NextFlex: Enabling a Domestic Manufacturing Ecosystem for Flexible Hybrid Electronics

(Extended Abstract)

Benjamin J. Leever*, Eric W. Forsythe+

*Air Force Research Laboratory, 2179 12th St., B652/R122, Wright-Patterson AFB, OH 45433, Benjamin.Leever@us.af.mil, +Army Research Laboratory, 2800 Powder Mill Rd, Adelphi, MD 20783, Eric.W.Forsythe.civ@mail.mil.

Abstract. In August 2015, the Department of Defense announced a $171M initiative to establish a Flexible Hybrid Electronics (FHE) Manufacturing Innovation Institute, subsequently named NextFlex, based in San Jose, CA. FHE technologies are emerging at the intersection of the electronics and high performance printing industries and will enable revolutionary form factors for new products. The mission of NextFlex is to catalyze a domestic manufacturing ecosystem in FHE, with an initial focus in human performance monitoring/wearable medical devices, asset monitoring/Internet of Things, flexible array antennas, and soft robotics. The key elements of NextFlex include: (1) Institute-funded project calls in which company and university members partner to address the pervasive manufacturing gaps, (2) a hub facility in San Jose that will provide access to state-of-the-art FHE manufacturing and characterization facilities as well as low-volume manufacturing services, and (3) a robust education and workforce development program that spans from K-12 outreach activities to courses to retrain the existing manufacturing workforce. This presentation will provide an overview of NextFlex with an emphasis on manufacturing roadmaps for thin device integration, electronics packaging, and printed flexible components.

1. Introduction

In 2011 the President's Council of Advisors on Science & Technology (PCAST) released a report on ensuring American leadership in advanced manufacturing, which recommended the formation of an Advanced Manufacturing Partnership (AMP).[1] The goal of AMP is to capture a domestic economic advantage through innovative manufacturing by launching a network of public/private partnerships/institutes, which in 2014 became the National Network for Manufacturing Innovation (NMMI). In response, the Department of Defense (DoD) established the National Additive Manufacturing Institute, America Makes, as a pilot institute in 2012. Today the NNMI[2] includes eight additional Institutes, with headquarters from Boston to Los

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[1] "Report to the President on Ensuring American Leadership in Advanced Manufacturing," President's Council of Advisors on Science and Technology, June 2011, https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf.

[2] "National Network for Manufacturing Innovation," https://www.manufacturing.gov/nnmi/.

Angeles and manufacturing focus areas ranging from lightweight metal manufacturing processes to the large-scale production of wide bandgap semiconductors for high power electronics.

Citing the opportunity to keep technology and commercialization processes in the United States, the National Research Council recommended in 2014 that a manufacturing institute be established with a focus on processes for flexible electronics,[3] a conclusion also reached through a Department of Defense Request for Information process that same year. Subsequently, on August 28, 2015, Secretary of Defense Ashton Carter announced the creation of the Flexible Hybrid Electronics Manufacturing Innovation Institute, later called NextFlex, based in San Jose, CA.[4] At the intersection of the high performance printing and electronic manufacturing services industries, NextFlex has a goal of establishing a domestic manufacturing ecosystem in flexible hybrid electronics (FHE). As a public-private partnership, $75M in defense funding over the next five years will be matched by at least $96M in funding from companies, universities, state & local governments, and economic development agencies toward this common goal.

2. Scope

Flexible Hybrid Electronics (FHE) describes technology that combines flexible high performance components (e.g., flexible Si CMOS microprocessors) with printed components (e.g., interconnects, sensors, or microfluidic channels) on non-traditional substrates (e.g., polymers and fabrics) that can flex, bend, stretch, and/or fold. Figure 1 provides a schematic diagram of a generic FHE device. Rather than traditional electronics that are based on rigid circuit boards and include fragile components requiring protective packaging, the goal of FHE is to enable electronics that conform to the shape of vehicles, infrastructure, or our bodies while being inherently more resilient. While applications for military and commercial FHE devices could be almost endless, NextFlex focuses primarily in four technology areas: (1) human monitoring systems, (2) asset monitoring systems, (3) integrated array antennas, and (4) soft robotics.

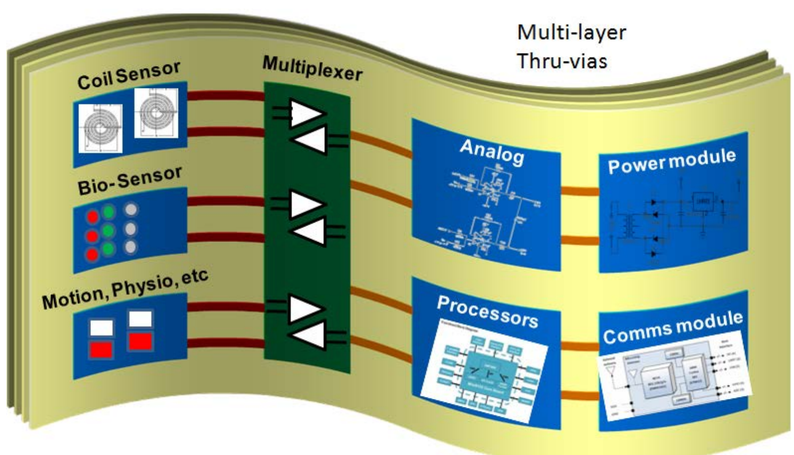

Figure 1. Schematic diagram of generic FHE device.

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[3] *The Flexible Electronics Opportunity*, The National Academies Press, Washington, D.C., 2014.

[4] "Defense Secretary Ashton Carter courts tech leaders in silicon valley," W.J. Hennigan, *Los Angeles Times,* August 28, 2015, http://www.latimes.com/nation/nationnow/la-na-ash-carter-silicon-valley-20150828-story.html.

Distinct from many DoD funding opportunities that focus on basic or applied research, NextFlex specifically addresses FHE manufacturing science and technology gaps by funding projects that mature manufacturing processes from the state of being demonstrated in a laboratory environment (Manufacturing Readiness Level 4) to producing systems, subsystems, or components in a production relevant environment (Manufacturing Readiness Level 7). In the context of FHE, NextFlex addresses manufacturing challenges in five areas: (1) device integration & packaging, (2) printed flexible components & microfluidics, (3) materials, (4) modeling & design, and (5) standards, testing, and reliability. Although all of these areas present pervasive challenges, device integration & packaging are expected to be of particular focus due to the fundamental need for new processes to handle, assemble, and encapsulate flexible components on flexible substrates.

3. Processes

The cooperative agreement serving as the basis for NextFlex was competitively awarded to FlexTech Alliance, a non-profit, industry-focused organization in San Jose, CA. As a public-private partnership, NextFlex is jointly led by FlexTech Alliance personnel including Dr. Malcolm Thompson, the NextFlex Executive Director, as well as by a Government Program Manager & Chief Technology Officer. In addition, the strategic and technical visions for NextFlex are driven by the Governing Council and Technical Council, respectively, which are comprised of subject matter experts and stakeholders from industrial, academic, and governmental member organizations. Companies and universities join NextFlex based on a tiered membership structure, with higher cash and in-kind dues providing greater influence on the technical and strategic directions of the Institute.

Approximately ¾ of the NextFlex funds are allocated toward manufacturing projects executed by company and university teams. Rights to pre-existing intellectual property (IP) that members bring to their projects are not impacted by project participation. Concerning IP that's developed through NextFlex projects, the IP rights belong to the entity (or entities) that generate it. However project teams must agree to provide a no-cost R&D license for NextFlex-funded IP to all members, and they must also agree to negotiate in good faith with any member interested in a commercial license for the IP.

Projects are awarded through an open project call process that occurs approximately every nine months. Project call topics are generated through a roadmap-driven gap analysis that targets identifying the critical paths for the key FHE manufacturing capabilities. These roadmaps (discussed more in the next section) are constructed by Technical Working Groups aligned with the nine application and manufacturing areas identified Section 2. These TWGs are comprised of subject matter experts from industry, academia, and the government who address both the application requirements for potential commercial and government products as well as the FHE manufacturing gaps preventing those products from being produced today. The process is depicted below in Figure 2, which shows the applications driven roadmaps feeding device/platform requirements to the manufacturing roadmaps as well as the manufacturing roadmaps delivering FHE manufacturing capabilities to meet device/platform needs. The roadmaps are revised annually and provide members a tool to guide their own internal investments in addition to driving the NextFlex project call process.

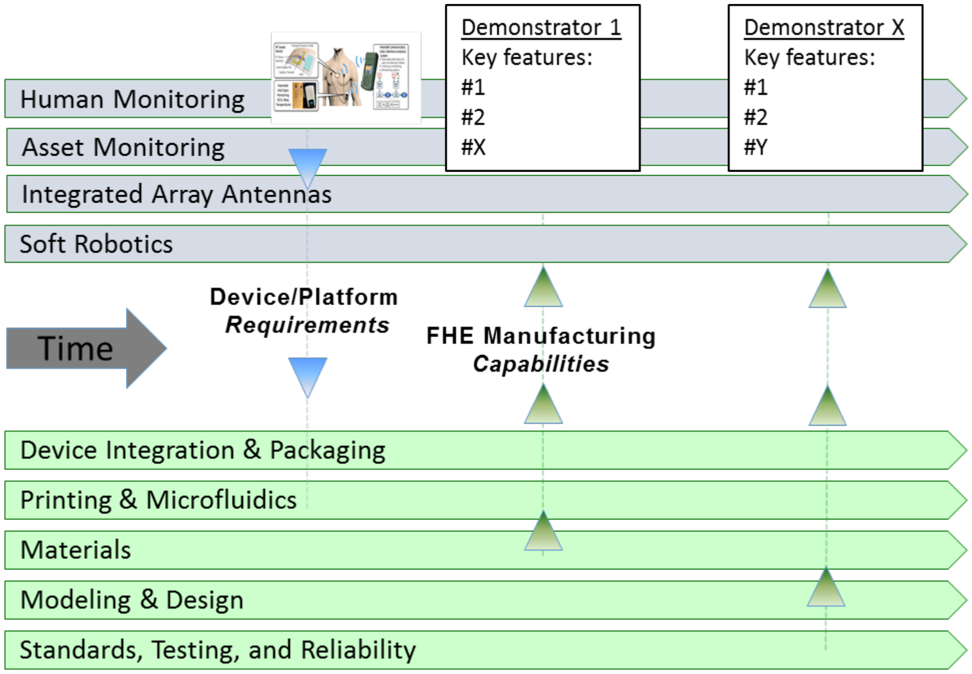

Figure 2. NextFlex Roadmap Process.

4. Roadmaps

NextFlex Technical Working Groups have generated nine roadmaps, which are indicated by the grey and green horizontal bars in Figure 2. The roadmaps for the application areas are called Technology Platform Demonstrations (TPDs), and consist of specific performance capabilities (to meet both government and commercial requirements) that would be demonstrated through projects over the next five years. TPDs are not meant to result in specific products that are immediately ready for commercialization but instead are intended to demonstrate pre-competitive capabilities that highlight the potential for flexible hybrid electronics. These capabilities may be related to specific types of functionality, such as a smart bandage for wound monitoring and accelerated healing – or they could be related to specific use cases, such as a specific battery life or durability. Each of these TPD roadmaps has a specific taxonomy based on overarching application. In the example of the Human Monitoring Systems TPD, the four application areas are: (1) medical, (2) extreme performance, (3) occupational, and (4) wellness/fitness. A portion of the Human Monitoring Systems roadmap is provided in Figure 3. Note that NextFlex maintains publically sharable versions of the roadmaps, which are high level to communicate the scope of the investments and gaps. A second more detailed set of roadmaps are accessible to NextFlex members only, which indicate quantitative requirements and performance targets.

In addition to the Technology Platform Demonstration roadmaps, NextFlex also maintains Manufacturing Thrust Area (MTA) roadmaps in the five topic areas depicted in the green (bottom) arrows in Figure 2. MTA roadmaps identify the pervasive manufacturing gaps that prevent the proliferation of FHE devices today. These manufacturing gaps ranges from processes (e.g., ultra-thin die handling) to computer design tools (e.g., process design kits) to testing standards. Like the TPD roadmaps, each MTA roadmap consists of a subdivided taxonomy. In the case of the Device Packaging and Integration roadmap, these areas are: (1) Circuitization, (2) Encapsulation, (3) Non-Printed Components, and (4) Device Assembly. Roadmaps will be discussed in much greater detail during the presentation.

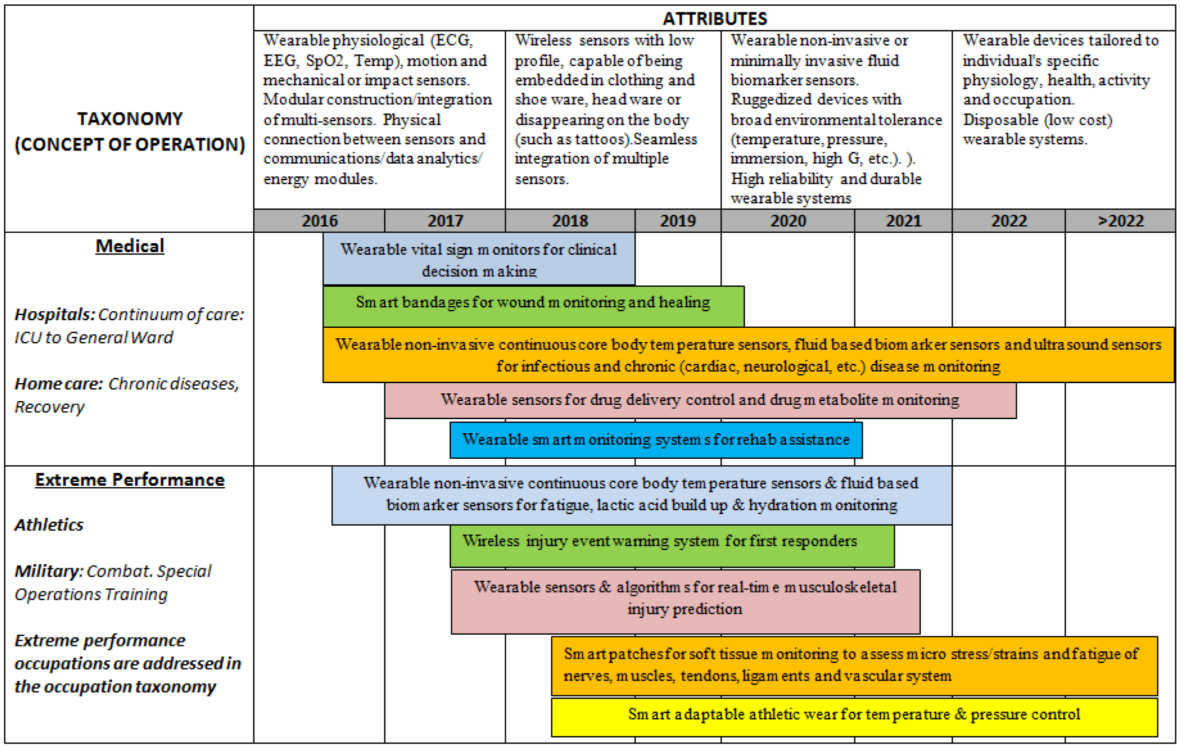

Figure 3. Partial roadmap for Human Monitoring Systems Technology Platform Demonstration roadmap.

5. NextFlex San Jose Hub

In addition to the roadmap-driven project calls, a second major component of NextFlex is its Hub facility in San Jose, CA. The hub provides members and the FHE community more broadly with a unique set of co-located capabilities for electronics manufacturing and printing. In addition to housing commercially available, state-of-the art tools in a class-10,000 cleanroom environment, the Hub will house include pilot tools developed and built through NextFlex funded projects. For example, Project Call 2.0 will result in the delivery of a pilot-scale, sheet-based tool that incorporates direct-write interconnects to surface mounted silicon die and passive components in multi-layer geometries. The Hub will also include an FHE Test & Measurement Lab as well as significant classroom type space for workforce development activities, workshops, and meetings. In addition to serving as a user facility for its members, the NextFlex Hub will also provide contract low-volume prototyping and manufacturing services to both members and non-members.

6. Education and Workforce Development

A key requirement for a robust domestic manufacturing ecosystem in FHE is a highly trained workforce that can accomplish tasks ranging from operating advanced manufacturing tools to using CAD software for reliability predictions. To meet this goal, NextFlex is putting in place programs designed to spark interest in FHE at a K-12 level, programs that target community college, college, and graduate students through new FHE curricula and internship opportunities, and programs that will assist companies in retraining their existing workforce. Workforce development objectives are addressed both as part of manufacturing projects, for example by including student interns or developing an educational seminar, or through stand-alone projects that focus solely on education & workforce development.

7. Conclusions

NextFlex is a public-private partnership established by the Department of Defense and FlexTech Alliance in 2015 with a goal of establishing a domestic manufacturing ecosystem in flexible hybrid electronics to meet the needs of both government and the commercial sector. This objective is accomplished primarily through competitive manufacturing projects completed by company-university teams, but NextFlex is also standing up workforce development initiatives and San Jose Hub with unique FHE manufacturing and testing tools. As a member-driven organization, the NextFlex investments are guided by manufacturing and capability focused roadmaps, which also serve as an investment guide to the FHE industry and government agencies more generally.