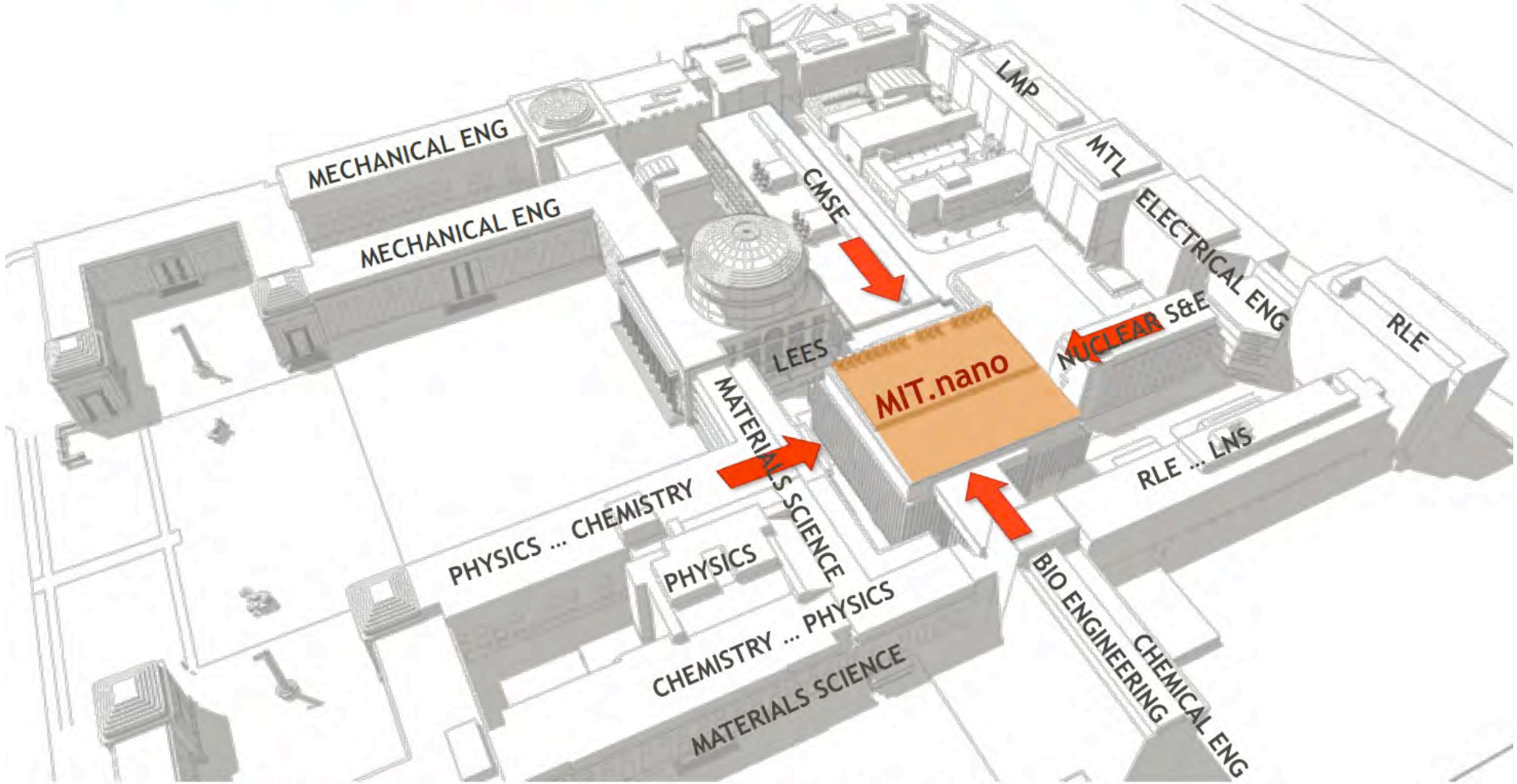
SENSE.nano

From Person-and-Machine to Environment-and-Ecosystem

Kai E. Thomenius
Research Scientist, Institute of Medical Engineering & Science, MIT
Chief Technologist Emeritus, GE Global Research
ket@mit.edu


MIT nano
to open June 2018

MIT.nano at the Center of MIT



DOUBLING SHARED FABRICATION AND IMAGING CAPABILITIES,
INCREASING OPPORTUNITIES FOR CROSS-DISCIPLINARY
INTERACTIONS OF **2000+ USERS**

Nanotechnology in Action

will lead to "disruptive technologies" that will reimagine:

- Medicine and Life Sciences
- Energy Systems
- Computing and Information
- Manufacturing
- Materials and Structures
- Quantum Science and Technology
- Education

Term "nanotechnology" was coined by Prof. Norio Taniguchi in 1974. **Tools** to understand and take advantage of nanoscale phenomena have been under development since then. We have reached a key point in this process.

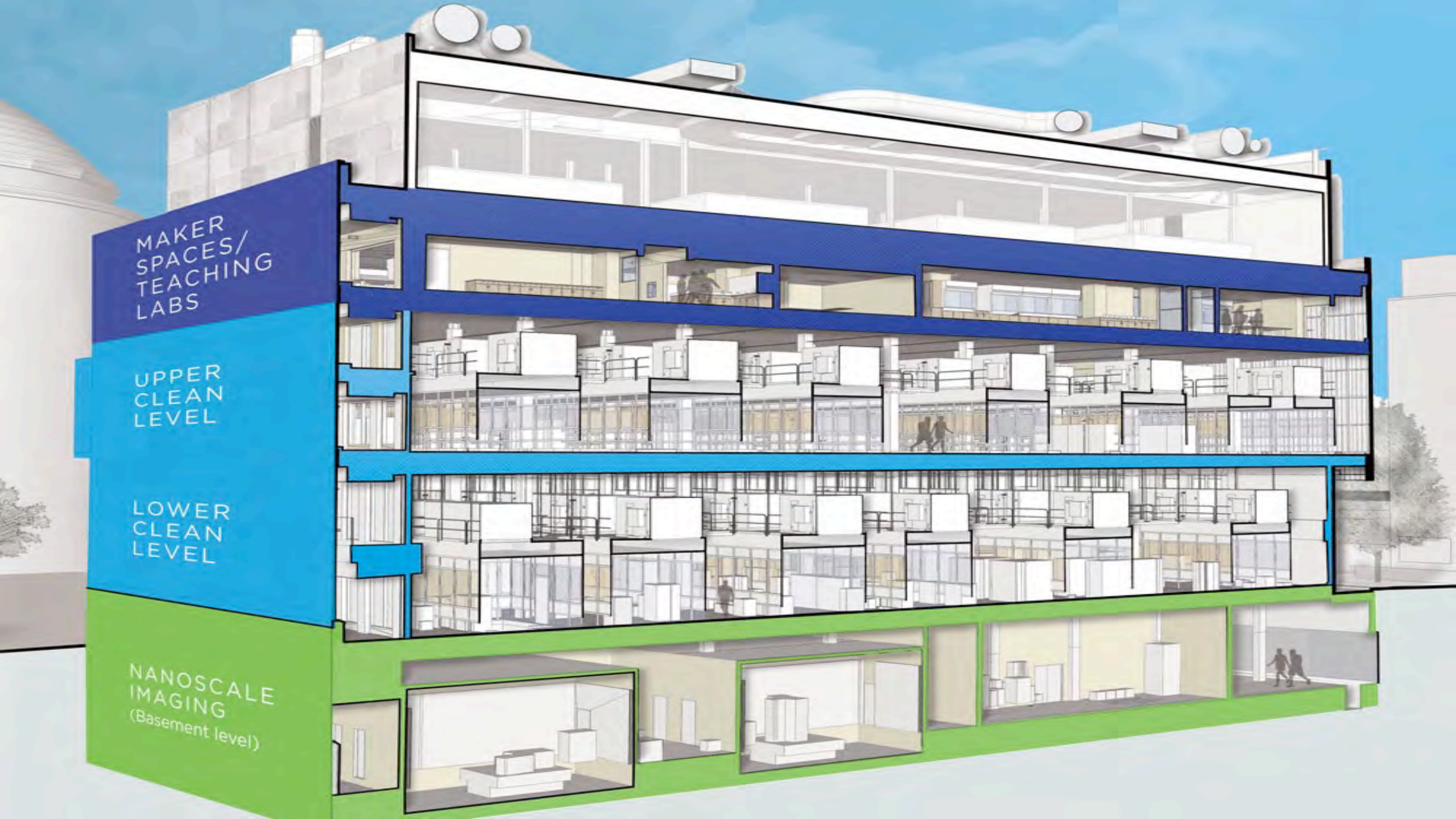





Why MIT.nano?

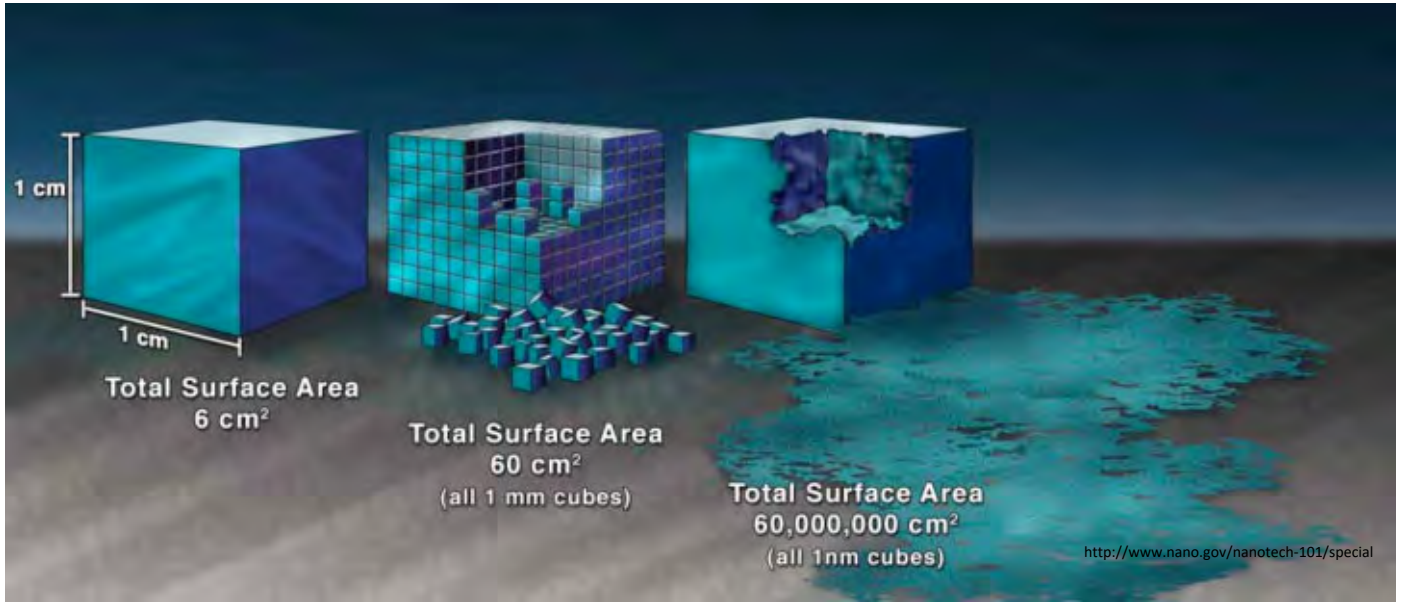
Vision: *Enabling anyone at MIT who wants to practice their field at the nanoscale to do so -- MIT.nano will provide community, expertise, facility and connections to funding.*

Democratized access to the equipment and facilities necessary to enable anyone who wants to do Nano scale research to do so.


MAKER SPACES/ TEACHING LABS
UPPER CLEAN LEVEL
LOWER CLEAN LEVEL
NANOSCALE IMAGING
(Basement level)

What is so special about the Nanoscale?

- Scale at which Quantum Effects Dominate Properties of Materials
  - Physical properties of particles depend on their size unlike with usual dimensions.
- Scale at which Much of Biology Occurs
  - Hemoglobin molecule is 5.5 nm in diameter, DNA strand is 2 nm in diameter.
- Scale at which Surfaces and Interfaces Play a larger role in Materials Properties and Interactions

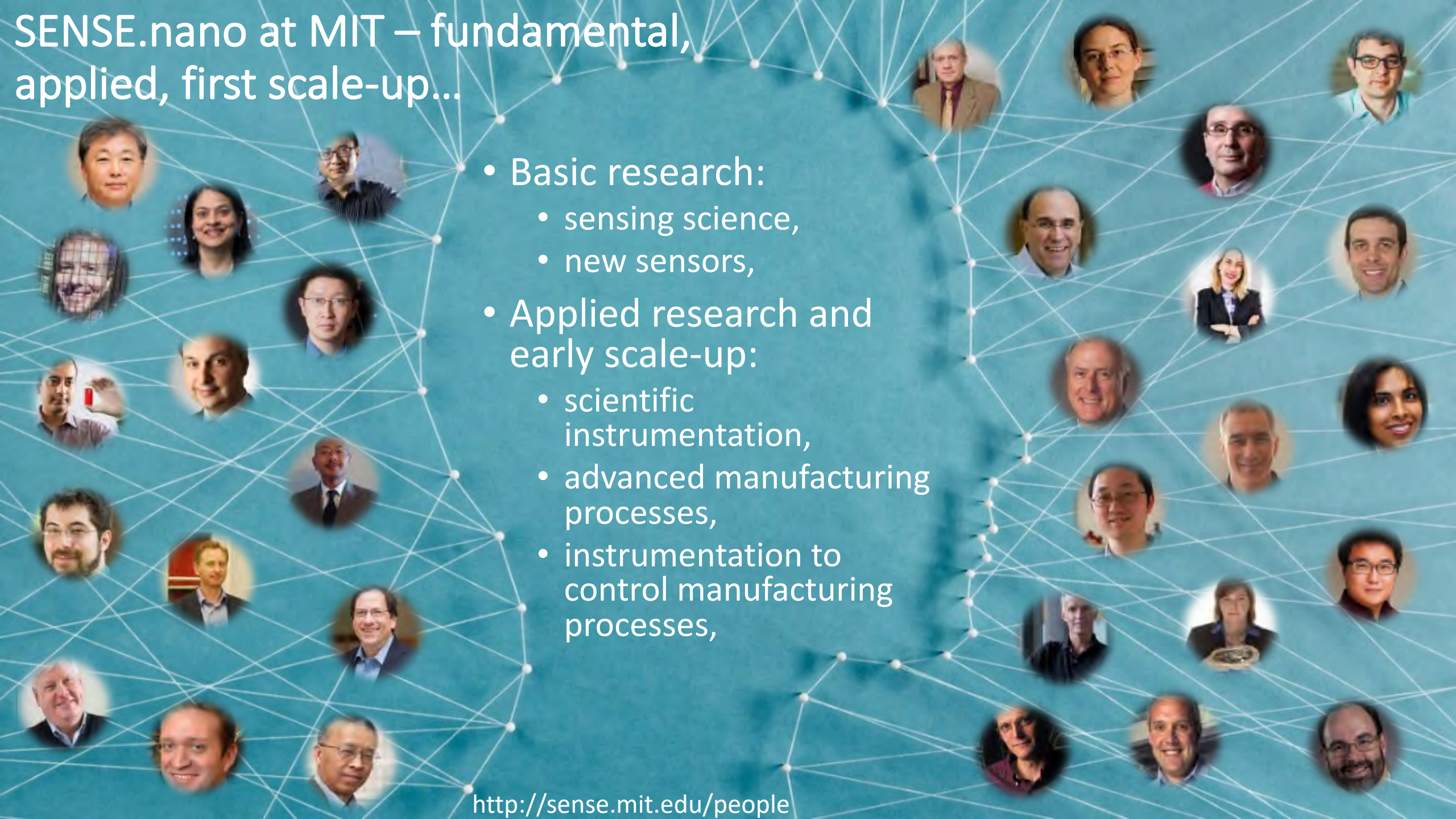


Why SENSE.nano?

- Novel sensors and sensing systems will provide previously unimaginable **insight into the condition** of *individuals to positively impact people, machines, and environment*.
- Advances in **nano-sciences and nano-technologies**, pursued by many at MIT, now offer unprecedented opportunities to realize designs for, and at-scale **manufacturing** of, unique **sensors and sensing systems**, while leveraging **data-science and IoT infrastructure**.
- Hence SENSE.nano, the first **Center of Excellence** of MIT.nano

SENSE.nano Symposium, June 5-6, 2018 at MIT

SENSE.nano at MIT – fundamental, applied, first scale-up…

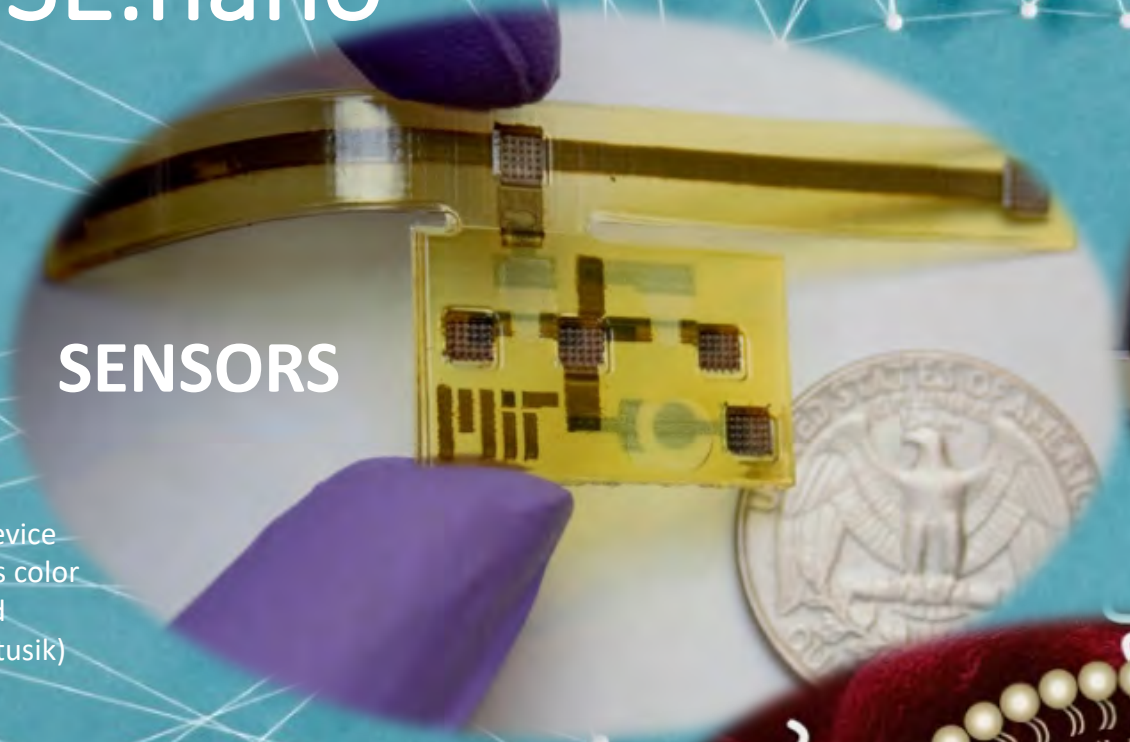


- Basic research:
  - sensing science,
  - new sensors,
- Applied research and early scale-up:
  - scientific instrumentation,
  - advanced manufacturing processes,
  - instrumentation to control manufacturing processes,

http://sense.mit.edu/people

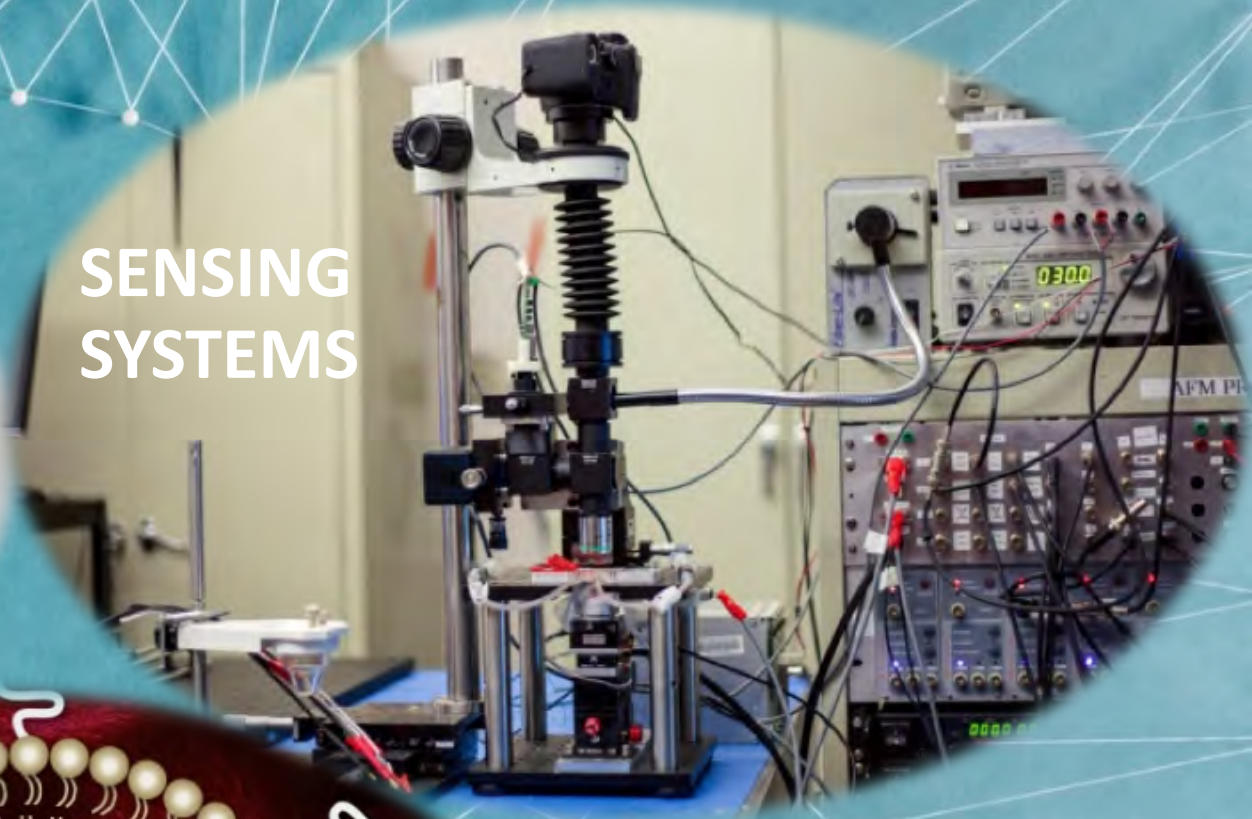
SENSE.nano

SENSORS



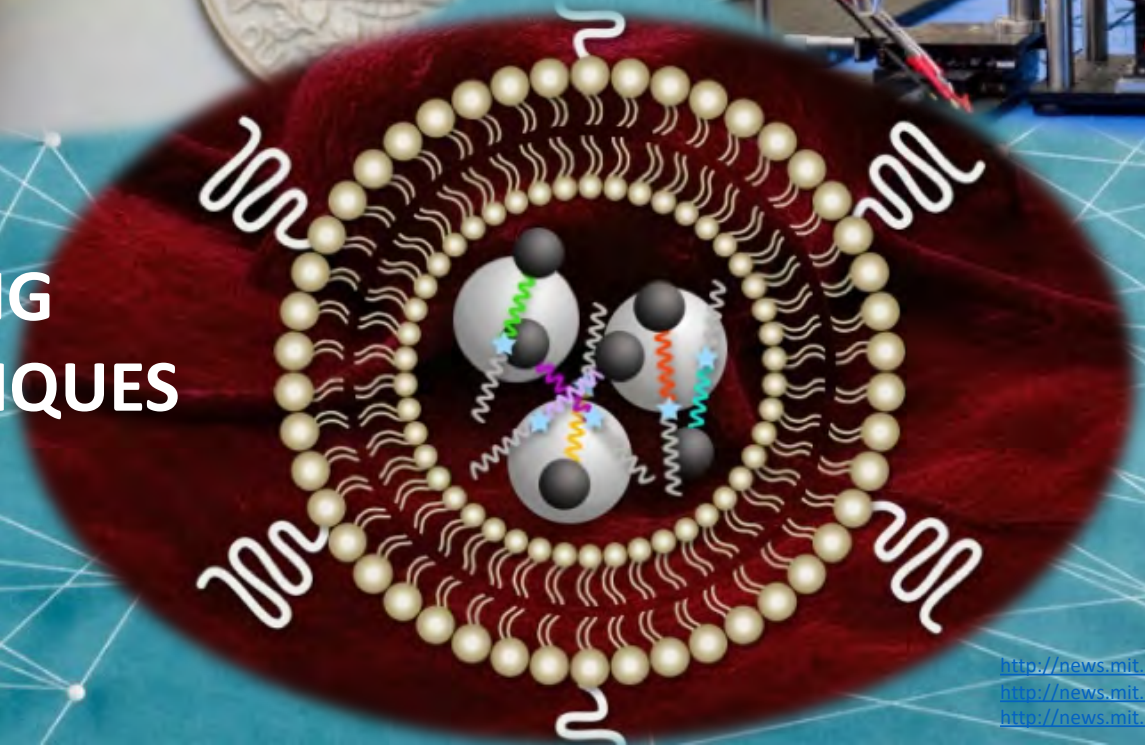
3-D-printed device which changes color when prodded (Wojciech Matusik)

SENSING SYSTEMS



atomic force microscope that scans images 2,000 times faster than existing commercial models, images of chemical processes taking place at the nanoscale, at a rate that is close to real-time video (Kamal Youcef-Toumi)

SENSING TECHNIQUES



injected into the tumor site, the nanosensors activated by magnetic field harmless to healthy tissue, interact with and modified by the tumor proteins, secreted in the urine, detected (Sangeeta Bhatia)

http://news.mit.edu/2017/goldbug-beetle-printable-sensor-laden-skin-robots-0323
http://news.mit.edu/2017/high-res-biomolecule-imaging-single-molecules-0214
http://news.mit.edu/2016/nanosensors-determine-tumors-ability-to-remodel-tissue-0929

SENSE.nano in context

Advanced Manufacturing – innovative processes, machines, materials, etc.

MIT.nano

IoT, The Cloud, and Big Data

http://dashboard.net/wp-content/uploads/2016/08/IoT-Cloud-Big-Data-Image.jpg
https://cdn.businessfacilities.com/wp-content/uploads/2016/10/BF-SO16_CovStory_ATC-Automation_500x284.jpg

IoT, Big Data, and the Cloud

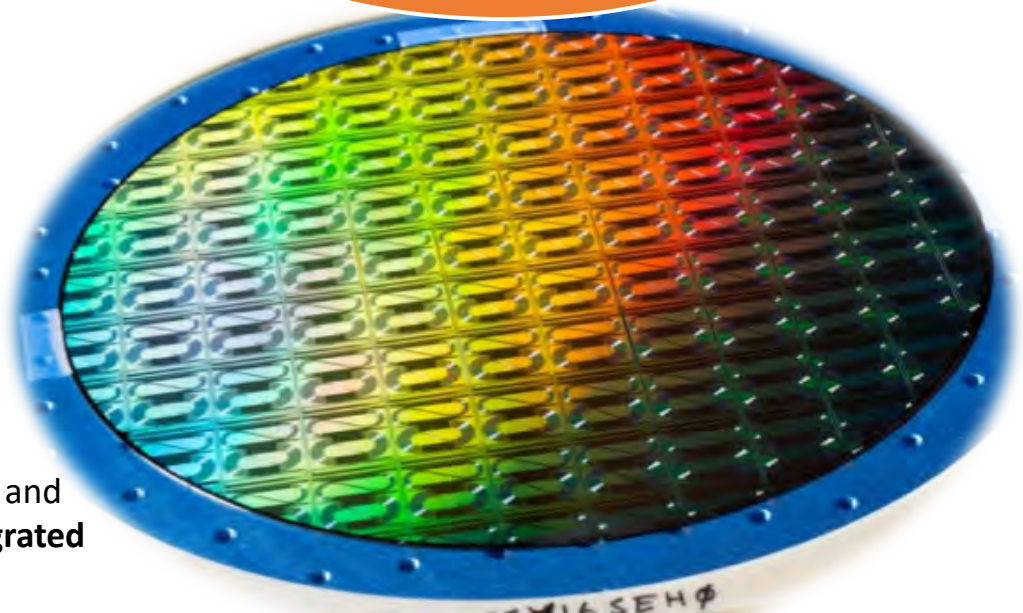
http://seoulspace.co.kr/wp-content/uploads/2017/04/big_data_main.jpg
By Wilgengebroed on Flickr - Cropped and sign removed from Internet of things signed by the author.jpg, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=32745645
https://venturebeat.com/wp-content/uploads/2016/06/datacenters.jpg?fit=930%2C546&strip=all

Advanced Manufacturing Innovation

electronics on a **flexible stretchable** substrate - traditional electronic circuits in wearable and conformable architectures.

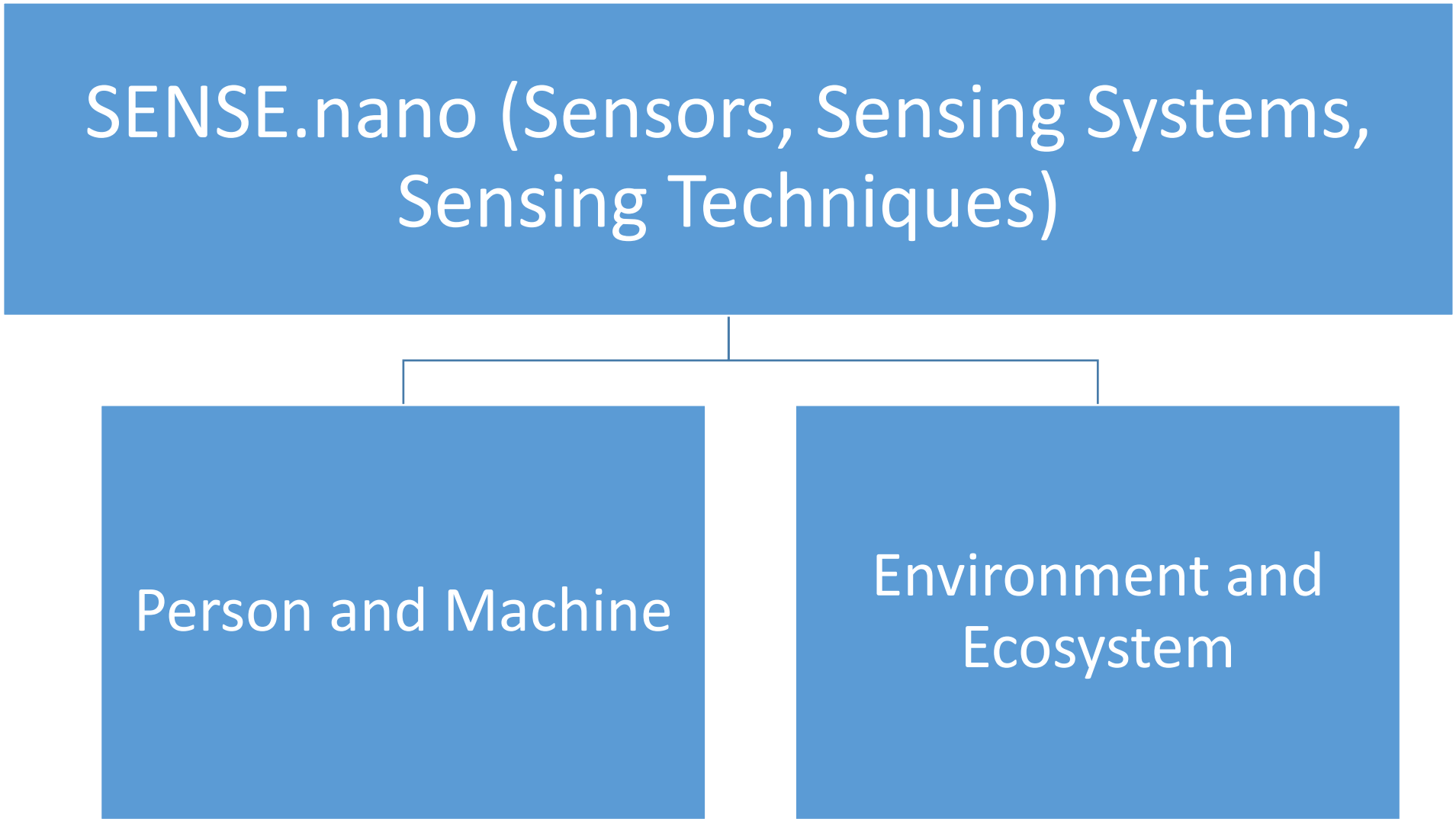
Advanced Sensors

transforming traditional **fibers**, yarns, and **fabrics** into highly sophisticated, integrated and networked devices and systems



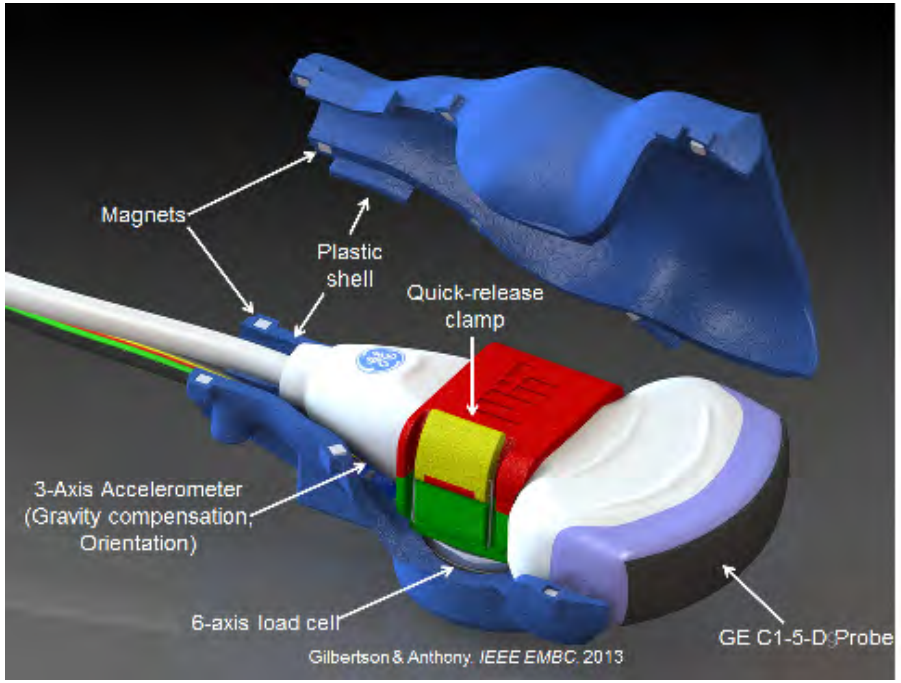
leverage the electronics industry, transition key lessons, processes, and approaches to the **photonic integrated circuit** (PIC) industry.

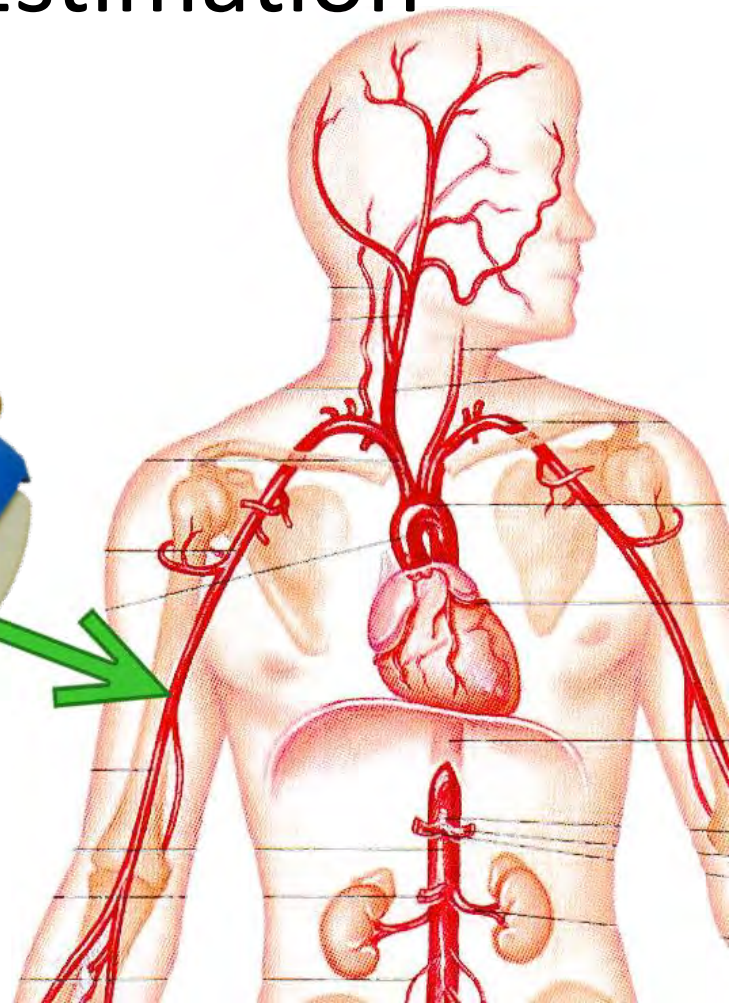
Photo: M. Scott Brauer
http://news.mit.edu/sites/mit.edu.newsoffice/files/styles/news_article_imag_top_slideshow/public/images/2016/MIT-AFFOA-Fink-2.jpg?itok=op7hLV8o
http://news.mit.edu/sites/mit.edu.newsoffice/files/styles/news_article_imag_top_slideshow/public/images/2015/Flexi-Circuit.jpg?itok=OCKP94te
Photo: Bryce Vickmark
http://news.mit.edu/sites/mit.edu.newsoffice/files/styles/news_article_imag_top_slideshow/public/images/2015/02-photonics-wafer_bv26.jpg?itok=OdhK2xo1

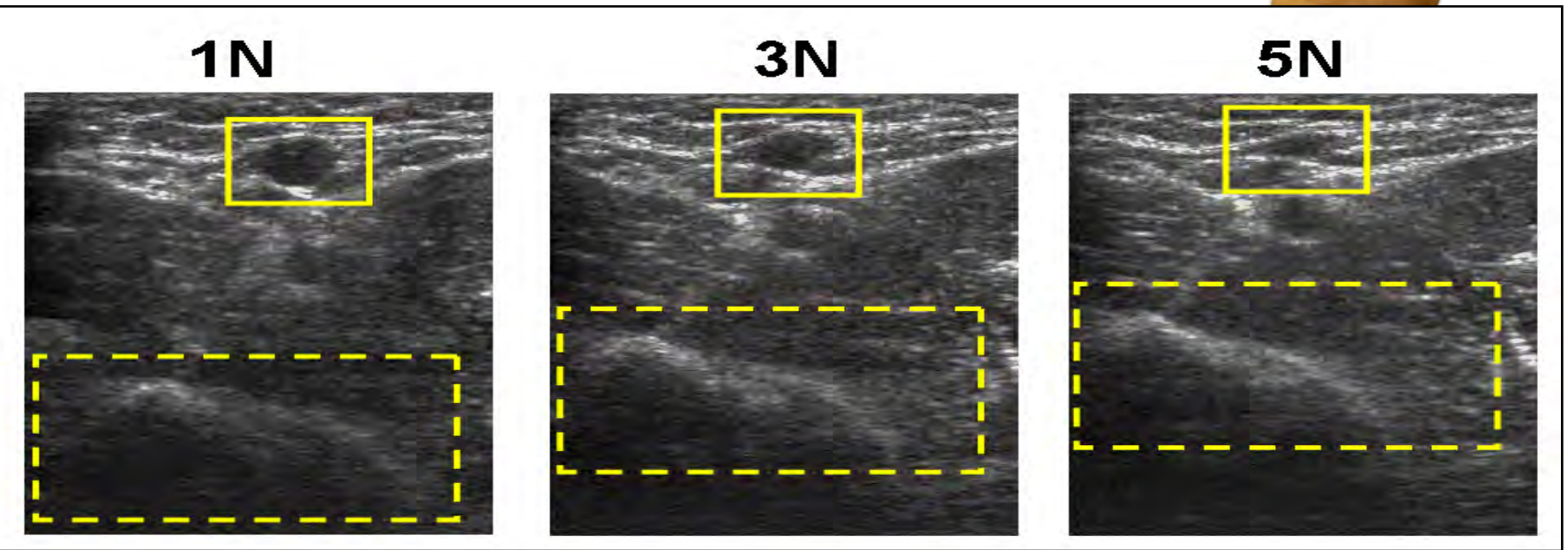

SENSE.nano (Sensors, Sensing Systems, Sensing Techniques)
Person and Machine
Environment and Ecosystem

One microscale story that weaves some of this together…

Enhanced Ultrasound for Blood Pressure Estimation

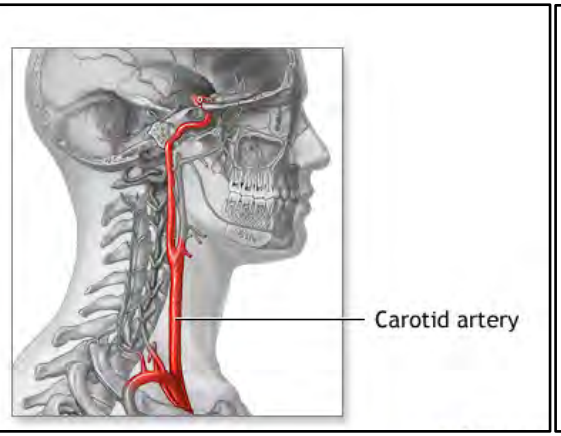




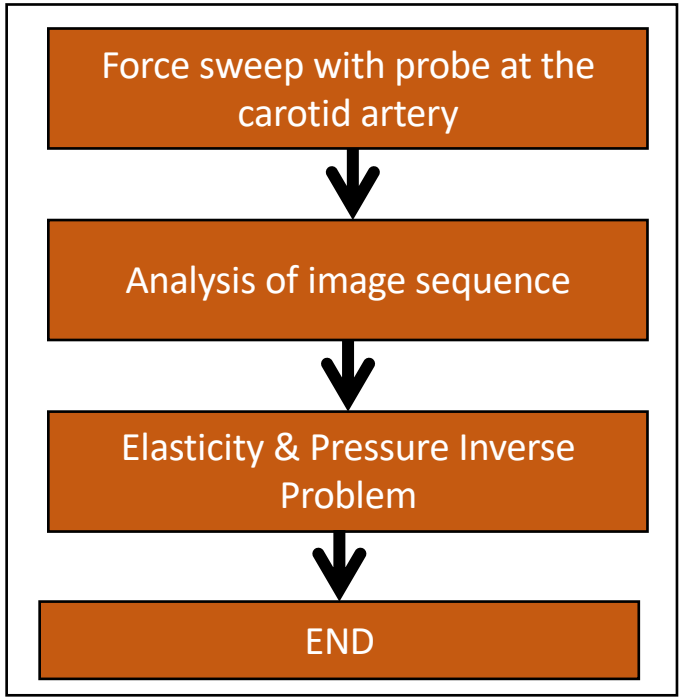


Matthew Gilbertson
Athena Huang

Enhanced Ultrasound for Blood Pressure Estimation

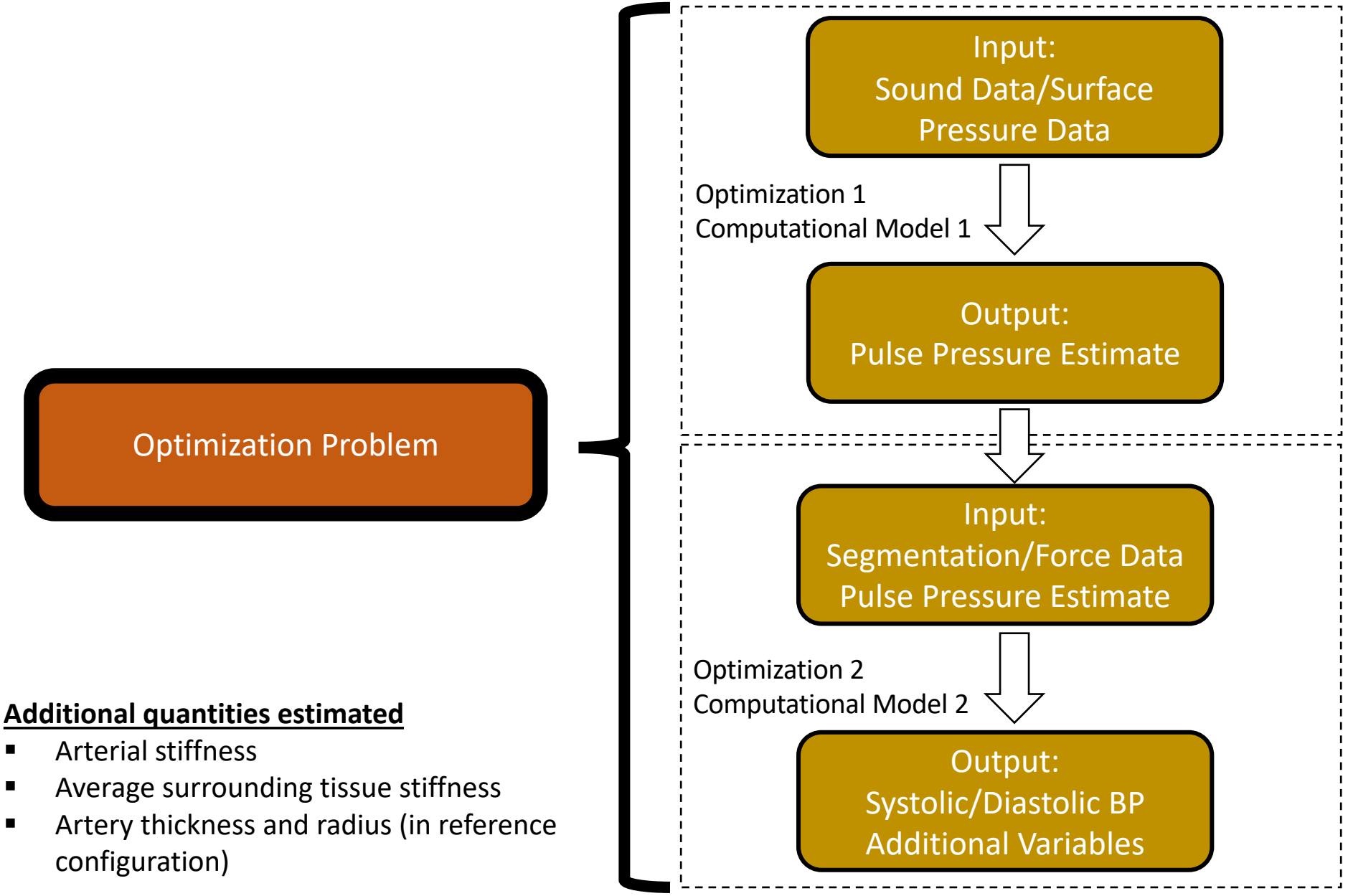


Develop a medical device that measures blood pressure:
(1) non-invasively,
(2) at the carotid artery,
(3) without needing calibration,
(4) in a way that is potentially continuous



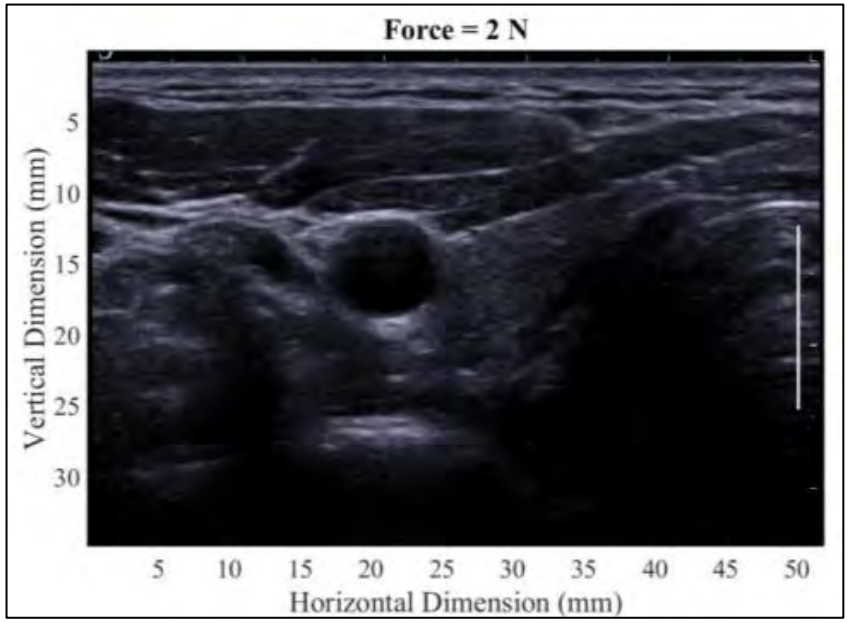
Aaron Zakrzewski

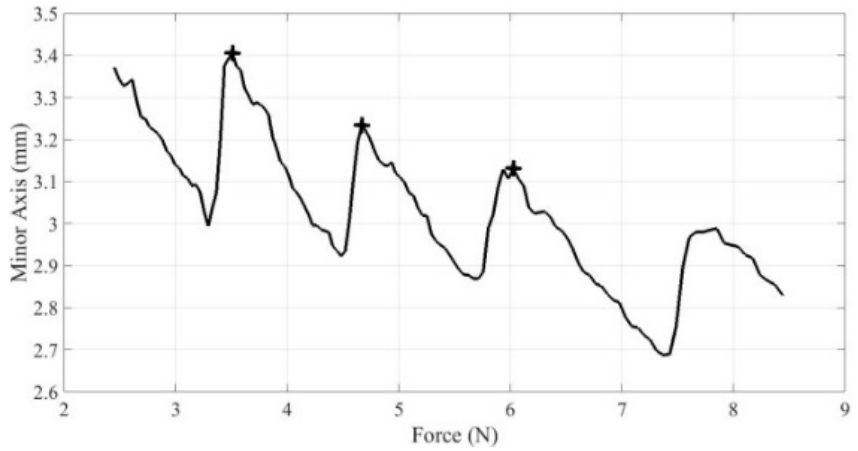
Overview of Optimization Process



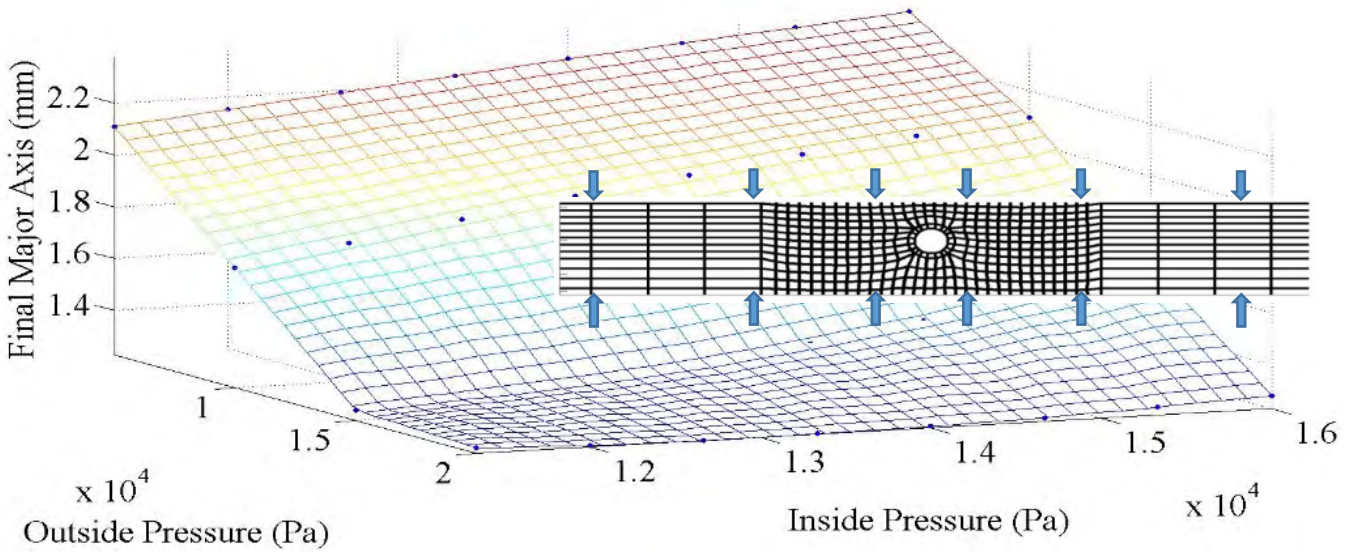
Additional quantities estimated

- Arterial stiffness
- Average surrounding tissue stiffness
- Artery thickness and radius (in reference configuration)





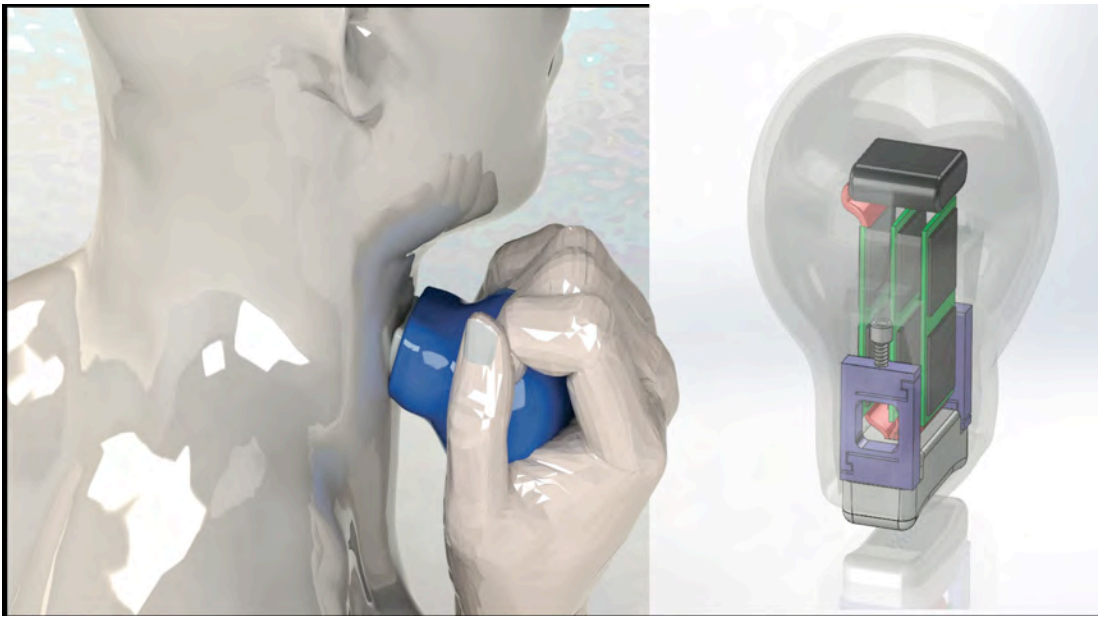
- Artery minor axis versus force.
- Ultrasound images corresponding to the three points in the force sweep at systole.



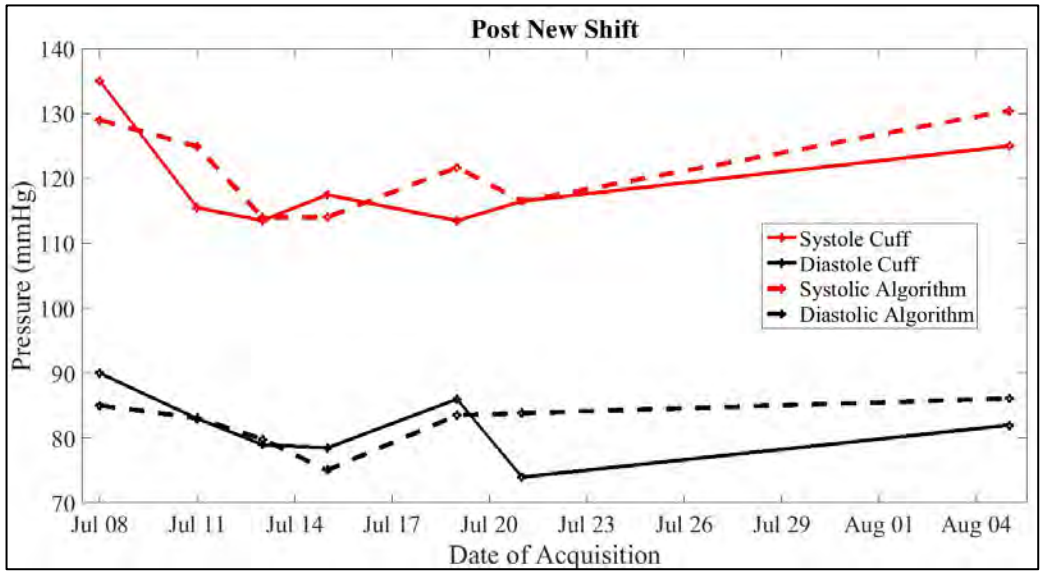
Tissue model

Aaron Zakrzewski

Enhanced Ultrasound for Blood Pressure Estimation

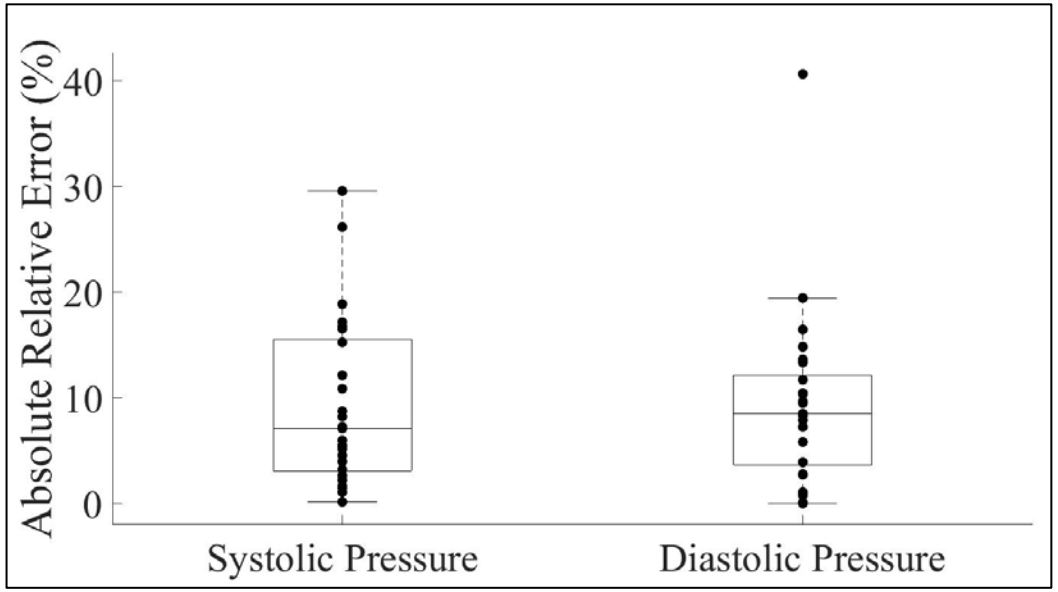


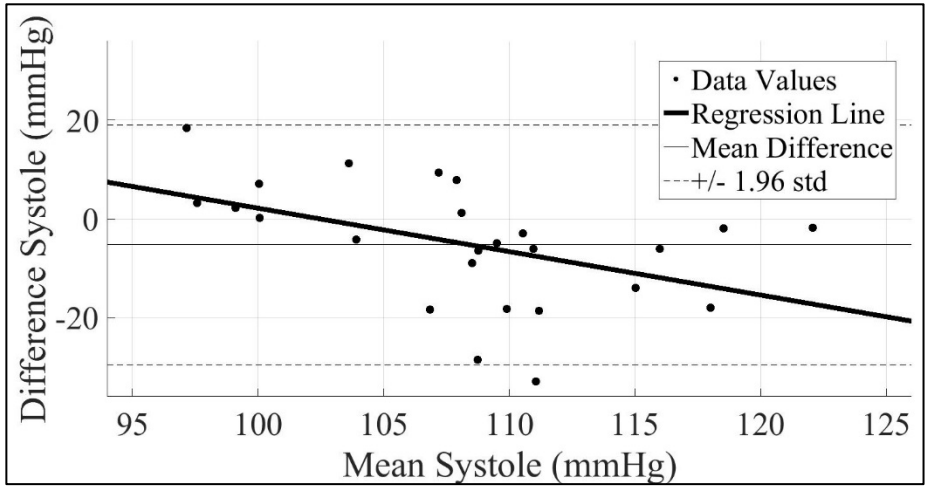
Blood Pressure (mmHg) vs. Date; Hypertensive Patient over 2 months

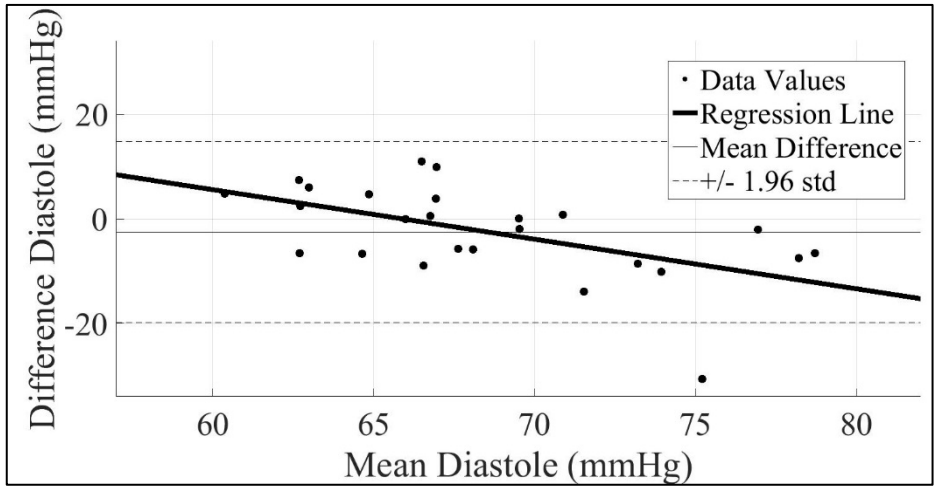


Aaron Zakrzewski, Athena Huang

24 Single-Visit Healthy Volunteers







healthy volunteer results indicate agreement between cuff and algorithm

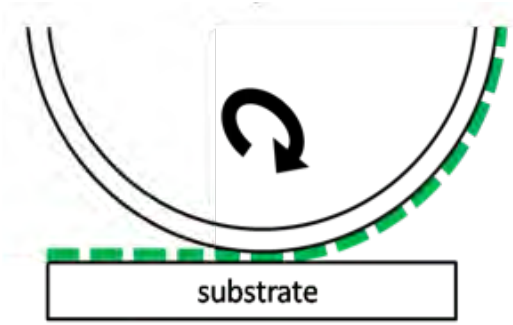
A wearable ultrasound BP sensor patch?

A way to analyze the data?
Realizable, cost-appropriate, wearable design?
A manufacturing process?

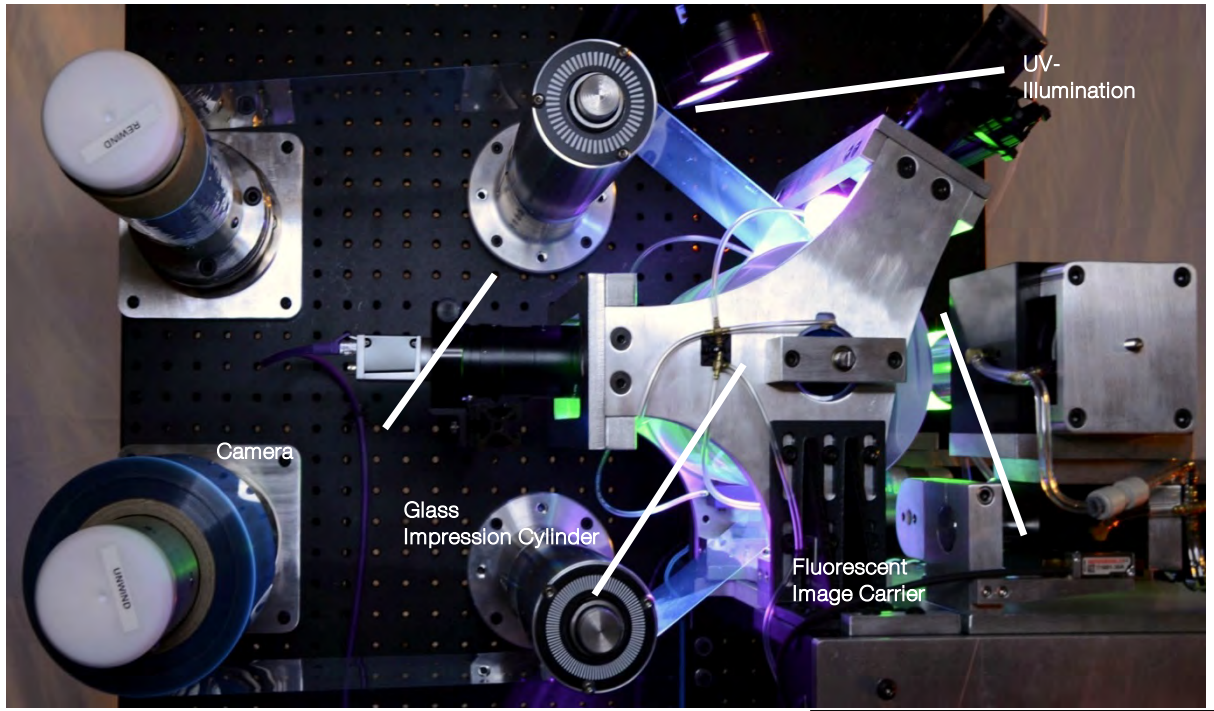
http://www.3m.com/wps/wcm/connect/eb21717b-1908-4509-95df-01edcf2c2b8e/Wearable+Smart+Medical+Sensor+003+rgb.jpg?MOD=AJPERES&CACHEID=ROOTWORKSPACE-eb21717b-1908-4509-95df-01edcf2c2b8e-lglo1Ws

Scale up with Contact-Transfer Printing of MEMS

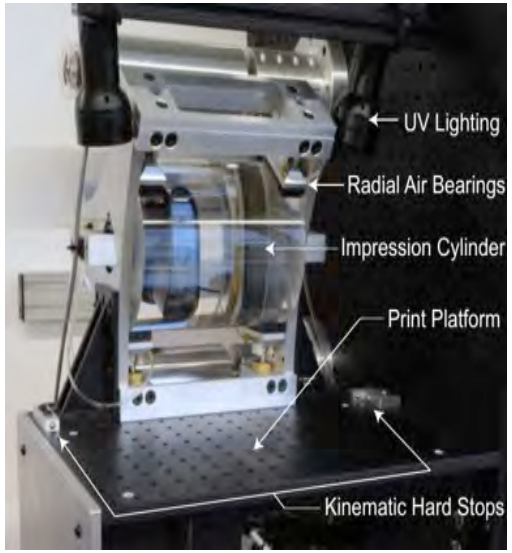
- Roll-to-roll processing over large areas
- Integration with flexible electronics

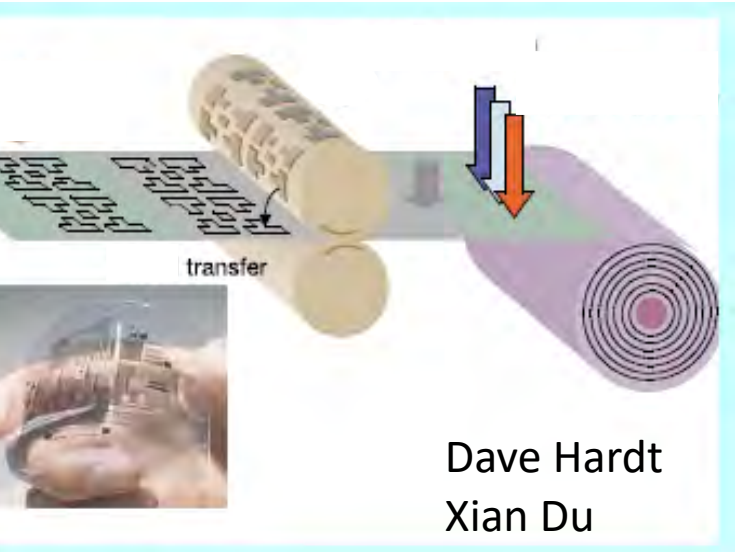


In-situ sensing systems, precision print-head control

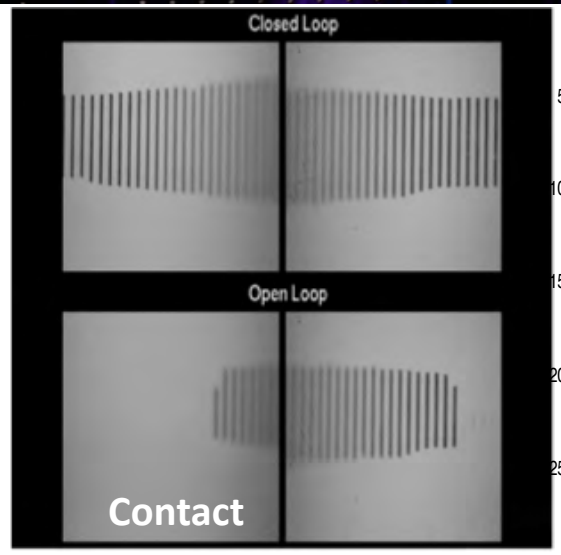


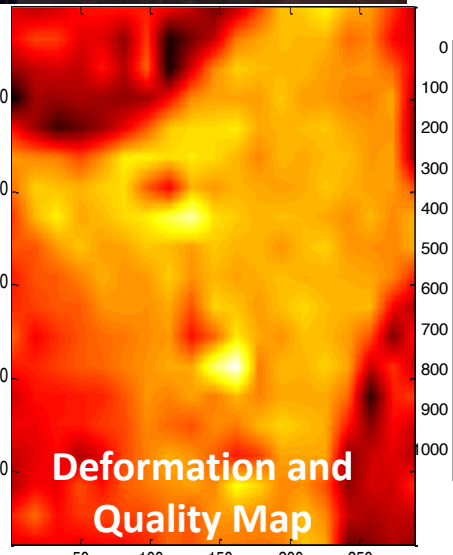
Continuous R2R Contact Tracking, Control, Alignment

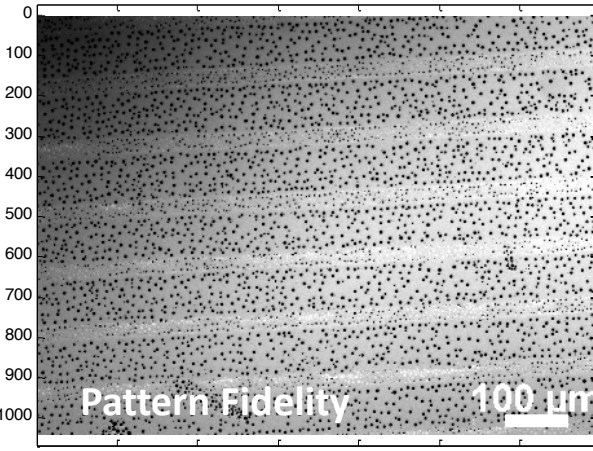




In-Process **Sensing** for Control

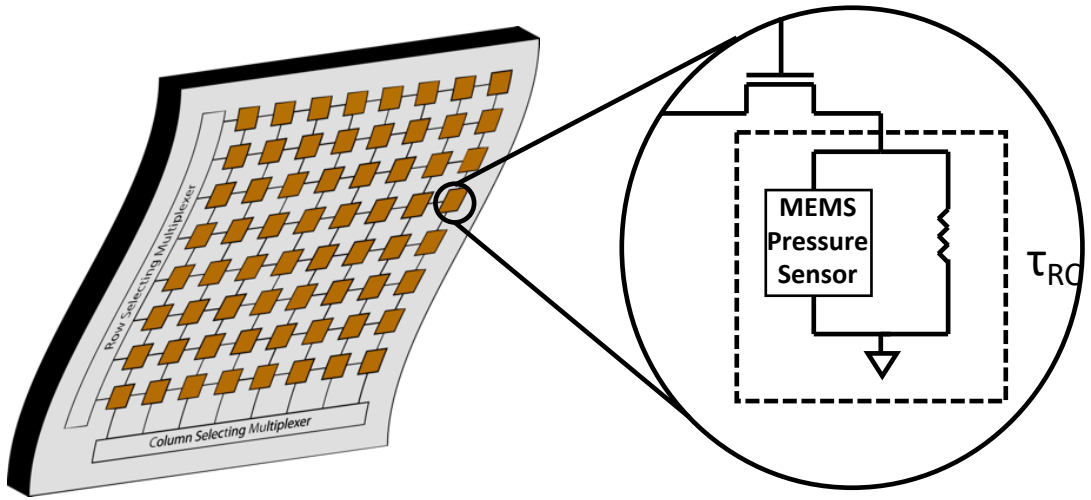




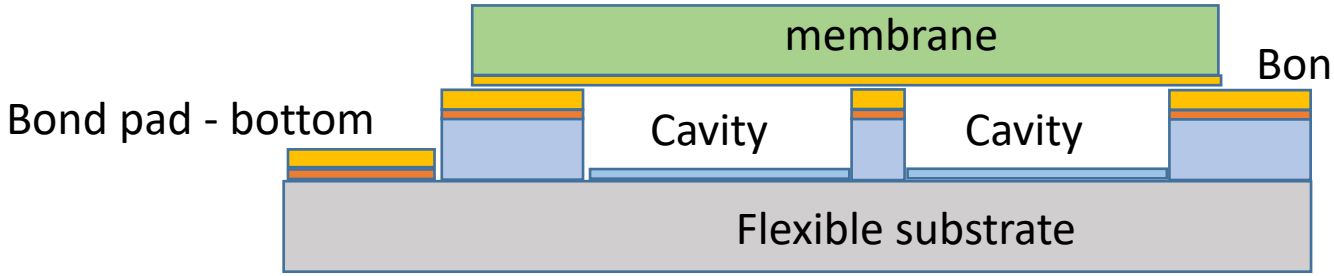


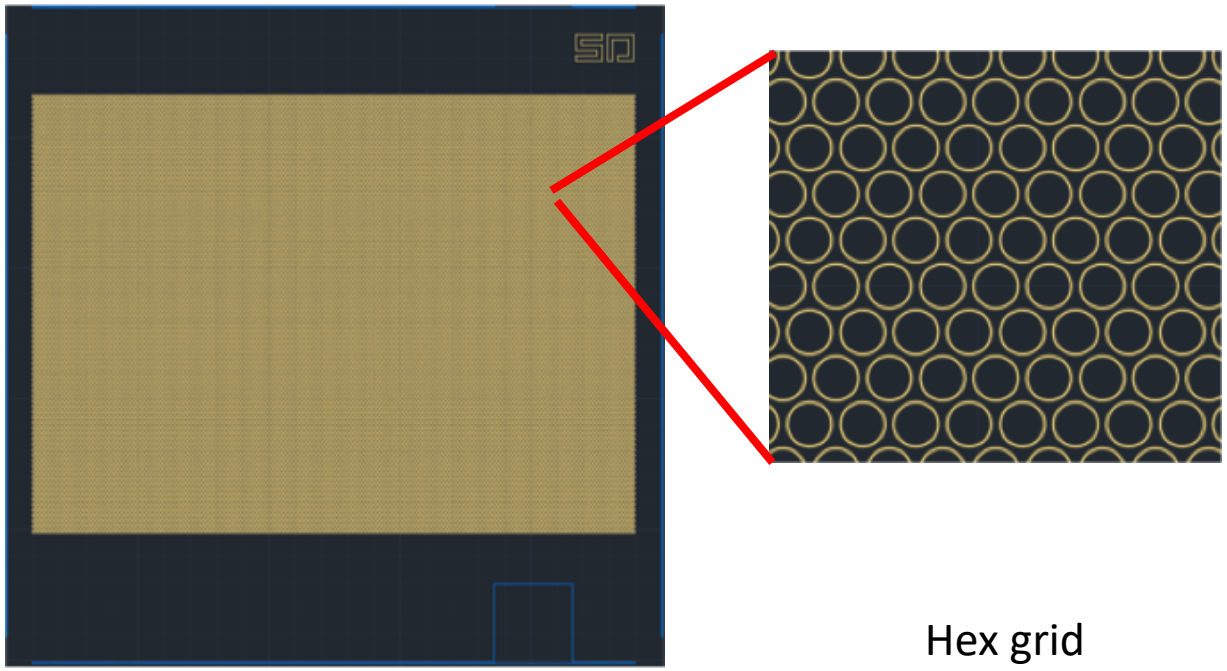
Device Design

- Individual capacitive cavities
- Array of flexible elements



Addressable Pressure Sensor/Actuator Array

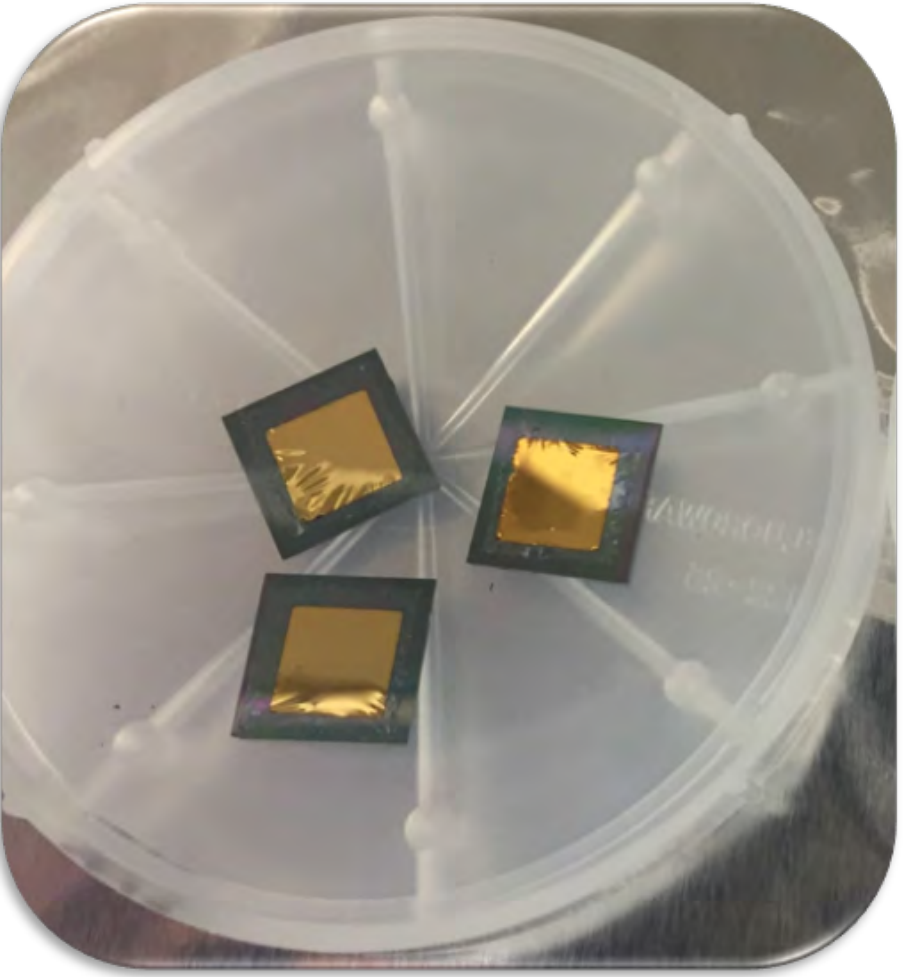


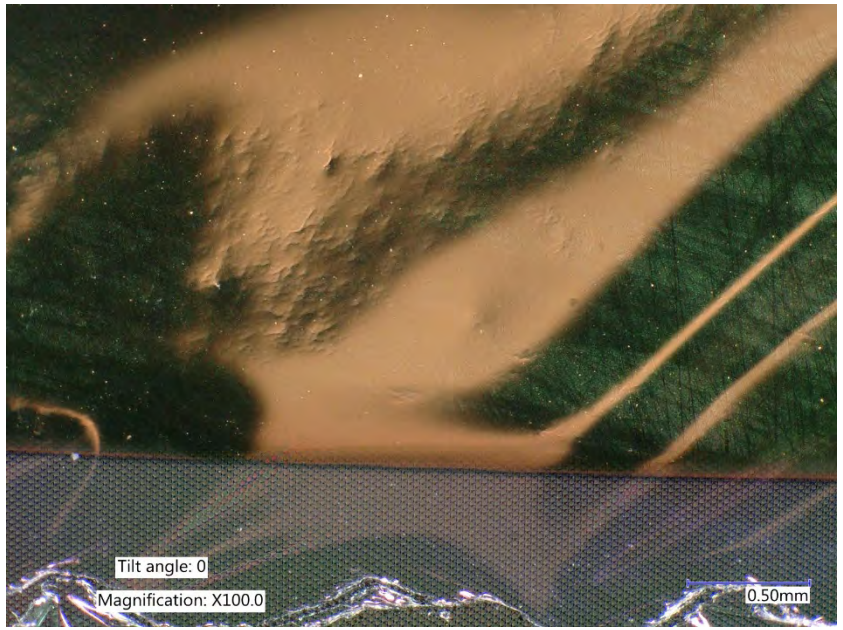


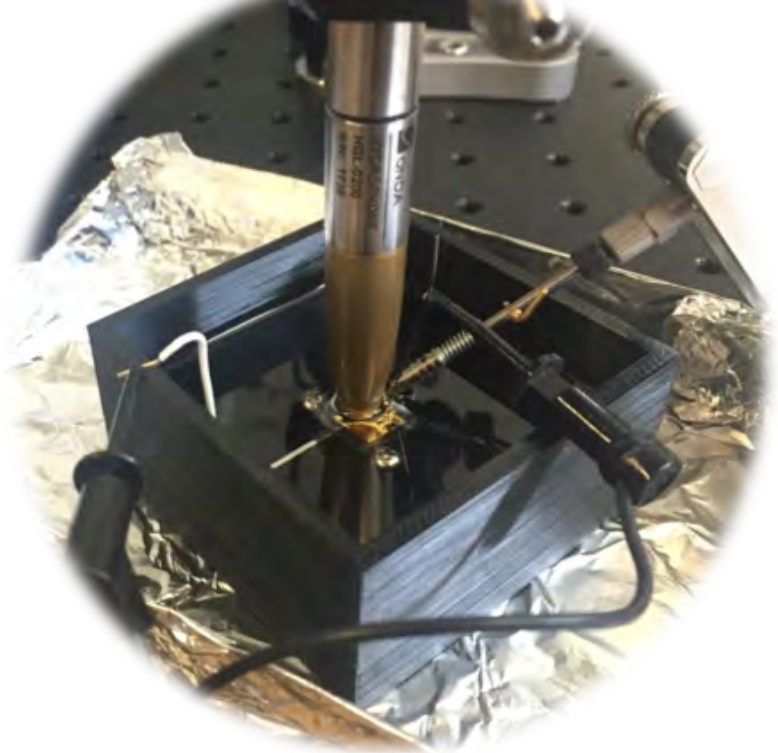
Hex grid

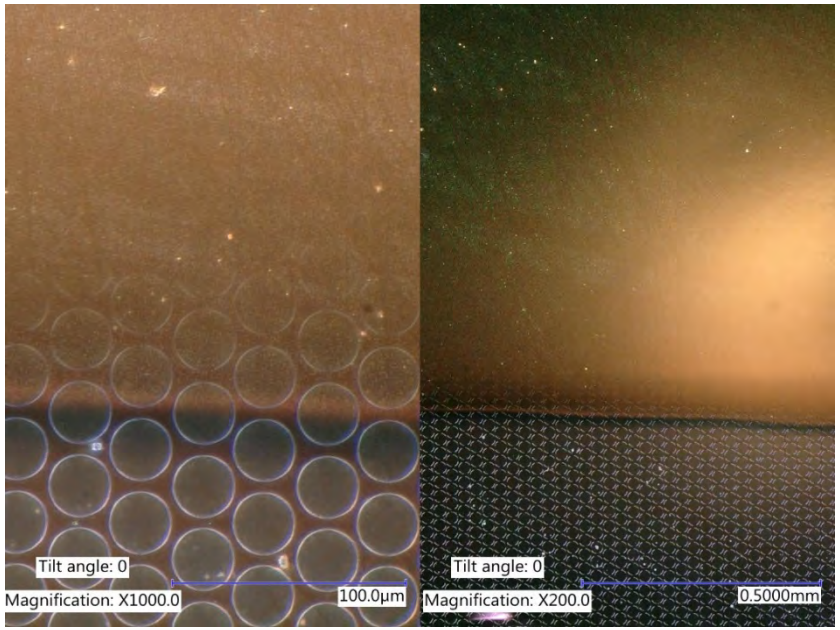
Megan Roberts
Apoorva Murarka
Vladimir Bulovic

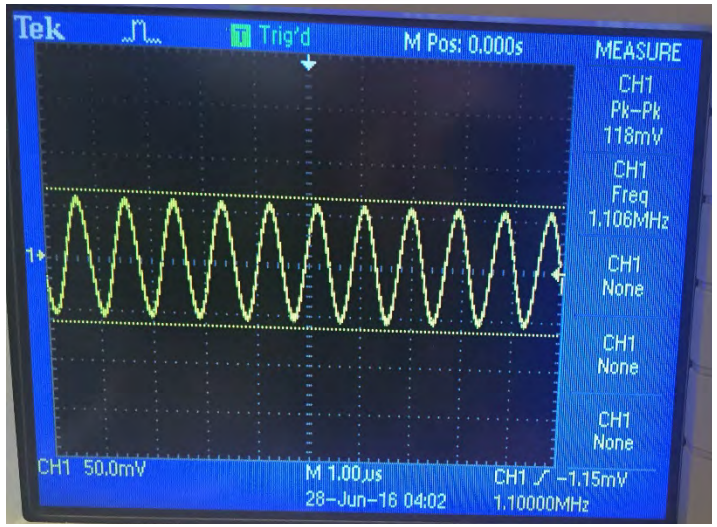
Device Prototype











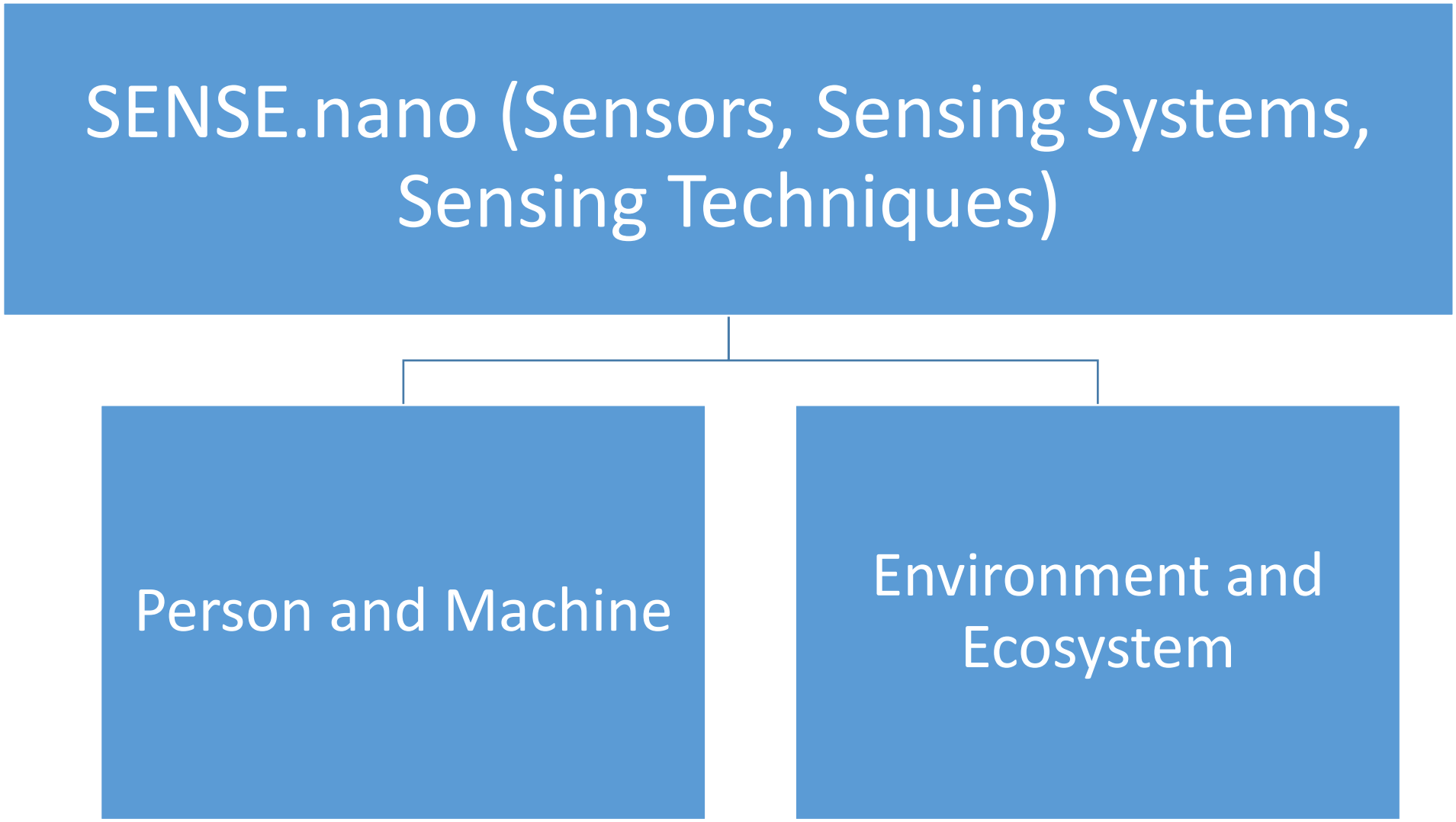
This 118mV signal corresponds .193 MPa signal observed by the hydrophone

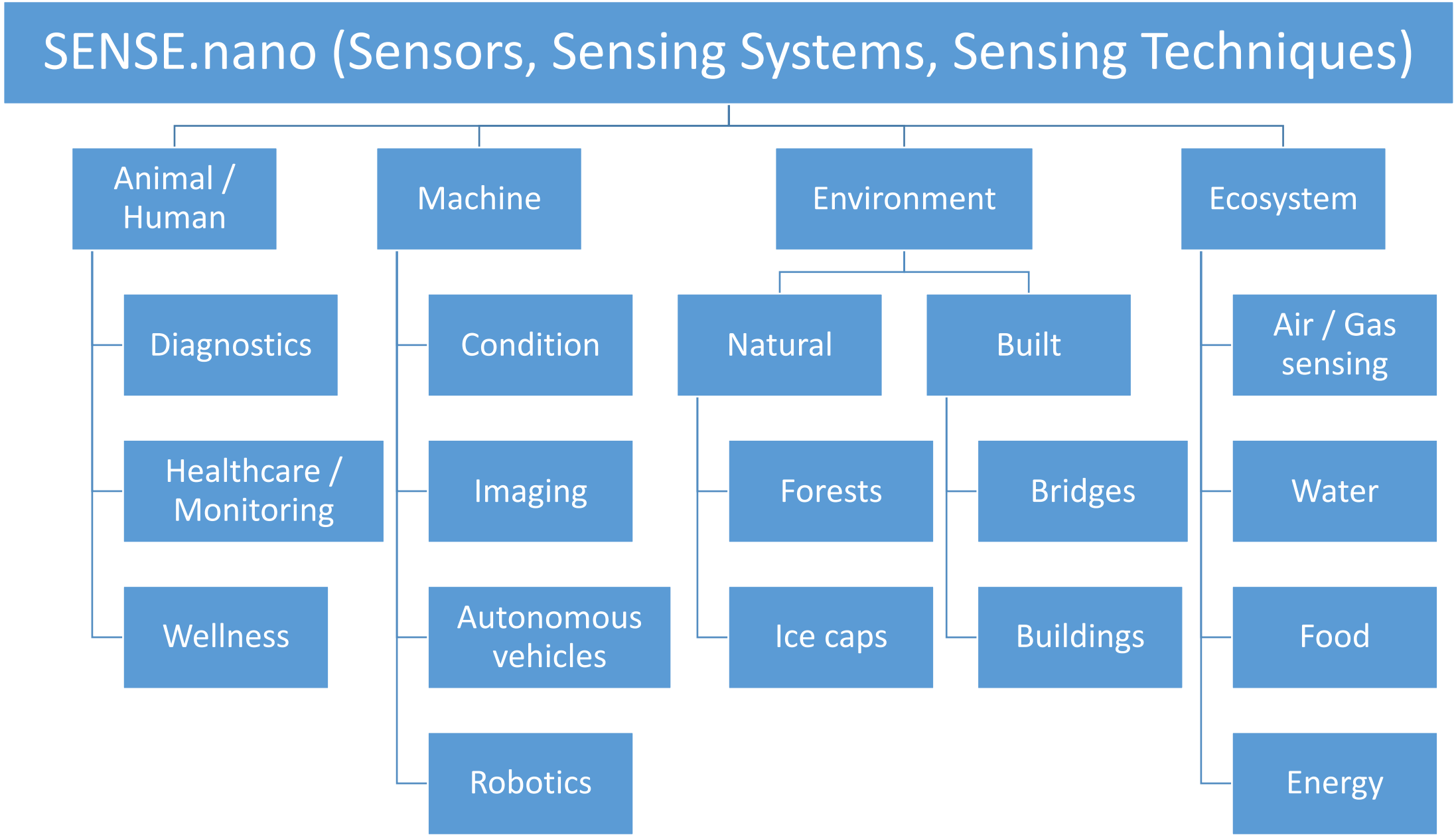
Megan Roberts
Apoorva Murarka
Vladimir Bulovic

A wearable ultrasound BP sensor patch?

A way to analyze the data?
Realizable, cost-appropriate, wearable design?
A manufacturing process?

http://www.3m.com/wps/wcm/connect/eb21717b-1908-4509-95df-01edcf2c2b8e/Wearable+Smart+Medical+Sensor+003+rgb.jpg?MOD=AJPERES&CACHEID=ROOTWORKSPACE-eb21717b-1908-4509-95df-01edcf2c2b8e-lglo1Ws


SENSE.nano (Sensors, Sensing Systems, Sensing Techniques)
Person and Machine
Environment and Ecosystem


SENSE.nano (Sensors, Sensing Systems, Sensing Techniques)
Animal / Human
Machine
Environment
Ecosystem
Diagnostics
Healthcare / Monitoring
Wellness
Condition
Imaging
Autonomous vehicles
Robotics
Natural
Built
Forests
Ice caps
Bridges
Buildings
Air / Gas sensing
Water
Food
Energy


MIT.nano
+ Advanced Manufacturing
+ IoT, Big Data, and the Cloud
+ SENSE related researchers
across entire campus
SENSE.nano
http://sense.mit.edu/

SENSE.nano seeking your input and help!

What are the Grand Challenges on which we should focus? On which we should lock arms and work together?

Thank you.

banthony@mit.edu
ket@mit.edu

Thanks to:
Aaron Zakrzewski
Athena Huang
Matthew Gilbertson
Xian Du
Megan Roberts
Apoorva Murarka
Vladimir Bulovic
Kamal Youcef-Toumi
Dave Hardt
Kai Thomenius