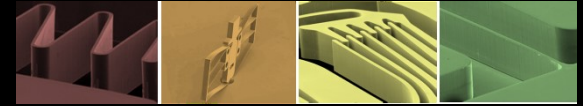
9th World Engineering Education Forum 2019

Disruptive Engineering Education for Sustainable Development

13-16 November 2019 | ITC Grand Chola, Chennai, India



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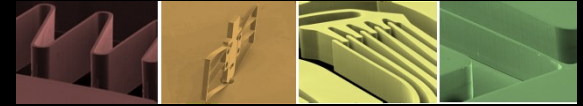
WEEF-GEDC 2020 Cape Town

November 15, 2020 - November 20, 2020

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



Summary



What will a
A sensor based economy / soon large and
microfabricated components and nano materials
will fuel much of it

transcon
Emerging skill set needs have emphasis on
interfaces

'convoy' be in

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

July 21 19 ?

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