FLEXIBLE HYBRID ELECTRONCIS

SYSTEM AS PACKAGE

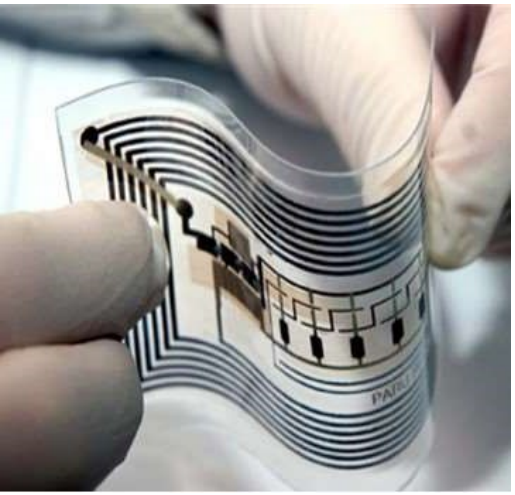
WILFRIED BAIR

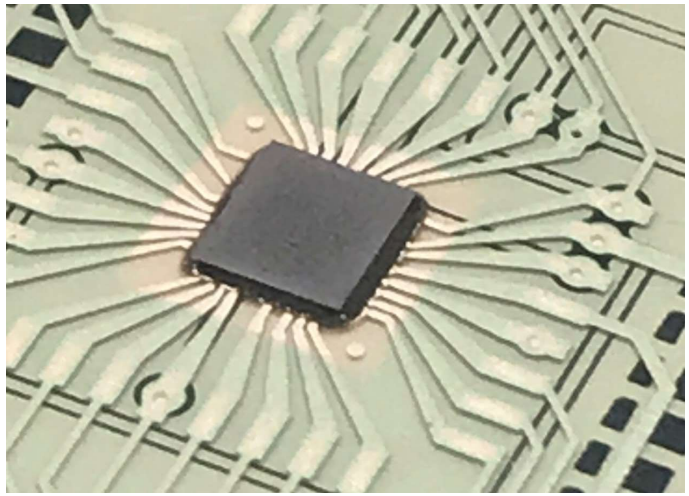
SEPTEMBER 2018

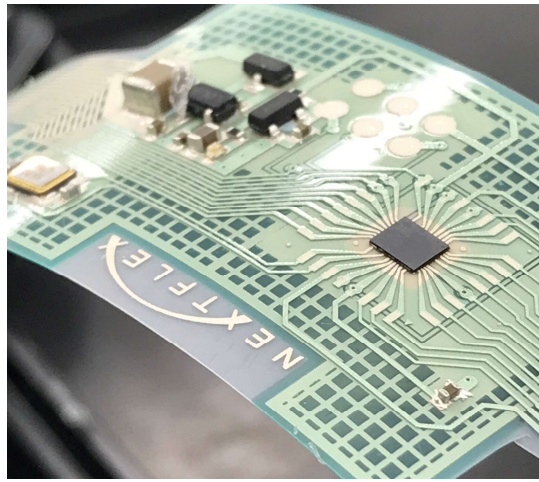
WHAT IS FHE?

AT IS FHE?

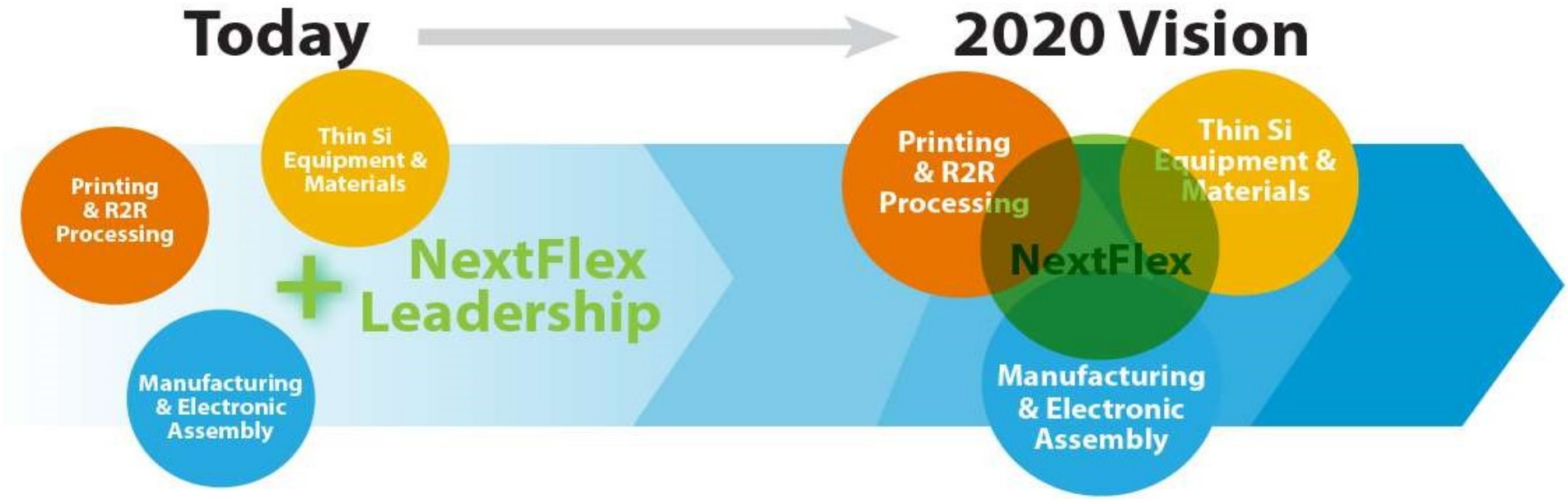
E (Flexible Hybrid Electronics) combine the flexibility and low cost of printed plastic film strates with the performance of semiconductor devices to create a new category of ctronics.







NGING TOGETHER EXISTING CAPABILITIES



Disparate FHE Capabilities

- Centers of excellence with world class capabilities; Project-based interaction
- Evolved out of established, once US-led technologies

MII Funding Helps Connect Manufacturing

- Silicon Valley hub provides critical mass to 'pull' industries together
- Fills missing infrastructure in modeling, design, new assembly, and test
- Creates links between today's separate capabilities, existing assembly and end-user needs
- FHE leverages other industry eco-systems and marketing channels
- Relationships and communications ensures efficiencies in investments

MBERSHIP

NEXTFL

Corporate

Academic / Non-Profit

* Founding Member

Equipment Affiliate

Observer

Honorary

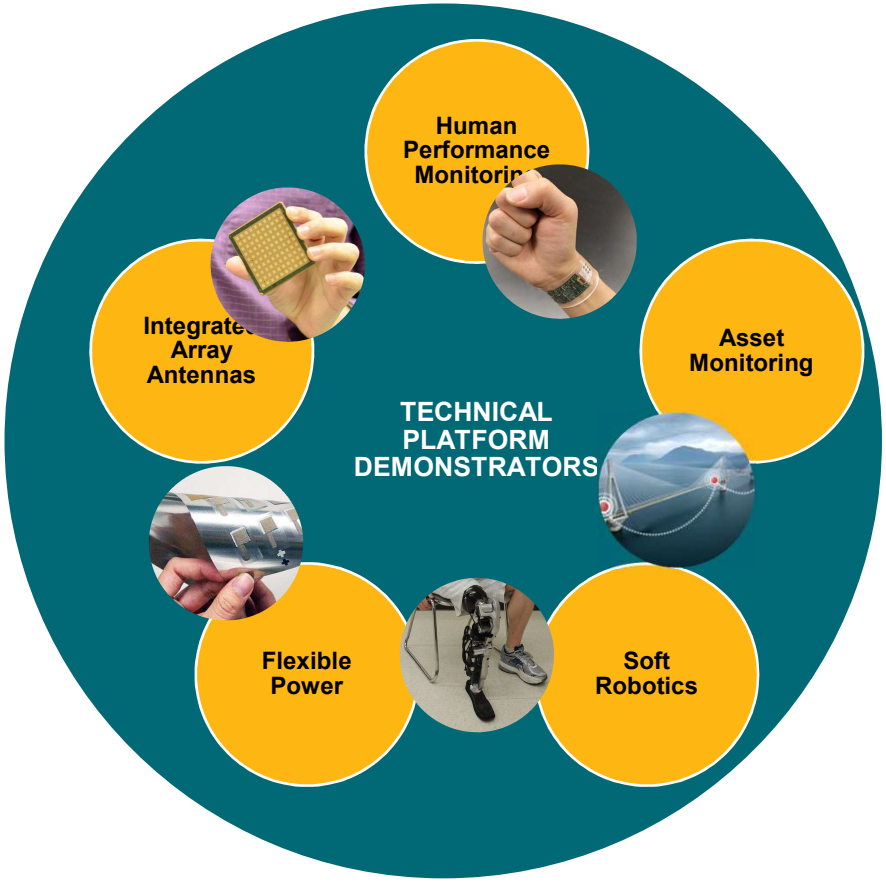
ADMAP FOR MANUFACTURING PROCESSES

NEXTFL

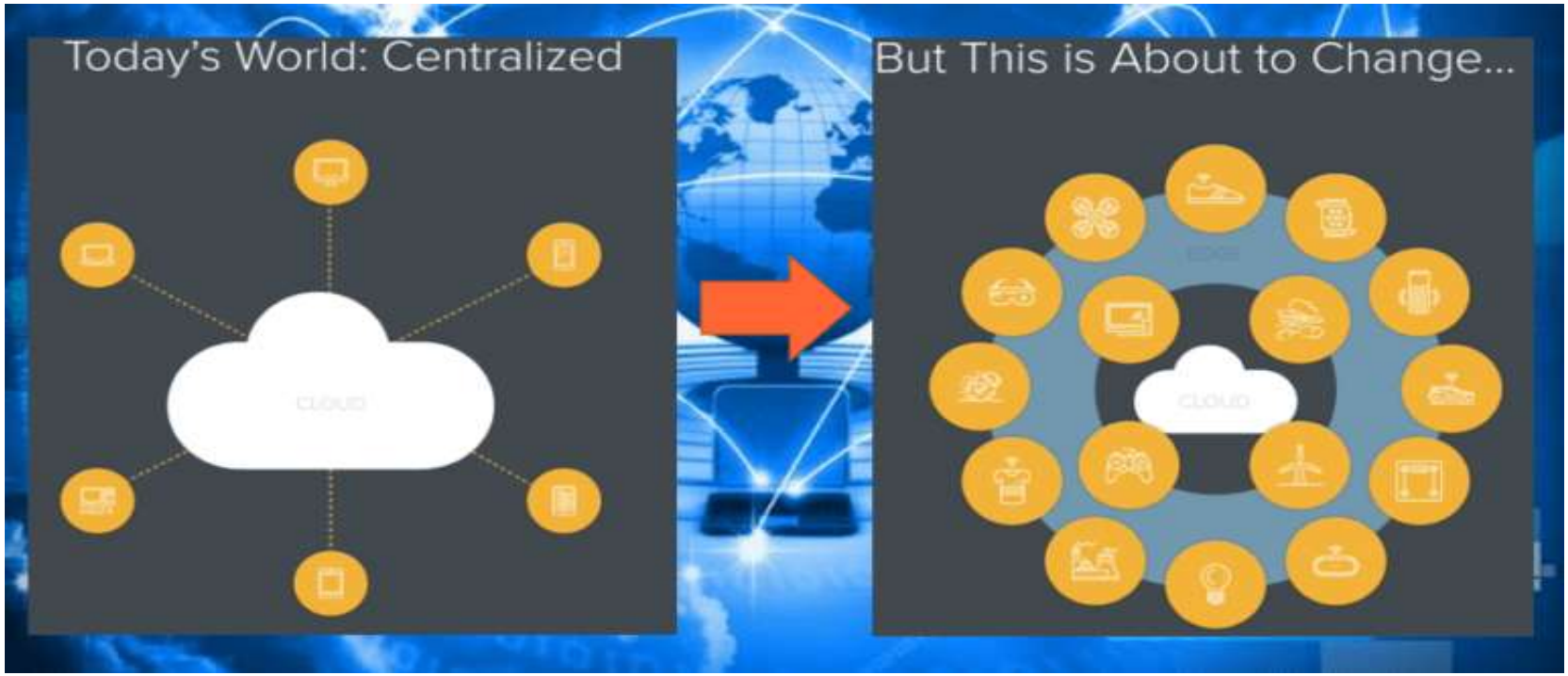
5 Focus Areas

- Device Integration & Packaging
- Printing & Microfluidics
- Materials
- Modeling & Design
- Standards, Testing, & Reliability

HNICAL WORKING GROUPS AND APPLICATION FOCUS AREAS



E – THE IOT ENABLER FOR EDGE PROCESSING?

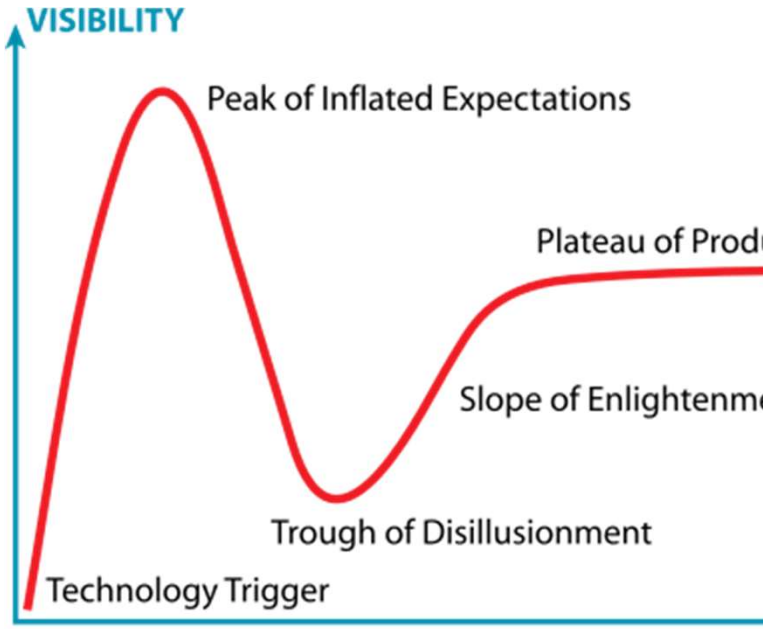


0 ESTIMATES FOR IOT OBJECTS

2010 Cisco and Ericsson predicted 50Billion IoT objects

2012 IBM predicted 1 Trillion objects

2016 IEEE Spectrum report: 30 Billion



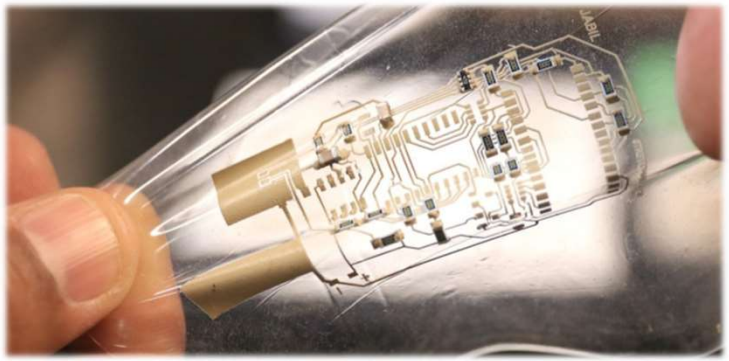
NEXTFL

What is missing?

- Low cost system for edge devices
- Easy and inexpensive to deploy
- Changing the form factor
- Reducing size and weight
- Mass customizable

- Flexible
- Stretchable
- Conformable
- Transparent
- Biocompatible
- Lightweight

Peel and Stick Electronics



OCESS FOR CREATING ELECTRONICS

Conventional process

- Design the IC
- Design a package for the IC
- Design a board for the packaged IC
- Design an enclosure / housing for the board
- Fit everything into the final system/device

Reversing the flow

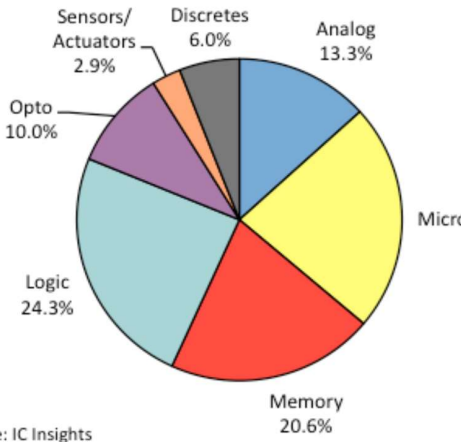
- Design the desired system and form factor
- Design the system level board and BOM needed
- Design the IC (use COTS or custom designed)
- Assemble and encapsulate

LTI-DIE AND HETEROGENEOUS INTEGRATION

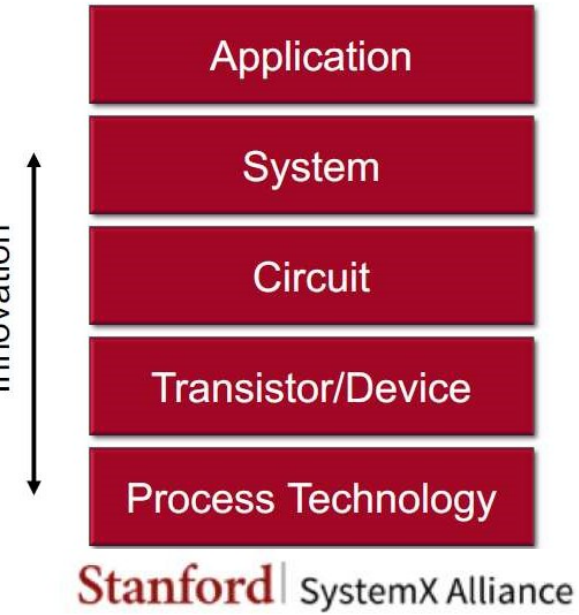
HE by design enables multi-die integration and heterogeneous integration for ystem builds

tay with existing supply chain for wafer sourcing

mphasis on direct die attach vs packaged device integration



Source: IC Insights

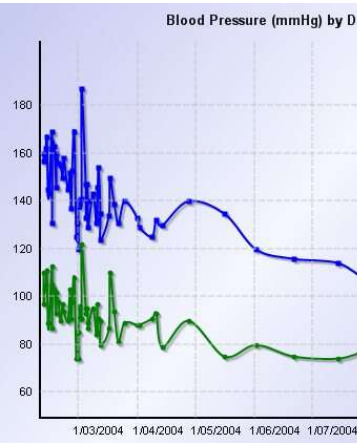


	New Market Requirements	Multi-die Solutions Offer
Revenue Drivers	Broad	Flexible and Modular Approach
Life of a Design	Quarters to Years	Easy to Update/Change
Functionality	Logic, RAM, NVM, RF,…	Heterogeneous Integration
Formfactor / Power Diss.	Smaller / Lower Power	Small / Low power
Life-time Volume	Low / Medium / High ?	Adaptable Architecture
Development Cost / Time	Lower vs 2D / <<1 Year	Building Blocks (“LEGOs”)
Unit Cost Sensitivity	LOW, if minor System Part	Cost-reduction Efforts Ongoing
Standards Support	Emerging, Regional, …	Adaptable to Changes
EcoSystem / Supply Chain	Emerging, Changes Likely	Maturing fast, in particular 2.5D &

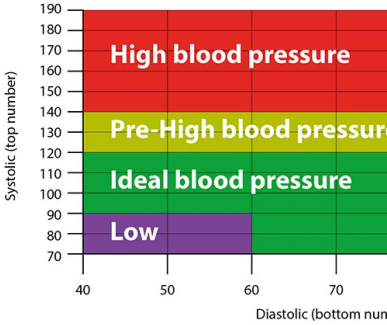
FHE USE CASE SCENARIO

FITNESS AND HEALTHCARE

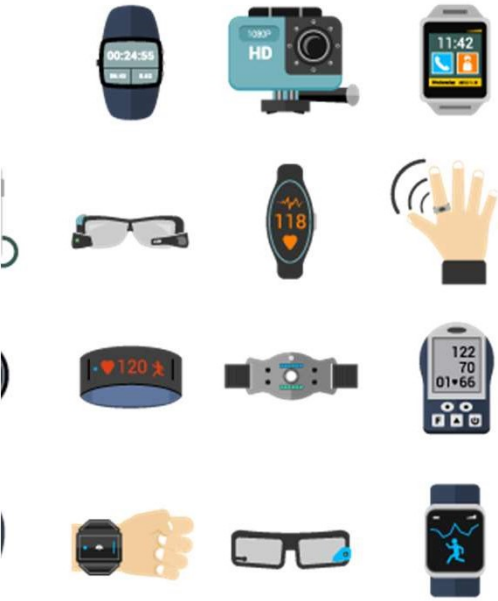
HY WEARABLES?

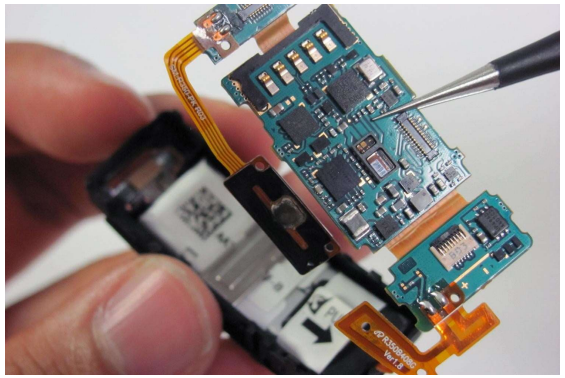


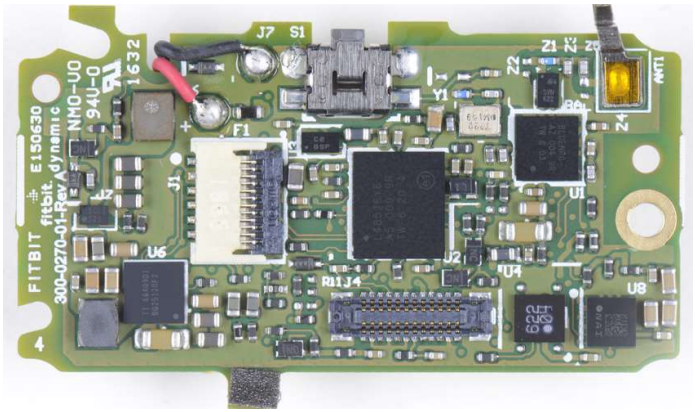
VS



AMPLE: WEARABLES 2016







ARABLES 2020 AND BEYOND

NEXTFL

Factor

nformability

etchability

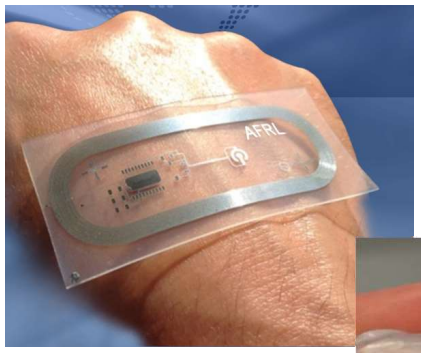
nsparency

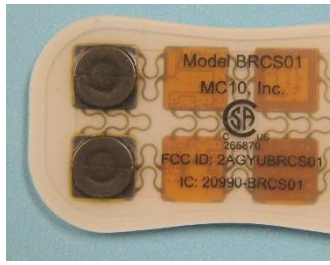
ni-Breathability

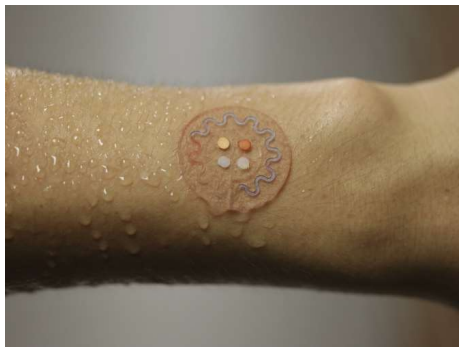
ors

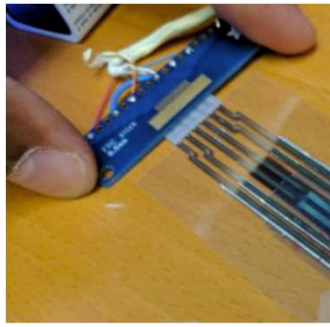
emical

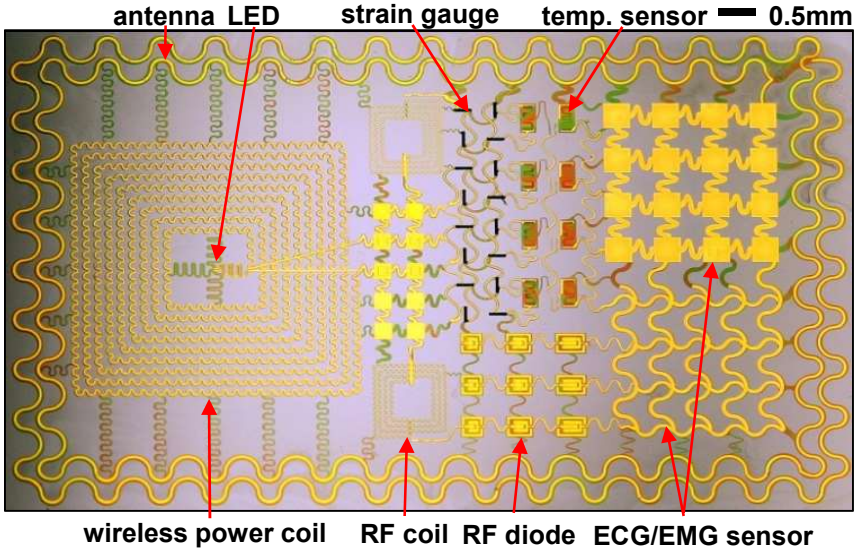
ctrical

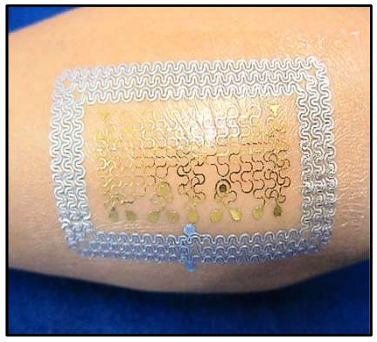


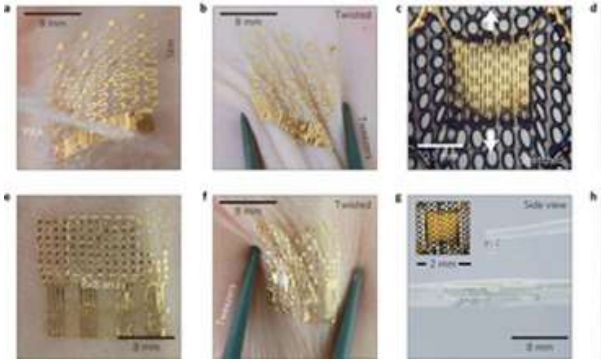






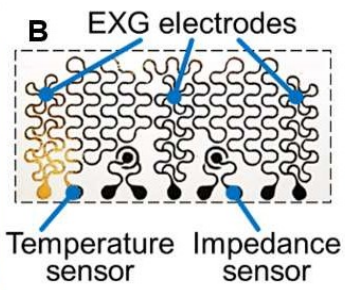


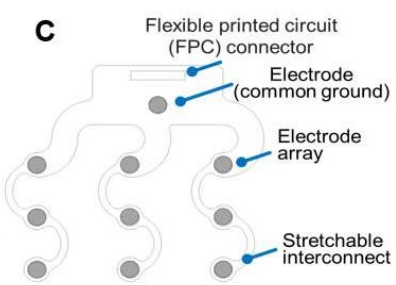




PROJECT CALL EXAMPLES

OFT EXOSKELETON KNEE BRACE



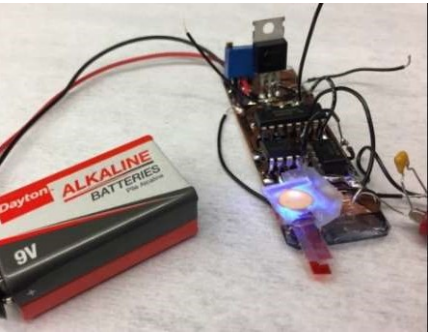


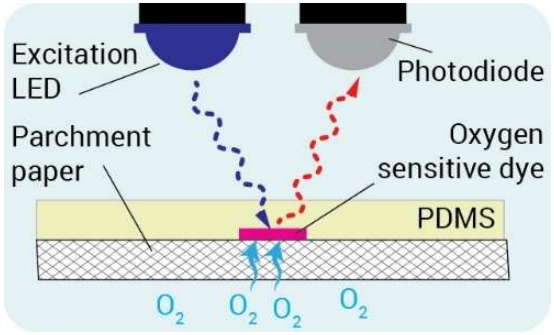
XIBLE SMART WOUND DRESSING

NEXTFL

lem:

nic non-healing wounds impact over 6.5 million Americans a and are increasing. Current treatments are expensive and intensive.





pe Powered by 9V Battery

efit:

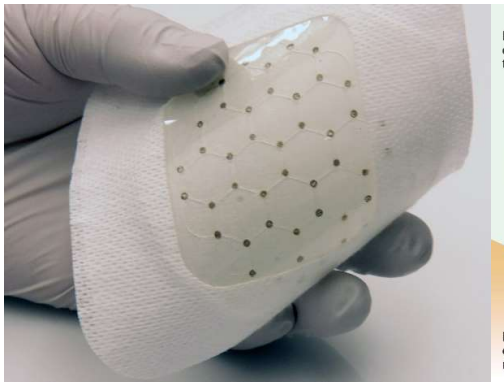
cated on a biocompatible paper substrate that provides tural stability and flexibility while simultaneously offering bility, selected gaseous filtering, and physical/chemical ction.

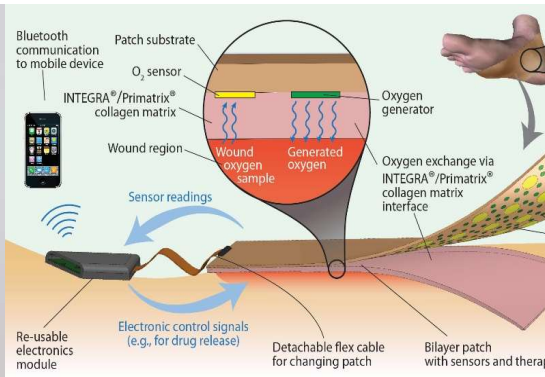
verable:

cal samples of device and subsystems, as well as sample g data.

Objective:

Demonstrate integrated oxygen delivery and sensing onto a si low-cost, manufacturable, flexible dressing. Provide possible solution for wound care for an average annualized cost of $25E the US market.





Approach:

Print materials at WMU; assemble and benchtop-test devices a Purdue; evaluate (in vitro and in vivo) at IUSM; collaborate with Integra throughout, optimize preproduction manufacturing proc

PURDUE UNIVERSITY

INTEGRA LIMIT UNCERTAINTY

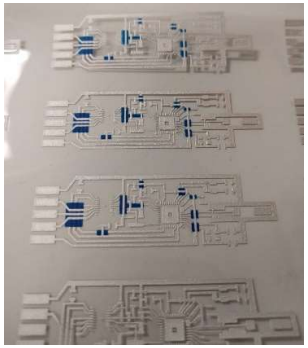
SCHOOL OF MEDICINE INDIANA UNIVERSITY

XIBLE ORAL BIOCHEMISTRY SENSING SYSTEM

lem:

dic measures of bio analytes are insufficient to determine if es or warfighters are nearing exhaustion or dehydration.

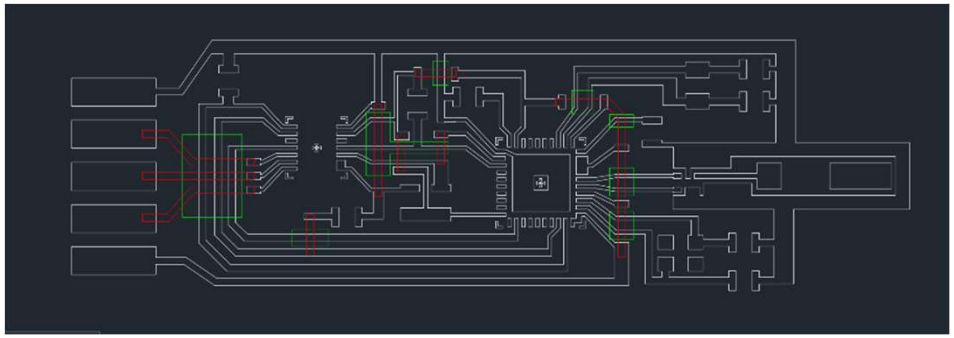
Working Electrode System



Print Sample

Objective:

Continuous monitoring of bio analytes to infer hydration, exhaustion and mental engagement levels in high performing athletes and warfighters.



Screen Layout

fit:

nuous remote monitoring of bioanalyte concentrations in saliva.
le, small printed electrode form factor.
capabilities demonstrated include biostability in saliva for up to rs and removable, disposable printed electrode strip.

Approach:

Develop an FHE circuit, Prussian Blue (PB)/Carbon (C), with a counter electrode PB/C, and reference electrode AG/AGCl an co-molded in silicon

erable:

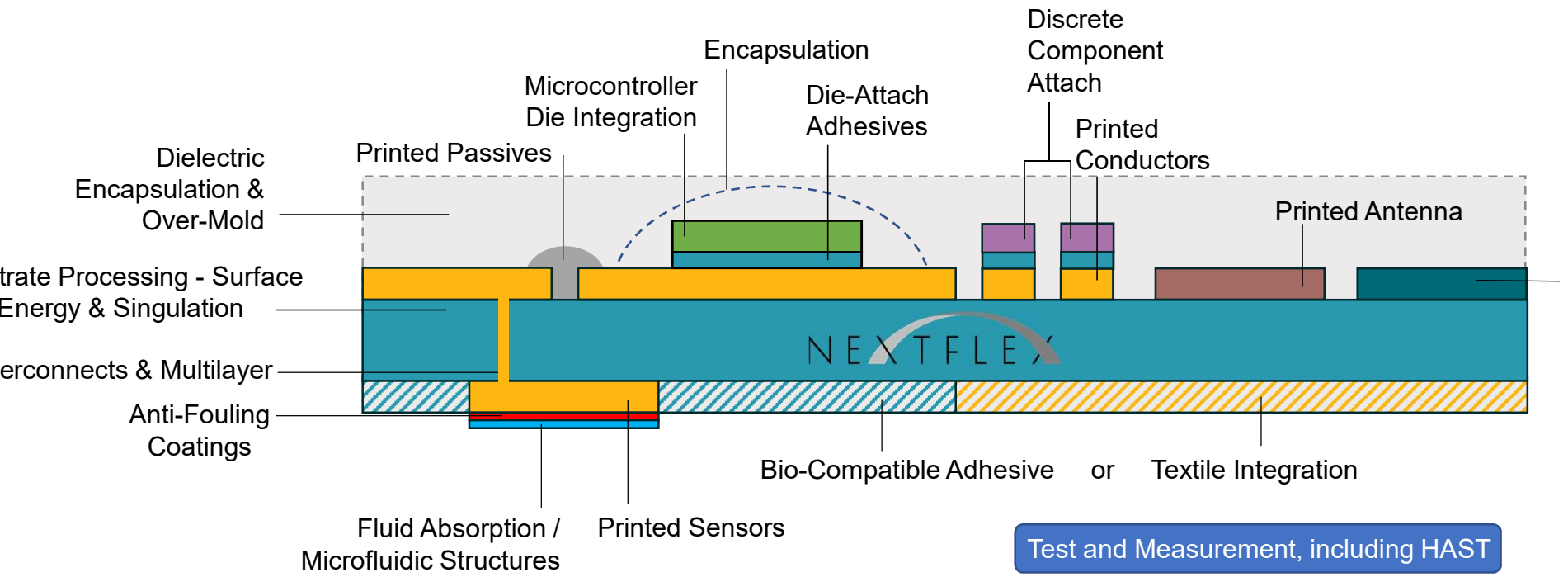
er a flexible mouth guard sensor label with wireless charging ead-out, and new sustainable manufacturing process.

parc
A Xerox Company

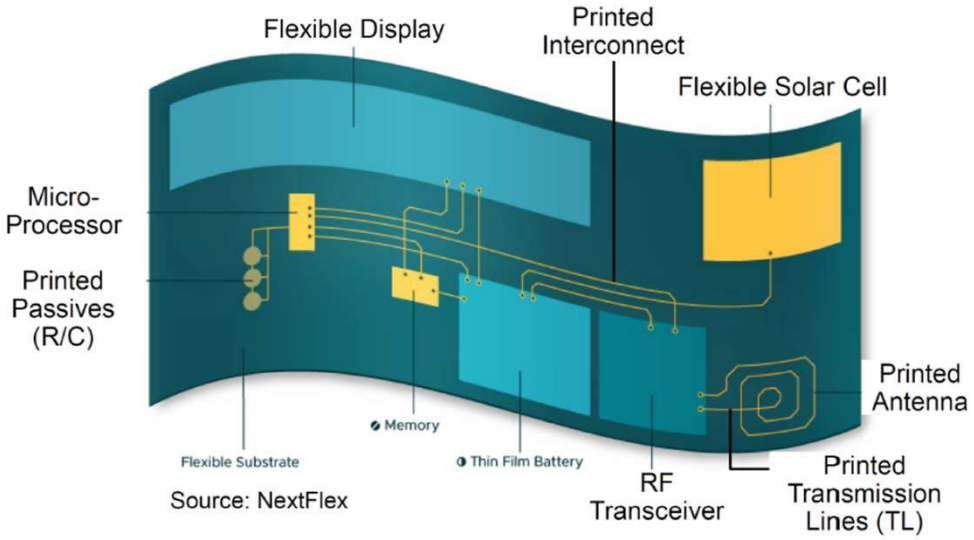
UNIVERSITY OF CALIFORNIA · SAN DIEGO ·

FHE DESIGN APPROACH

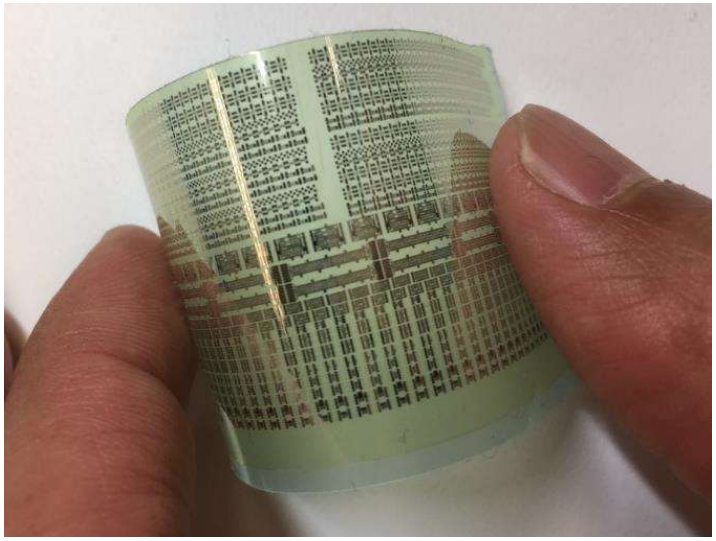
PICAL FHE CROSS SECTION



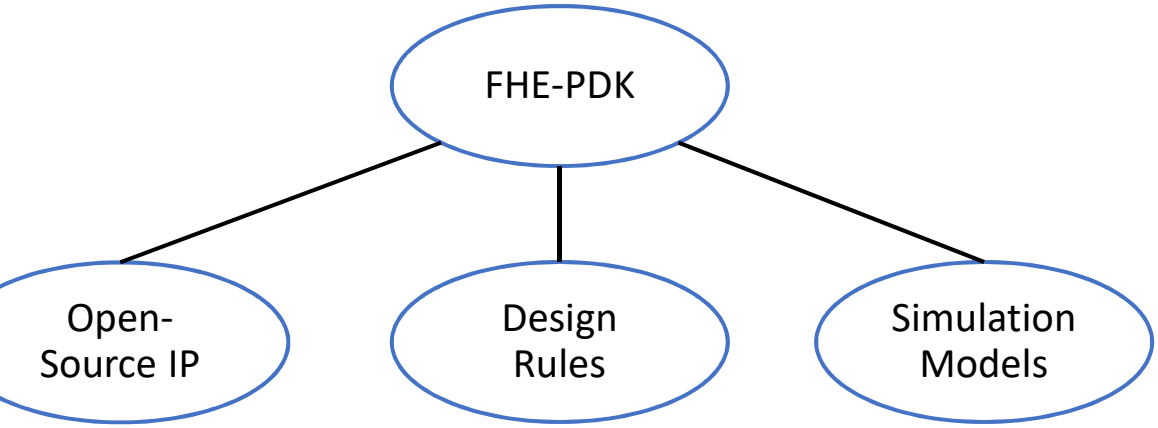
E MISSING TOOLBOX TO JUMP-START A FHE DESIGN PROJECT

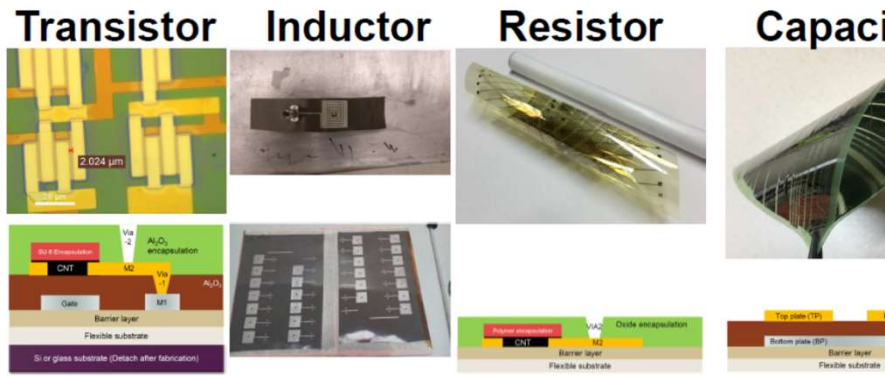


Source: NextFlex



Open-source digital and analog IP
(ex. sensor interface and amplifiers)





E PDK Project Participants

ewlett Packard Enterprise (Labs) – FHE circuit & system design and testing (prime)

Dr. Ray Beausoleil (HPE Senior Fellow), Dr. Cullen Bash (System Lab Director), Dr. Sicheng Li

eorgia Institute of Technology (C3PS) – Multiphysics co-simulation and printed TL/inductor/ar

Prof. Madhavan Swaminathan, Prof. Suresh Sitaraman, Sridhar Sivapurapu, Nahid Aslani Amoli, Mohamed Bella
Chirag Mehta, Rui Chen, Yi Zhou

anford University (Bao Group) – Device (r/c/transistor/antenna) fabrication (printing/lithograp

Prof. Zhenan Bao, Dr. Ting Lei, Dr. Simiao Niu

niversity of California at Santa Barbara (ECE) – Device modeling and EDA tool interface

Prof. Kwang-Ting (Tim) Cheng, Prof. Yuan Xie, Leilai Shao

estern Michigan University – Printed antenna

Dr. Binu Baby Narakathu (technical advisor), Prof. Atashbar Massood

adence Design Systems – Academic licenses and PDK technology transfer

Saugat Sen (VP of R&D) John Park, Dr. Patrick Haspel, Cheryl Mendenhall

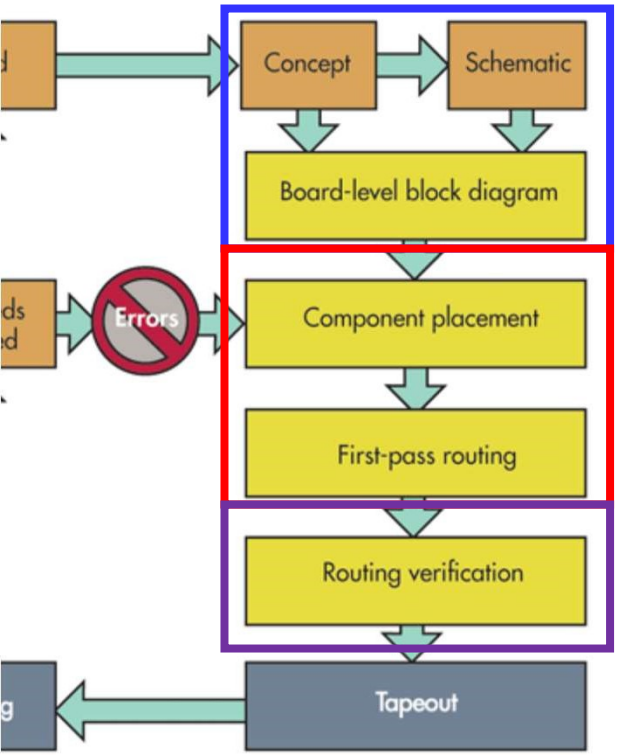
nsys – Technical advices

Dr. Norman Chang (Chief technologist/VP R&D)

t Packard
se
Georgia Institute of Technology
UCSB
cadence

E MUST-HAVE TOOLBOX TO SAVE YOU DESIGN TIME AND $$$

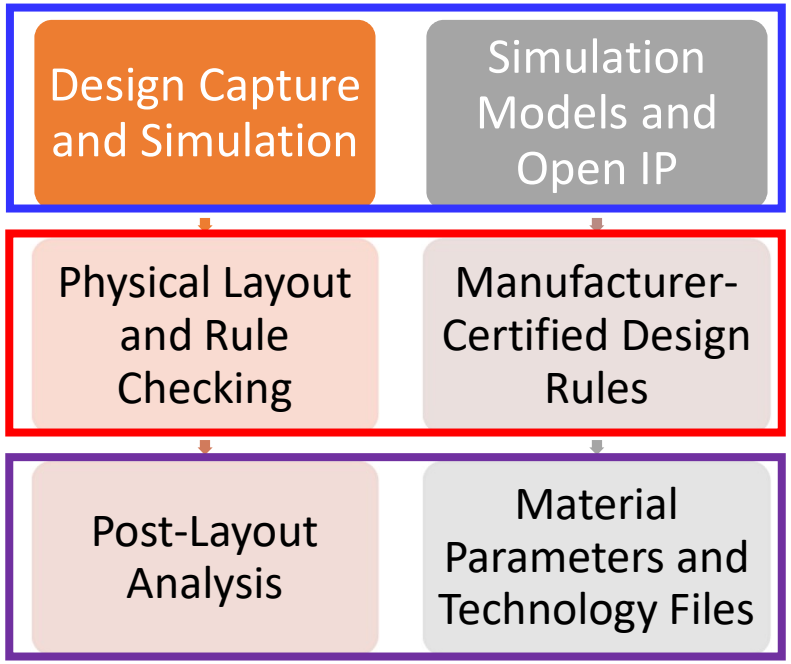
PCB Design Flow



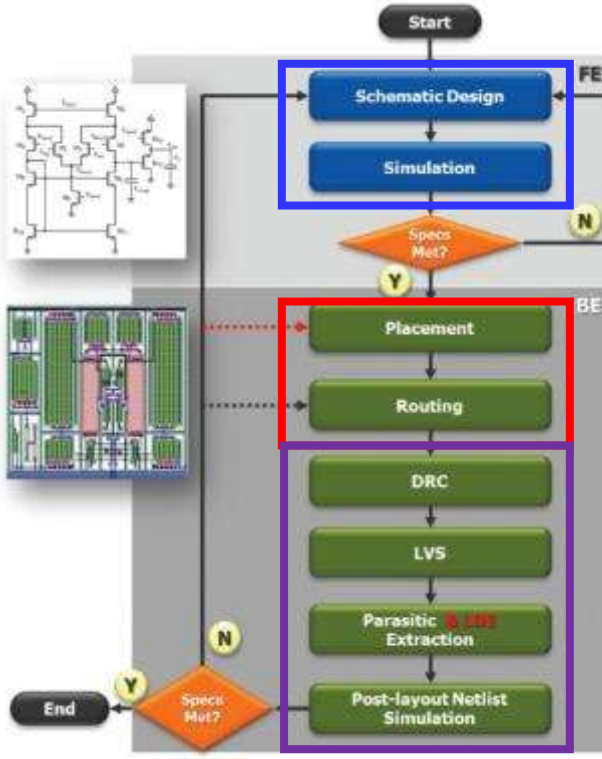
e engineer's guide to high-quality PCB design,"
ectronicdesign.com

FHE Design Flow

FHE-PDK



IC Design Flow



Ref: "Catching layout-dependent effects on-the-fly,"
www.techdesignforums.com

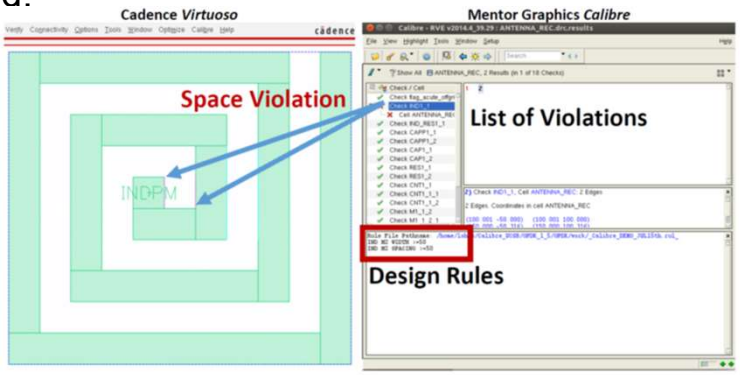
thout FHE-PDK and experimentally-proven models and design rules, FHE design wi
a gamble and time-consuming with a lot of trials-and-errors

E PROCESS DESIGN KIT

wlett Packard Enterprise - Georgia Institute of Technology, Stanford University, versity of California, Santa Barbara

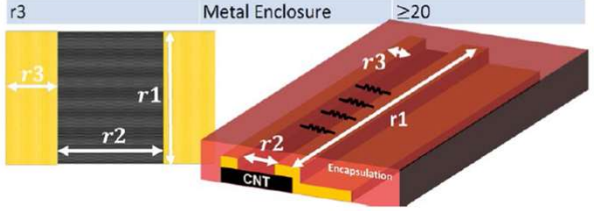
em: Designing FHE products encompasses numerous facturing methods and unconventional process flows. In order able wide-scale adoption of FHE, a qualified PDK that can map facturing design capabilities to manufacturing capabilities is ed.

Objective: Program and demonstrate an FHE PDK for heterogeneous integration of both discrete and deposited elements of electronic systems.



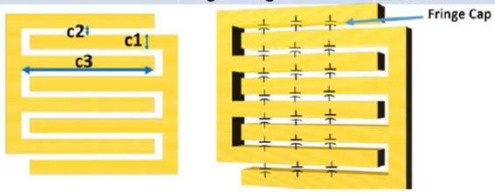
Printed Resistor

Design Rules	Descriptions	Dimensions (µm)
r1 (W)	Resistor Width	≥25
r2 (L)	Resistor Length	≥25
r3	Metal Enclosure	≥20



Printed Fringe Capacitor

Design Rules	Descriptions	Dimensions (µm)
c1	Finger Width	≥ 25
c2	Finger Spacing	≥ 10
c3	Finger Length	≥ 150



efit: The ability to design FHE systems using industry ard layout and EDA tools in order to enable market tration of flex hybrid products.

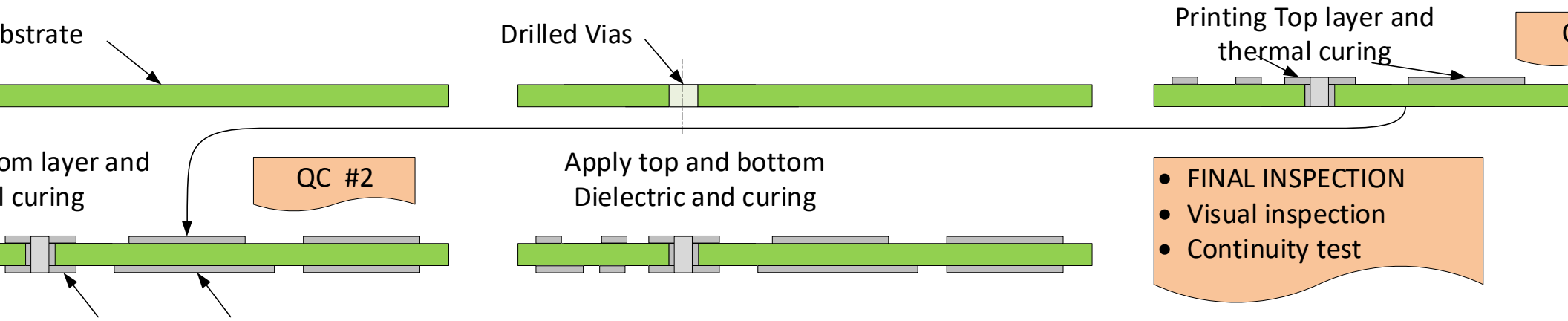
Approach: Create device class structures for resistors, capacitors, inductors, and transistors, and characterize large quantities of these devices based on representative manufacturing methods.

verable: Delivery of a tested PDK using silver-based arbon nanotube device structures. NextFlex shall have the right to manage licensing and use of the PDK across the FHE community.

Duration: 18 months
PC - 10015

NEXTFLEX IOT PROCESS FLOW

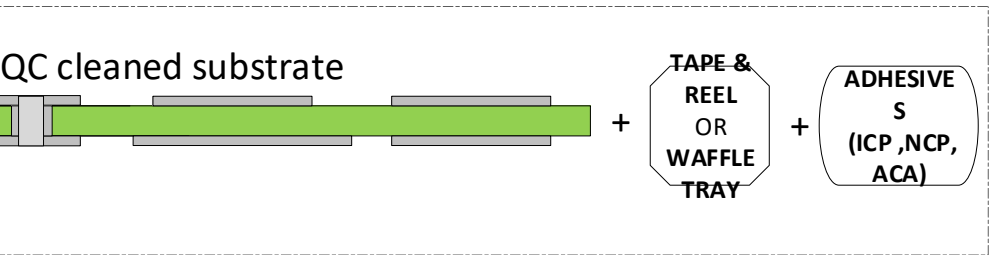
SUBSTRATE w/THROUGH HOLES and PRINTING

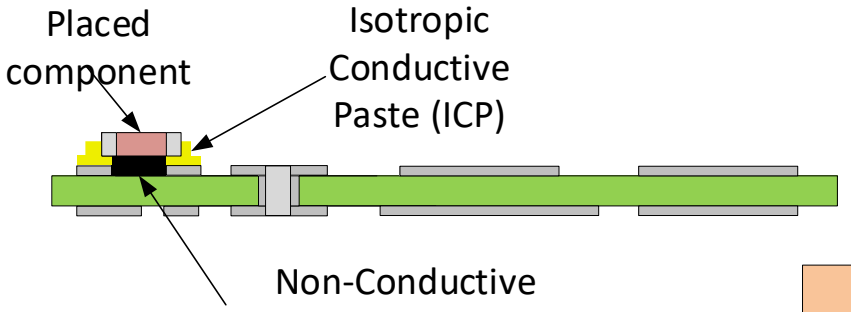


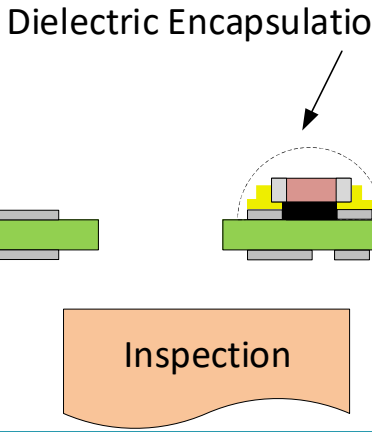
COMPONENT PLACEMENT (SM Discretes, Passive, etc.)

for assembly
, Build Sheet, BOM and components / materials)

Dispense, Pick , Align, Place and Oven (or UV) curing.







HOW TO BUILD FLEXIBLE HYBRID ELECTRONICS

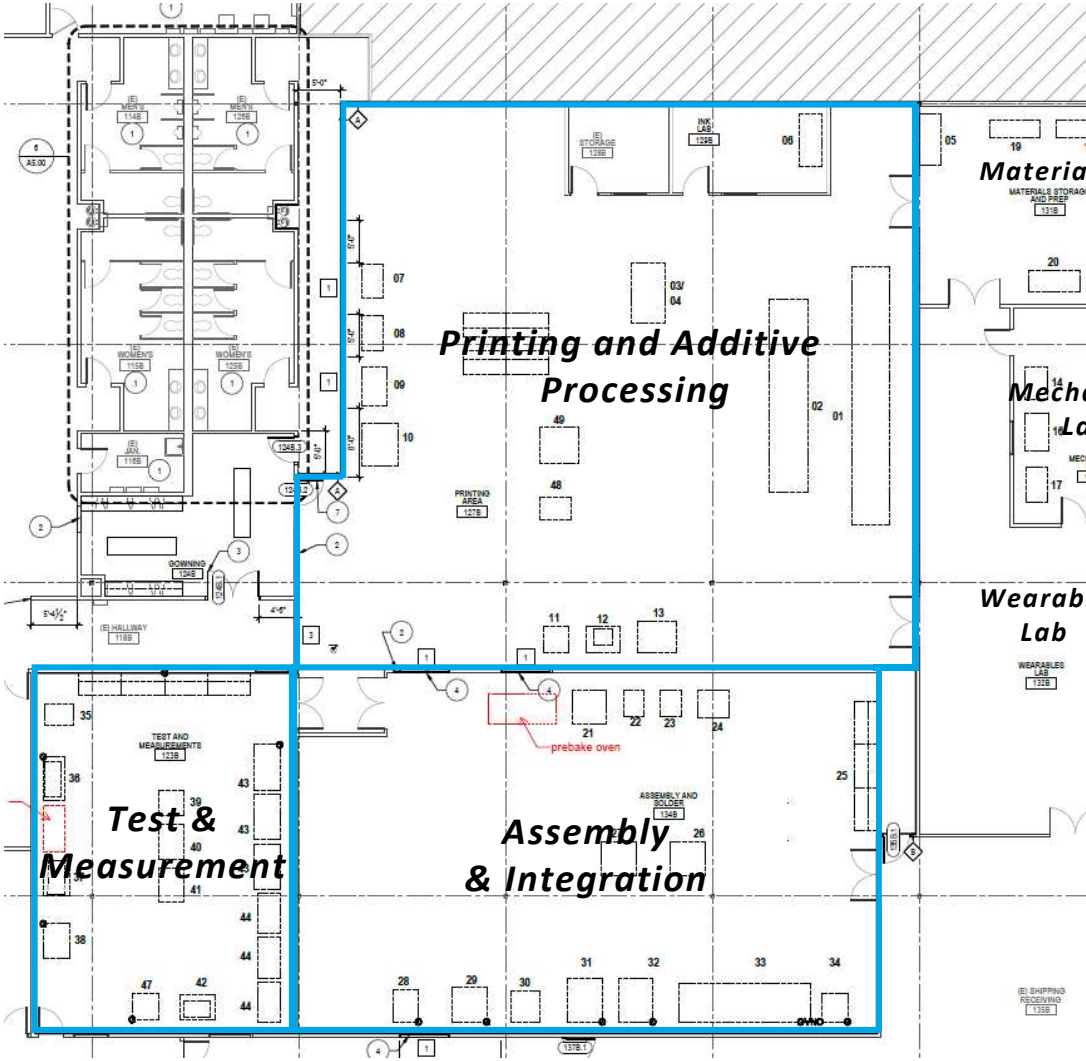
E NEXTFLEX TECHNOLOGY HUB

oximately 15,000 sf of Class 10,000 cleanroom, lab, pport space combined:

nt Room:	~4,500 sf
sembly:	~2,700 sf
st:	~1,300 sf
pport Labs	~6,500 sf

nroom Features:

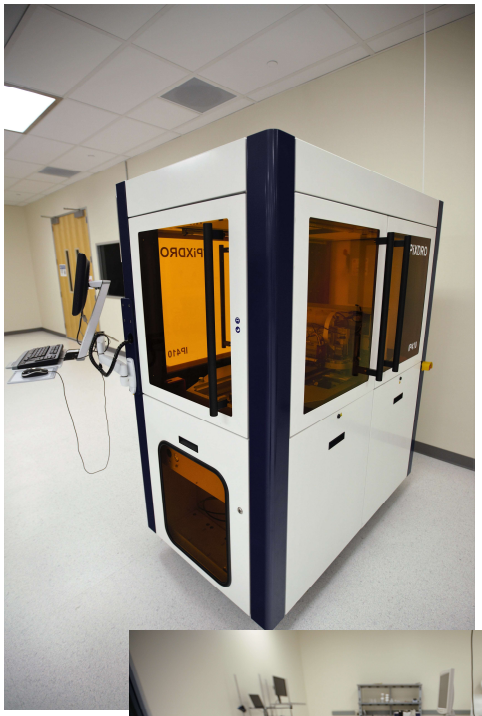
- 24/7 monitoring and alarming
- Flexibility in tool placement to create processing cells/flow
- Localized exhaust, electrical, CDA
- Localized upgrade to higher cleanroom classification, e.g. class 100 at critical processes
- Real time process and test data gathering directly to network for distribution & analysis

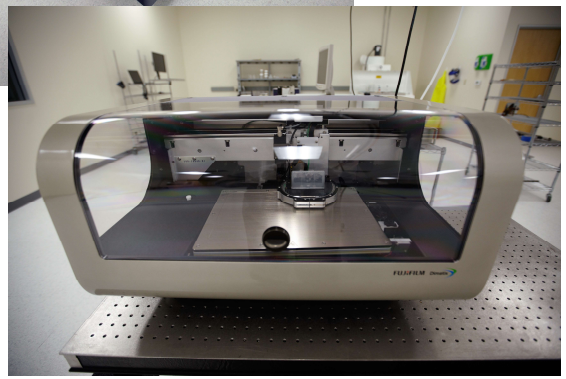


NTING EQUIPMENT

EEN PRINTER

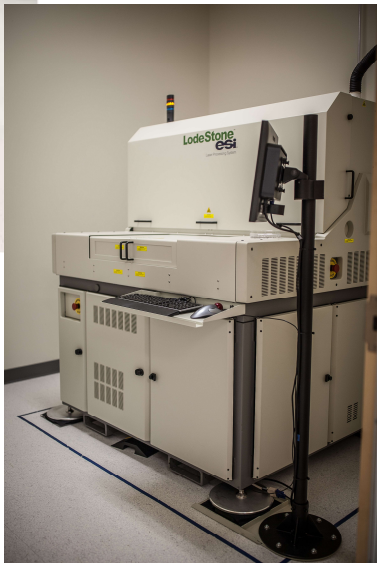
VURE OFFSET PRINTER





INK JET PRINTERS

AEROSOL JET



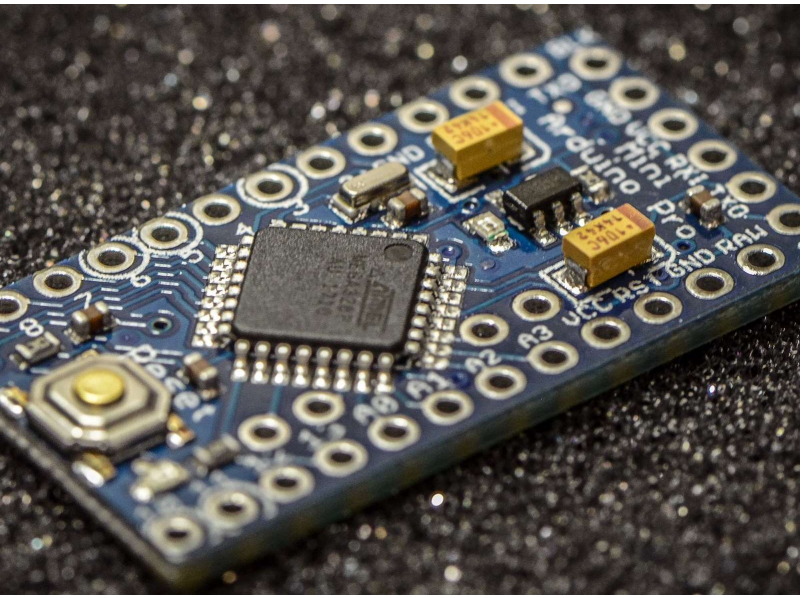
FEMTOSECOND LASER

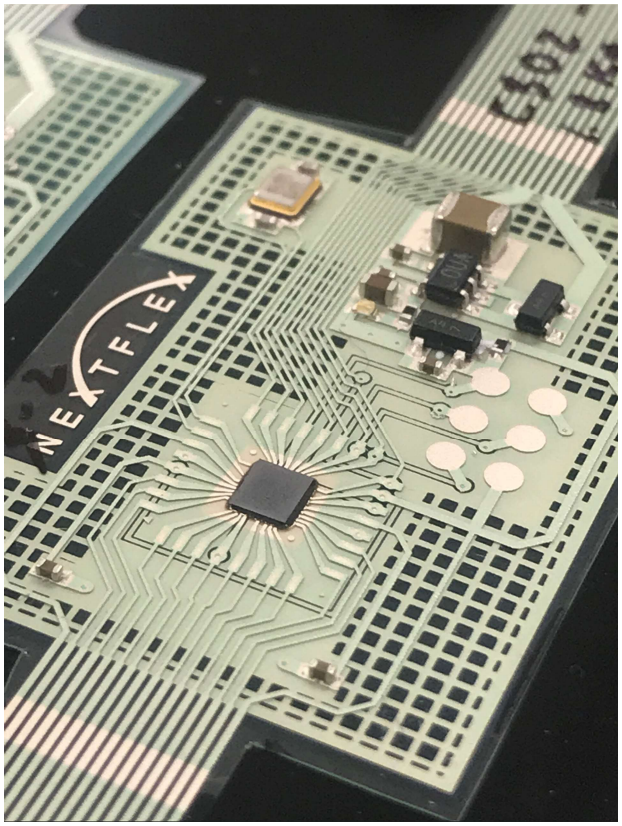
DIE BONDER

FLEX ARDUINO PROJECT

OJECT SCOPE

ld a flexible version of an Arduino microcontroller board to demonstrate E capability.





LATIVE MASS

Arduino Uno

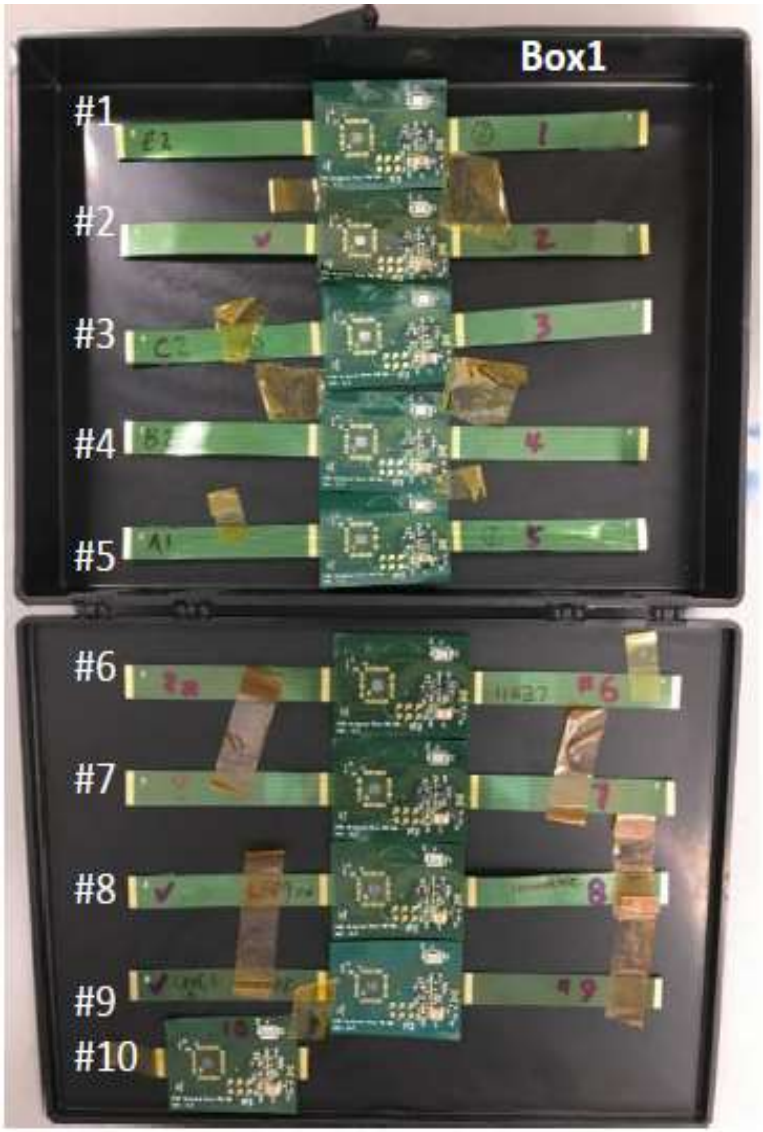
Arduino Mini

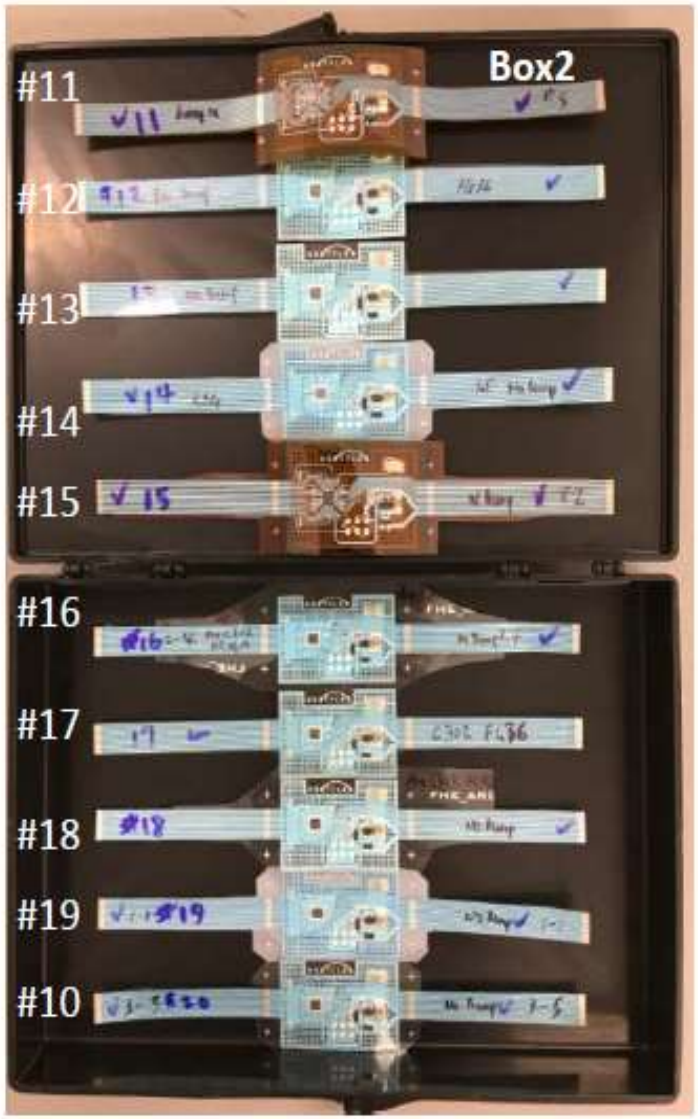
Arduino FPCB Bare Die

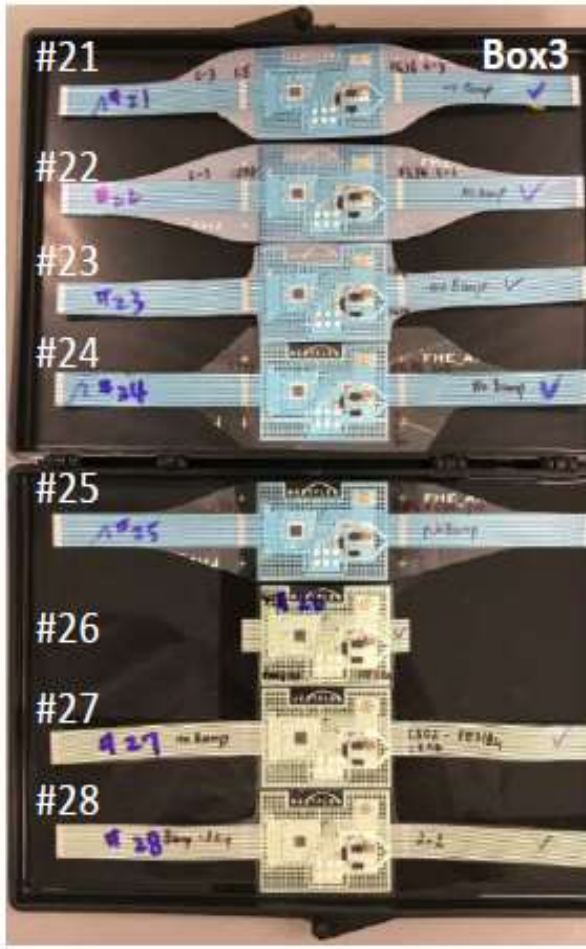
Arduino FHE

HE Arduino is nearly 70% lighter than commercial Arduino Mini rigid board

X ARDUINO – FIRST SET OF BUILDS







ANK YOU!

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