

# NSF Nanosystems Engineering Research Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)



*Veena Misra, Director, NSF ASSIST ERC Center*  
*Distinguished Professor, ECE, NC State University*  
**NAE Extraordinary Engineering Impact NSF**  
**August 18<sup>th</sup>-19<sup>th</sup>, 2022**



**NC STATE UNIVERSITY**





# Outline

- ▶ Vision
- ▶ Engineered systems, testbeds and enabling research
- ▶ Metrics and Impact
- ▶ Innovation Ecosystem
- ▶ Education Mission
- ▶ Diversity and Culture of inclusion
- ▶ ASSIST<sup>+</sup>



# Chronic Diseases and COVID-19

## CHRONIC DISEASES IN AMERICA

**6 IN 10**  
Adults in the US  
have a **chronic disease**

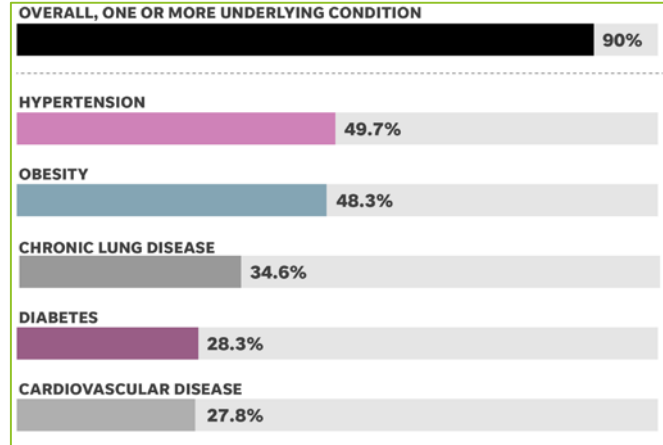


**4 IN 10**  
Adults in the US  
have **two or more**

**THE LEADING CAUSES OF DEATH AND DISABILITY**  
and Leading Drivers of the Nation's **\$3.5 Trillion** in Annual Health Care Costs



*CDC, NCCDPHP, 2020*



*Hospitalized Patients (usatoday.com)*



Mary Ann Liebert, Inc. publishers  
Celebrating 40 Years

ABOUT US PUBLICATIONS FOR

Population Health Management, Ahead of Print | Point of View Free Access

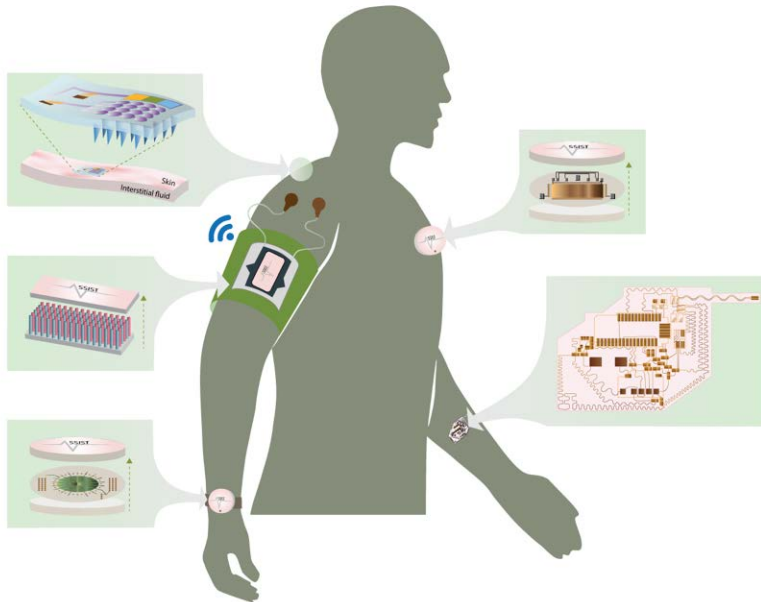
### Pandemic Makes Chronic Disease Prevention a Priority

Karen S. Kmetik, Alexis Skoufalos , and David B. Nash

Published Online: 12 Jun 2020 | <https://doi.org/10.1089/pop.2020.0126>

*Population Health Management, 2020*

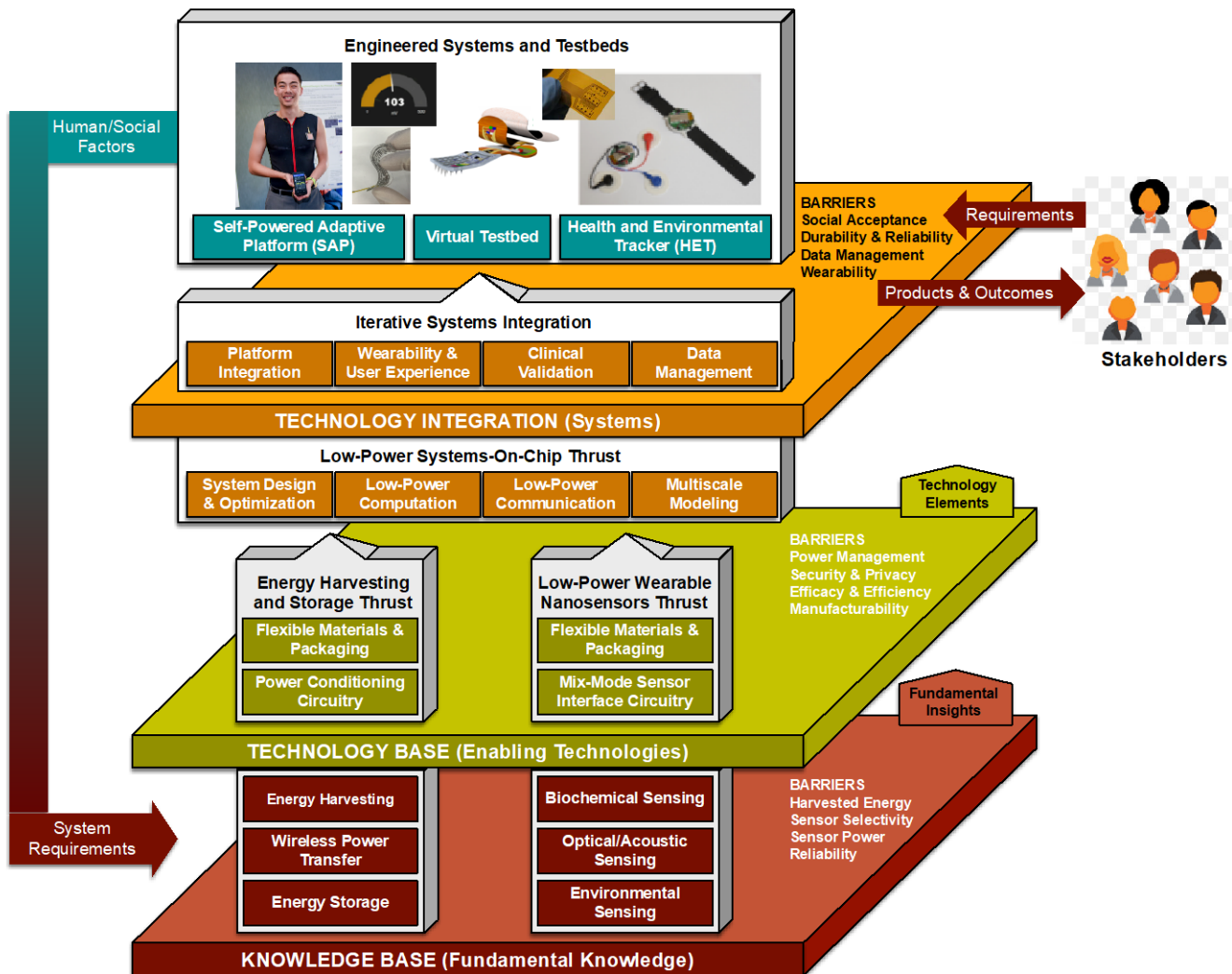
*ASSIST's vision is to create self-powered sensing, computing, and communication systems to enable data-driven insights for a smart and healthy world*



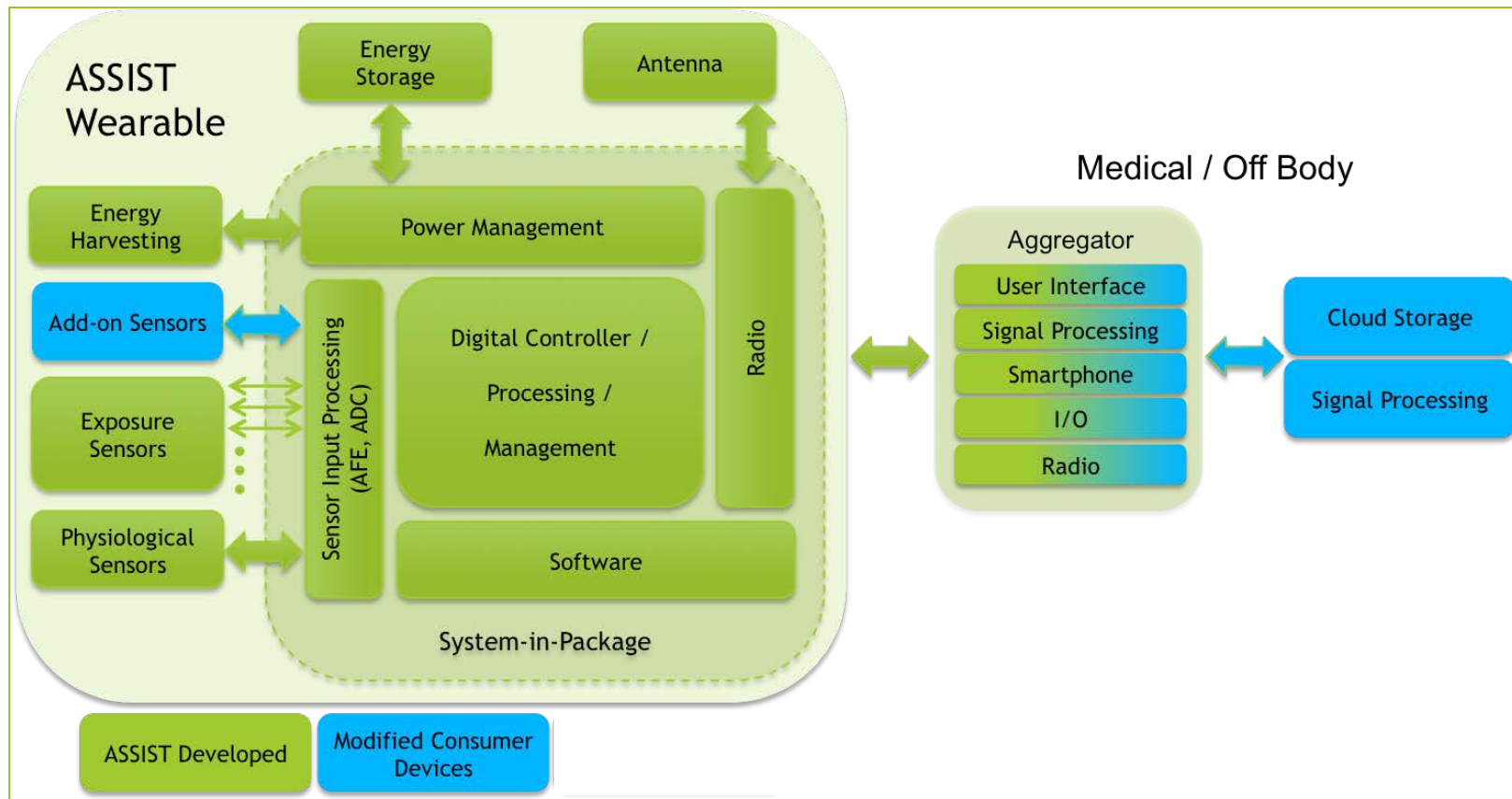
- *Self-powered*
- *Physiological, biochemical and environmental sensors*
- *Wearable, wireless and comfortable*
- *Informative and continuous data*

# *ASSIST enables continuous health monitoring for chronic disease management*

- ▶ **Continuous** operation via self-powered/low powered electronics
- ▶ **Multimodal sensing** of physiological, biochemical & environmental targets
- ▶ **New digital biomarkers** from correlating different sensor data streams
- ▶ **Explain/ Influence/ Predict** health outcomes
- ▶ Gain fundamental **insight** into disease origins



# ASSIST's Engineered System



# ASSIST's Targeted Health Use Cases



Michelle Hernandez,  
MD, UNC



Randall Moorman,  
MD, UVA



David Peden, MD  
UNC



Ayse Belger, PhD,  
Neuroscience and  
Psychiatry, UNC



Robert Kirsner,  
MD  
Univ. of Miami



Nirmish Shah, MD  
Duke



Delesha  
Carpenter, Ph.D.  
UNC Eschelman  
School of  
Pharmacy



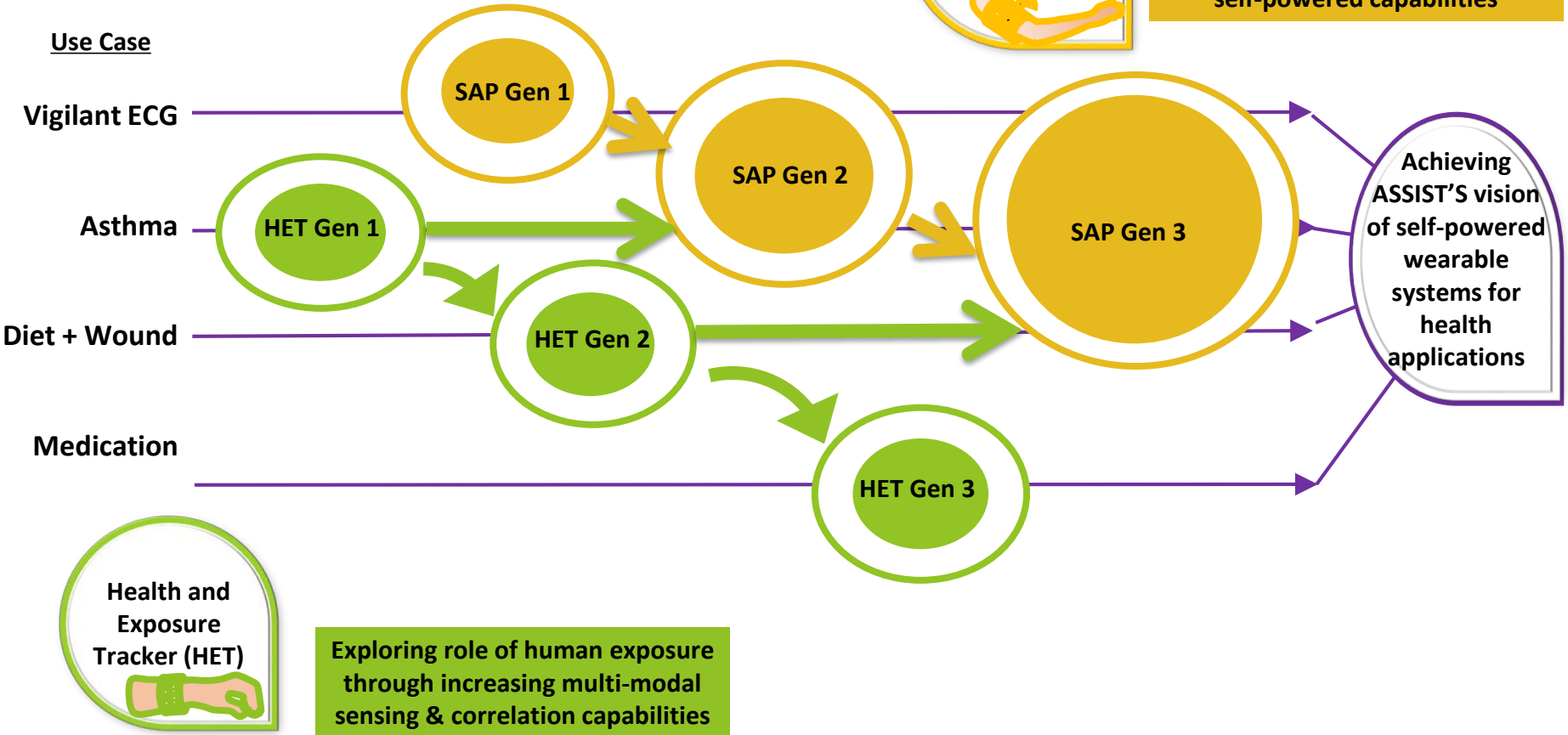
Jon Piccini, M.D.,  
Duke Cardiology



Dr. Sean  
Pokorney, M.D.,  
Duke Cardiology

1. **Asthma** (1 in 12 Americans)
2. **Atrial Fibrillation** (>600,000 deaths per year)
3. **Diet management** in pre-diabetics (36% adults w/BMI > 30kg/m<sup>2</sup>)
4. **Wound Healing** in Post-surgery/diabetic patients (~\$15B)
5. **Medication Detection** (> \$300B avoidable costs)

# ASSIST Roadmap Plan

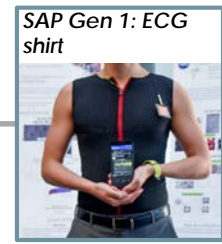




# ASSIST Roadmap Actual: 2012 to Today

## Use Case

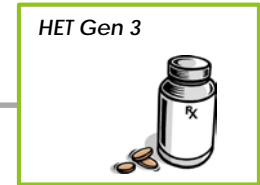
Vigilant ECG



Asthma



Diet & Wound



Medication

Achieving ASSIST's vision of self-powered wearable systems for healthcare

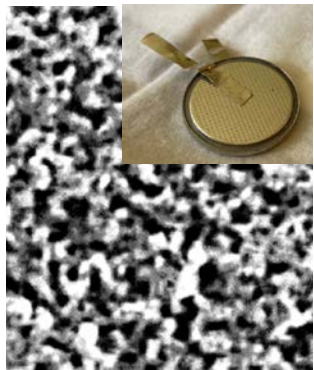




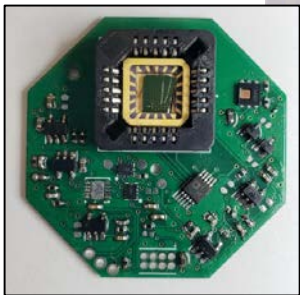
Use cases: Vigilant atrial-fibrillation, asthma monitoring, diet management, wound monitoring and medication compliance



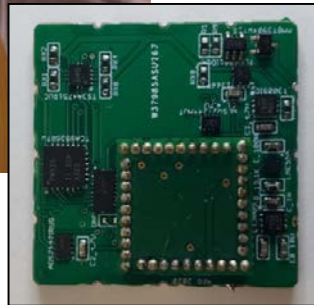
Flexible TEGs with integrated solar cell



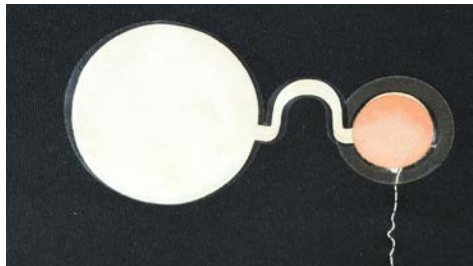
Supercapacitor with high capacitance retention



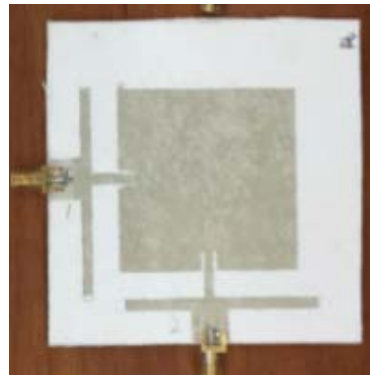
Custom AFE with Ozone & ECG



Compressed Sensing PPG



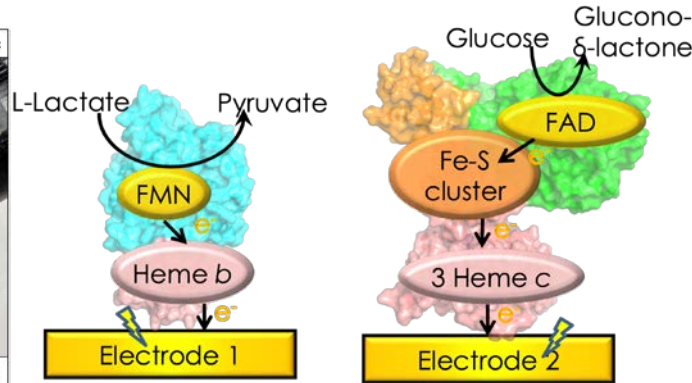
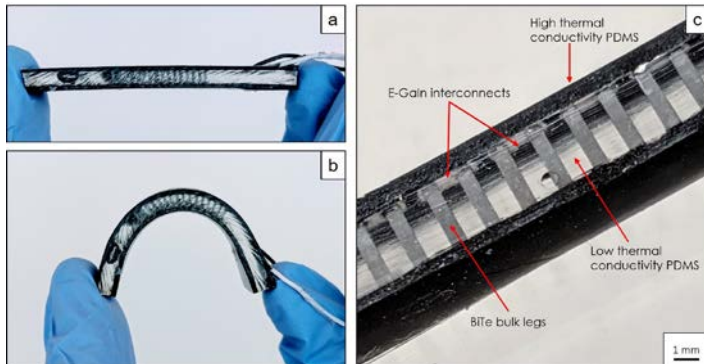
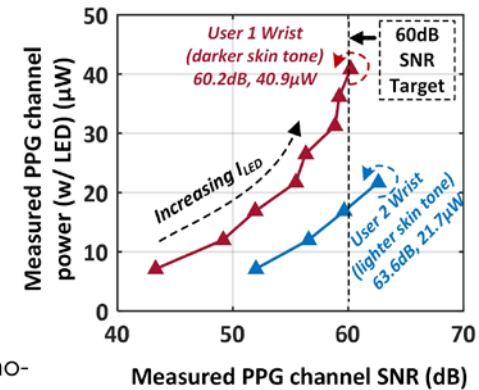
Washable ECG electrodes and cabling



Screen-Printed Full Duplex antenna

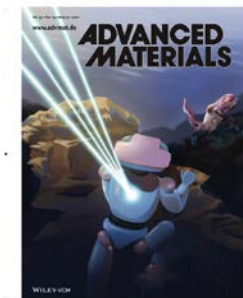
# ASSIST Convergent Research

- ASSIST thermoelectrics have highest reported efficiencies via liquid metals for stretchability
- ASSIST's low power electronics designed and refined for human body
- Sweat collection using osmotic pressure with material design
- New enzymes for energy harvesting from sweat for human body
- MEMS for ultrasound energy transfer to implanted sensors



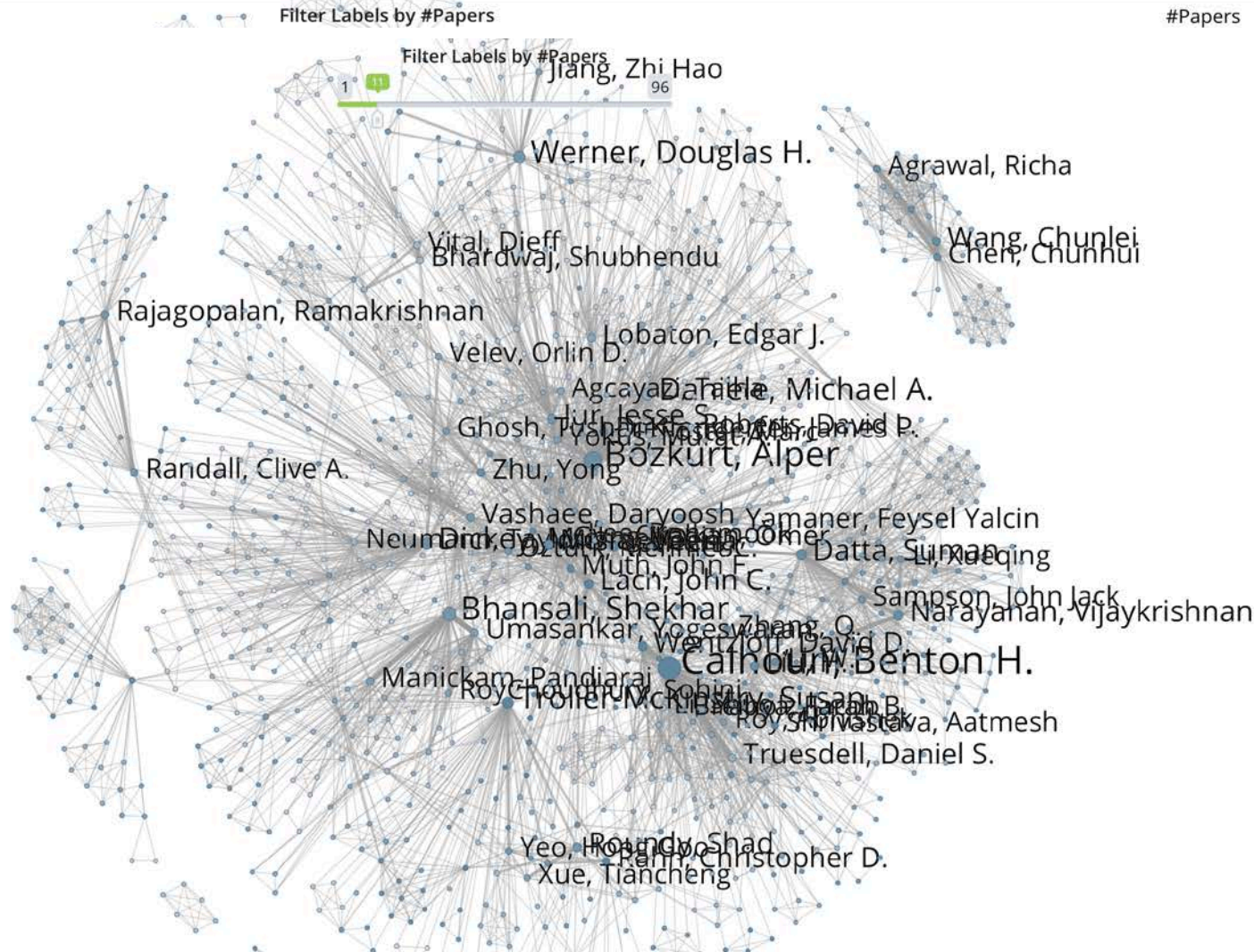
# Research Metrics and Recognition

- ▶ 91 PhD degrees awarded since inception
- ▶ Over 650 total publications
- ▶ Spun out 10 companies, 3 additional licenses
- ▶ 82 inventions and 32 full patents filed
- ▶ Numerous joint publications across partner schools
- ▶ Multiple Faculty and Student Awards



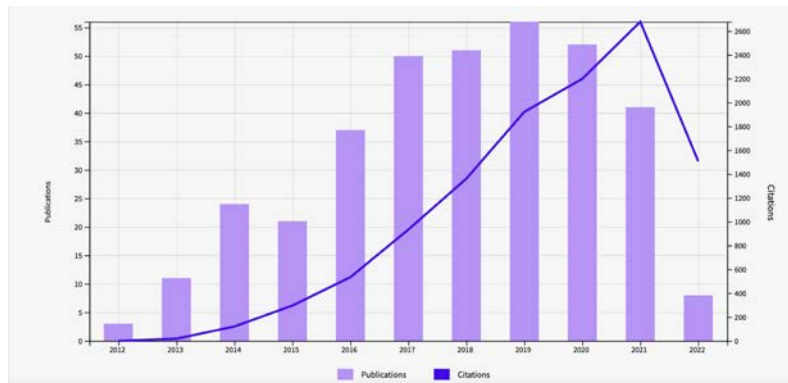


## Year 10



# Impact of ASSIST Publications

ASSIST H-index = 50



## Science News

from research organizations

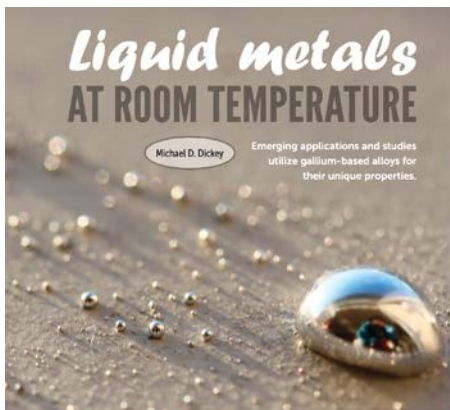
### Paper-based device provides low-power, long-term method for analyzing sweat

Date: June 9, 2020

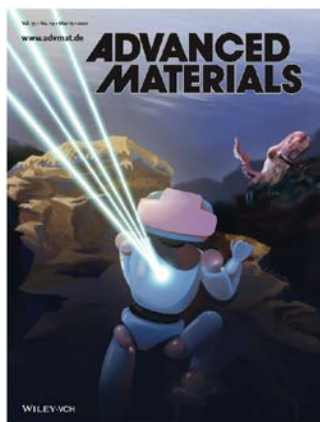
Source: American Institute of Physics

Summary: Researchers have constructed a paper-based device as a model of wearables that can collect, transport and analyze sweat in next-generation wearable technology. Using a process known as capillary action, akin to water transport in plants, the device uses evaporation to wick fluid that mimics the features of human sweat to a sensor for up to 10 days or longer.

Share: [f](#) [t](#) [p](#) [in](#) [e](#)



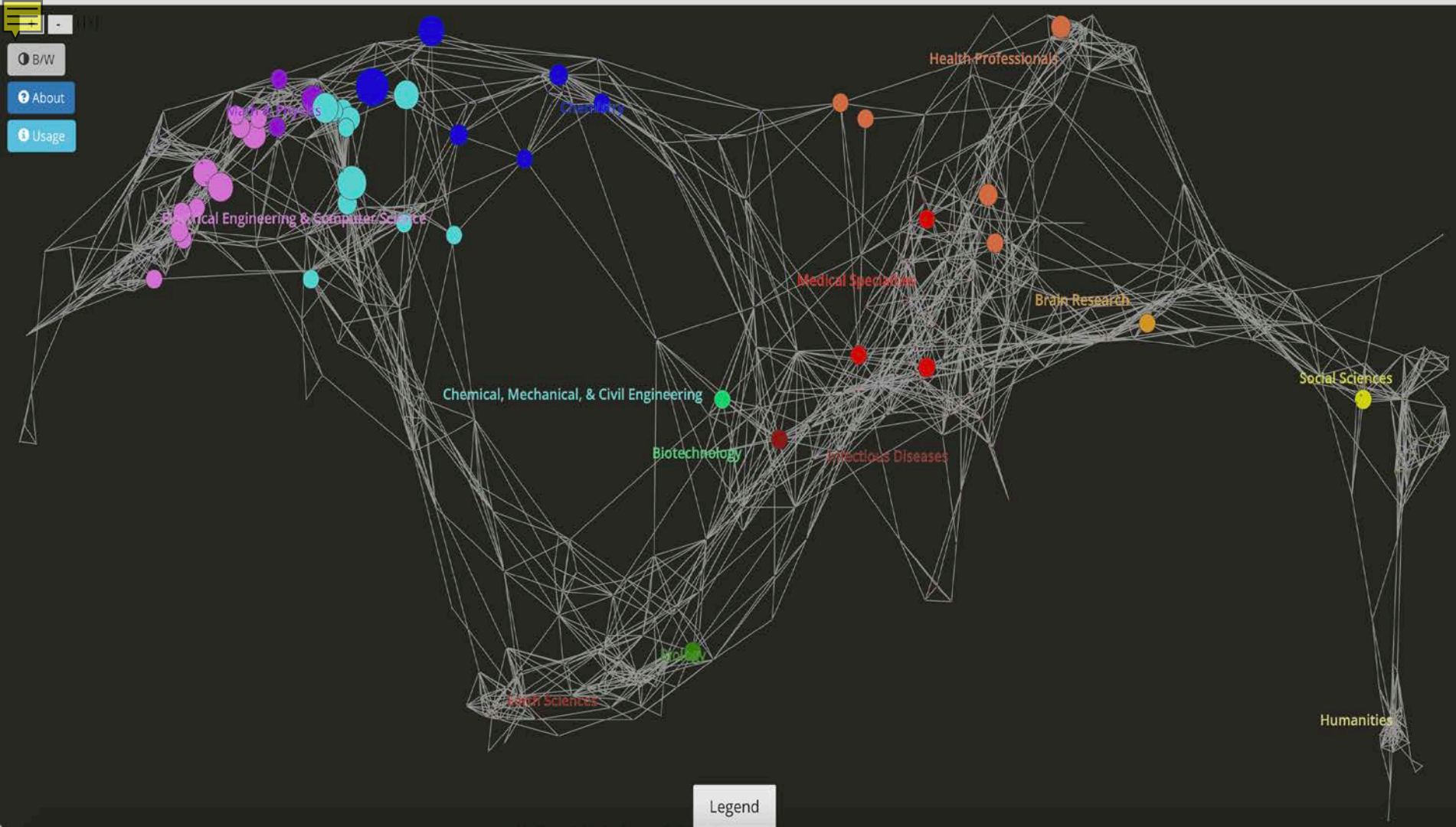
Physics  
Today,  
2021







- B/W
- About
- Usage



# Innovation in Education

## Wearable Device Challenge K-12 Engineering Competition



- 15 middle/high school teams at NCSU, 14 expected at PSU
- > 1,750 students
- > 80 Teachers

## Nanoscience Minor and Capstone Projects



- 5 Capstone Teams in Yr 7, 30 total
- Multidisciplinary minor enrollment
- 33% win awards!

## Translational Engineering Skills Program



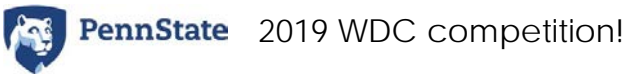
- Systems Thinking
- Entrepreneurship/Innovation
- Industry/Manufacturing
- Mentoring/Leadership
- Communication
- Ethics/Diversity Awareness



- ▶ Engineering Design Competition for Middle and High School

Year	# Teams	# students
2015	2	8
2016	17	60
2017	23	100
2018	24	117
2019	27	140
2020	15 NCSU teams registered pre-COVID*	
2021	~15 NCSU Teams	

Evaluation of virtual young scholar program with a focus on hands-on engineering design projects in an online setting, 2021 ASEE



Teacher Comment: "This was the most educational trip I've ever been on." ...They are already thinking about next year and trying to find problems to solve with a wearable device

NC STATE UNIVERSITY

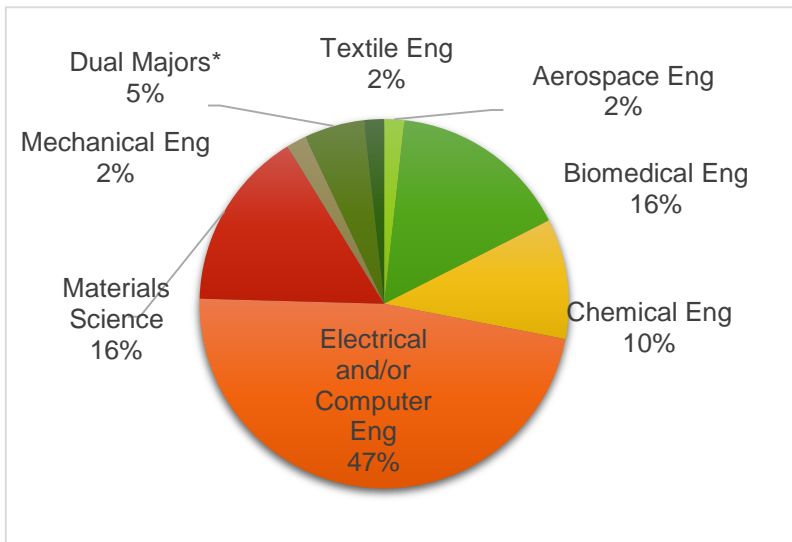
2020 Virtual WDC competition!



- **First Place: Team Salus** - A life-jacket-worn detector for continuous CO monitoring during recreational boating.
- **Second Place: Mosquito Stoppers** - Solar-powered, sound-based, mosquito repellant device

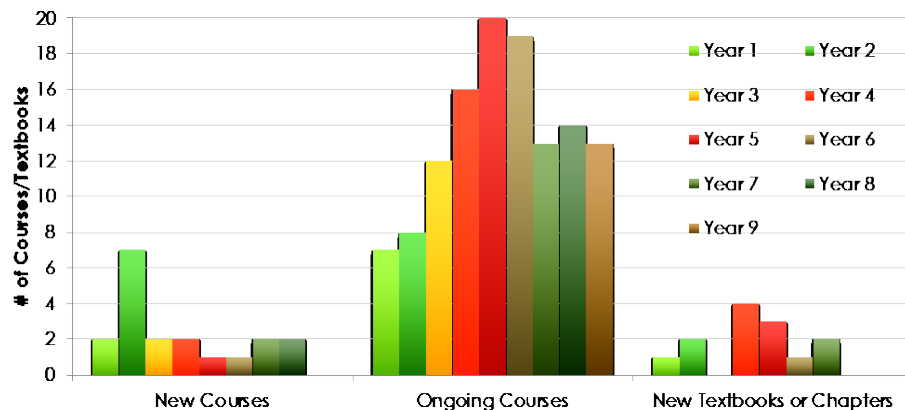


# Undergraduate Curriculum

ASSIST senior design



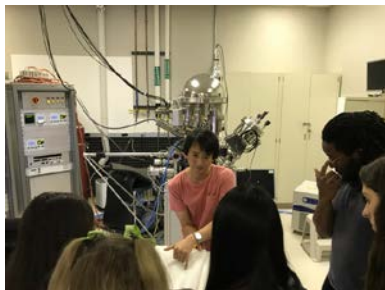
<b>NC STATE UNIVERSITY</b>  	<b>A.G.I.L.E.</b> Assisting Geriatrics in Independent Living through Engineering	
	<b>Team Members:</b> Sloane Cox, Chase Browning, Bryana Polk, Alex Masone, Yuran Li	
	<b>Mentors:</b> Dr. Elena Veety, Dr. Adam Curry	<b>Sponsors:</b> Murata, ASSIST Center



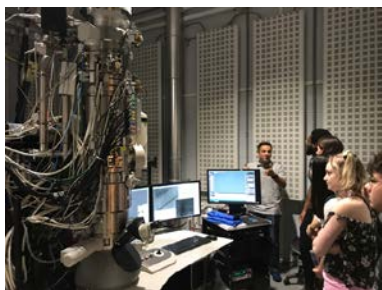
Undergraduate Minor in Nanoscience and Technology

# Undergraduate Research : Joint ASSIST and FREEDM

- ▶ **REU SITE:** *From The Body To The Grid: Joint ERC REU Explores Energy From Nano-scale Harvesting To Smart Grid Technology*
- ▶ ~50% community college or non-STEM institutions



Tours of Nanofabrication Facility and AIF



Wilson College of Textiles



FREEDM High Power Lab and Roof Solar Array



Lunch and Learn on Diversity & Inclusion



Communication Workshops



Research Updates



Joint Poster Symposium

# Translational Engineering Skills Program (TESP)

## Systems Thinking Workshop



Dr. Matt Johnson, and Dr. Kathleen Hill  
PSU Center for Science and the Schools



**CSATS** Center for Science and the Schools

## ASSIST SLC Online Independent Learning Fellowship

- Student-led initiative providing fellowships to pursue an online certification offered by an online coursework platform (e.g. Coursera).

**NC STATE UNIVERSITY**

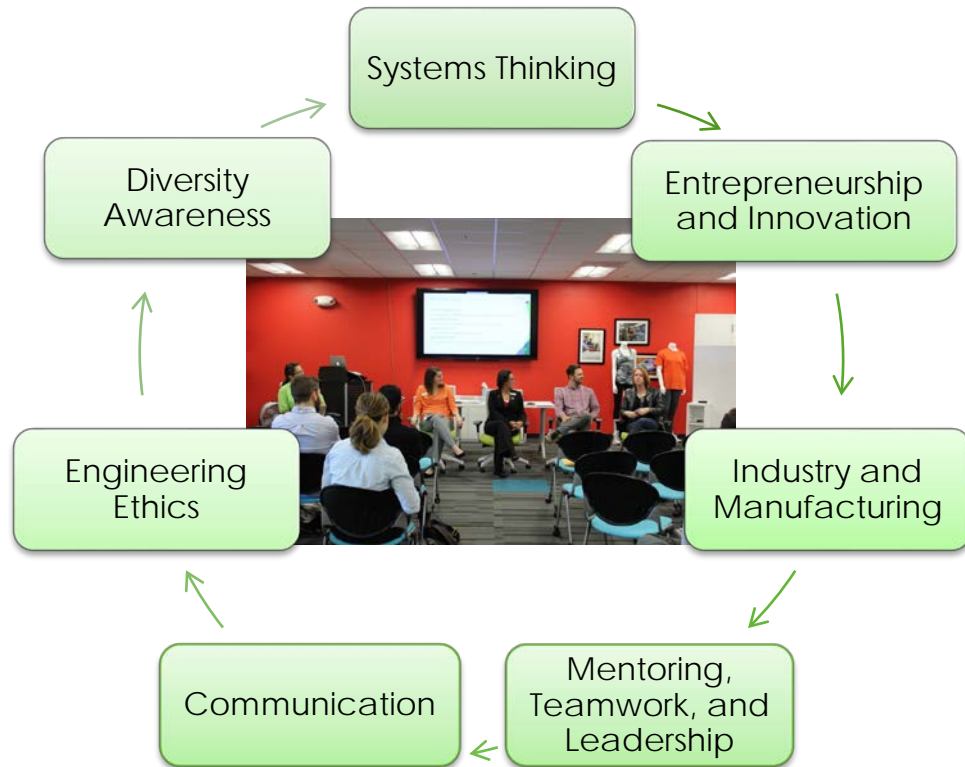
The Graduate School



**Katie Hornor**  
Director of Academic and Engineering Writing Support

Partnership to provide **Virtual Technical Writing Workshop** series for graduate students and postdocs across partner institutions:

- May 14, 2020 : How to write compelling abstracts and intros
- July 16, 2020: Literature Review Toolkit





Veety, E. N. et al. (2014), *Translational Engineering Skills Program (TESP): Training innovative, adaptive, and competitive graduate students for the 21st Century Work Force*. ASEE Annual Conference & Exposition.




# Student Impact and Achievement






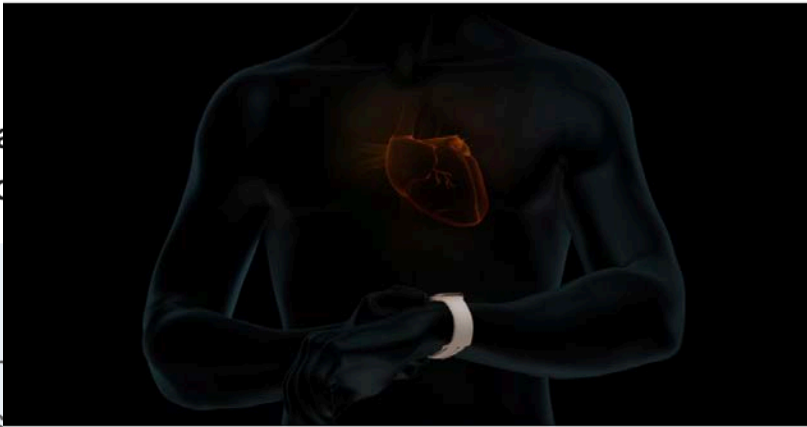


**Saba Emrani, PhD** • 1st  
Senior Machine Learning Engineer at Apple  
2yr • Edited • 

<https://lnkd.in/gx795t9>



Big day: it feels amazing when your work is out in the world to be used by millions of people and detect their irregular heart rhythms! [#ECG](#)  
[#AfibDetection](#)



ECG app and irregular heart rhythm notification available today on Apple Watch

[+ Follow](#)

Proud  
Journal  
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Healthcare OPE  
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Journal A new class of...

# ASSIST Industry Members

Full



Associate



Affiliate



# Industry Partnerships

- ▶ Successful track record of startups and licensing



ONDA VISION TECHNOLOGIES, LLC.  
Seeing Beyond The Surface



- ▶ Industry enabling new ASSIST funding



- ▶ Exploring new models of industry engagement

- ▶ Industry webinars
- ▶ Joint technology development
- ▶ Joint Publications



# VitalFlo is like having a *Pulmonologist in your Pocket*

We help Primary Care Providers measure and understand their patients' lung health in every setting

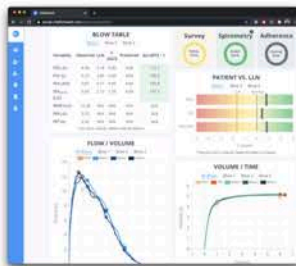
## Hybrid Platform for both In-Person & Virtual Care



3<sup>rd</sup> Party  
Spirometers  
& Data Partners



VitalFlo Mobile  
Apps



VitalFlo  
Clinical Decision  
Support & Reporting

## Intuitive for General Practitioners

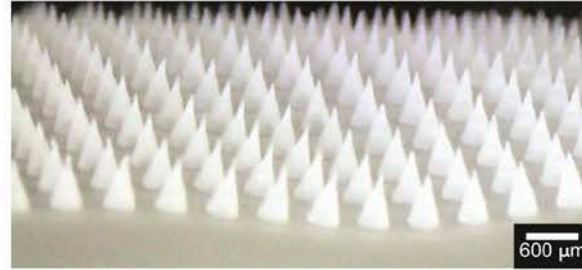
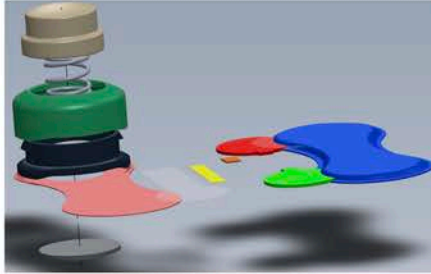
- Simple and quick to use – both in the clinic and at home
- Portable, flexible system frees up nurse time and exam rooms
- Built-in coaching for high quality data

## Powerful Insights for Specialists

- Advanced trends, patient status alerts and analytics
- Predictive forecasting POC demonstrated in clinical study



# Increase remote diagnosis with easier systems



**Painless**  
**Zero Power**  
**Easy**  
**Low Cost**  
**Scalable**  
**Safe**

**Not deep enough for nerves**  
**Swells and wicks ISF**  
**Spring-loaded applicator applies set pressure**  
**Common materials**  
**Standard manufacturing techniques**  
**Biocomp. certified (no toxicity, reactivity, or sensitivity)**

## Problem Addressed

- Early recognition of severe dehydration in athletes.

### Current Field-based Methods

- Body Mass Changes
- Urine Test
- Urine Color Charts
- Visual Observation

### Commercial Opportunity

Onda Vision Technologies  
addresses the *unmet need of real-time,  
non-invasive, field-based hydration monitoring.*

### Corresponding Limitations

- Labor and *time* intensive
- Invasive* requires fluid samples
- Static* measurements
- Subjective* assessment



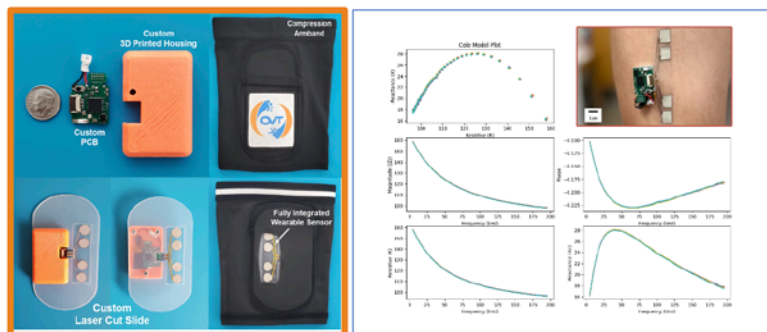
## Commercialization Opportunity



- Transition:** Mature ASSIST wearable technology into viable commercial products
- Innovation:** Wearable sensor performs Bioimpedance Spectroscopy (5 – 200 kHz)
- Features:** Non-invasive, continuous, low-cost hydration monitoring
- Target Market:** Collegiate and High school athletes exposed to hot and humid conditions (e.g., football, soccer, track).

## Wearable Hydration Sensor (Prototype)

- Cellular** level measure of hydration: **complex** bioimpedance response of biological tissue.



## Program Status:

- NSF SBIR Phase I: Feasibility
  - NC State Academic Partner
  - Developed prototype wearable hydration sensor
  - 27 April 2020 - 30 November 2021**
- NSF SBIR Phase II: Commercialization
  - Currently under review**
  - Extend research towards commercialization
  - Perform field studies (MVP Testing)

# Diversity and ASSIST's Culture of Inclusion

## Effective Mentoring: A Catalyst to Improved Climate for Research Productivity

### Second Session in 2021 Series

Date: June 2, 2021

Time: 11:30 AM to 2:30 PM

RSVP by May 24<sup>th</sup>, 2021 to attend [here!](#)

#### Facilitators:

1. Olgha Qaqish, PhD  
Engineering Postdoc. & Lecturer
2. Ashleigh Wright, PhD  
Program Coordinator for NSF SEAS Research
3. Joel Ducoste, PhD  
Engineering Professor & Interim Associate Dean



## Women's Keynote Presentation featuring Susan Trolier-McKinstry

Wednesday, December 2

11:30 am - 1:00 pm

► Research opportunities:  
transgender women with HIV  
@UNC

PPG human subject studies  
SBIR on hydration monitoring  
with Onda Vision



ONDA VISION TECHNOLOGIES, LLC.  
Seeing Beyond The Surface



ASSIST's distinguished  
speaker series

Stéphanie P. Lacour,

May 20, 2021 | 10am -11am EDT

Soft bioelectronics for wearable  
and implantable interfaces



*Trolier-McKinstry Keynote:  
Crafting a Scientific Career  
from Successes and  
Failures*



*Misra, chair of ECE  
search committee*



**William Reynolds** ·  
Founder at Onda Vision

# *All ERC Engineering Workforce Development, Diversity and Culture of Inclusion, Evaluation, and Student Leadership Workshop*

- ▶ Held in November 2020 → 120 attendees from across all active ERCs
- ▶ Supplemental funding from NSF, and collaboration with multi-ERC organizing committee
- ▶ Featured Sessions:
  - ▶ keynote address from Dr. Calvin Mackie
  - ▶ poster and conference sessions
  - ▶ NSF-led discussion Panel
  - ▶ professional development workshops
  - ▶ self-sufficiency session

**If you do not  
intentionally,  
deliberately and  
proactively  
include, you  
unintentionally  
exclude.**



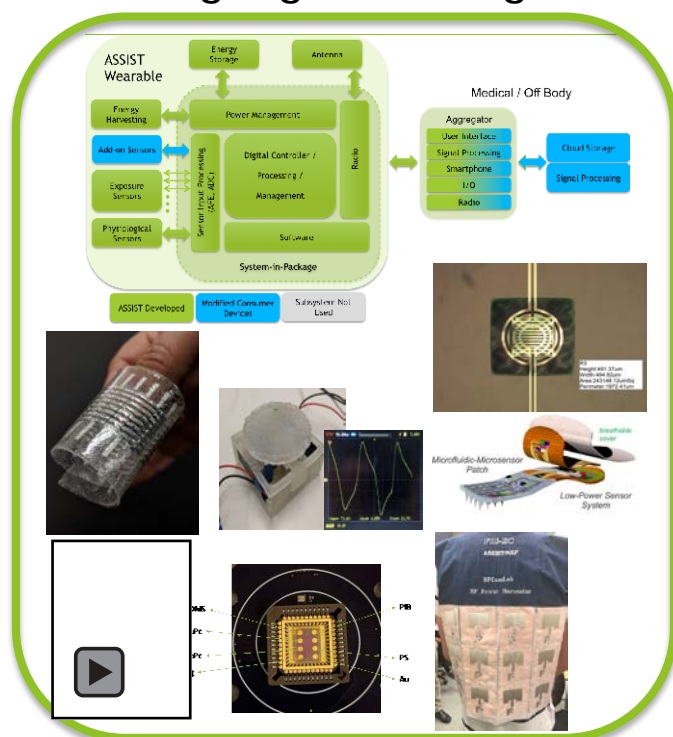
# ***ASSIST<sup>+</sup> Vision***



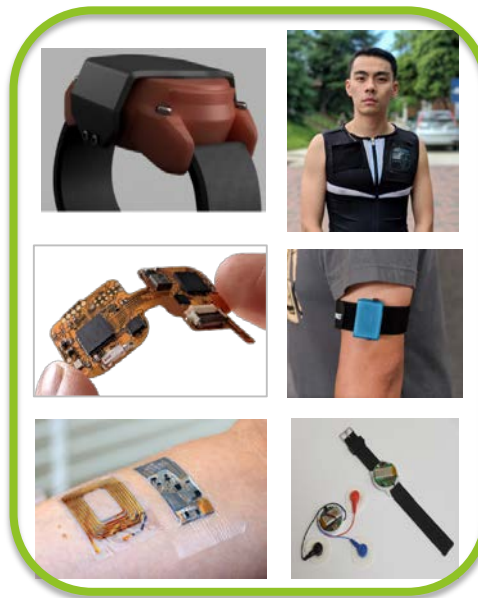
# ASSIST<sup>+</sup> vision is to enable health monitoring that does not miss a beat

- ASSIST<sup>+</sup> will accomplish this through cutting edge wearables and implantable devices
- ASSIST<sup>+</sup> will focus on cutting edge technologies in powering, sensing, analysis and packaging
- ASSIST<sup>+</sup> will enhance capacity to rapidly prototype systems/subsystems and drive partnerships

## Cutting Edge Technologies



## Wearable and Implantable Systems

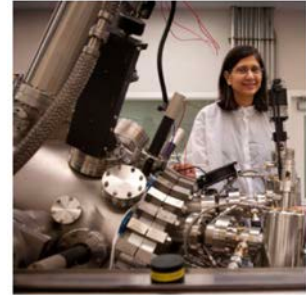


## Health Applications



# Expanding use cases : NIH, DoD, USDA

- ▶ NIH
  - ▶ Alzheimer's Disease and Related Dementias, asthma,
- ▶ DoD
  - ▶ Warfighter health and performance
- ▶ USDA
  - ▶ Sensors for early detection of diseases in plants



Misra Named to DARPA  
Microsystems  
Exploratory Council →



# ***ASSIST ERC Platforms are enabling***

- ▶ Leading edge systems that are use case driven
- ▶ Cross-disciplinary team science driven by Testbeds
- ▶ Collaboration with clinicians on human subject studies
- ▶ A pipeline of next generation of global leaders
- ▶ Diversity in all Center activities
- ▶ Startups and licenses and jobs
- ▶ Self-sufficiency plan that expands use cases



# Acknowledgements

- ▶ NSF EEC-1160483
- ▶ NC State Leadership
- ▶ ASSIST Industry members
- ▶ ASSIST PIs, staff and students

- Mehmet Ozturk
- Michael Dickey
- Ben Calhoun
- Jess Jur
- John Lach
- Doug Werner
- Dave Wentzloff
- Susan Trolie-McKinstry
- Shad Roundy
- Mehdi Kiani

- Alper Bozkurt
- Omer Oralkan
- Bongmook Lee
- Veena Misra
- James Dieffenderfer
- Edgar Lobaton
- Michelle Hernandez, MD
- Michael Lim

- Michael Daniele
- Orlin Velez
- Michael Dickey
- Shekhar Bhansali
- Shubhendu Bhardwaj

***THANK YOU***