Flexible Hybrid Electronics for Aerospace Applications

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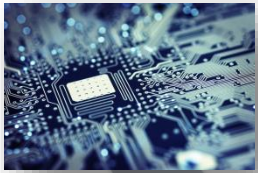
Integrity ★ Service ★ Excellence

AFRL: Turning Science Into Capability

Driven by Service Core Functions

Vectored by Air Force Strategy + S&T Vision/Horizons + Product Center Needs + MAJCOM Needs

6.1 Basic Research



6.2 Applied Research

6.3 Advanced Tech Demo

~ $5B

Science Knowledge → **Technologies** → **Capability Concepts** → **Warfighter**

Outputs:
New Technologies

Outputs:
Mature Technologies

Outputs:
Flagship Capability Concepts

25 Years → *10 Years* → *5 Years* → *1 Year*

Initial Operating Capability Timeline

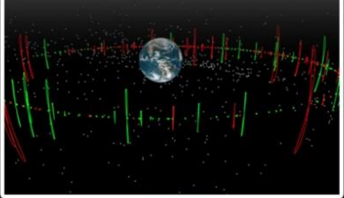
Air Force Research Laboratory Technical Competencies

AF Office of Scientific Research
- Aero-structure power and control
- Physics and electronic
- Mathematics, Information, and life sciences

Aerospace Systems
- Turbine Engines
- High-Speed/Hypersonics
- Space and Missile Prop
- Aeronautical Sciences
- Structural and Control Sciences

Directed Energy
- Lasers
- Beam Control
- High Power Microwaves

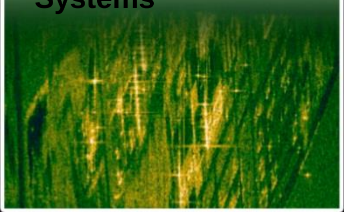
Information
- Computing Architecture
- Information Exploitation
- Command & Control



Human Performance
- Forecasting
- Training
- Decision Making

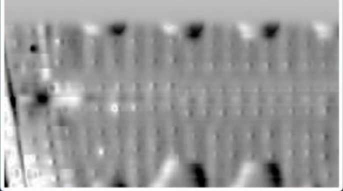
Munitions
- Damage Mech Science
- Fuze Technology
- Munitions AGN&C
- Energetic Materials
- Terminal Seeker Sciences
- Munitions System Effects Science

Sensors
- RF Sensing and Warfare
- EO Sensing and Warfare
- Trust in Complex Systems



Space Vehicles
- Intelligence, Surveillance & Reconnaissance
- Responsive Space
- Space Situational Awareness

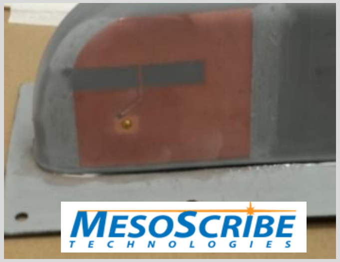
Materials and Manufacturing
- Materials & Processes
- Materials Applications
- Manufacturing Technology



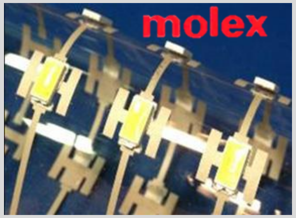
What are Flexible Hybrid Electronics?

Convergence of Electronics Manufacturing Services & Roll-to-Roll / Digital Printing Industries

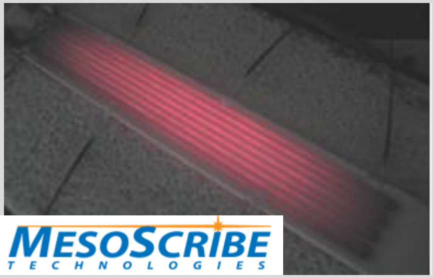
Printed Electronics



Antennas

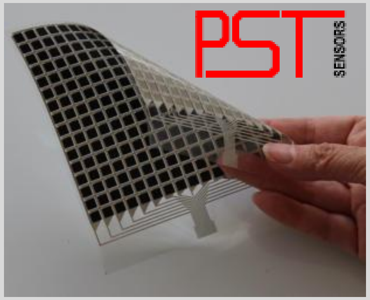


Passive Elements



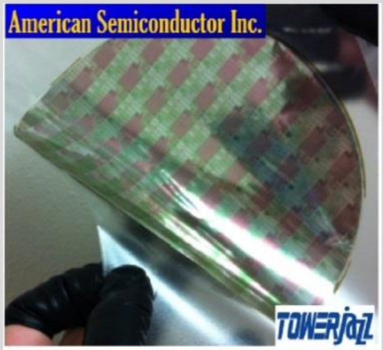
Heaters

Batteries & Solar



Sensors

Placed Electronics



Silicon ICs

High Perf. Elements

How could Flexible Hybrid Electronics Impact the Air Force?

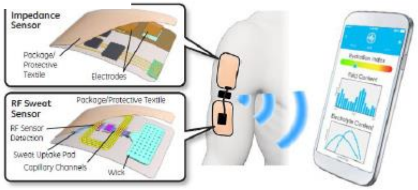
Man-Machine Interface

Airman performance limits capability in MANY military missions ….and new technologies are needed to sense, assess and augment the "Airman-in-the-Loop"

- **Information Overload**
- **Missed Intelligence**
- **Threat/Danger Missed**

Today

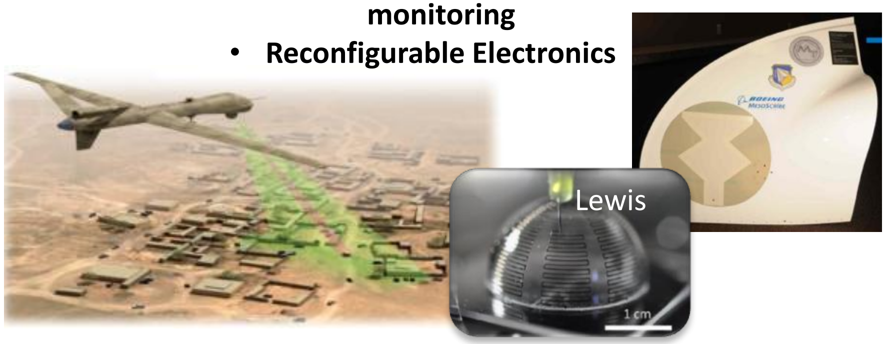
Future



Embedded/Conformal Electronics for ISR/EW

Information and tracking in contested environments is foundational to decision making and force projection

- **Communication (conformal apertures)**
- **Distributed electronics for feedback and structural health monitoring**
- **Reconfigurable Electronics**



Integrated & Flexible Power

Energy limits operational capabilities and mission impact for unmanned vehicles and wearable electronics

Issues:
- **Cost & Weight**
- **Scale-up**
- **Durability**

Integrated Power harvesting, storage, and management

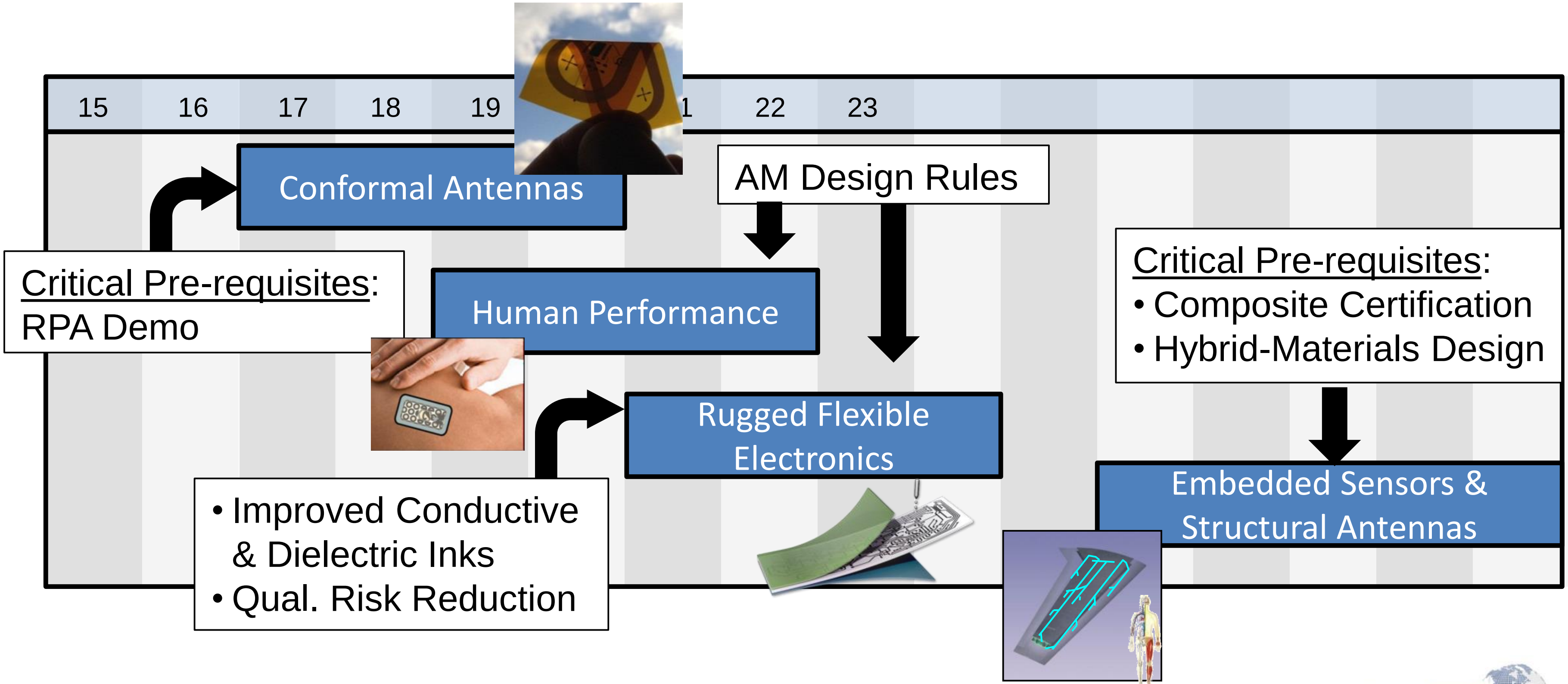
Survivable Electronics

Precision effects with smaller, low profile munitions pressing requirement for current and future platform effectiveness

- **Robust electronics in extreme environments (shock, vibration, thermal)**

Technology Development Strategy

- **Accelerate development and transition of FHE technologies to Air Force functional materials community**
- **Phased plan for FHE technology insertions**



Direct-Write Conformal Antenna on MQ-9

Need

- Additional communications capabilities are required on the MQ-9.
- Conventional approaches to add antennas often requires new tooling (high cost, long lead time) and drilling of holes in the carbon fiber structure.
- Fuselage is crowded with apertures for communications, leading to co-site interference.

GENERAL ATOMICS AERONAUTICAL

MESOSCRIBE TECHNOLOGIES

Technical Approach

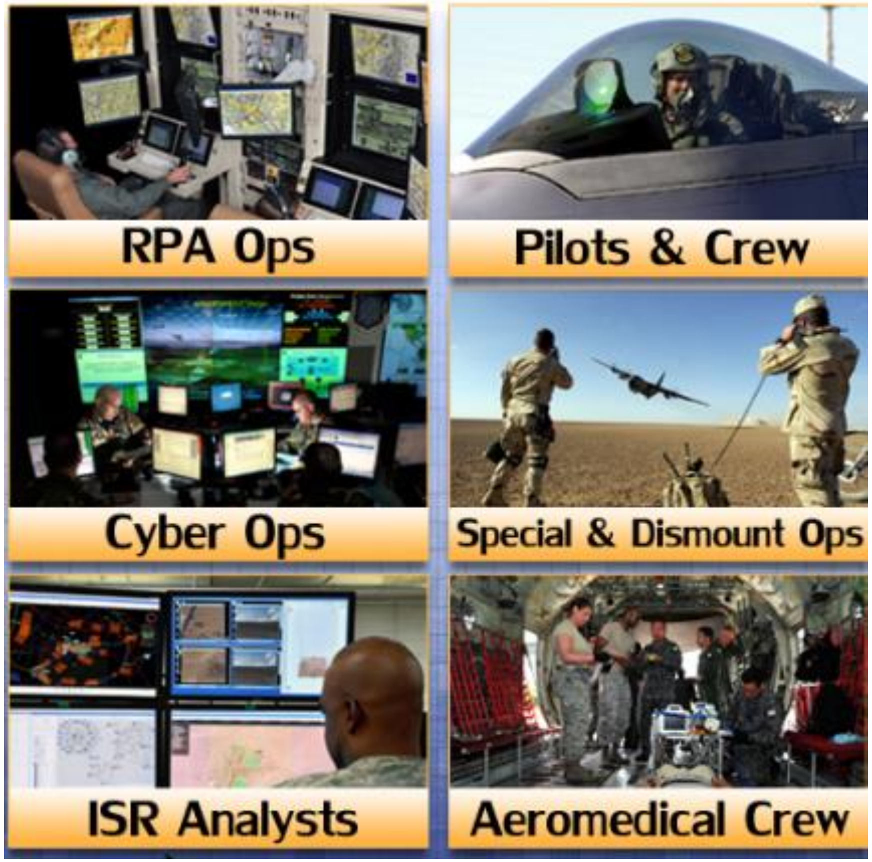
- Retro-fit existing fleet with conformal antennas by simply replacing existing servo covers.
- Design and direct-write Cu antenna onto servo cover using plasma spray technique.
- Minimize co-site interference by installing onto unique locations of aircraft.

Phase I Results

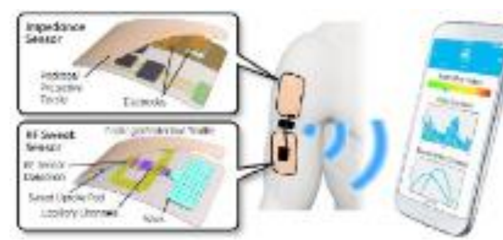
- Indoor range data showed VSWR and directivity comparable with COTS components.
- Cu removal from part required a grinder.
- Significant directivity benefit in cross-polarization performance due to location

Air Force Needs for Performance Monitoring

AF Mission Areas



- COTS products focus on primarily on motion and cardio-respiratory sensing, *with innovation/IP primarily targeting algorithm development*
- AF needs advanced biosignatures sensing for cognition, stress, fatigue, etc.
- Consumer products will not survive challenging AF environments
- AF needs unobtrusive devices with chemical and mechanical durability



Traditional electronic components and packaging will not meet Air Force requirements.

Flexible Materials & Devices

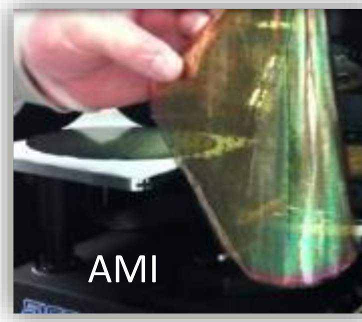
Research Leader: Dr. Benji Maruyama

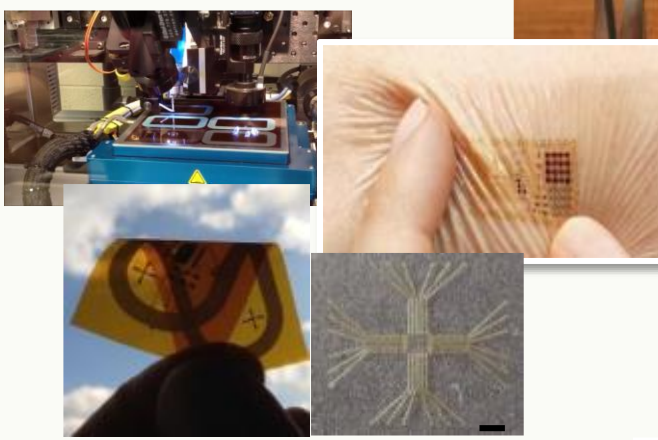
Developing critical Materials & Processes to enable flexible hybrid electronic systems for airman performance monitoring

……..lightweight, flex/stretch, conformal, multifunctional, robust, autonomous

Novel materials

- Inherently strain-resilient
- Wafer thinning
- Liquid metals



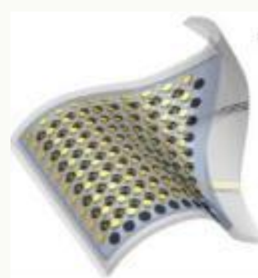


Conformal & integrated printing approaches

- Rapid design cycle
- Enables retrofit
- Tailored materials and properties

Innovative packaging schemes

- Flex *and* performance
- Ensure survivability



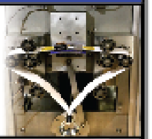
Understanding Reliability and Physics of Failure for Wearable Devices

Project Team

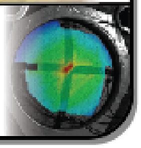
BINGHAMTON UNIVERSITY
STATE UNIVERSITY OF NEW YORK

Prior Work

BU: Environmental FlexTesting (NBMC)



DuPont: Deformation Analysis of Stretchable Materials



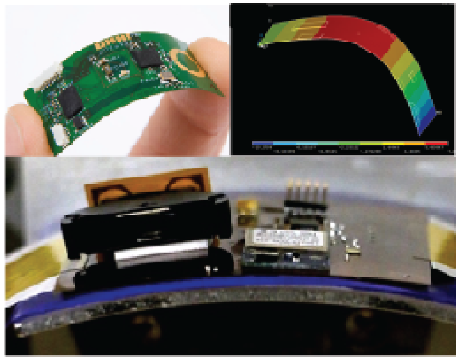
Assessment & Optimization of the Reliability of Wearable Performance Monitors

(24 months, $3.1MM)

Objective: Develop infrastructure for testing and understanding the physics of failure for wearable human health/performance monitoring devices in a variety of use conditions

Technical Approach:

- Evaluate wearable monitoring devices by identifying operation ranges, corresponding stresses & conducting appropriate reliability testing
- Develop physics based failure models validated by experiments on WPMs & custom designed test vehicles
- Develop models and appropriate accelerated testing capabilities for life prediction



Technical Challenges:

- The wearable performance monitoring devices may not reflect realistic defects and/or d process variations and baseline performance may remain unknown
- Accelerated tests may cause different damage mechanisms than in use, leading to incorrect life predictions
- Mechanistic models may not apply to the selected WPMs and input materials properties for the models may be lacking

Deliverables & Benefits:

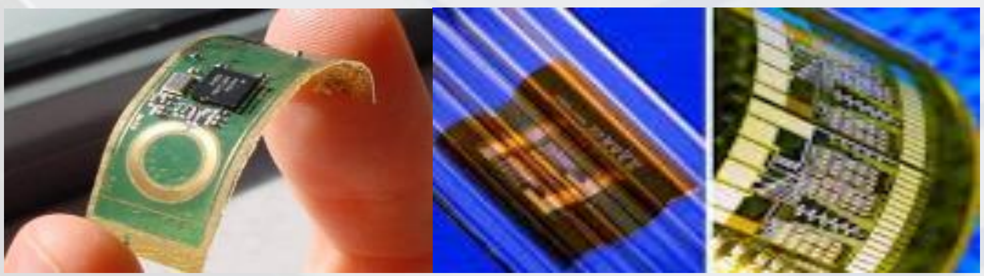
- Fundamental understanding of the physics of failure in wearable performance monitoring devices under operationally relevant conditions
- Recommendations for design, manufacturing and quality assessment of next generation robust, high performing WPMs
- Centralized Reliability Labs with broad simulation and testing capabilities at Binghamton University, available to NextFlex Community for quality & reliability assessment of WPMs under military, athletic & clinical use conditions

- AFRL program executed through NextFlex
- Program Manager: Laura Sowards

NEXTFLEX

NextFlex: America's Flexible Hybrid Electronics Manufacturing Institute

Established: August 2015
Lead: FlexTech Alliance
Hub location: San Jose, California
Members: 72 in 25 states
Federal Funding: $75M
Cost Share: > $95M
Government agencies engaged: 17



Catalyzing a robust and innovative manufacturing ecosystem at the intersection of the electronics and high performance printing industries.

<u>Focus:</u> Combining the entrepreneurial & innovative culture of Silicon Valley with a national network of regional & technology nodes to commercialize FHE technology through manufacturing advancements in integrated printing & packaging, system design tools, materials scale-up, thinned device processing, and reliability testing & modeling.