Convergent Research Case Study: NSF Nanosystems Engineering Research Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)

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Distinguished Professor, ECE, NC State University

ERC Planning Workshop, September 21st, 2021

NC STATE UNIVERSITY

FIU FLORIDA INTERNATIONAL UNIVERSITY

PennState

UNIVERSITY of VIRGINIA SCHOOL OF ENGINEERING

UNC SCHOOL OF MEDICINE

UNIVERSITY OF MICHIGAN

THE UNIVERSITY OF UTAH

Outline

- Vision and Mission
- Engineered systems, testbeds and enabling research
- Innovation Ecosystem
- Education Mission
- Diversity and Culture of inclusion
- Metrics and Impact
- Wish we knew these in Year 1!

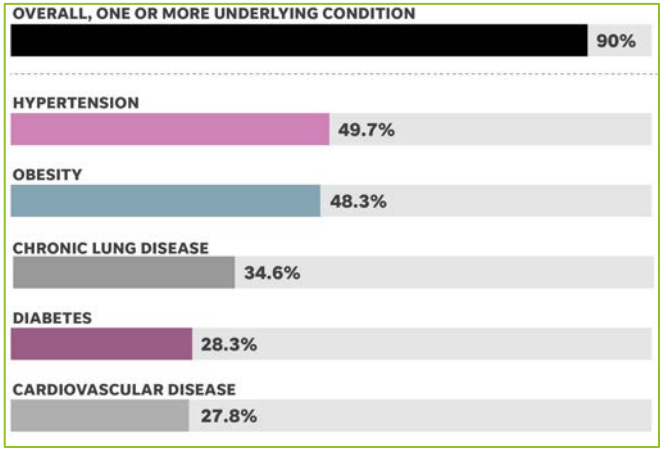
ASSIST's vision evolved through numerous iterations and discussions with clinical, industry and community stakeholders

We knew we were on the right track when in 1 sentence we got people excited about our vision

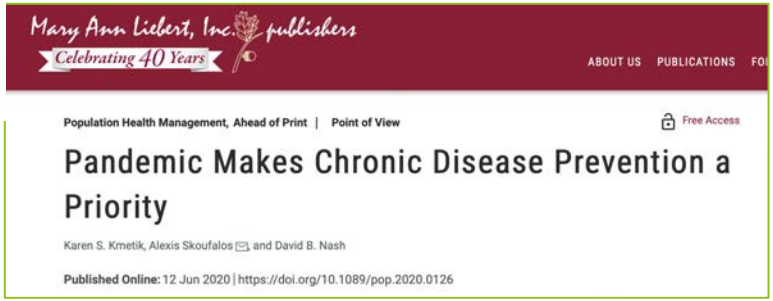
The most important criteria: people should readily recognize that your vision solves a big societal problem

Chronic Diseases and COVID-19

CDC, NCCDPHP, 2020

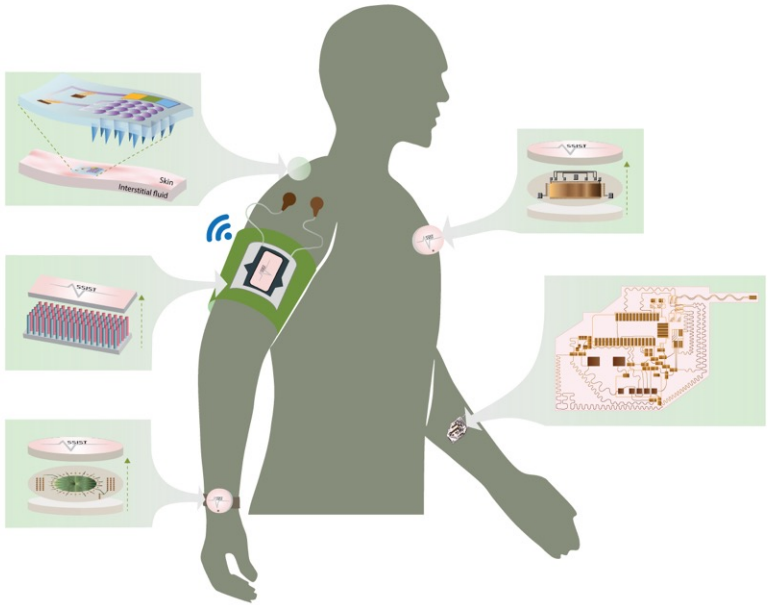


Hospitalized Patients (usatoday.com)



Population Health Management, 2020

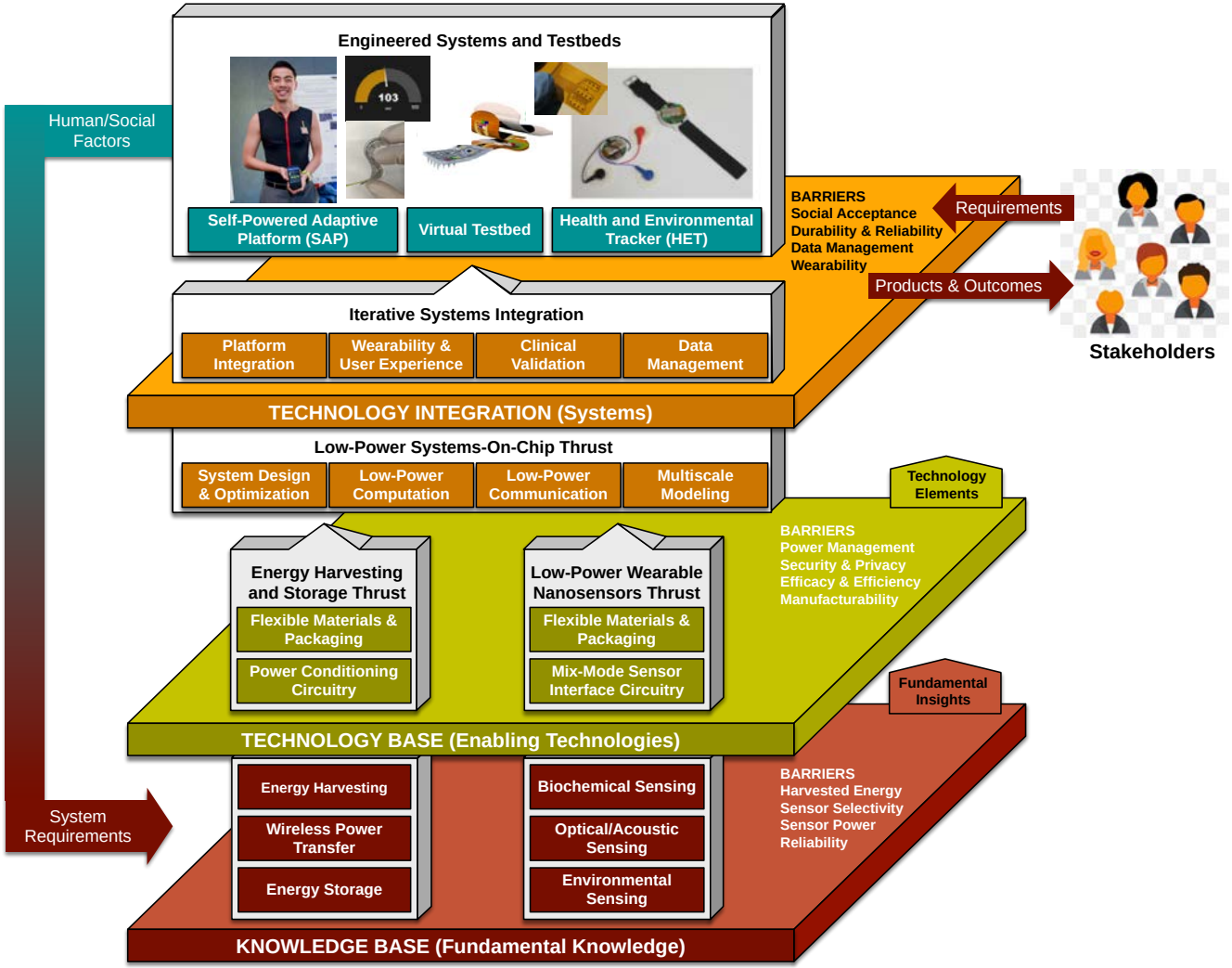
ASSIST's vision is to create self-powered sensing, computing, and communication systems to enable data-driven insights for a smart and healthy world



- *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

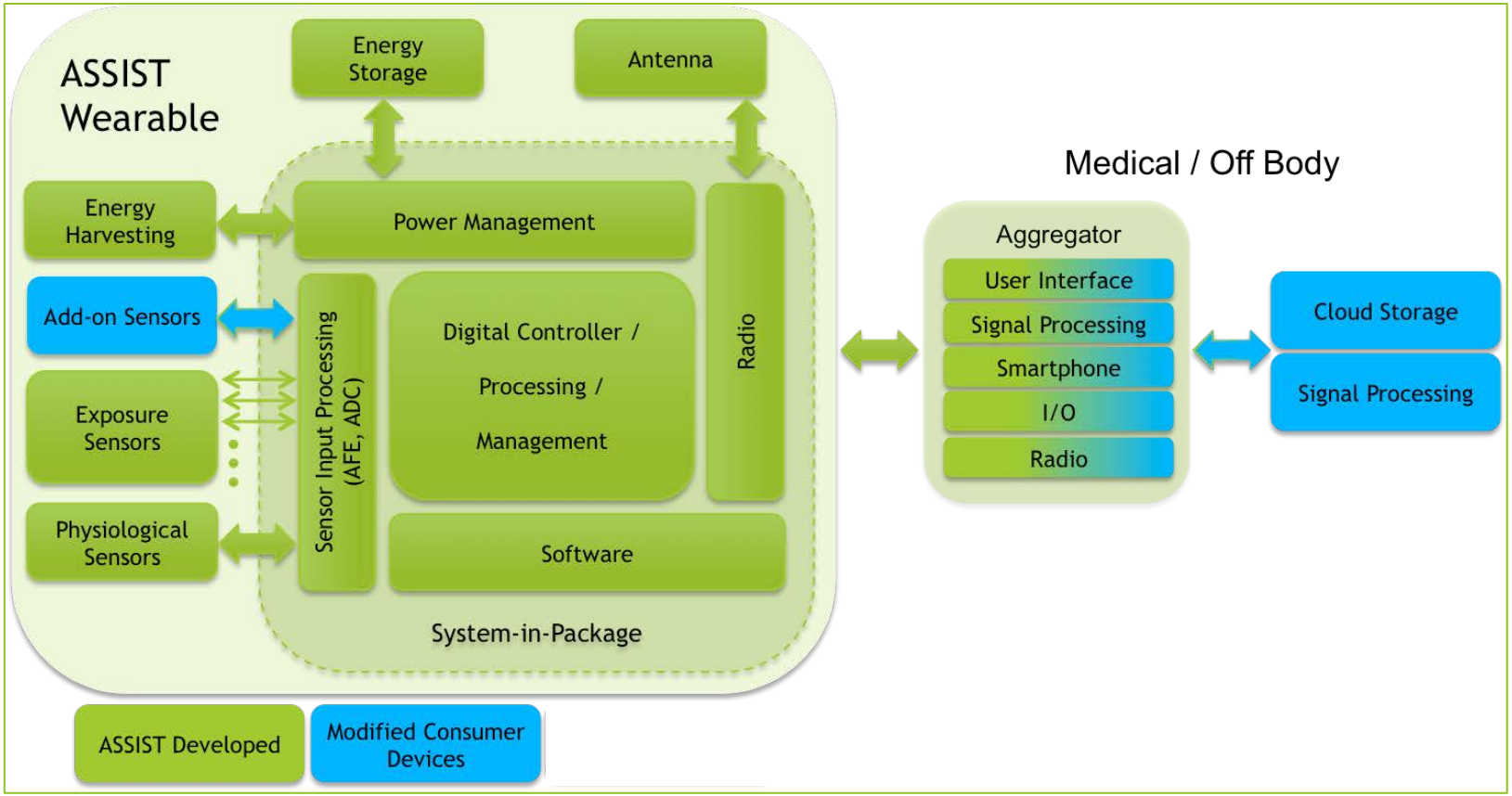

Engineered Systems and Testbeds
Human/Social Factors
Self-Powered Adaptive Platform (SAP)
Virtual Testbed
Health and Environmental Tracker (HET)
BARRIERS
Social Acceptance
Durability & Reliability
Data Management
Wearability
Requirements
Products & Outcomes
Stakeholders
Iterative Systems Integration
Platform Integration
Wearability & User Experience
Clinical Validation
Data Management
TECHNOLOGY INTEGRATION (Systems)
Low-Power Systems-On-Chip Thrust
System Design & Optimization
Low-Power Computation
Low-Power Communication
Multiscale Modeling
Technology Elements
BARRIERS
Power Management
Security & Privacy
Efficacy & Efficiency
Manufacturability
Energy Harvesting and Storage Thrust
Flexible Materials & Packaging
Power Conditioning Circuitry
Low-Power Wearable Nanosensors Thrust
Flexible Materials & Packaging
Mix-Mode Sensor Interface Circuitry
TECHNOLOGY BASE (Enabling Technologies)
Fundamental Insights
BARRIERS
Harvested Energy
Sensor Selectivity
Sensor Power
Reliability
Energy Harvesting
Wireless Power Transfer
Energy Storage
Biochemical Sensing
Optical/Acoustic Sensing
Environmental Sensing
KNOWLEDGE BASE (Fundamental Knowledge)
System Requirements

Defining the ASSIST's engineered system

Connecting our engineered system to Testbed

Recognizing how powerful the Testbed is to drive research success and Center cohesion

ASSIST's Engineered System



ASSIST's Targeted Health Use Cases


Michelle Hernandez, MD, UNC


Randall Moorman, MD, UVA


David Peden, MD UNC

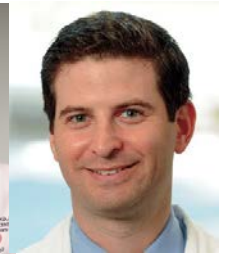

Ayse Belger, PhD, Neuroscience and Psychiatry, UNC


Robert Kirsner, MD Univ. of Miami


Nirmish Shah, MD Duke

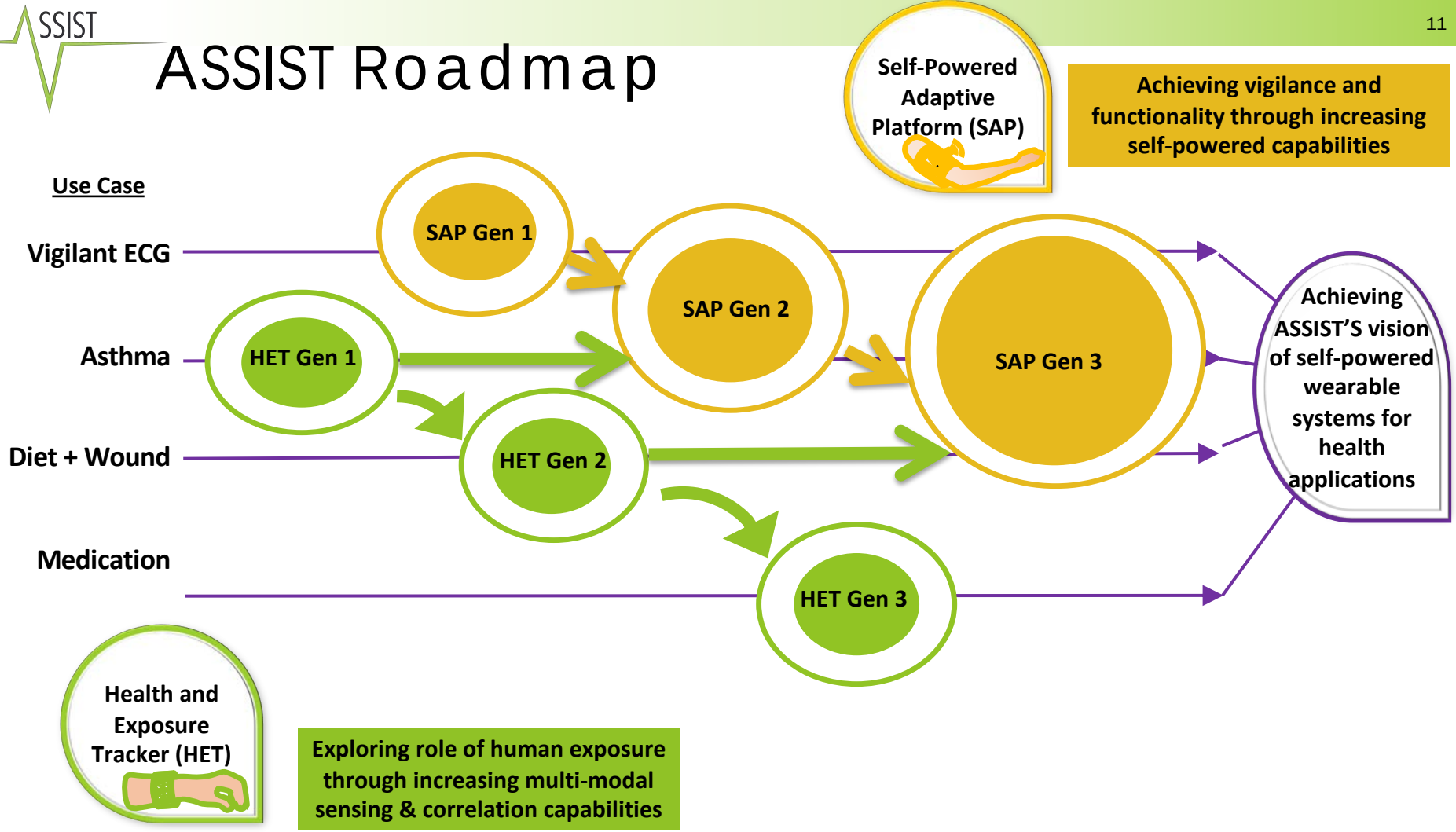

Delesha Carpenter, Ph.D. UNC Eschelman School of Pharmacy


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/m2)
4. Wound Healing in Post-surgery/diabetic patients (~$15B)
5. Medication Detection (> $300B avoidable costs)

ASSIST Roadmap



ASSIST's research thrusts must be driven by the needs of the systems and its use cases, i.e. Testbeds

Research Thrust and Systems Testbed Thrust interact with each other iteratively.

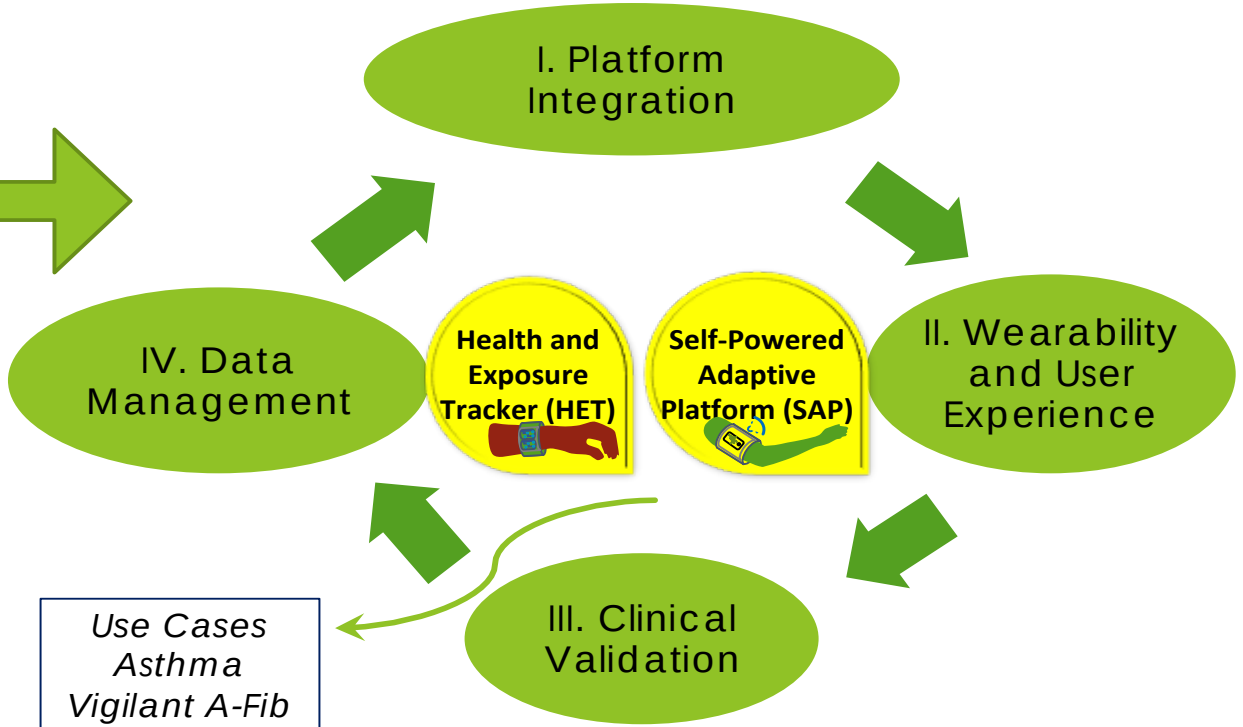
Research portfolio MUST be excellent, convergent and dynamic

SSIST

Research Thrusts

- Energy Harvesting and Storage
- Low Power Nanosensors
- Low Power systems on chip

Systems Testbeds Thrusts

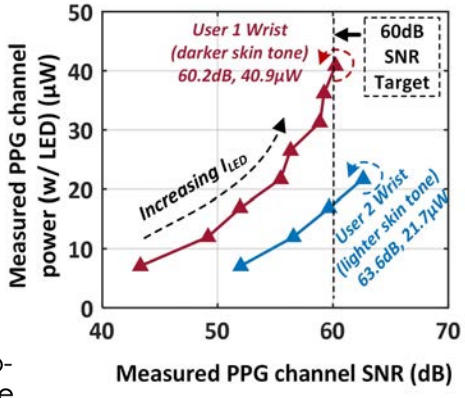


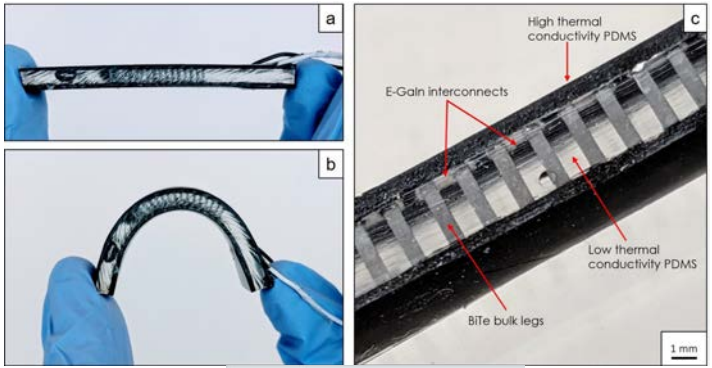
Testbed Development Cycle

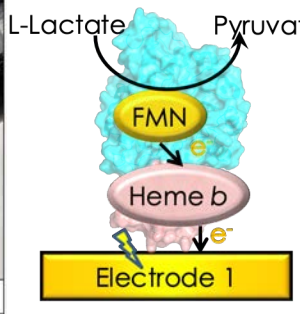
Use Cases
Asthma
Vigilant A-Fib
Pre-Diabetes
Wound Health

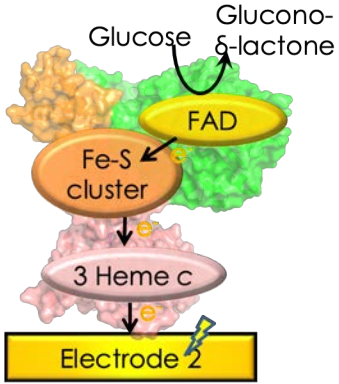
ASSIST Convergent Research

- 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









npj | Flexible Electronics

Glucose and Lactate

ASSIST's Testbed Driven Wearable Systems

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

Flex Electrochemical Patch

ASSIST Roadmap: 2012 to Today

Use Case

Vigilant ECG

Asthma

Diet & Wound

Medication

SAP Gen 1: ECG shirt

SAP Gen 1.9: Cardio-Respiratory Sleeve

SAP Gen 3: Biochemical

TEG- powered being developed

HET Gen 1

HET Gen 2

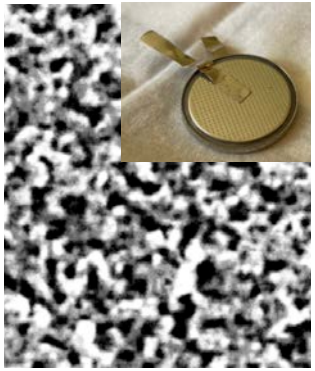
Wound Monitoring

HET Gen 3

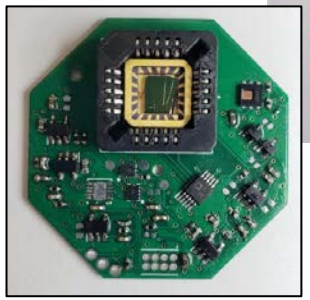
Achieving ASSIST's vision of self-powered wearable systems for healthcare

Vigilant ECG Armband Testbed

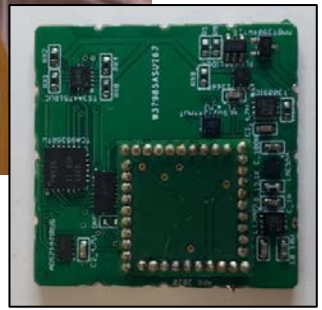
Flexible TEGs with integrated solar cell



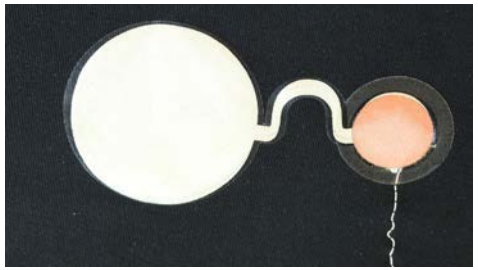
Supercapacitor with high capacitance retention



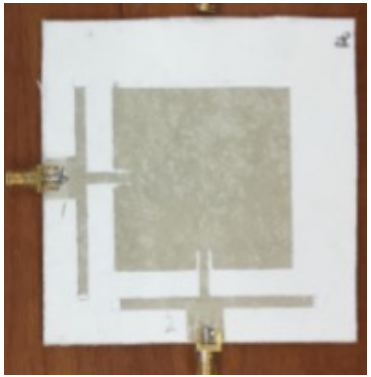
Custom AFE with Ozone & ECG



Compressed Sensing PPG



Washable ECG electrodes and cabling



Screen-Printed Full Duplex antenna

Industry program is the most critical aspect of an ERC

It needs effective recruiting and retention strategies

Consider including industry in all Center activities

Find a balance between large firms and startup firms

Industry Programming

- Successful track record of startups and licensing

- Industry *enabling* new ASSIST funding

- Exploring new models of industry engagement
  - Industry webinars
  - Joint technology development
  - Joint Publications

Educational activities thrive when customized and tailored to the Center mission

Education team should seek additional funding early on

Involve industry in student development

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

Diversity and Culture of Inclusion should not be a separate activity

While diversity is measurable, culture is much harder to measure

Measure and discuss your culture of inclusion

Diversity and ASSIST's Culture of Inclusion

Effective Mentoring: A Catalyst to Improved Climate for Research Productivity

DCI Committee, May 2021

- *Research proposal on transgender women with HIV @UNC*
- *PPG human subject studies*
- *SBIR on hydration monitoring with Onda Vision*

MRS MATERIALS RESEARCH SOCIETY®
Advancing materials. Improving the quality of life.

Women's Keynote Presentation featuring Susan Trolier-McKinstry

Wednesday, December 2
11:30 am – 1:00 pm

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

Misra, chair of ECE search committee

ONDA VISION TECHNOLOGIES, LLC.
Seeing Beyond The Surface

William Reynolds ·
Founder at Onda Vision

Measuring and marketing your success is critical!

Measuring the productivity of your team is critical!

Find stable physical and digital spaces for regular and safe communication

Final messages…Wish we knew these early!

- Systems Integration
  - Get a dedicated systems integration team upfront
- Center Cohesion
  - Establish a strong, robust, regular communication strategy (weekly if possible)
  - Make meetings meaningful
- Research Portfolio
  - Don’t start with a large team
  - Annual proposals and quarterly reviews are your best friends. Use boards effectively
  - Keep adding new blood in the Center
- External engagements
  - Send prototypes to as many people as possible!
  - Have a fantastic website that is also industry facing and market yourself early
- Leaders of core pillars (non-tenure track) also need retention strategies
- Legacy and sustainability
  - Grow leaders in your Center. They are the future.
  - Keep your Deans informed of good and bad issues frequently
  - Write new Center focused proposals: early.
- As the director, put aside at least 50% of your time to lead the Center!

Acknowledgements

- NSF EEC-1160483
- ASSIST Industry members
- ASSIST PIs, staff and students

ASSIST Membership

Full

Associate

Affiliate

ASSIST Team (PIs and their Students)

- Mehmet Ozturk
- Michael Dickey
- Ben Calhoun
- Jess Jur
- John Lach
- Doug Werner
- Dave Wentzloff
- Susan Trolier-McKinstry
- Shad Roundy
- Mehdi Kiani
- Alper Bozkurt
- Omer Oralkan
- Bongmook Lee
- Veena Misra
- James Dieffenderfer
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- Michael Lim
- Michael Daniele
- Orlin Velev
- Michael Dickey
- Shekhar Bhansali
- Shubhendu Bhardwaj

THANK YOU