Flexible and Hybrid Electronics Institute for Manufacturing Innovation

Organizing Considerations & Concepts

Technical POC

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Business POC

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George White, Senior Director Industry Collaboration

Georgia Institute of Technology

Fibers & Textiles Workshop

Attributes of a successful IMI

***A national focal point for supporting the translational activities that bridge the gap between fundamental research and manufacturing*:**

- Long-term partnership between industry and universities, enabled by government;
- A sustained focus on technology innovation with a strong brand identity and reputation;
- Ability to identify critical emerging technologies with transformational impact;
- Capacity to translate these technologies into products and businesses for the market;
- Ability to form effective teams of industrial and academic experts from multiple disciplines to solve difficult problems and to educate students as members of such teams.
- Viable business model based on commercial services & products

The IMI focuses on national impact

- National focal point for high impact innovations for commercial and defense applications
- Focused on translation of emerging, high potential technologies to commercial practice (Technology Readiness Levels (TRLs) 4–7 and Manufacturing Readiness Levels (MRLs) 4 to 7.)
- Federal funding of $30m to $100m over 5 years to co-fund initial translational innovation projects
- Minimum 1:1 cost share from industry to match government funds over 5 years;
- Leverage existing facilities and capabilities
- Self-sustaining free standing institute by year 5
- Requires establishing a separate 501(c)(3) entity in “partnership” with a “cluster of industry, academia and associated institutes”
- Prohibits building new or rehabilitating facilities at government cost

Key Elements in a Successful IMI Bid

Depth & Reputation for TRL 4-7 Transition in Target Technology

Regional Economic Synergy & Political Support

Compelling & Realistic Business & Technical Strategy

Viable Industry Led & Driven Consortia Structure

Established Collaborations with Technology Leaders

Seasoned Enterprise Leadership with Operating Experience

Supporting Administrative Structure

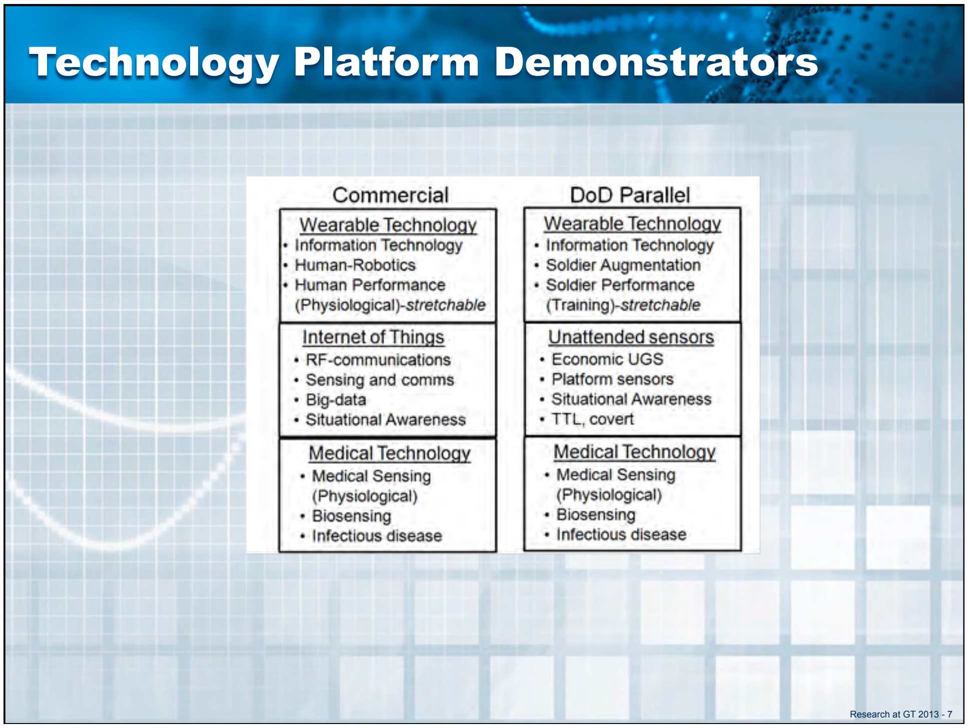
IMI Comparison and Contrast

Criteria	America Makes	DMDI Institute	LIFT LM3I	Advanced Composites	Power Electronics	Integrated Photonics	Flexible Hybrid Electronics	Smart Mfg.	Fibers & Textiles
Federal 5 yr. Funding	$50M ($30M)	$70M	$70	$70M	$70m	$100M	$75M	TBD	TBD
Industry Match	$39M 1:1.3	$106M 1:1.51	$78m 1:	$180M	$70m	$100M min.	$75M min.	1:1 min.	1:1 min.
Parent Corporation	National Center for Defense Manufacturing and Machining	UI Labs	Edison Welding Institute	University of Tennessee / ORNL	NC State	TBD	TBD	TBD	TBD
Collaborators	Industry 50 Univ. 28 Other 16	Industry 41 Univ. 23 Other 9	Industry 36 Univ. 12 Other 18	Industry 41 Univ. 23 Other 9	Industry 18 Univ. 7 Other	Industry Univ. Other	Industry Univ. Other	Industry Univ. Other	Industry Univ. Other
Technology Focus Areas	Industry Nominated	Industry Nominated	Industry Nominated	Industry Nominated	Industry Nominated	DOD Topic Areas	Industry Nominated	TBD	TBD
Lead Agency	USAF/ AFRL	ARMY/ AMRDEC	DON/ ONR	DOE Adv. Mfg. Office	DOE Adv. Mfg. Office	USAF / AFRL	USAF/ AFRL	DOE /EERE Adv. Mfg. Office	

DOD Expectations for an FHE-IMI

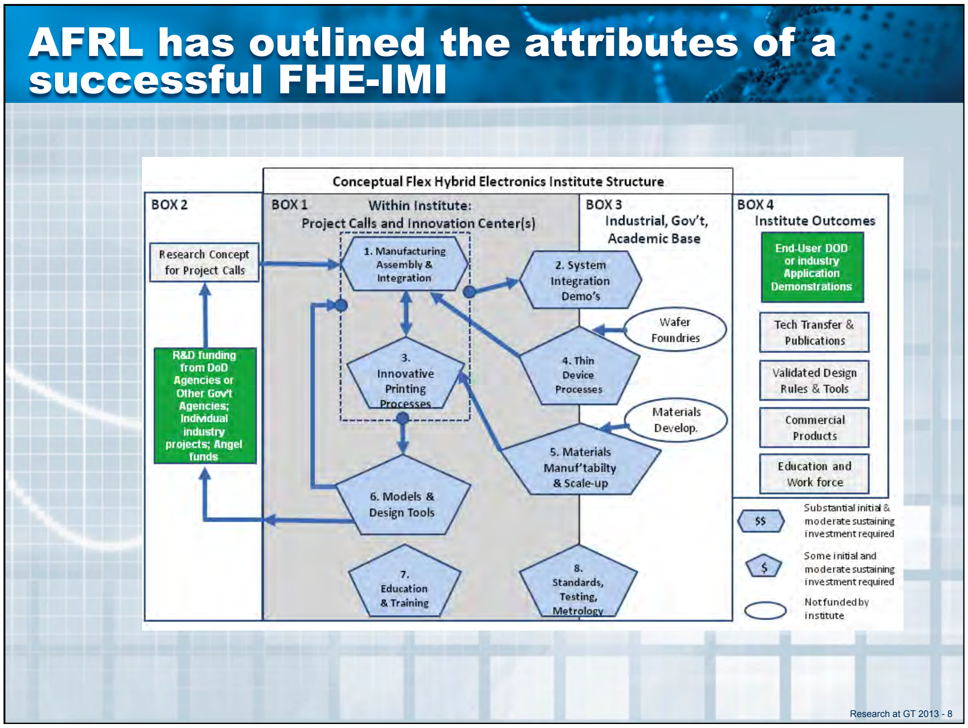
Enable a new manufacturing sector of the US economy:

- Support an end-to-end ‘ecosystem’ in the U.S. for flexible hybrid electronics manufacturing
- Include domestic manufacturing development facility(ies) to scale-up manufacturing processes
- Technology platform demonstrations based on:
  - Validated computational design tools,
  - Automated component-level integration,
  - Integrated computational materials engineering (ICME),
  - Assembly, and in-situ process development and test
- Establish integrated FHE standards, metrology, quality systems, and in-situ functional testing capabilities
- Train a new workforce through educational outreach programs and workforce re-training



Technology Platform Demonstrators

Commercial	DoD Parallel
<u>Wearable Technology</u> • Information Technology • Human-Robotics • Human Performance (Physiological)-*stretchable*	<u>Wearable Technology</u> • Information Technology • Soldier Augmentation • Soldier Performance (Training)-*stretchable*
<u>Internet of Things</u> • RF-communications • Sensing and comms • Big-data • Situational Awareness	<u>Unattended sensors</u> • Economic UGS • Platform sensors • Situational Awareness • TTL, covert
<u>Medical Technology</u> • Medical Sensing (Physiological) • Biosensing • Infectious disease	<u>Medical Technology</u> • Medical Sensing (Physiological) • Biosensing • Infectious disease



AFRL has outlined the attributes of a successful FHE-IMI

Conceptual Flex Hybrid Electronics Institute Structure

BOX 2

Research Concept for Project Calls

R&D funding from DoD Agencies or Other Gov't Agencies; Individual industry projects; Angel funds

BOX 1 Within Institute: Project Calls and Innovation Center(s)

1. Manufacturing Assembly & Integration

3. Innovative Printing Processes

6. Models & Design Tools

7. Education & Training

BOX 3 Industrial, Gov't, Academic Base

2. System Integration Demo's

Wafer Foundries

4. Thin Device Processes

Materials Develop.

5. Materials Manuf'tabilty & Scale-up

8. Standards, Testing, Metrology

BOX 4 Institute Outcomes

End-User DOD or industry Application Demonstrations

Tech Transfer & Publications

Validated Design Rules & Tools

Commercial Products

Education and Work force

$$ Substantial initial & moderate sustaining investment required

$ Some initial and moderate sustaining investment required

○ Not funded by institute

Features of FHE-IMI

1. Manufacturing, Assembly and Integration

- Integration of foundry-based components with printed components and interconnects
- Pick and place tools must be compatible with both thinned devices and flexible substrates

2. System Integration Demonstrators

- Thermal management, registry, interconnects
- Packaging concepts, demonstrations, and tools to simultaneously optimize performance, manufacturability, and survivability
- Encapsulation challenges

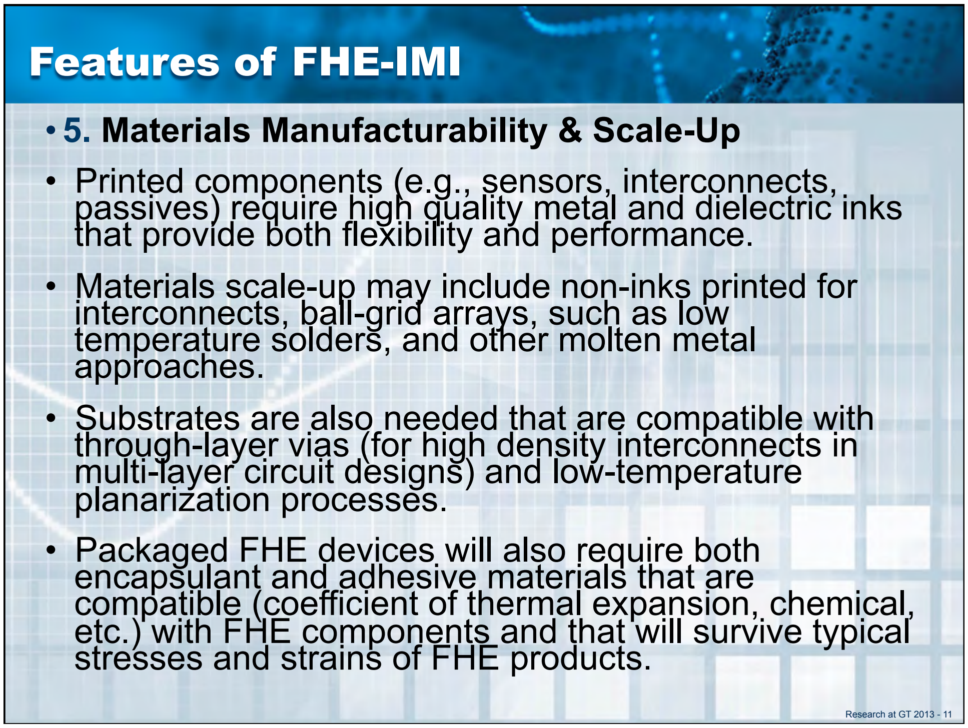
Features of FHE-IMI

3. Innovative Printing Processes

- Screen printing and lead/lead-free, copper printed BGAs or interconnects
- Emerging printing processes such as Inkjet, Extrusion, Aerosol Jet, Micro dispensing
- Challenges – feature size reduction for higher I/O die, precise registration for multi-layer devices, printing on surfaces with various surface energy and roughness, and depositing vias in multi-layer circuit boards

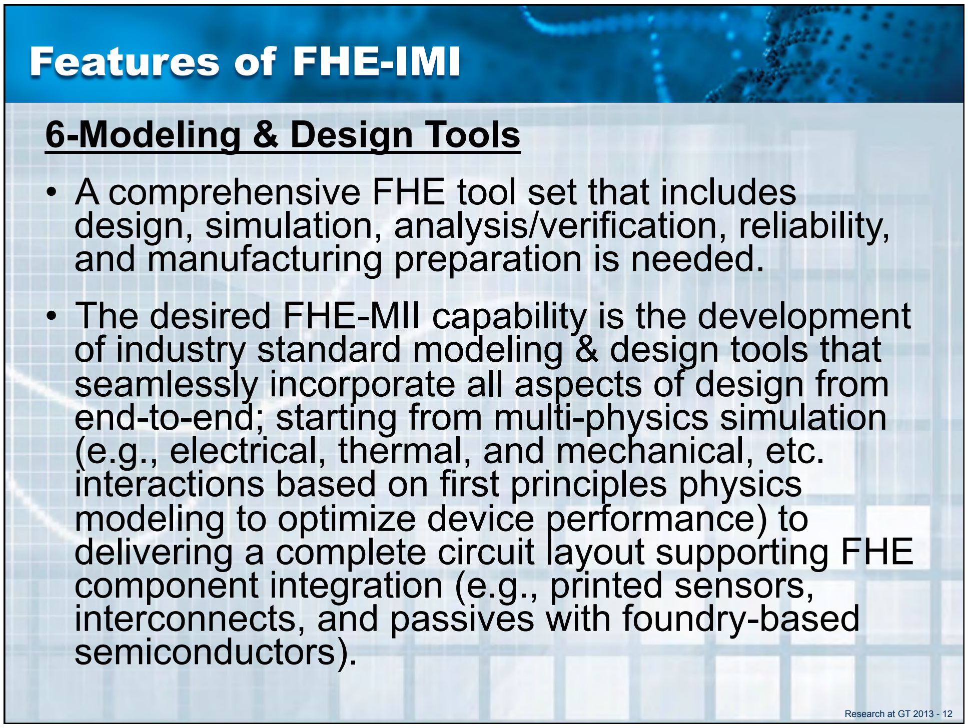
4. Thin Device Processes

- Thin device designs to mitigate interconnect problems
- Optimize and mature thin device manufacturing process



Features of FHE-IMI

- **5. Materials Manufacturability & Scale-Up**
- Printed components (e.g., sensors, interconnects, passives) require high quality metal and dielectric inks that provide both flexibility and performance.
- Materials scale-up may include non-inks printed for interconnects, ball-grid arrays, such as low temperature solders, and other molten metal approaches.
- Substrates are also needed that are compatible with through-layer vias (for high density interconnects in multi-layer circuit designs) and low-temperature planarization processes.
- Packaged FHE devices will also require both encapsulant and adhesive materials that are compatible (coefficient of thermal expansion, chemical, etc.) with FHE components and that will survive typical stresses and strains of FHE products.



Features of FHE-IMI

6-Modeling & Design Tools

- A comprehensive FHE tool set that includes design, simulation, analysis/verification, reliability, and manufacturing preparation is needed.
- The desired FHE-MII capability is the development of industry standard modeling & design tools that seamlessly incorporate all aspects of design from end-to-end; starting from multi-physics simulation (e.g., electrical, thermal, and mechanical, etc. interactions based on first principles physics modeling to optimize device performance) to delivering a complete circuit layout supporting FHE component integration (e.g., printed sensors, interconnects, and passives with foundry-based semiconductors).

Features of FHE-IMI

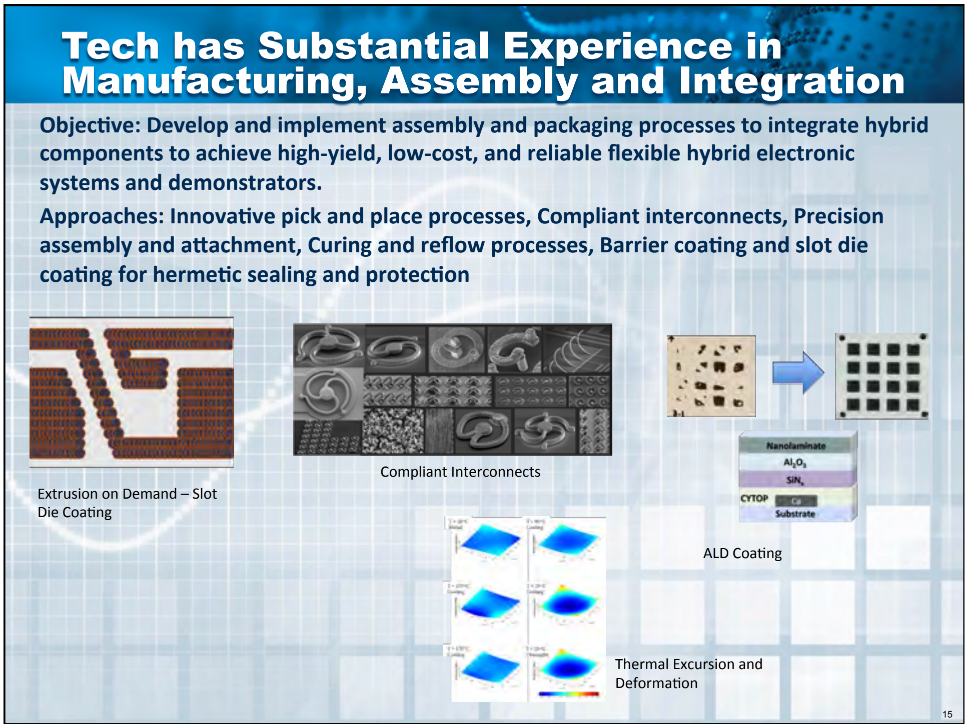
7-Education & Training

- Curriculum development related to this Institute should include (but not be limited to): materials, mechanical, and electrical engineering; device physics; computer-aided electronic device modeling, simulation, and design; electronics printing;
- Partnering with existing science, technology, engineering, and mathematics (STEM) related activities
- An integral aspect to Education & Training is free or low-cost access to the design tools and software that can enable academic institutions and publicly funded research laboratories to participate in the FHE design cycles that would otherwise be inaccessible due to high costs.

Features of FHE-IMI

8-Standards, Testing, and Metrology

- In-line, high-speed, and automated quality control tools are needed to monitor performance (e.g., conductivity) as well geometry/registration of the multi-component devices.
- Durability testing should evaluate, for example, the mechanical, thermal, and chemical response of FHE products. Although standards, testing, and metrology are well-established for traditional PCBs, FHE manufacturers have only begun to consider standards for new materials sets and manufacturing processes as well as the metrology needed to test FHE devices.
- Key outcomes of the FHE-MII will be industrially adopted FHE standards as well as validation/maturation of in-line metrology tools.



Tech has Substantial Experience in Manufacturing, Assembly and Integration

Objective: Develop and implement assembly and packaging processes to integrate hybrid components to achieve high-yield, low-cost, and reliable flexible hybrid electronic systems and demonstrators.

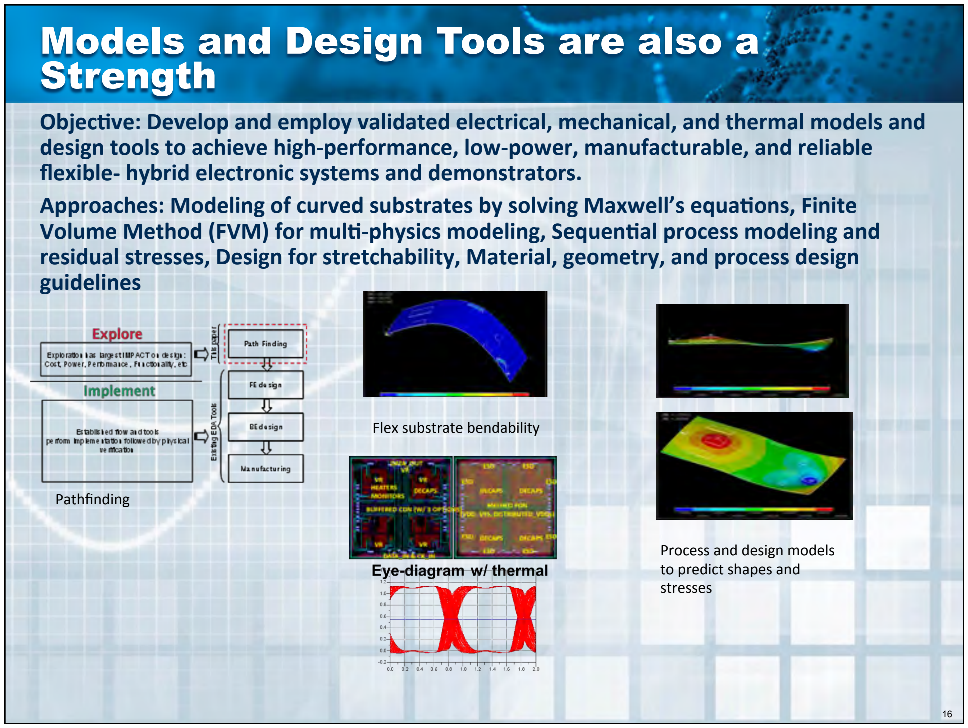
Approaches: Innovative pick and place processes, Compliant interconnects, Precision assembly and attachment, Curing and reflow processes, Barrier coating and slot die coating for hermetic sealing and protection

Extrusion on Demand – Slot Die Coating

Compliant Interconnects

ALD Coating

Thermal Excursion and Deformation



Models and Design Tools are also a Strength

Objective: Develop and employ validated electrical, mechanical, and thermal models and design tools to achieve high-performance, low-power, manufacturable, and reliable flexible- hybrid electronic systems and demonstrators.

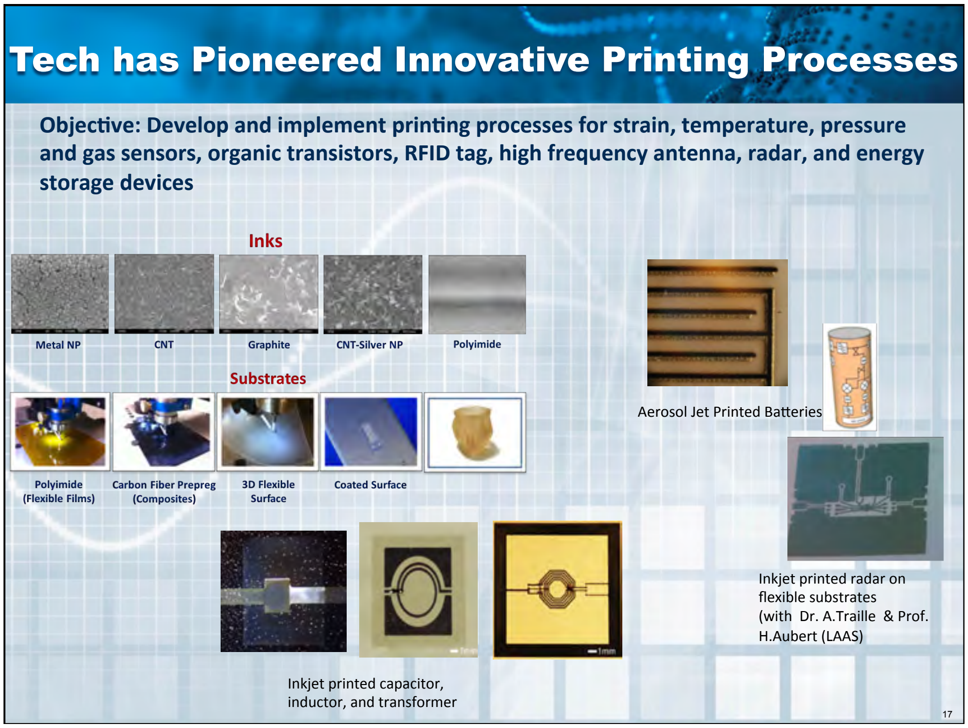
Approaches: Modeling of curved substrates by solving Maxwell's equations, Finite Volume Method (FVM) for multi-physics modeling, Sequential process modeling and residual stresses, Design for stretchability, Material, geometry, and process design guidelines

Pathfinding

Flex substrate bendability

Eye-diagram w/ thermal

Process and design models to predict shapes and stresses



Tech has Pioneered Innovative Printing Processes

Objective: Develop and implement printing processes for strain, temperature, pressure and gas sensors, organic transistors, RFID tag, high frequency antenna, radar, and energy storage devices

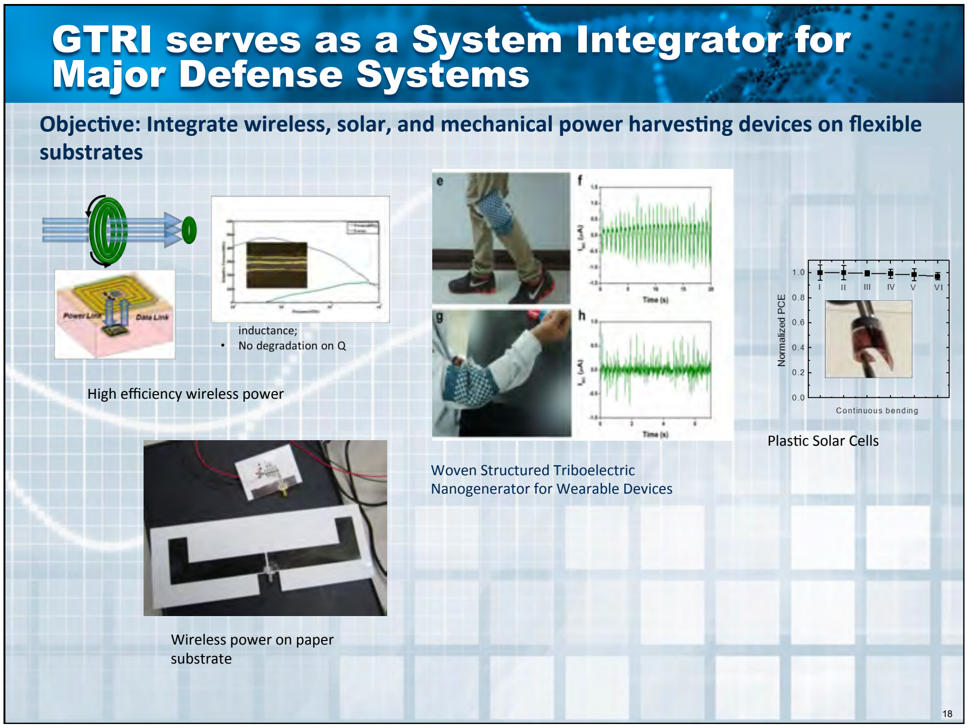
Inks

Substrates

Aerosol Jet Printed Batteries

Inkjet printed radar on flexible substrates (with Dr. A.Traille & Prof. H.Aubert (LAAS)

Inkjet printed capacitor, inductor, and transformer



GTRI serves as a System Integrator for Major Defense Systems

Objective: Integrate wireless, solar, and mechanical power harvesting devices on flexible substrates

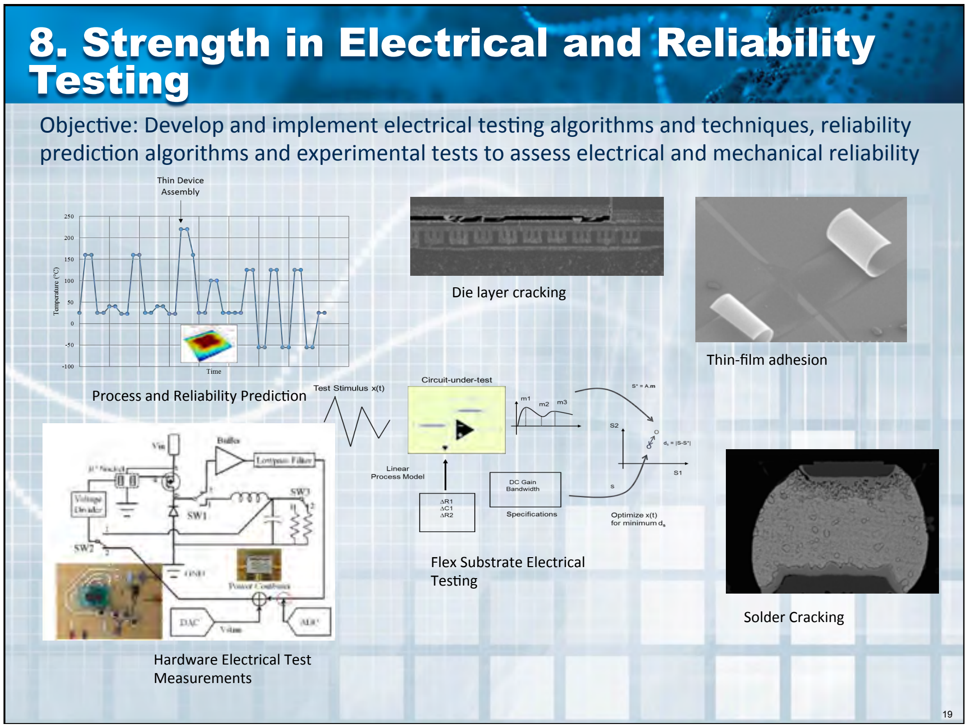
inductance;
- No degradation on Q

High efficiency wireless power

Wireless power on paper substrate

Woven Structured Triboelectric Nanogenerator for Wearable Devices

Plastic Solar Cells



8. Strength in Electrical and Reliability Testing

Objective: Develop and implement electrical testing algorithms and techniques, reliability prediction algorithms and experimental tests to assess electrical and mechanical reliability

Process and Reliability Prediction

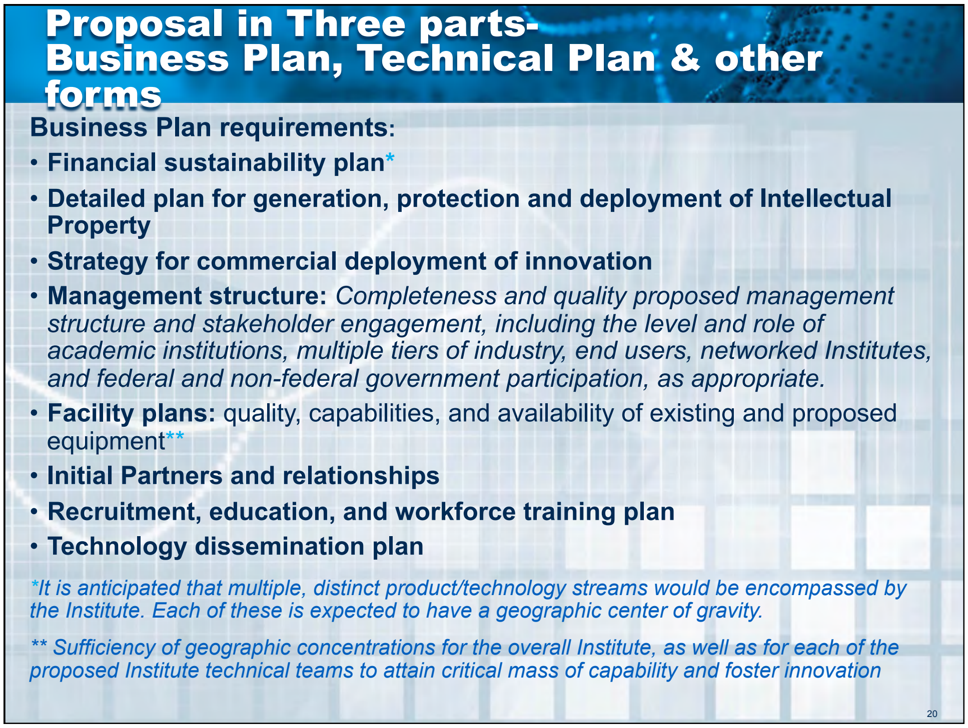
Die layer cracking

Thin-film adhesion

Flex Substrate Electrical Testing

Solder Cracking

Hardware Electrical Test Measurements



Proposal in Three parts- Business Plan, Technical Plan & other forms

Business Plan requirements:

- **Financial sustainability plan***
- **Detailed plan for generation, protection and deployment of Intellectual Property**
- **Strategy for commercial deployment of innovation**
- **Management structure:** *Completeness and quality proposed management structure and stakeholder engagement, including the level and role of academic institutions, multiple tiers of industry, end users, networked Institutes, and federal and non-federal government participation, as appropriate.*
- **Facility plans:** quality, capabilities, and availability of existing and proposed equipment**
- **Initial Partners and relationships**
- **Recruitment, education, and workforce training plan**
- **Technology dissemination plan**

**It is anticipated that multiple, distinct product/technology streams would be encompassed by the Institute. Each of these is expected to have a geographic center of gravity.*

*** Sufficiency of geographic concentrations for the overall Institute, as well as for each of the proposed Institute technical teams to attain critical mass of capability and foster innovation*

Participating Academic and Research Faculty

- Mechanical Engineering
  - Sam Graham, PhD, Professor
  - Tequila Harris, PhD, Associate Professor
  - Suresh Sitaraman, PhD, Professor
  - Charles Ume, PhD, Professor
- Electrical and Computer Engineering
  - Abhijit Chatterjee, PhD, Professor
  - Bernard Kippelin, PhD, Professor
  - John Papapolymerou, PhD, Professor
  - Madhavan Swaminathan, PhD, Professor
  - Manos Tentzeris, PhD, Professor
- Materials Science and Engieering
  - Gleb Yushin, PhD, Professor
  - ZL Wang, PhD, Associate Professor
- GTMI/Industrial and Systems Engineering
  - Ben Wang, PhD, Professor and Executive Director
  - Chuck Zhang, PhD, Professor
- Packaging Research Center
  - Rao Tummala, PhD, Professor and Director
  - P. Markondeya Raj , PhD
  - Vanessa Smet, PhD

Thank you.

Questions?