Nanosensor Manufacturing Workshop

Presented by
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Principle Research Engineer

June 13, 2017

Be Curious SM

United Technologies Business Units

UTC Aerospace Systems

United Technologies
Climate | Controls | Security

Pratt & Whitney
A United Technologies Company

Otis
A United Technologies Company

United Technologies Research Center

Cork, Ireland

Established in 2010, focuses on energy, security and aerospace systems

Shanghai, China

Established in 1997, focuses on integrated buildings, fluid and mechanical systems

Berkeley, CA

Established in 2009, focuses on cyber physical systems and embedded intelligence

East Hartford, CT

Founded in 1929, focuses on a broad range of system engineering, thermal, fluid, material, and informational sciences

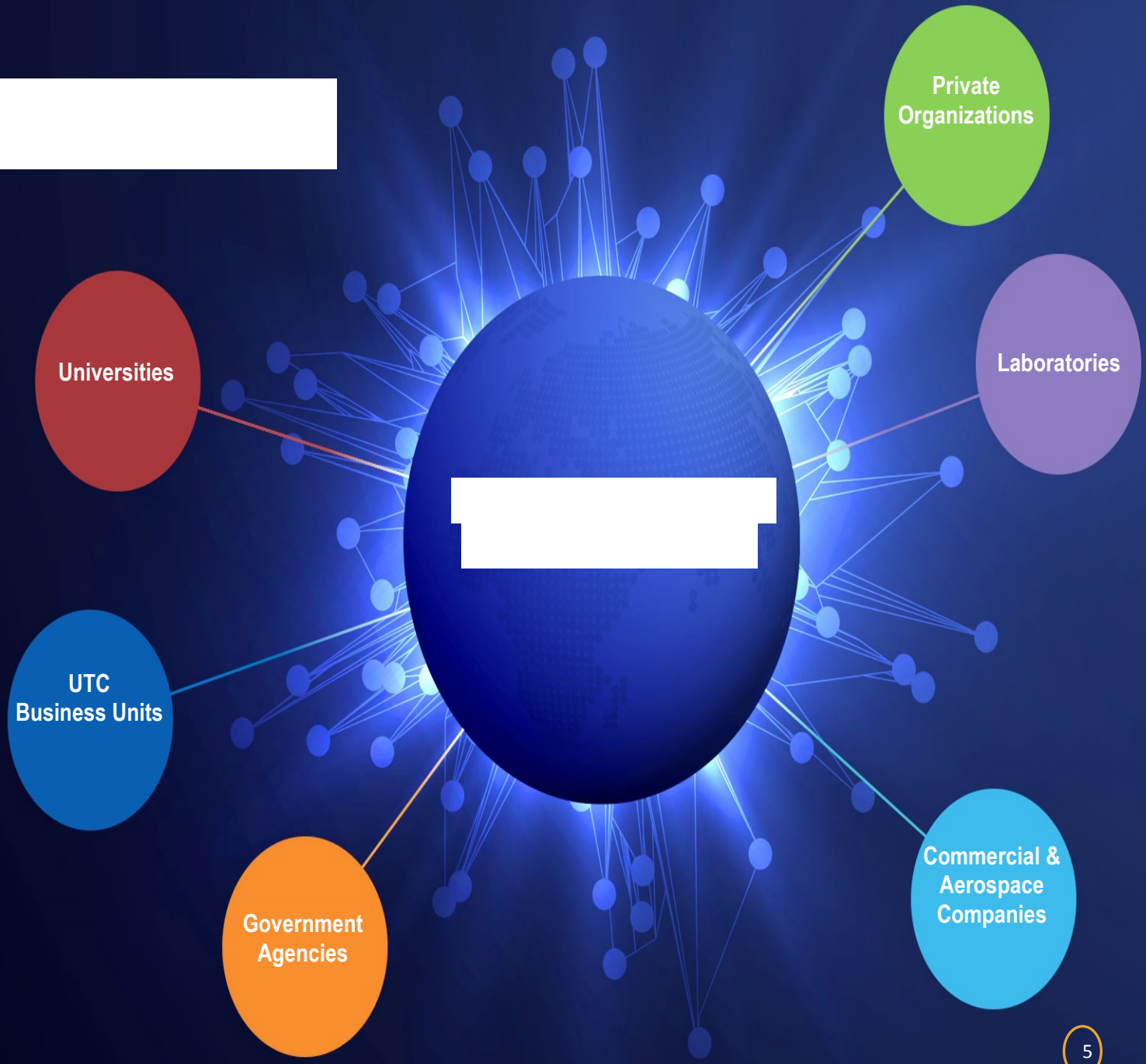
Rome, Italy

Joined UTC in 2012, focuses on model-based design and embedded systems engineering

Defining the

cutting edge

- Advanced Manufacturing
- Aerodynamics & Acoustics
- Applied Mechanics
- Autonomy & Controls
- Combustion
- Cyber Physical Security
- Data Science
- Embedded Intelligence
- Materials
- Networks & Communications
- Power Electronics
- Thermal Management



United Technologies Research Center

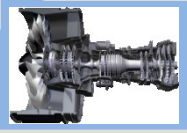
DIRECT WRITE AND PRINTED ELECTRONICS

UTC Applications

Aerospace Systems

Hybrid Manufacturing

Verification



Wireless Systems

Electrical Systems

High Temp Sensors

Heaters

Diagnostics & Prognostics

Integrated Building Systems

Embedded Sensors

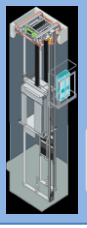
Functional Packaging

Lighting - Displays

Environmental Sensors

Energy Management

Security Systems



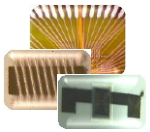
Control & Positioning

Technician Safety

Delivering Solutions

Functional Components

Electronics



Resistive Heaters

Temperature

Sensing

Capacitors

Strain

Logic & Memory

Photonics

Accelerometers

Communications

Antennas

Actuation

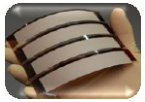
RFID

Piezoelectrics

Touch

Haptics

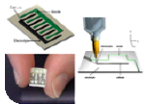
Energy Harvesting



Photovoltaics

Fuel Cells

Energy Storage



Electrophoretics

Piezoelectrics

Batteries

Lighting

OLEDs

Electroluminescent

Displays

Electrochromics

Liquid crystals

Design for Integrated Structures

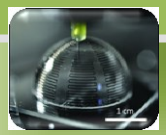
Materials & Structures

Additive Manufacturing

Conductors

Metals

Conformal Integration



Semiconductors

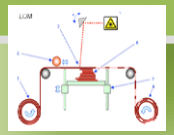
3D Assembly

Ceramics

Large Area Components

Polymers

Lamination

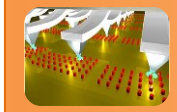


Dielectrics

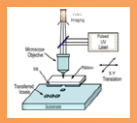
Technologies

Direct Write

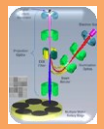
Dip Pen Nanolithography



Laser-Based

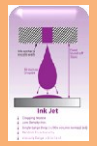


Beam Writing & Lithography



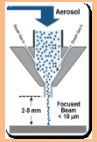
Thermal/Plasma Spray

Ink Jet



Filament-Based

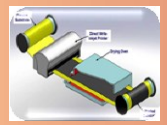
Aerosol Jet



Micro Cold Spray

Roll-to-Roll

DW/R2R

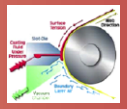


Screen

Gravure

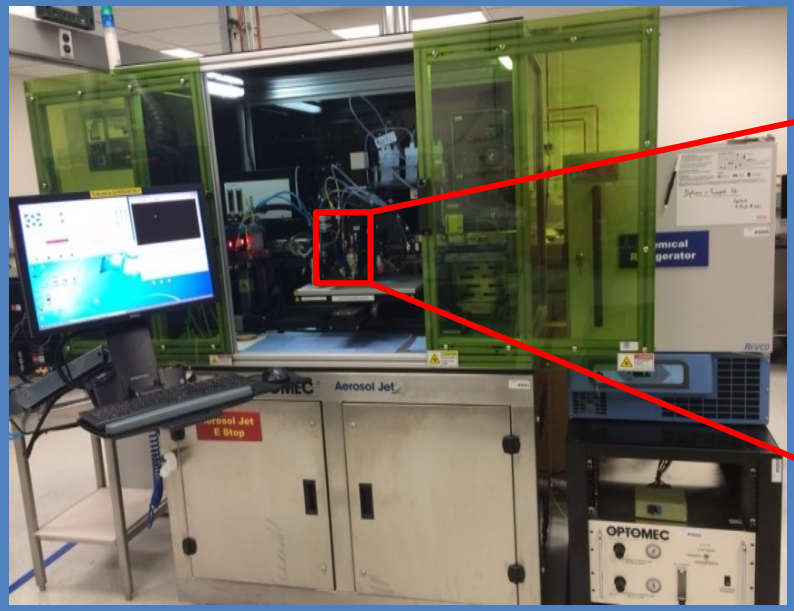
Flexo

Slot Die



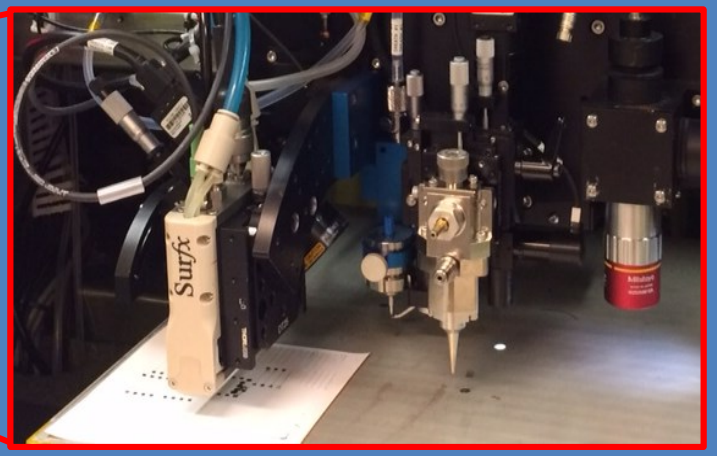
Sensors Manufacturing at UTRC

Multi-head Aerosol Jet System by Optomec



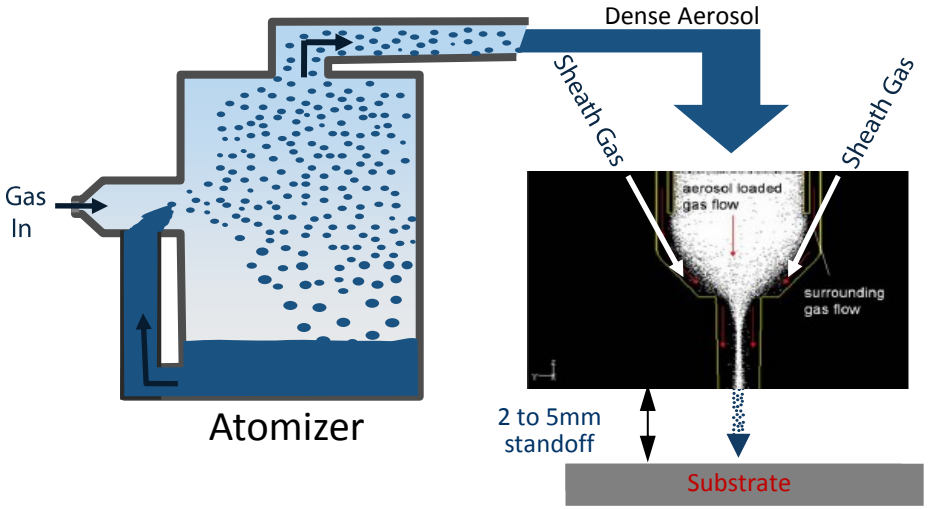
Fine Feature Print Head
(trace width 15µm-300µm)

Laser Cure
(1 W @ 700 nm)



Plasma Head
(Air, N_2, Ar, O_2, H_2, etc.)

Wide Nozzle Print Head
(trace width 0.3-3 mm)



Key benefits

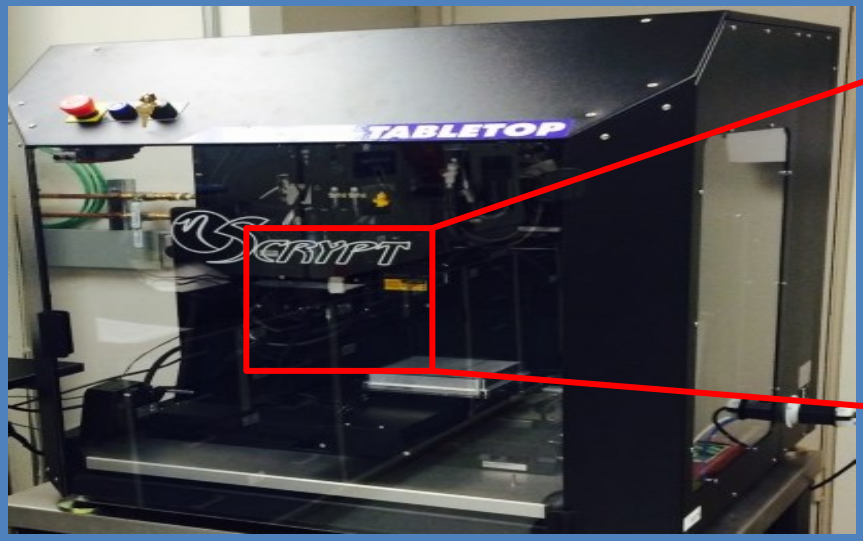
Widest range of working distances and line widths
coaxial laser treatment

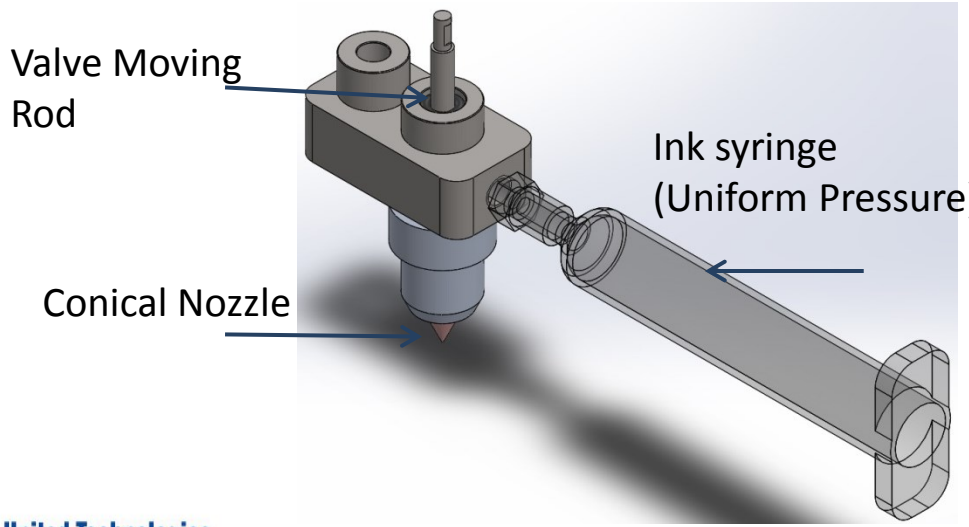
Key drawbacks

Complex apparatus
Requires inks which can be aerosolized

Direct Write Manufacturing of Micro/Nano Sensors

Multi-head Dispensing System by nScrypt





Key benefits

Greatest range of viscosities, simplicity, capable of 3D lattice structures

Key drawbacks

Knowledge of surface topography needed to maintain constant stand-off distance

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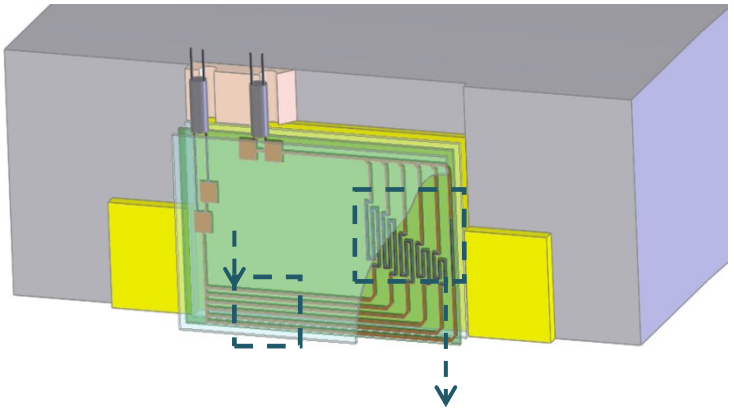
Wear Sensing Concept

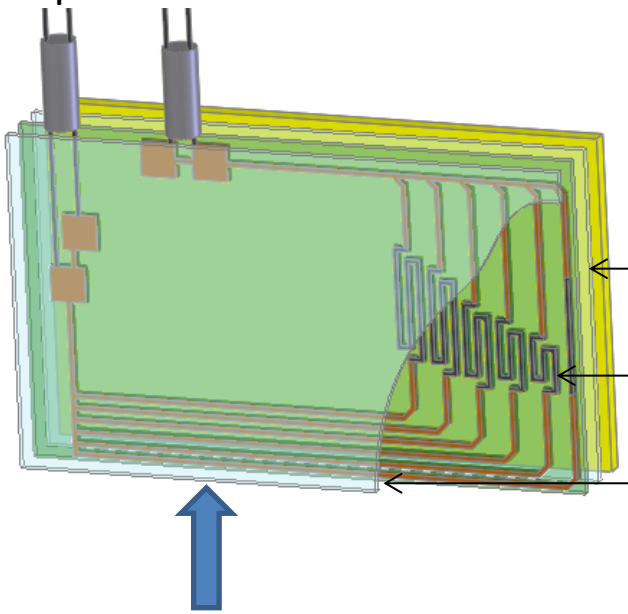
Embedded Wear Sensor



Closely-spaced high conductivity lines

Parallel resistors

4-probe measurement



Insulating layer (**printed**)

Device layer (**printed**)

Encapsulating glass layer (**printed**)

Wear Direction

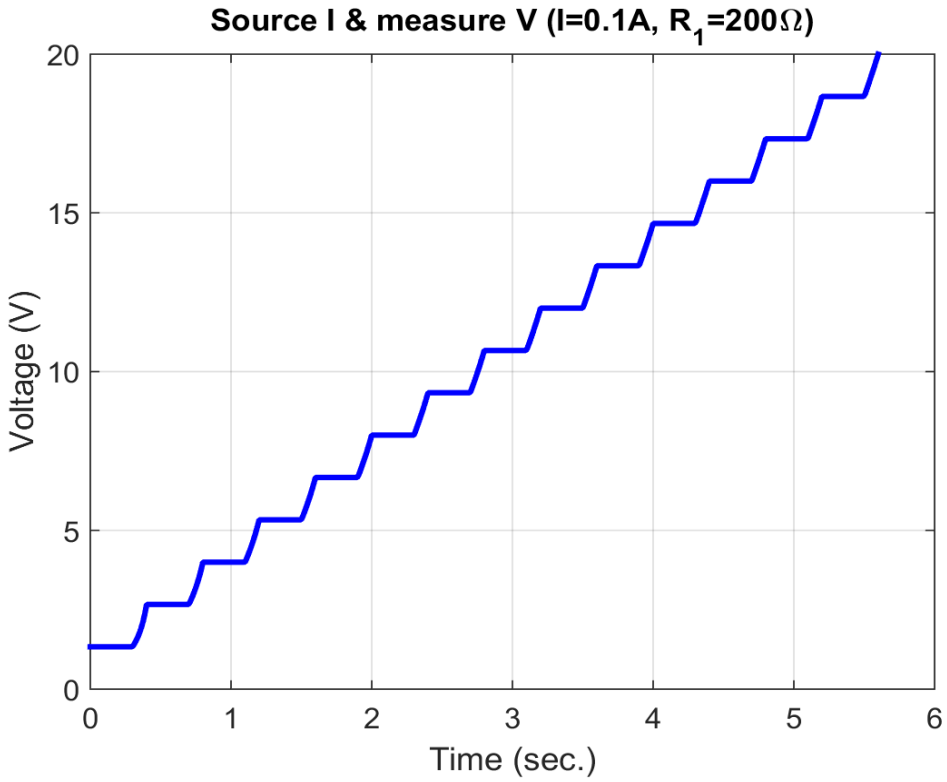
Device Circuit Design & Simulation

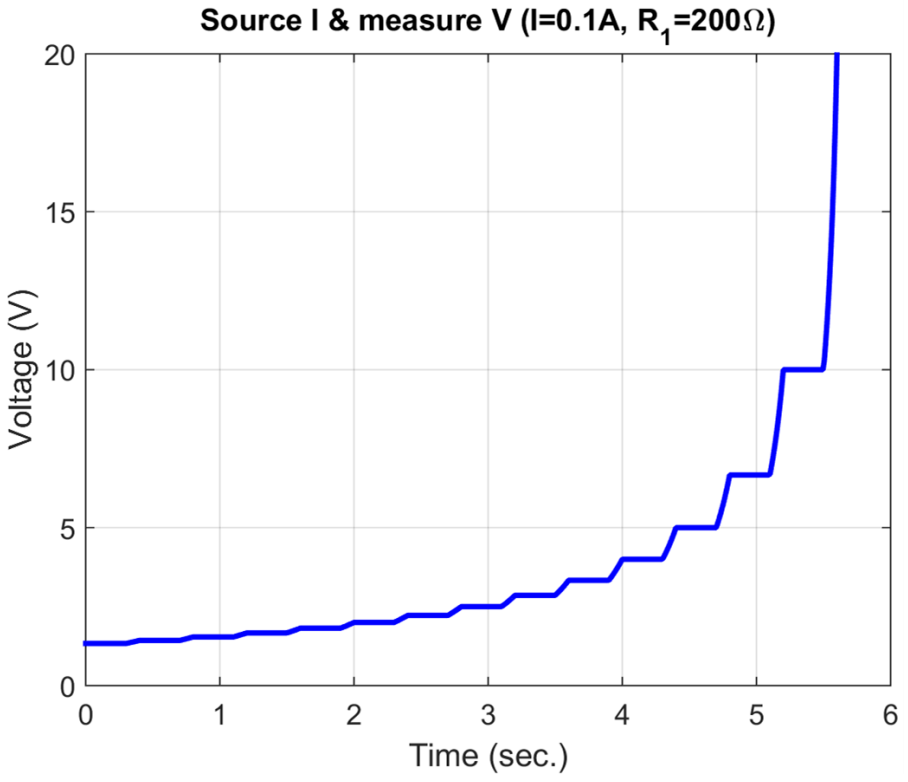
Unequal Value Resistors

1) Equal changes in voltage as blade rubs the coating
2) Change in voltage is higher than noise level
3) Broad range of resistor values needed

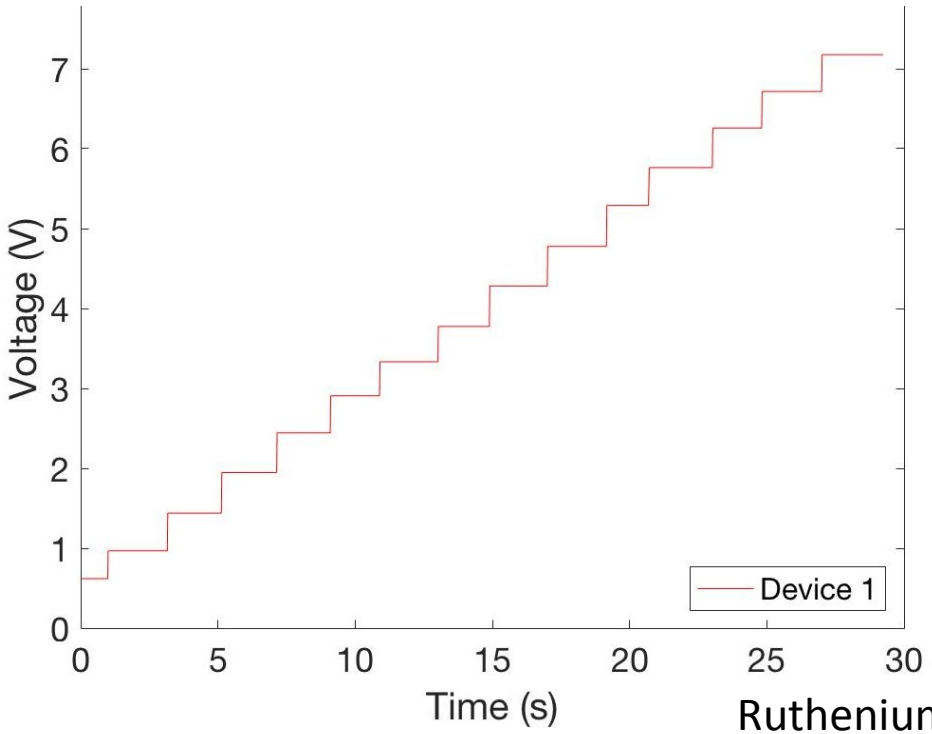
Equal Value Resistors

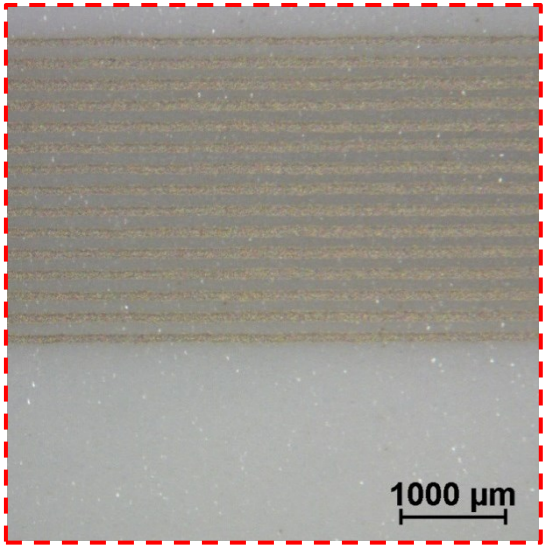
1) Small change in voltage as blade initially rubs the coating
2) Some of the voltage changes could be below the noise level during operation (high temperature)





Wear Sensor Design & Manufacturing



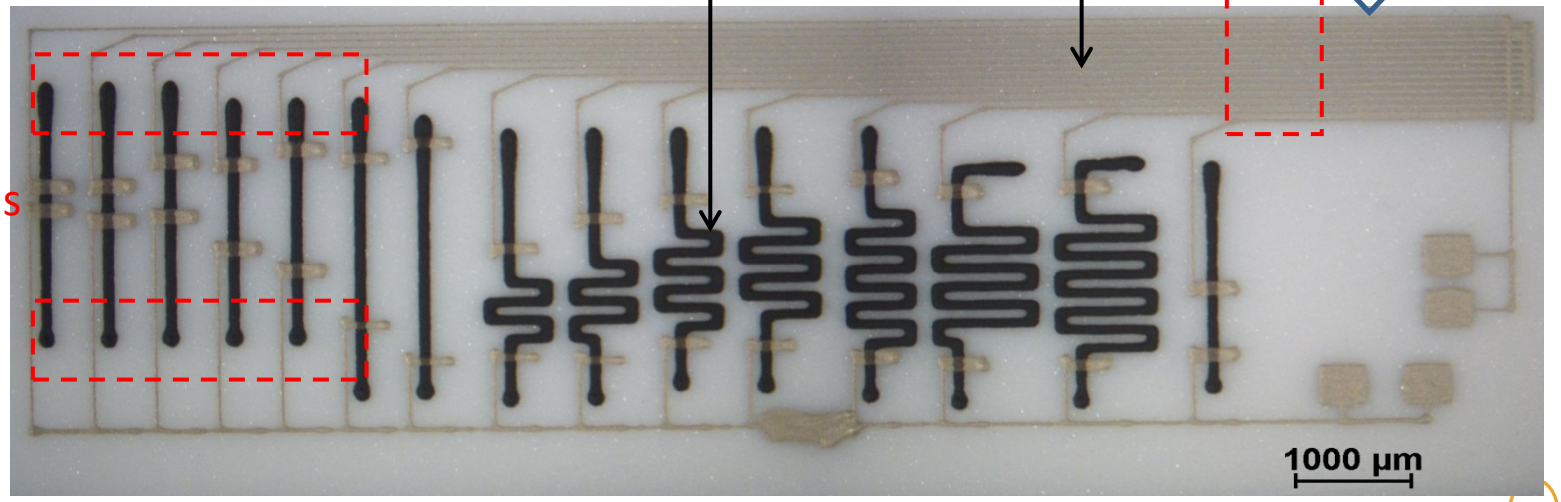


Silver nano-particles

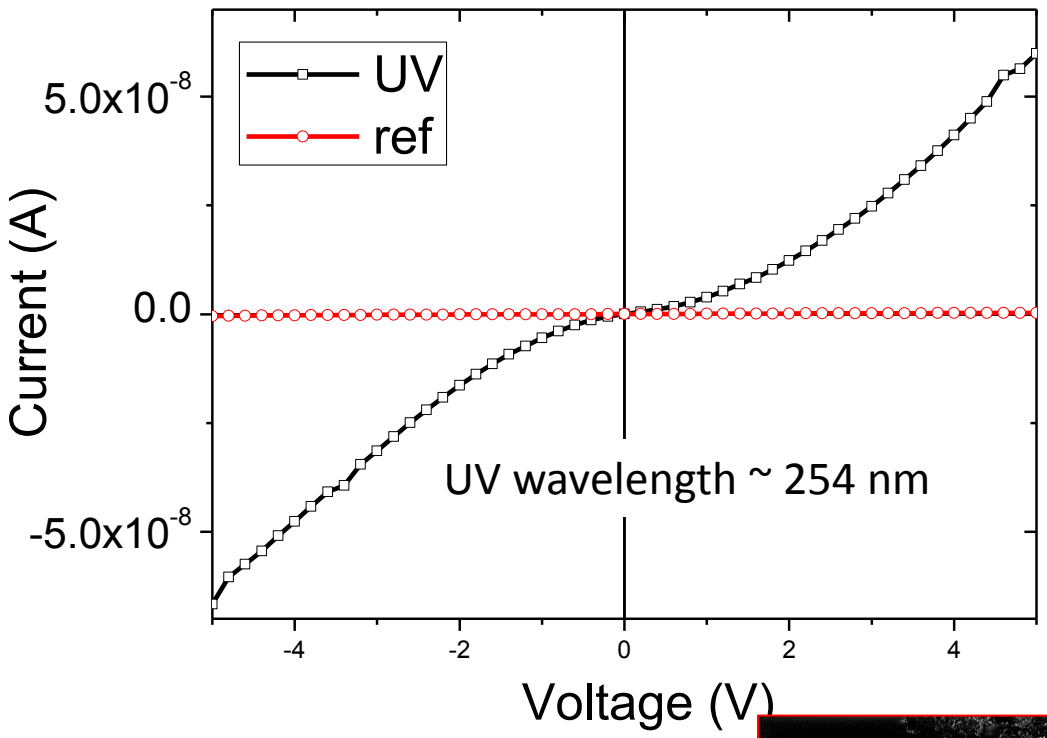
Wear Direction

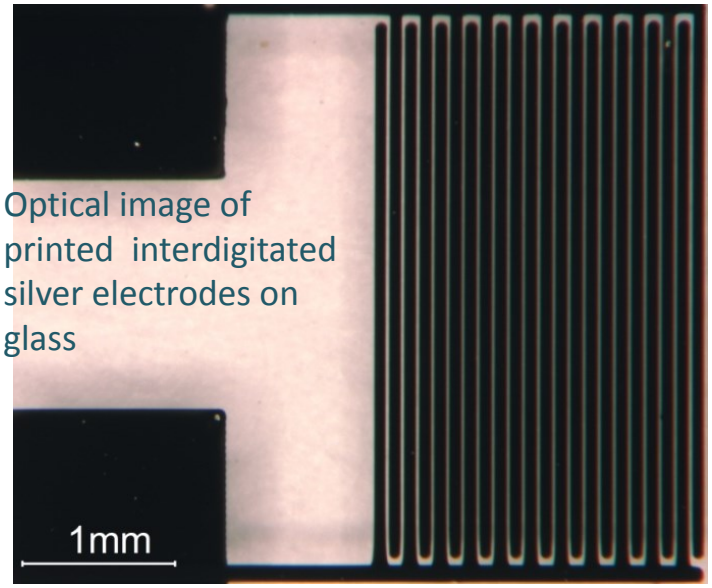
Ruthenium nano-particles

End of lines create large variations



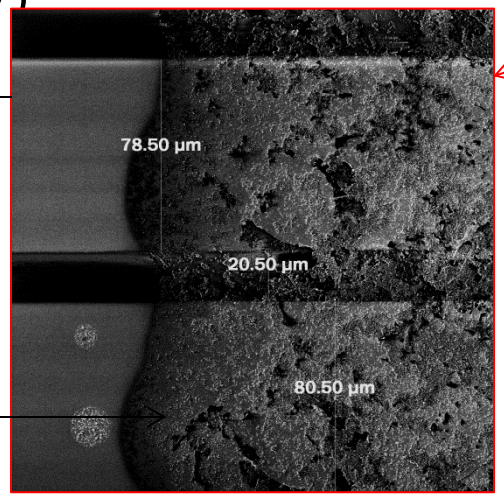
Printed Photoconductive Flame Detector

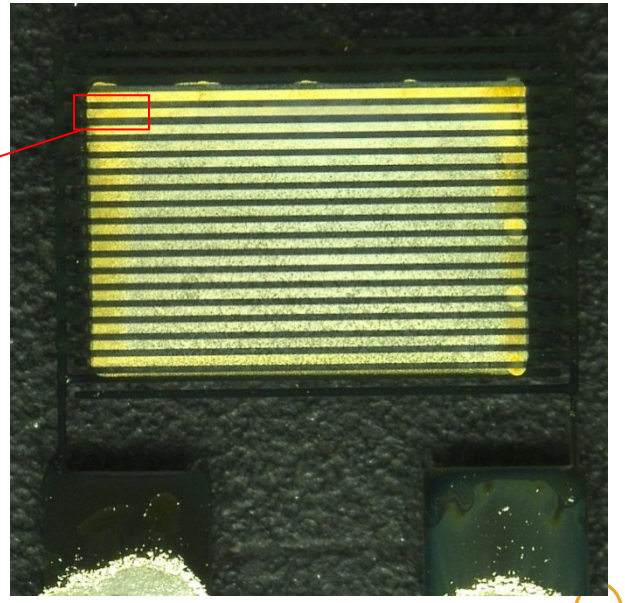




Optical image of printed interdigitated silver electrodes on glass

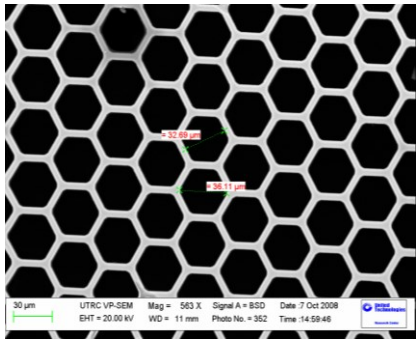
SEM image of all printed Zn_2SnO_3 film and Ag electrodes





Zinc Tin Oxide Film (Zn_2SnO_4)

Low Energy Electron Source (non-radioactive)



supporting mesh
(electron anode)

Thin Film of BN/SiN

Applications:
1) Smoke detection
2) Gas detection

Challenges:
1) Lifetime of CNTs/ZnO

NextFlex Overview

NextFlex is a public-private consortium of companies, academic institutions, nonprofits and governments with a mission to advance US manufacturing of flexible-hybrid electronics.

$50K membership fee
$50K in-kind contribution
Technical council seat (1 vote)
Governing council (1/3 vote)

Proposal Activities

- Project call 1.0 12/2015
- Project call 2.0 04/2016
- Project call 3.0 05/2017

Membership (www.nextflex.us)

CORPORATE

Tier 1

The Boeing Company*

Tier 2

Brewer Science, Inc*

Eastman Chemical Co*

DuPont

General Electric Company

United Technologies Research Center

Tier 3

Acellent Technologies Inc.*

American Semiconductor, Inc.*

Custom Electronics, Inc.*

E Ink Corporation*

Jabil*

Molex, LLC*

On Semiconductor*

ACADEMIC & NON-PROFIT

Tier 1

Auburn Univesity*

Binghamton University*

Georgia Institute of Technology*

University of Massachusetts Lowell*

University of Texas at Austin*

Tier 2

Purdue University*

University of Arizona*

University of Connecticut*

University of Washington*

Washington State University*

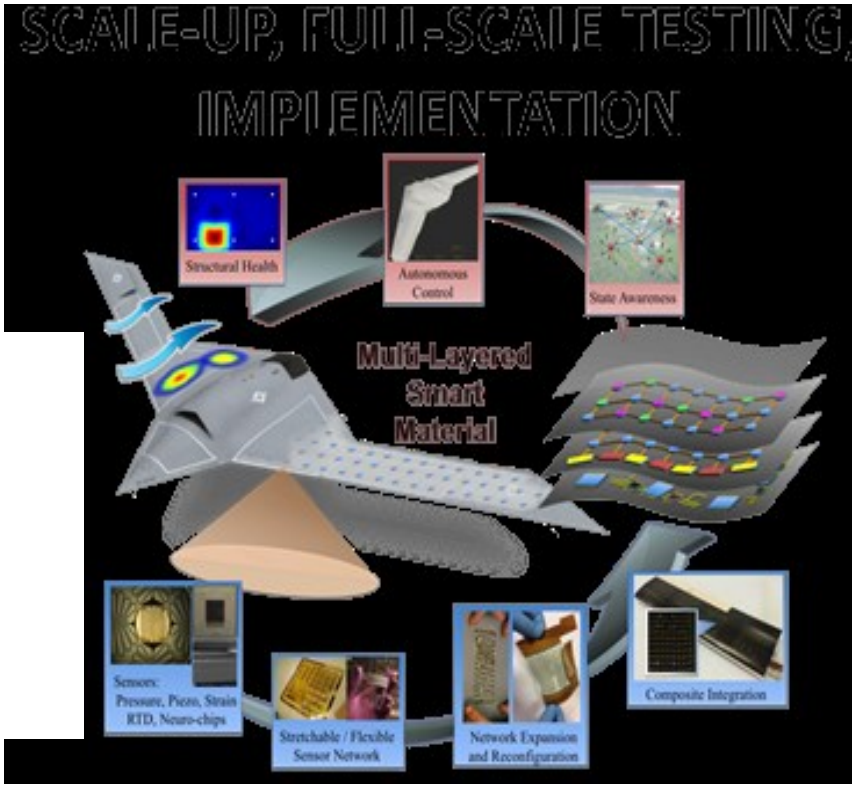
Western Michigan University*

Tier 3

University of Arkansas*

California Polytechnic State University

Distributed and Stretchable Hybrid Asset Monitoring Platform

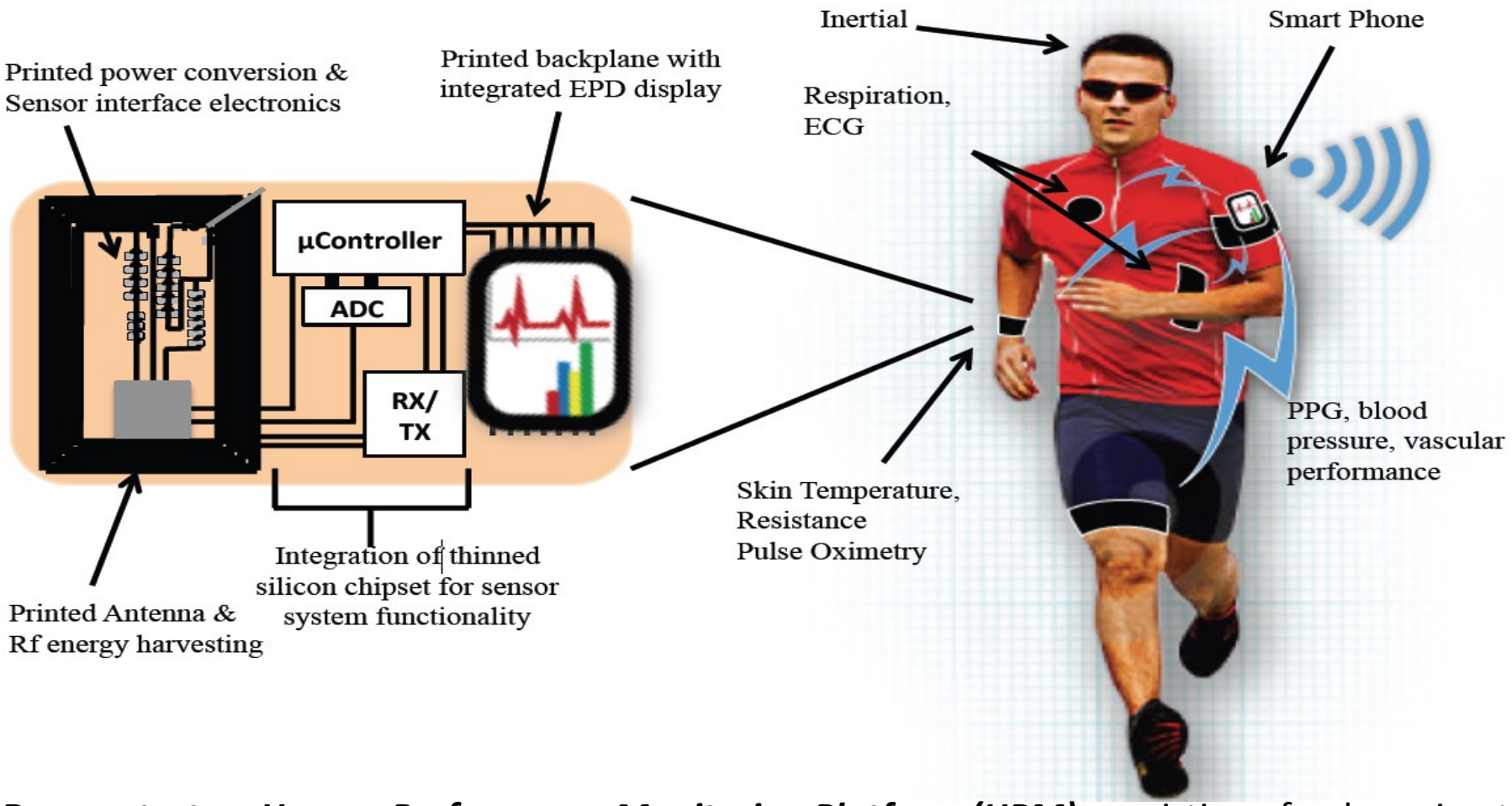


Overall Objectives

- Improve reliability and robustness of sensor nodes and wires using CMOS manufacturing
- Identify and develop pick and place technology
- Tooling for uniform and in-plane stretching and handling of substrates
- Integration and implementation of sensor network qualification tool into manufacturing process
- A demonstrator prototype of value to industry

United Technologies Research Center

Scalable Manufacturing for a Wearable, Integrated Human Performance Monitoring System



Demonstrate a Human Performance Monitoring Platform (HPM) consisting of pulse oximeter and heart rate sensors printed on flexible substrates integrated with conductive trace interconnects. Demonstrator includes integrated power management with energy harvesting, low energy Bluetooth (BLE) with printed antenna architecture, and low-power display and display controller electronic sub-systems.

THANK YOU

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