NEXTFLEX PROPOSER'S DAY: PROJECT CALL 8.0

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ACKNOWLEDGMENT

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AGENDA

- Additional Resources
- NextFlex Background
- PC 8.0 Process, Schedule, and Themes
- PC 8.0 Topics
- Evaluation Criteria
- Q&A
- PC 8.0 Teaming Event

ADDITIONAL RESOURCES

PC 8.0 Events

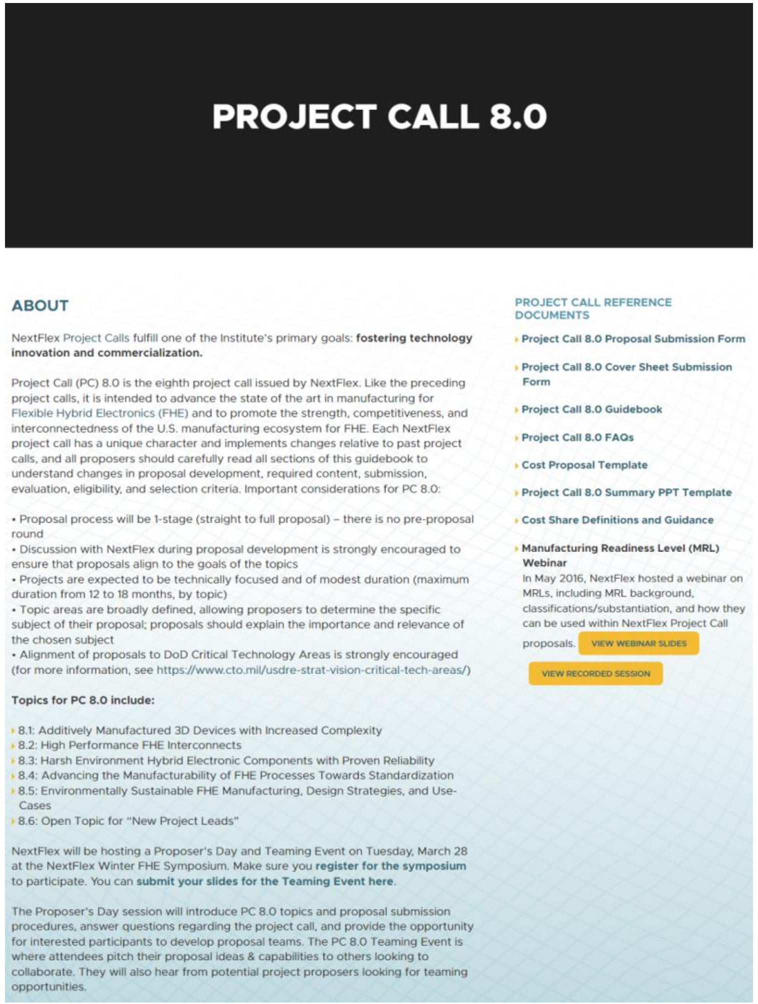
- PC 8.0 Teaming Event – to follow

PC 8.0 Guidebook

- Definitive reference for PC 8.0

Still have questions?

- proposal@nextflex.us



PROJECT CALL 8.0

ABOUT

NextFlex Project Calls fulfill one of the Institute's primary goals: **fostering technology innovation and commercialization.**

Project Call (PC) 8.0 is the eighth project call issued by NextFlex. Like the preceding project calls, it is intended to advance the state of the art in manufacturing for Flexible Hybrid Electronics (FHE) and to promote the strength, competitiveness, and interconnectedness of the U.S. manufacturing ecosystem for FHE. Each NextFlex project call has a unique character and implements changes relative to past project calls, and all proposers should carefully read all sections of this guidebook to understand changes in proposal development, required content, submission, evaluation, eligibility, and selection criteria. Important considerations for PC 8.0:

• Proposal process will be 1-stage (straight to full proposal) – there is no pre-proposal round
• Discussion with NextFlex during proposal development is strongly encouraged to ensure that proposals align to the goals of the topics
• Projects are expected to be technically focused and of modest duration (maximum duration from 12 to 18 months, by topic)
• Topic areas are broadly defined, allowing proposers to determine the specific subject of their proposal; proposals should explain the importance and relevance of the chosen subject
• Alignment of proposals to DoD Critical Technology Areas is strongly encouraged (for more information, see https://www.cto.mil/usdre-strat-vision-critical-tech-areas/)

Topics for PC 8.0 include:

- 8.1: Additively Manufactured 3D Devices with Increased Complexity
- 8.2: High Performance FHE Interconnects
- 8.3: Harsh Environment Hybrid Electronic Components with Proven Reliability
- 8.4: Advancing the Manufacturability of FHE Processes Towards Standardization
- 8.5: Environmentally Sustainable FHE Manufacturing, Design Strategies, and Use-Cases
- 8.6: Open Topic for "New Project Leads"

NextFlex will be hosting a Proposer's Day and Teaming Event on Tuesday, March 28 at the NextFlex Winter FHE Symposium. Make sure you **register for the symposium** to participate. You can **submit your slides for the Teaming Event here**.

The Proposer's Day session will introduce PC 8.0 topics and proposal submission procedures, answer questions regarding the project call, and provide the opportunity for interested participants to develop proposal teams. The PC 8.0 Teaming Event is where attendees pitch their proposal ideas & capabilities to others looking to collaborate. They will also hear from potential project proposers looking for teaming opportunities.

PROJECT CALL REFERENCE DOCUMENTS

- **Project Call 8.0 Proposal Submission Form**
- **Project Call 8.0 Cover Sheet Submission Form**
- **Project Call 8.0 Guidebook**
- **Project Call 8.0 FAQs**
- **Cost Proposal Template**
- **Project Call 8.0 Summary PPT Template**
- **Cost Share Definitions and Guidance**
- **Manufacturing Readiness Level (MRL) Webinar**
  In May 2016, NextFlex hosted a webinar on MRLs, including MRL background, classifications/substantiation, and how they can be used within NextFlex Project Call proposals. VIEW WEBINAR SLIDES
  VIEW RECORDED SESSION

https://www.nextflex.us/project-call/project-call-8-0/

NEXTFLEX BACKGROUND

PROJECT CALL 8.0

INSTITUTES BUILD POWERFUL CONNECTIONS

Manufacturing USA connects people, ideas and technology to solve industry-relevant advanced manufacturing challenges. The 16 Manufacturing Innovation Institutes, 9 of which are funded by the Department of Defense, are enhancing industrial competitiveness and economic growth and strengthening our national security. The Institutes have three shared goals:

1. **Advance the manufacturing & technology process to full scale production**

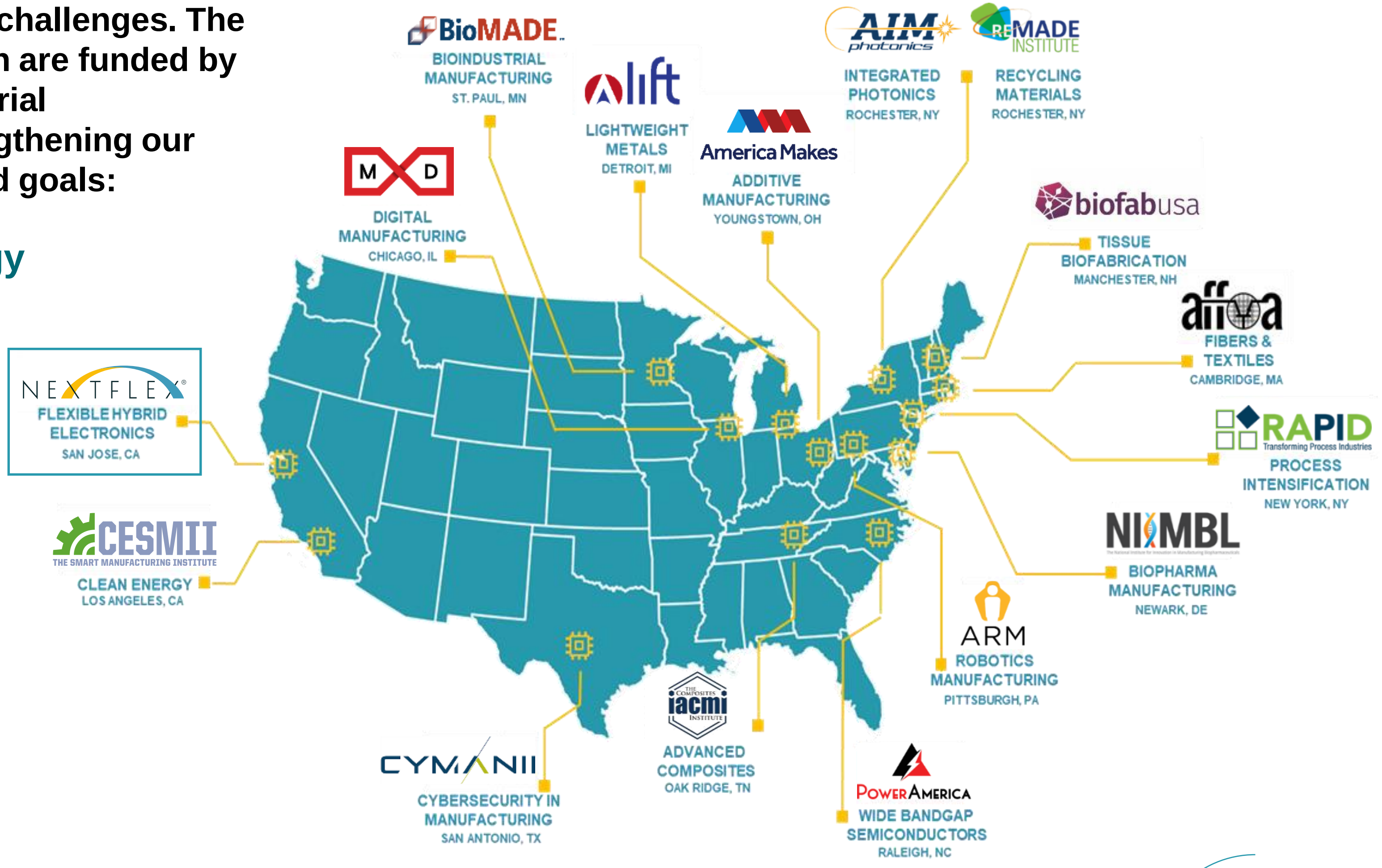
   Partner with industry to investment in applied research and industrially-relevant manufacturing technologies

2. **Create a robust commercial ecosystem around the technology**

   Establish regional manufacturing hubs and ecosystems for long-term, national impact

3. **Secure human capital**

   Develop manufacturing-specific education and workforce development resources to ensure innovative technology is manufacturable

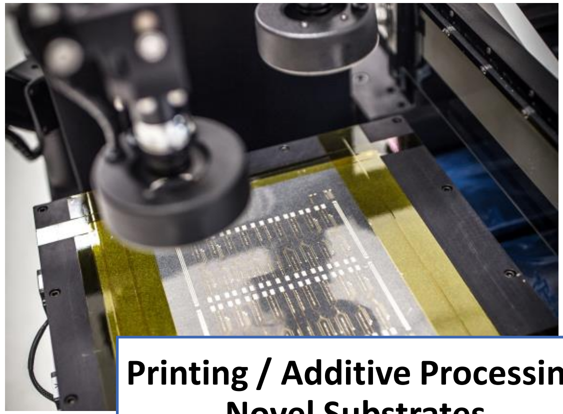


NEXTFLEX: A PUBLIC-PRIVATE PARTNERSHIP

MII Established	28 August 2015
Technology Hub Location	San Jose, California
Facility / Fab Size	34,000 ft^2 total, 10,700 ft^2 fab
Industry & Academic Members	100 members across supply chain
Gov't Organizations Engaged	>40 DoD & OGAs
State / Regional Hubs	New York, Massachusetts, Missouri
Workforce Partners	50 companies, 34 colleges, >100 K-12 districts
Core-Funded Project Calls	81 projects, $124M total value, $50M funding
Agency Projects	120 projects, $185M
Core Funding / Cost Matching	$102M (through 2027) / $125M (through 2022)
Technology Transitions	>25 DoD Prototypes Delivered; >10 Commercial Demos
Key Outcomes	Mfg Tools, Process, Products, & Prototypes to DoD & Industry; Integrated Knowledge

FLEXIBLE HYBRID ELECTRONICS: NEXTFLEX PERSPECTIVE

Flexible Hybrid Electronics (FHE) is an electronics technology and manufacturing approach that combines printed / additive manufacturing with the performance of semiconductor devices.



Printing / Additive Processing Novel Substrates

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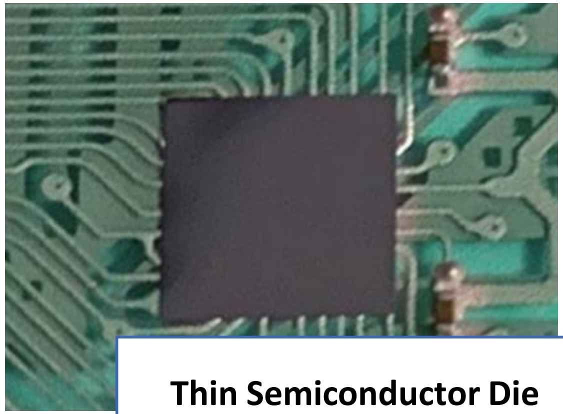

Thin Semiconductor Die

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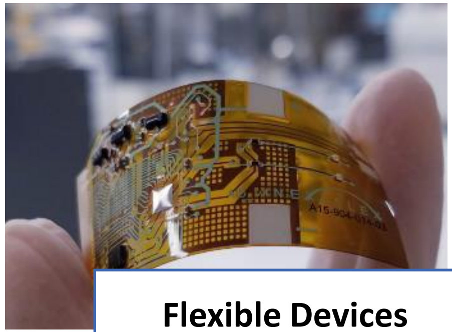
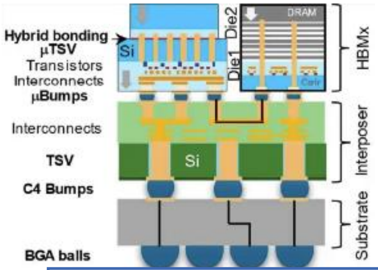


Flexible Devices

Structural / Conformal Electronics

Advanced Packaging & Automation



Heterogeneous Integration

https://semiwiki.com/eda/synopsys/306290-heterogeneous-integration-a-cost-analysis/

DIVERSE AND GROWING MEMBERSHIP: 100 MEMBERS

NEXTFLEX

CORPORATE

TIER 1
LOCKHEED MARTIN, BOEING

TIER 2
EASTMAN, GE, SIEMENS

TIER 3
FORTIFY, ACI Materials, AG Ames Goldsmith, Analog Devices, Anthro Energy, ANI Applied Nanotech Inc., APTIMA Human-Centered Engineering, Averatek,
Blueshift, Brewer Science, Caltronics, Carpe Diem Tech, Chem Cubed, Croda, Disco,
DuPont, E Ink, esi, electroninks, Epicore Biosystems, Fujifilm, General Dynamics Mission Systems,
Human Systems Integration, Impossible Objects, Infinite Corridor Technology, IDS, Jabil, Komori,
Kraetonics, Lamar, Liquid Wire, Lithoz, Lux, molex, Momentive, Nano Dimension,
NanoOPS, Northrop Grumman, NovaCentrix, NovaGard, nScrypt, NTV USA, Optomec, parc A Xerox Company,
plasmatreat, Promex Microelectronics Assembly Technologies, Raytheon Technologies, Shoei Chemical Inc., SI2, Space Foundry, Sunray Scientific,
Syght, Tapecon, tekna., TTM Technologies, UES Excellence in Science & Technology, Universal Instruments, Vivonics, Gore

ACADEMIC / NON-PROFIT

Auburn University Samuel Ginn College of Engineering, Binghamton University State University of New York, Georgia Tech, Northeastern University, UMass Lowell,
Purdue University, University of Washington, Western Michigan University,
Boise State University, Drexel University, Evergreen Valley College, EWI We Manufacture Innovation, Lorain County Community College,
Missouri State University, NJIT New Jersey Institute of Technology, Ohio University, Oregon State University, RIT,
Stanford University, University at Buffalo The State University of New York, Berkeley University of California, CU, University of Delaware,
University of Maryland, UMass Amherst, The University of Texas at Austin Cockrell School of Engineering,
WSU, WPI

OBSERVER

Aionx clean Surfaces, New Dalton Group Development Consulting, SafeSense Technologies

HONORARY

Bestronics, Blach Construction, FlexTech, NBMC, City of San Jose, semi

BRINGING TOGETHER THE FHE ECOSYSTEM

NEXTFLEX

DESIGN/MANUFACTURING

JABIL · EWI We Manufacture Innovation · CALTRONICS · Averatek · tekna. · SIEMENS · TTM Technologies · molex · TC TAPECON · Promex Microelectronics Assembly Technologies · INFINITE CORRIDOR TECHNOLOGY · SYGHT · SAFESENSE TECHNOLOGIES

EQUIPMENT

OPTOMEC · NOVACENTRIX · Universal Instruments · Scrypt · Impossible Objects · Space Foundry · LITHOZ · FORTIFY · plasmatreat · CARPE DIEM TECH · FUJIFILM · KOMORI Kando Beyond Expectations · DISCO · esi Designed for Brilliance. Engineered for Production. · IDS · NanoOPS · NTV USA · NANODIMENSION

INDUSTRIAL/AEROSPACE

LOCKHEED MARTIN · GE · Raytheon · BOEING · GENERAL DYNAMICS Mission Systems · NORTHROP GRUMMAN

MEDICAL/WEARABLE DEVICES

HUMAN SYSTEMS INTEGRATION · EPICORE BIOSYSTEMS · Vivonics · APTIMA Human-Centered Engineering · AIONX makers of clean SURFACES

RESEARCH

UES Excellence in Science & Technology · parc A Xerox Company

DESIGN/COMPONENT MANUFACTURING

Liquid Wire · SI2 · E Ink

MATERIALS

DUPONT · brewer science · CRODA · NOVAGARD · SUNRAY SCIENTIFIC · EASTMAN · SHOEI · BLUESHIFT · AMES GOLDSMITH · ACI MATERIALS · electroninks · GORE · MOMENTIVE · ANI Applied Nanotech Inc.

INDUSTRY STANDARDS

semi | FlexTech

SEMICONDUCTOR

LUX · ANALOG DEVICES

ACADEMIC

Auburn University Samuel Ginn College of Engineering · Binghamton University State University of New York · Georgia Tech · Northeastern University · UMass Lowell · Washington State University · Purdue University · University of Washington · Western Michigan University · Lorain County Community College · NJIT New Jersey Institute of Technology · UMass Amherst · Boise State University · Drexel University · Evergreen Valley College · Ohio University · Oregon State University · RIT · Stanford University · WPI · Berkeley University of California · University at Buffalo The State University of New York · The University of Texas at Austin Cockrell School of Engineering · University of Delaware · University of Maryland · Missouri State University · CU

Department of Defense Manufacturing Technology Program · Innovating Manufacturing

GOVERNMENT PARTNERS AND SUPPORTERS

NEXTFLEX®

BARDA · CIA · DARPA · Defense Contract Management Agency · DEFENSE INNOVATION UNIT · Defense Microelectronics Activity

Defense Threat Reduction Agency · Department of the Air Force · Department of the Army · Department of Defense · Department of Defense Manufacturing Technology Program · Department of Education · Department of Energy

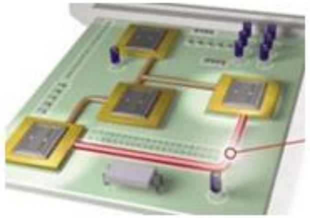
NASA · National Geospatial-Intelligence Agency · Missile Defense Agency · LPS LABORATORY FOR PHYSICAL SCIENCES · FDA · Department of the Navy

National Nanotechnology Initiative · NIH National Institutes of Health · NIST National Institute of Standards and Technology · NSF · Forest Service U.S. Department of Agriculture · Walter Reed National Military Medical Center

MRL AND TRL RELATIONSHIPS

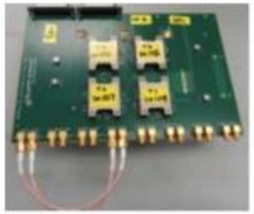
Pre-Material Solution Analysis			Materiel Solution Analysis	Technology Maturation and Risk Reduction		Engineering & Manufacturing Development		Production & Deployment	
MRL 1 Basic Mfg Implications Identified	**MRL 2** Mfg Concepts Identified	**MRL 3** Mfg Proof of Concept Developed	**MRL 4** Manufacturing Processes In Lab Env't	**MRL 5** Components In Production Relevant Env't	**MRL 6** System or Subsystem In Production Relevant Env't	**MRL 7** System or Subsystem In Production Representative Environment	**MRL 8** Pilot Line Demonstrated Ready for LRIP	**MRL 9** LRIP Demonstrated Ready for FRP	**MRL 10** FRP Demo'd Lean Production Practices in Place
TRL 1 Basic Principles Observed	**TRL 2** Concept Formulation	**TRL 3** Proof of Concept	**TRL 4** Breadboard in Lab	**TRL 5** Breadboard in Representative Environment	**TRL 6** Prototype in Representative Environment	**TRL 7** Prototype in Operational Environment		**TRL 8** System Qual	**TRL 9** Mission Proven

Breadboard



Focus Examples:
- Technology and Industrial Base
- Materials
- Cost and Funding

Brassboard



Focus Examples:
- Design
- Process Capability and Control
- Quality Management

Production

Focus Examples:
- Manufacturing Workforce
- Facilities
- Manufacturing Management

Slide adapted from AFRL Materials and Manufacturing Directorate

PROJECT CALL 8.0
PROCESS, SCHEDULE, AND THEMES

PROJECT CALL PROGRESSION

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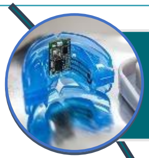
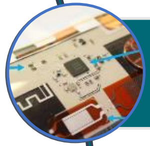

PC 1.0: FHE application areas in two large markets – human health monitoring and asset monitoring


PC 2.0: Equipment development efforts were launched to create tools tailored for FHE production process development & demonstrators


PC 3.0: Subsystem development and manufacturing process or capability gaps

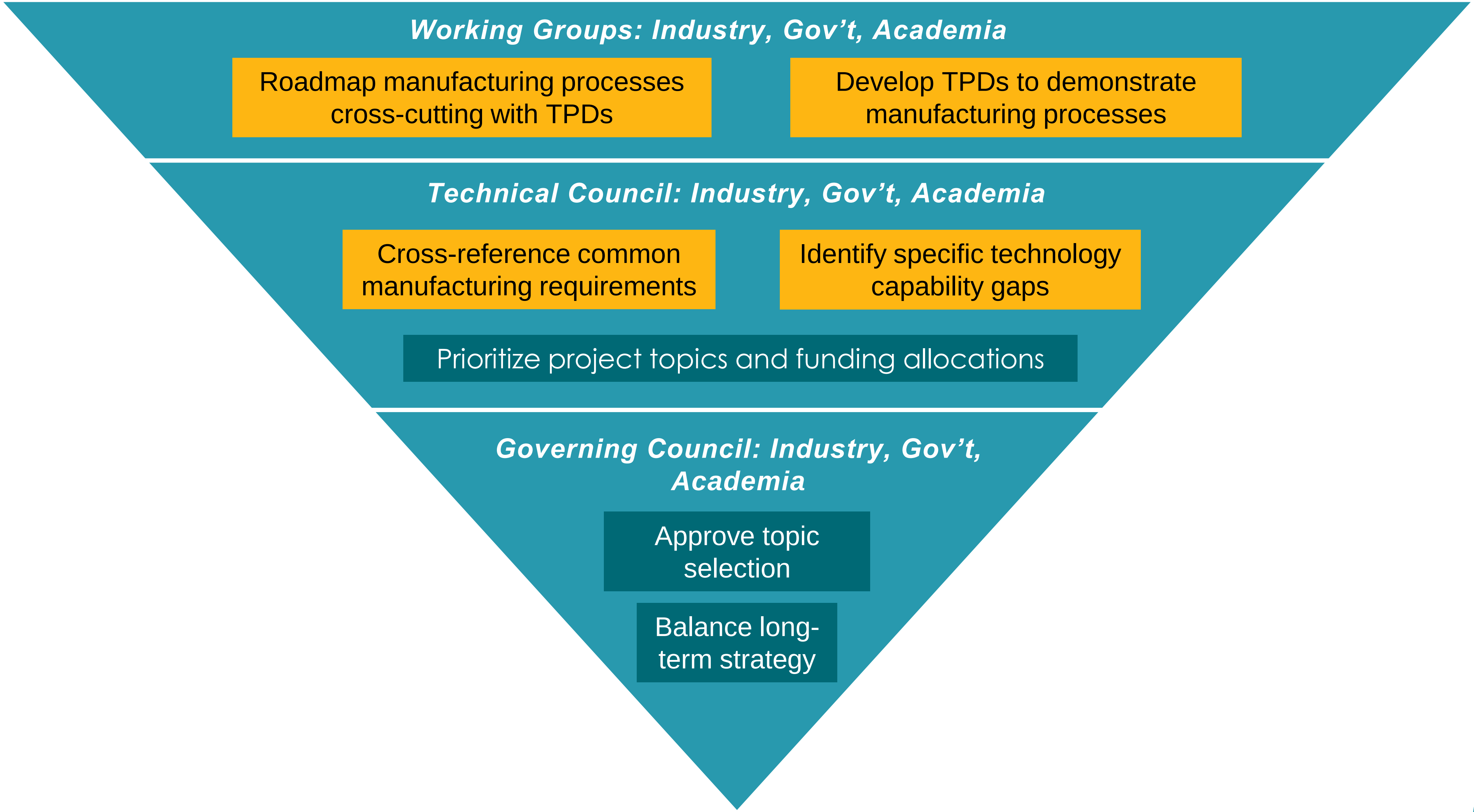

PC 4.0: Areas lacking in MRL and demonstrators showing newly enabled applications


PC 5.0: Manufacturing gaps and growing DoD agency connections


PC 6.0: Broad topics addressing manufacturing and technology gaps from FHE Technology Roadmap


PC 7.0: Prioritized manufacturing gaps and additive semiconductor packaging and PCBs

PROJECT CALL TOPIC DEVELOPMENT



PC 8.0 PROCESS

NEXTFLEX

Roadmap-Based Topic Development
- Technical Working Groups
- Government Partners
- NextFlex Staff

Project Call Guidebook (RFP)
- NextFlex Staff
- Government Partners
- Technical Council & Governing Council

Pre-Submission Consultation
- Proposers
- NextFlex Staff

Proposal Development & Submission
- Proposers

Peer Review
- Tech council members, member volunteers
- NextFlex Staff
- Government SMEs

Project Selection
- Tech Council (Voting Members)
- Governing Council

PC 8.0 IMPORTANT DATES

Event	Date
Project Call Announcement and Posting	03/21/2023
Optional PC 8.0 Proposers Day Webinar	03/28/2023
Teaming Event	03/28/2023
First date for optional pre-submission consultation	04/03/2023
Proposal Online Cover Sheet Due	05/04/2023
Proposal Submission Deadline	**05/11/2023**
Anticipated Technical Council Review	Mid-June
Anticipated Governing Council Review	Late-June

PROJECT CALL 8.0 OVERVIEW

Focus of PC 8.0

- Addressing critical hybrid electronics manufacturing challenges
- Enabling the transition of FHE devices into applications that require superior performance, assured reliability, and improved environmental sustainability

Important Considerations

- Proposal process will be 1-stage (straight to full proposal) – there is no pre-proposal round
- Discussion with NextFlex during proposal development is strongly encouraged to ensure that proposals align to the goals of the topics
- NextFlex anticipates funding one or more project in each topic area; however, other outcomes are possible depending on the cost and quality of the projects proposed
- Given the clear focus on projects that have a near-term commercial impact, teams that are industry-led or have a strong industry partner as part of the commercialization plan will be favorably considered in the evaluation process
- Proposals that fall within the topics area definitions that address DoD Critical Technology Areas will be viewed favorably
- Prior to final granting of awards, recipients and their partners who are not already NextFlex members will be required to become members of the Institute and execute a development agreement
- NextFlex always welcomes suggestions for future project call topics; recommendations should be brought to the attention of the NextFlex TWGs

PC 8.0: ITEMS TO CONSIDER

- Proposals should build on and take advantage of developments from prior project calls, where appropriate, as well as the best available technology.
- Total NextFlex Funds: $4.4M
- Estimated total project value (with cost share): $9.4M
- NextFlex Funding: ≤ $400k – $500k per topic
- Duration: 12 – 18 months (maximum varies by topic)

PROJECT FUNDING & NEXTFLEX MEMBERSHIP

- Minimum of 50% of each project's cost must be cost-share provided by recipients
- 50% minimum cost-share requirement is based on entire team – not individual contributors
- Cost share can include labor, materials, use of equipment, travel
- Any recipient of NextFlex funding must be a member
  - This applies to sub-recipients / project partners
  - Companies supplying standard COTS components or services (e.g. build-to-print) to team members are not required to be members of NextFlex.

MANUFACTURING USA – A NEW WAY OF DOING THINGS

Submitters with experience in government funding should take special note that the ways in which NextFlex and Manufacturing USA Institutes operate may be quite different than those to which proposers may be accustomed.

NextFlex development projects should not be compared to SBIR, STTR, NIH, or other similar programs, nor should they be compared to commercial customer activities. Unlike acquisitions programs, these efforts are aimed at co-funded development; thus, a cost share element is required.

NextFlex projects are designed around time-bound and measurable deliverables with clear performance metrics. If these cannot be established at the outset of the project, the subject matter under consideration may be of too low an MRL and thus more suitable for another funding mechanism.

The objective is not to develop a specific product, but rather to solve a common gap that many companies in the FHE manufacturing ecosystem are facing. Developments are reported to and benefit all members, so the approach taken is as important as the promised outcomes. The proposal evaluation criteria reflect this.

Project funding will follow a cost reimbursement mechanism. If the lead or any team partners have audited indirect rates, please use those. Commercial rates or profit (fee) may not be included in project submissions.

PROJECT OBJECTIVES AND DELIVERABLES

These projects focus on developing and qualifying manufacturing processes, methods, or tools identified as FHE needs via the roadmapping process and discussions with TWG leads and members.

Any development of software tools should include licenses or provisions to allow NextFlex members and Institute personnel.

Projects focused on process development must document those processes with enough detail that they are reliably replicable and that they may be included in manufacturing guidelines for relevant processes in the future.

These projects shall include, but are not limited to, the following deliverables:

- Material & Process Database inputs at quarterly reporting intervals following the acquisition of the data.
- A flow chart of the process steps and design information for device fabrication or process repetition.
- Relevant process information including material properties obtained, tolerance and yield with comparison to current industry processes, consistency of process specifications and device performance, and optimized equipment parameters.
- Details of the method of test and measurement performed during development to establish TRL and MRL advancements.
- Identification of the specific task and outcome that results in TRL and/or MRL advancements.
- Cost model framework and associated assumptions for the proposed manufacturing technique.

Reliability and standards cut across all topics; although not called out in every topic, all PC 8.0 proposals are encouraged to address these needs within their project plans.

BROADLY DEFINED TOPICS WITH EXAMPLE AREAS OF INTEREST

- Topics aim to advance FHE technology and fill gaps identified by the TWGs in the FHE Roadmaps. The outcomes of the projects that are selected are expected to have broad impact on both commercial and defense applications and to advance U.S. FHE manufacturing capability.
- Each topic has a maximum funding and duration; proposals that seek lower levels of funding and shorter duration are welcome.
- Topics are structured with a description that include all requirements followed by examples of proposal areas that would meet the topic area requirements and align to prioritized roadmap gaps.
  - These examples are not sub-topics into which proposals must fit, and any proposal that meets the overall topic area requirements will be equally considered whether it addresses one of the examples or not.
  - A proposal may address only part of an example area and still be responsive to the Topic so long as it meets all requirements of the Topic.

PROJECT CALL 8.0 TOPICS

PROJECT CALL 8.0 TOPICS

Topic #	Topic Description	Max Duration (months)	Max Funding *	Technical Working Group Alignment										
				Printed Components & Microfluidics	Materials	Device Integration & Packaging	Modeling & Design	Standard, Test & Reliability	Human Monitoring Systems	Asset Monitoring Systems	Integrated Array Antennas	Soft & Wearable Robotics	Flexible Power	Automotive
8.1	Additively Manufactured 3D Devices with Increased Complexity	18	$ 500k	X		X	O	O		O	X			X
8.2	High Performance FHE Interconnects	18	$ 500k	X		X			O		O	X		O
8.3	Harsh Environment Hybrid Electronic Components with Proven Reliability	18	$ 500k	O	O	X		X	O	X	O		X	X
8.4	Advancing the Manufacturability of FHE Processes Towards Standardization	18	$ 500k	X		X	X	O			O			
8.5	Environmentally Sustainable FHE Manufacturing, Design Strategies, and Use-Cases	18	$ 500k		X	O		O		O				
8.6	Open Topic for "New Project Leads"	12	$ 400k	X	X	X	X	X	X	X	X	X	X	X
				X	Direct TWG Alignment									
				O	Indirect TWG Alignment									

*Max Funding reflects the maximum funding from NextFlex for an individual project on each topic. Total program value must include the required minimum 1:1 cost share.

TOPIC 8.1: ADDITIVELY MANUFACTURED 3D DEVICES WITH INCREASED COMPLEXITY

$500,000 maximum Institute funds / Up to an 18-month duration

Hybrid electronic manufacturing has shown potential to complement and potentially supplant traditional device and component processes. To achieve this, complex 3D architectures are required to fully utilize the advantages of additive approaches. This topic seeks development and evaluation of manufacturing approaches for multilayer electrical devices that can be transitioned to volume-manufacturing scale. Proposers are encouraged to produce enough test articles to estimate yield and include modeling and simulation of RF performance, if appropriate. Proposers must identify why the manufacturing approach is preferred over the state-of-the-art. Examples of possible approaches of interest include, but are not limited to:

a. Manufacturing of Multilayer, Multifunctional FHE Devices
b. Devices with Embedded Printed Passives
c. Miniaturization of 3D Printed Antennas
d. Conformal FHE-based mmWave Radar Sensors

TOPIC 8.2: HIGH PERFORMANCE FHE INTERCONNECTS

$500,000 maximum Institute funds / Up to an 18-month duration

Recent advances in FHE technologies have pushed the state-of-the-art for manufacturing robust electromechanical interconnects in devices with conventional requirements. This topic seeks to continue to push development of interconnect manufacturing into focus areas of particular interest including, high temperature packaging, high performance co-packaged optics, and highly stretchable electronics. Examples of possible topics include:

a. Additive Packaging for Sustained High Temperature Operation
b. FHE Manufacturing of Electro-Optical Circuits
c. FHE Interfaces for Rigid, Flex, and Stretch Components

TOPIC 8.3: HARSH ENVIRONMENT FHE COMPONENTS WITH PROVEN RELIABILITY

$500,000 maximum Institute funds / Up to an 18-month duration

This topic seeks evaluation of FHE components designed for harsh environment applications that include high or low temperatures, extreme thermal cycling, high power, high vibration, G-force / shock, vacuum, and / or radiation. Projects should include full reliability testing appropriate for the target use-case. Alignment to specific standards (i.e. MIL-STD-810G, or similar) is required. Examples of projects of interest include, but are not limited to:

a. Evaluation of Hybrid Electronics for Space Applications

b. Reliability of FHE Devices for Harsh Automotive Applications

c. Printed Coatings with Improved Electromagnetic Interference Shielding

TOPIC 8.4: ADVANCING THE MANUFACTURABILITY OF FHE PROCESSES TOWARDS STANDARDIZATION

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$500,000 maximum Institute funds / Up to an 18-month duration

For hybrid electronics to achieve wide-spread adoption, advancement of manufacturability and standardization of processes is critical. This topic seeks to standardize processing parameters and develop manufacturing design rules for common manufacturing approaches for hybrid electronic components and devices. Successful projects will focus on fully characterizing the manufacturing processes of key components (passives, bare die handling and attach) and devices (circuitization of printed and COTS components, COTs connectors, encapsulation) and formalizing detailed processing parameters and expected performance. All collected processing data should be added to NextFlex's Materials and Process Database and detailed process flows should be disseminated to the NextFlex community. Examples of projects of interest include, but are not limited to:

a. Reliability Testing and Standardization of Fully Additively Manufactured Circuits

b. High Volume Manufacturing of Multilayer Passive Components

c. Process Parameters and Design Rules Development for Hybrid Electronics

TOPIC 8.5: ENVIRONMENTALLY SUSTAINABLE FHE MANUFACTURING, DESIGN STRATEGIES, AND USE-CASES

$500,000 maximum Institute funds / Up to an 18-month duration

For this topic, NextFlex has received dedicated funding, and based on the number and quality of proposals received, anticipates awarding three projects.

FHE manufacturing technologies present opportunities to adopt materials and processes that are friendlier to the environment and ecologically sustainable. The full product life cycle from design to recycle / disposal all directly and indirectly have an environmental impact that needs to be evaluated so that cleaner, more sustainable materials and methods can deliver a near-term impact. Additionally, the proven benefits of FHE devices, primarily reduced SWaP-C, can enable novel monitoring applications focused on addressing global climate change. This topic seeks to address sustainability in hybrid electronics manufacturing in three key areas: (1) more sustainable FHE manufacturing and repair processes and materials, (2) life cycle assessment of prototype devices, (3) using FHE devices to address global climate change. Examples of potential projects of interest include, but are not limited to:

a. FHE Manufacturing and Repair for Enhanced Environmental Sustainability

b. Life Cycle Assessment of Hybrid Electronic Devices

c. Using FHE Devices to Address Global Climate Change

TOPIC 8.6: OPEN TOPIC FOR “NEW PROJECT LEADS”

$400,000 maximum government funds / Up to a 12-month duration

Delivering the NextFlex mission requires participation from across the U.S. FHE ecosystem. The purpose of this topic is to encourage participation from organizations that have not led a NextFlex PC project in the recent past.

Projects must align to the NextFlex Technical Working Group FHE Roadmaps and may address either manufacturing thrust or technology demonstrator topics. In the case of technology demonstrator development, the project should, at least in part, address the challenge of manufacturing such a demonstrator. For this open topic, proposals must clearly identify the technical working group(s) to which the project aligns, and the manufacturing capability gaps to be addressed.

<u>Eligibility requirements:</u> The lead proposer organization for this project must not have led a NextFlex project call project under either of the two most recent project calls (PC 6.0 and PC 7.0), or an Open Project Call within the last two years. As with all proposals, teaming is strongly encouraged; organizations that have led projects under PC 6.0 and/or PC 7.0 may be project partners, however at least 60% of the NextFlex funding for projects in this category must be allocated to organizations that meet the eligibility requirement (there is no restriction on allocation of cost share).

EVALUATION CRITERIA

PROJECT CALL 8.0

PROPOSAL EVALUATION PROCESS

- Proposals are distributed to a slate of reviewers which include:
  - NextFlex members
  - Government subject-matter experts
  - NextFlex staff
  - NextFlex may occasionally engage other persons as part of the proposal review process (e.g., third-party SMEs)
- Reviewers evaluate the proposals, score each proposal in several categories, and provide comments.
- NextFlex compiles and analyzes the reviews and summarizes comments for the NextFlex Technical Council.
- Technical Council votes a set of recommendations to the NextFlex Governing Council.
- Governing Council votes to select projects for award negotiation.

PROPOSAL EVALUATION CRITERIA

NEXTFLEX®

PC8.0 Full Proposal Project Review Criteria / Score Card

Criteria for all Project Call topics | **Score Guide: Low=1, High=5; refer to scoring rubric worksheet**

Reviewer Name: ADD YOUR NAME HERE

Reviewer Organization: ADD YOUR ORGANIZATION HERE

	Proposal Section	Proposal Section	Criteria	Explanation of Criteria	Example Proposer Name Example Proposal Title Example Score
Technical Merit & Transition Potential	1.0	Background and Need	(1) Problem statement, innovative solution, and potential impact on technical gap and/or DoD priorities	Evaluate the problem definition in line with the background information and the gap analysis provided. Is the proposal aligned with TWG roadmaps and/or DoD Critical Technology Areas?	3
	2.0	Technical Objectives	(2) Technical scope and approach	Is the objective, scope and approach aligned with the problem definition? Are performance and reliability metrics and standards appropriately addressed? For demonstrator projects, what are the value to the ecosystem and the advantage of an FHE solution for this problem?	5
			(3) Logical technical plan; key deliverables and specifications	Do the specifications and deliverables meet the proposed objectives and final deliverables? What are the key tangible deliverables & how do we assess success?	5
	3.0	Work Plan	(4) Project organization	Is the project organized well with milestones and tasks; Are the task descriptions clearly articulated: Is the schedule aligned well with critical interdependencies identified?	4
			(5) Probability of success	Based on all of the above, including the cost and the team capability, assess the feasibility to achieve the stated goals within the planned timeline.	3
	4.0	Commercialization Strategy	(6) Business case/value proposition	What is the targeted application or market? How is the technology/product a differentiator or a game changer? Is the appropriateness of an FHE solution explained?	5
			(7) Manufacturing approach	Is the technology/approach matured and ready for manufacturing? Is it the right approach? Does it help advance the MRL/TRL goals? Does the team have the right partners? Are they US-based? How the mature is the process and/or manufacturing infrastructure? How does it impact US manufacturing?	4
Non-Technical Factors			(8) MRL/TRL assessment	Are the starting MRL/TRL accurate? Are the end MRL/TRL assessed correctly, and is it realistic considering the overall quality of the project and maturity of technology and approach?	5
			(9) Tool accessibility <u>(for proposals developing tool hardware and software proposals only)</u>	Will the equipment/tool/software developed as part of the proposal be available to the ecosystem, and where they will be located?	3
	5.0	Budget Justification and Cost Share	(10) Cost and cost realism	Evaluate if the cost assessment is pragmatic based on the overall assessment of the project relative to its objective, team, advancement, timeline etc.	4
			(11) Value and quality of cost share	Assess based on the cost share value, cost share source and the purpose of the cost share.	4
	6.0	Capability to Meet Technical and Business Goals	(12) Experience of personnel and quality of relevant facilities	Assess the strength of the PI team as well as the partner/subcontract organizations to achieve the proposal's goals.	4
	7.0	Workforce Development	(13) Quality of WFD section	What aspects of WFD is proposed? Is it intern, graduate student, or training etc.?	2
				Technical Score	**4.14**
				Technical Ranking	**-**
				Non-Technical Score	**3.67**

Technical Criteria

Non-technical Criteria

DEPARTMENT OF DEFENSE MANUFACTURING TECHNOLOGY PROGRAM INNOVATING MANUFACTURING

PROPOSAL EVALUATION AND SELECTION

- Technical Score and a Non-Technical Score are determined by averaging the scores in from each category. Scores from all reviewers produce average scores and a Technical Ranking.
- Project selection will rely heavily on the Technical Score and Ranking; Non-Technical Score and reviewer feedback are particularly useful to distinguish proposals that are rated closely to each other, as well as to identify potential outliers (high or low).
- Scores and comments from reviewers will be compiled, ranked, and prioritized for consideration by the Technical Council in voting.
- The Governing Council will consider input from reviewers, Technical Council recommendations, and factors such as alignment with the NextFlex dual mission to promote development and U.S. manufacturing of FHE and support DoD technology transitions, and balance of the project portfolio in selecting proposals.

proposal@nextflex.us

PROJECT CALL 8.0
TEAMING EVENT

TEAMING EVENT STRUCTURE

- We will progress though each of the topics sequentially
- In-person presenters will start each new topic, followed by virtual attendees
- Each proposer will be allowed a single slide to pitch their proposal idea, capabilities, and / or type of partnership sought
- Please reach out to the presenters on Whova or directly after the event for questions or to discuss collaboration opportunities

PC 8.1: ADDITIVELY MANUFACTURED 3D DEVICES WITH INCREASED COMPLEXITY

SWR TECHNOLOGY FOR PC 8.0

TOPICS: 8.1 (APPLICABLE FOR 8.2, 8.3, 8.5, 8.6)

USE CASE: TRANSPARENT AR (OTHERS POSSIBLE)

CAPABILITIES:

1. WIRELESS ELECTRONICS DESIGN COMPANY
2. THROUGH BARRIER WIRELESS POWER (KW+, 95%+) AND DATA (GBPS+)
3. TRANSPARENT HEATER

PARNERS: FHE MANUFACTURING, TRANSPARENT DISPLAY, SEEKING ELECTRONICS DESIGN EXPERTISE

CONTACT: SHENGMING SHAN SMSHAN@SWRTEC.COM

PC 8.2: HIGH PERFORMANCE FHE INTERCONNECTS

Thermally Enhanced Sustained High-Temperature High-Power Additive Packaging for Automotive Applications

Topic:

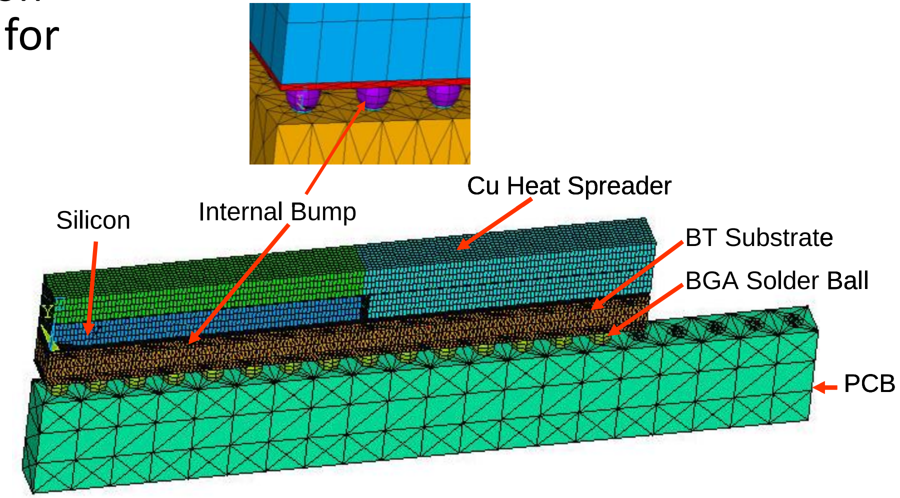
8.2 High Performance FHE Interconnects

Description:

Additive Packaging will be developed for sustained high temperature high power operation on the automotive xEV platforms with a focus on integration of SiC and GaN devices. Thermally enhanced packaging will be constructed for operation at temperatures higher than 250C.

Background and Related Work Performed:

- Significant body of prior work on the design of conventional electronic packaging for sustained high temperature operation at temperatures of 250C with Silicon Electronics.
- Leverage over 20-years of experience for automotive underhood electronics, OBD, and ADAS.
- Prior work on constitutive behavior characterization, modeling and life-prediction in automotive and defense applications.



Capabilities Sought in Potential Project Partners:

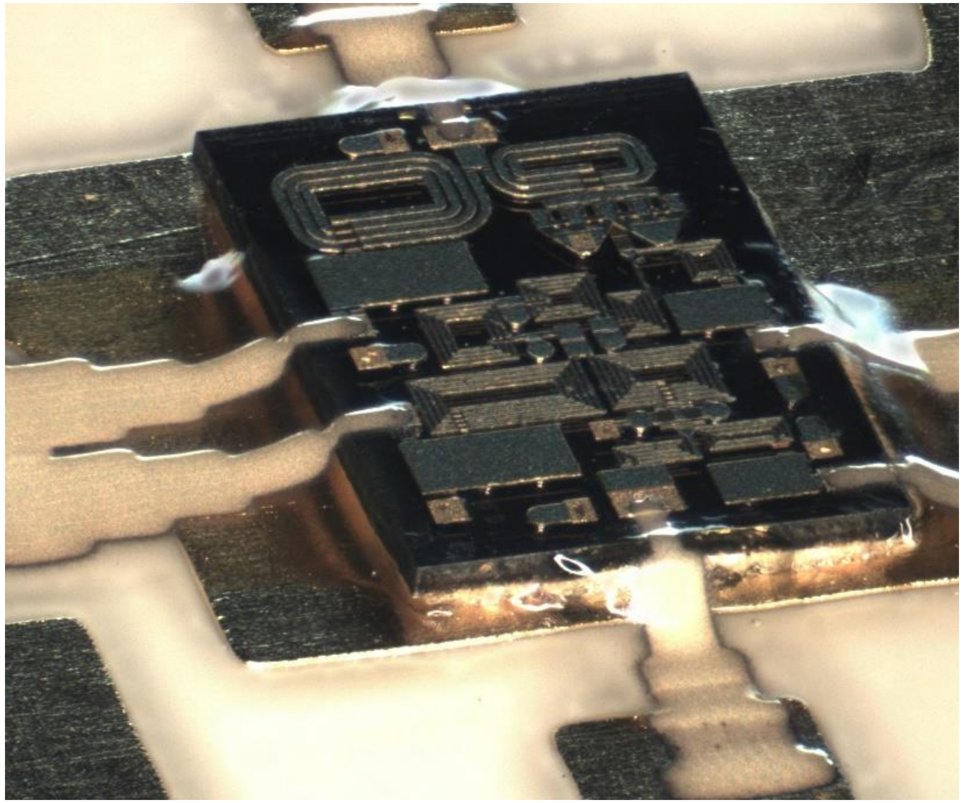
- Ink companies with materials compatible with sustained high temperature operation
- Solder and ECA Companies with materials intended for automotive underhood
- Automotive Companies with interest in risk mitigation in use of technology

Contact: Pradeep Lall, lall@auburn.edu; (334)740-3424

HIGH PERFORMANCE FHE INTERCONNECT

NEXTFLEX

- EXTEND THE NEXTFLEX 6.7 6 GHZ PHASED ARRAY RADAR (PAR) PROJECT TO 28 GHZ
  - OR SIMILAR PROJECT TO IMPROVE RF FHE SWAP-C
- FITS TOPICS 8.1 AND PARTICULARLY 8.2 *HIGH PERFORMANCE FHE ELECTRONICS*
  - 5G AND MILITARY APPLICABILITY
  - OPTOMEC INTERCONNECT TECHNOLOGY CURRENTLY BEING EVALUATED AT 120 GHZ
- PROJECT WILL EMPHASIZE DESIGN RULES, MATERIALS, THERMAL PERFORMANCE AND STRUCTURE OPTIMIZATION FOR RF PERFORMANCE



- RF amplifier interconnects for PAR
- Partnering with Lockheed Martin, Binghamton University and Optomec
- Funded by NextFlex 6.7

PC 8.3: HARSH ENVIRONMENT HYBRID ELECTRONIC COMPONENTS WITH PROVEN RELIABILITY

Western Michigan University
Printed/Flexible Electronics

Contact: Dr. Massood Atashbar

massood.atashbar@wmich.edu

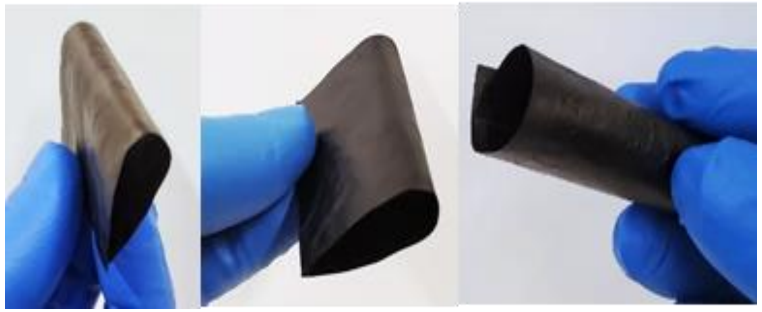
Topics

Topic 8.3:

c) Printed Coatings with Improved Electromagnetic Interference Shielding

Topic 8.4:

b) High Volume Manufacturing of Multilayer Passive Components



Highly Conductive Graphene Films

Conductivity >1300000 S/m

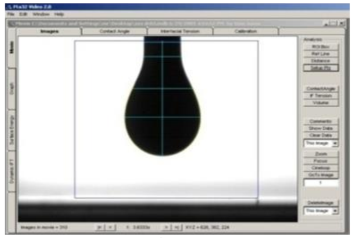
EMI shielding Efficiency >100dB

Roll-to-Roll Screen Printer

FHE Related Equipment at WMU

Gravure	Flexography	Screen	Inkjet
			

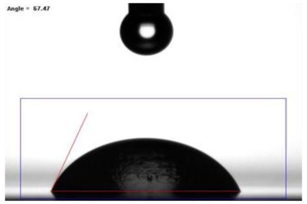
Surface Tension of Inks



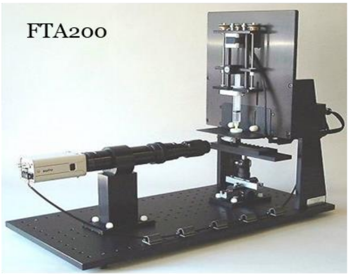
Static surface tension

Ink-Substrate Interactions

Dynamic contact angle



Substrate Properties



Surface Energy
Absorption

Roll-to-Roll Screen Printer

Rheological Behavior

Flow
Visco-Elastic Properties
Creep/Recovery
Gelation

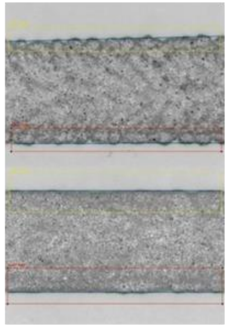
Anton Paar MCR 302

FHE Related Equipment at WMU

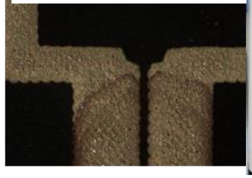
Print Characterization

Characterization of Printed Inks

Image Analysis
Coverage
Resolution
Line quality
Gap quality
Print Fidelity



SEM (JEOL JSM-IT200)



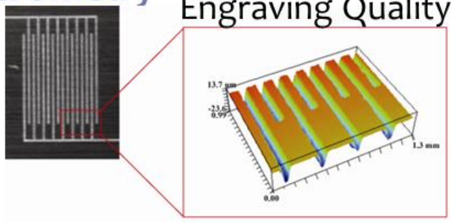
Atomic Force Microscopy

Contact mode
Non-contact mode
Tapping mode
Lateral Force Microscopy
Magnetic Force Microscopy
Phase Imaging

White Light Interferometry

Surface profile
Bruker

Engraving Quality



Print Quality

ESM301 - Motorized Force Test Stand

FHE Related Equipment at WMU

Other Equipment

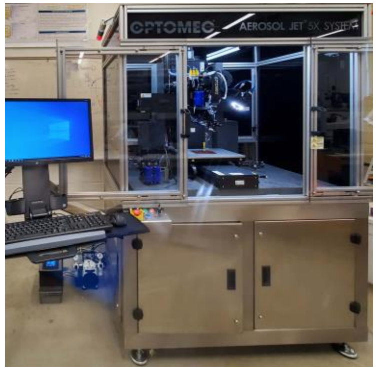
Thinky Mixer Nano-Premixer PR-1

Thinky Mixer AR-100

XRD (Panalytical Empyrean & Rigaku SmartLab SE)

Keysight E5080B Vector Network Analyzer (20GHz)

AutoGlow 200 Plasma System



Optomec Aerosol Jet Flex System

SE-3000 Environmental Chamber

NovaCentrix Photonic Sintering System

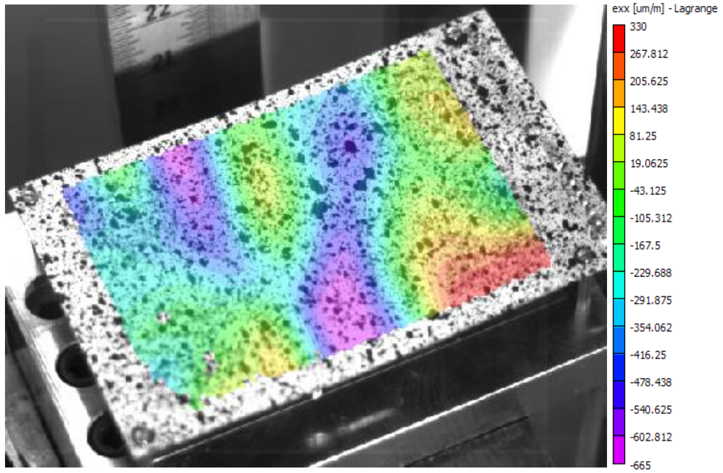
Laser System PLS 6MW ($75W$ CO_2 and 40W fiber laser cartridges)

Extreme High Temperature Wide Temperature Extreme High-G Reliability of FHE in Automotive Environments

NEXTFLEX®

Topic:

8.3 Harsh Environment FHE Components with Proven Reliability



Description:

Failure Modes Effects and Criticality Analysis of FHE assemblies operating in harsh environments. Development of meaningful accelerated tests, test-levels in comparison with conventional designs for standardization of fully additively manufactured circuits.

Background and Related Work Performed:

- Prior body of work in the failure modes-mechanisms, accelerated testing, development of acceleration factors, failure analysis and material reliability interactions.
- Prior Project lead on PC2.5: Development of Accelerated Test Methods for FHE; and PC7.6: In-Mold Electronics for Automotive Applications. Significant prior work on high temperature, wide temperature extremes and high-G reliability for conventional electronics.

Capabilities Sought in Potential Project Partners:

- Companies interested in migrating existing design to FHE technology solutions for harsh environments.
- Accelerated testing companies with solutions for accelerated testing for operation in extreme environments
- OEMs, 1st tier and 2nd tier companies with interest in risk mitigation in use of FHE technology

Contact: Pradeep Lall, lall@auburn.edu; (334)740-3424

PC 8.4: HARSH ENVIRONMENT HYBRID ELECTRONIC COMPONENTS WITH PROVEN RELIABILITY

Manufacturing Design Rules and Process-Reliability-Performance Interactions for Multi-Material Additively Manufactured Circuits

Topic:

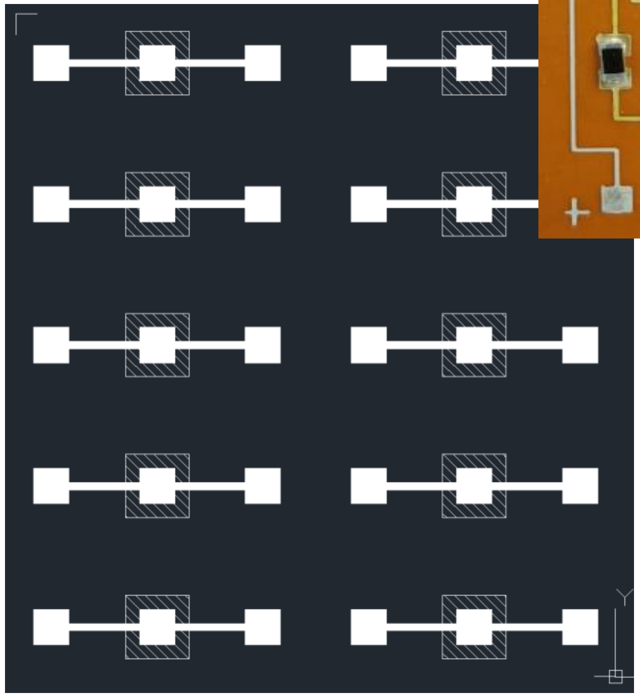
8.4 Advancing the Manufacturability of FHE Processes Towards Standardization

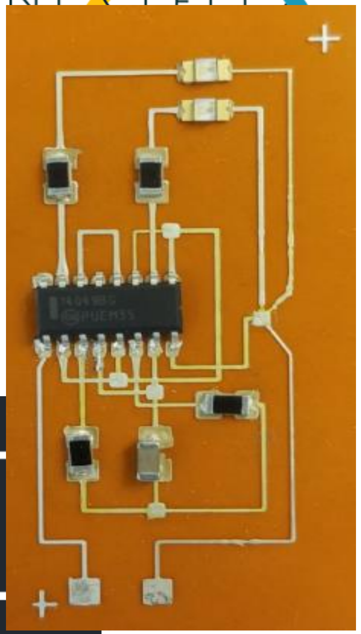
Description:

Standardize process parameters and develop manufacturing design rules for multi-material additively printed circuits. Quantify the reliability and performance of multiple designs relative to conventional circuits.

Background and Related Work Performed:

- Significant body of work in closed-loop control of additive process for component assembly in PC6.4; the printing of passives including resistor, inductors and capacitors in PC65.
- Worked on the reliability of the flexible additive printed interconnects in PC2.5. Developed the z-axis interconnects and process-yield interactions in OPC1.0.
- Quantified the sigma-levels for a number of additive print processes and developed foundational data for defect-reduction.





Capabilities Sought in Potential Project Partners:

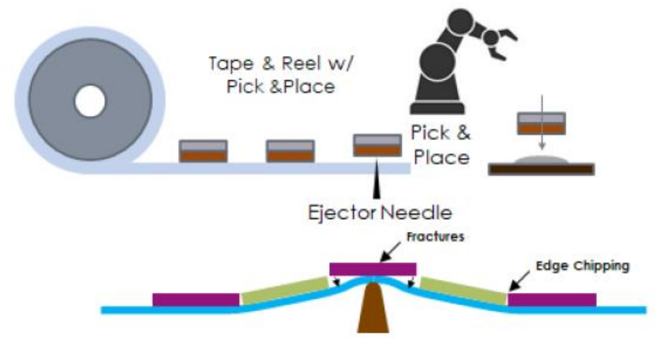
- Ink-Companies with offerings in dielectrics
- High conductivity and/or low-sintering temperature inks
- Flexible encapsulation materials companies.

Contact: Pradeep Lall, lall@auburn.edu; (334)740-3424

Terecircuits' Offering: Low Total Cost of Operation for Heterogeneous Integration

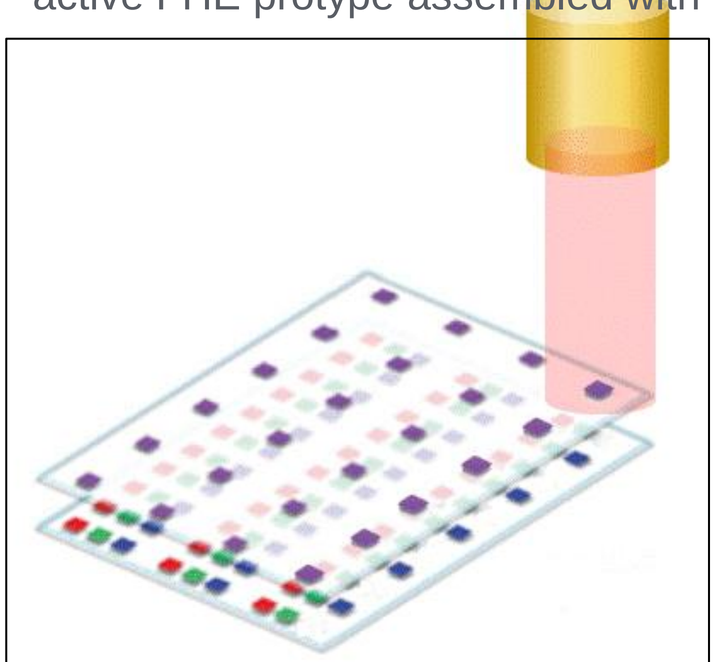
NEXTFLEX

Topic: 8.4 or 8.6 Light induced forward transfer process enabled by Terefilm®. The proposal concept is to demonstrate the advantages of Terecircuits' LIFT release layer and processes by showcasing an electrically active FHE protype assembled with high speed and yield using mass transfer.

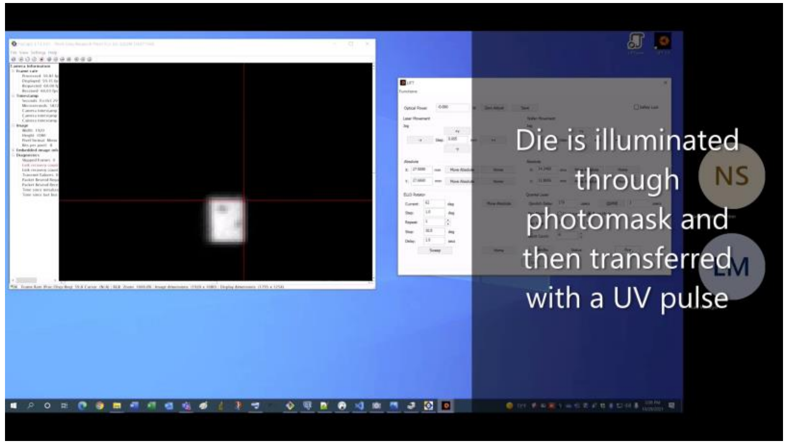


Problem: Incumbent methods are slow or damaging, inaccurate, and expensive

We have an R&D equipment that demonstrates the advantages advertised in the right pane. We seek partner(s) to help with (i) refining a proposal, (ii) designing suitable electrically live test vehicle, (iii) integrating equipment with our LIFT process to demonstrate high yield and throughout, and/or (iv) FEA or related modeling of chemical reactions and gas flow to guide continuous material improvement.



Solution: LIFT + Terefilm® slowed from milliseconds for illustration; parallel transfer possible



Terecircuits' LIFT Advantage:
1) A release material and process that works:
2) 1um placement accuracy on R&D tool (submicron in theory)
3) <5 mJ/cm2 fluence requirement
4) Controlled (via specific chemistry) propulsion direction and velocity
5) Reusable donor plates
6) In-situ customized projection masks

Matthew Robinson: mrobinson@terecircuits.com 805-729-1181

PC 8.5: ENVIRONMENTALLY SUSTAINABLE FHE MANUFACTURING, DESIGN STRATEGIES, AND USE-CASES

PC 8.6: OPEN TOPIC FOR "NEW PROJECT LEADS"

NEXTFLEX®

Project Call 8.0 Teaming Slide

LOOMIA

Proposal Name: FHE Heating System Benchmarking for Cold Weather Soldier Systems
Topic: 8.6: Open Topic
Military Critical Technology Area: Advanced Materials

Contact: Loomia Technologies, inc.
Madison Maxey, CEO and founder
Maddy@loomia.com
+1 (833) 727-4238

ADVERSE IMPACT ON MILITARY OPERATIONS; HISTORICALLY ACCOUNTING FOR 10% OF ALL CASUALTIES IN EARLIER WARS [1]. FHE CAN PROVIDE LIGHTWEIGHT AND EFFICIENT HEATING ELEMENTS TO PROVIDE HEATED COLD WEATHER GEAR, BUT THIS APPROACH TOWARDS GARMENT HEATING IS NOT YET WELL EVIDENCED AND RESEARCHED. THEREFORE, WE PROPOSE A BENCHMARKING PROJECT, COMPARING AND TESTING FHE HEATING SYSTEMS TO BE IMPLEMENTED IN WARFIGHTER GEAR. **WE SUGGEST COMPARING TRADITIONAL WIRE HEATERS AND CARBON FIBER HEATERS WITH PRINTED INK ON POLYESTER, KAPTON AND TPU, LIQUID METAL SOLUTIONS, NOVEL MAGNETICALLY ALIGNED CONDUCTIVE EPOXY AND OTHER UNIQUE MATERIALS TO CREATE A USEFUL DATABASE OF PERFORMANCE SPECIFICATIONS. THE PROTOTYPE WILL ALSO INCORPORATE A NOVEL ANISOTROPIC CONDUCTIVE EPOXY INTERCONNECT TECHNOLOGY THAT IS MORE LIGHTWEIGHT THAN TRADITIONAL INTERCONNECT METHODS AND HAS DEMONSTRATED STRONG PERFORMANCE AT CRYOGENIC TEMPERATURES, WHICH WILL BE BENCHMARKED TO STUDY IMPROVEMENTS IN PERFORMANCE, ADHESION, ROBUSTNESS, AND DURABILITY.**

SEEKING:
-TESTING LAB PARTNER WHO HAS EQUIPMENT NECESSARY FOR UL130 EVALUATION
- UNIQUE TECHNOLOGY PROVIDERS WHO CAN CREATE HEATING SAMPLES OF:
PRINTED INK ON TPU
LIQUID METAL ON SILICONE OR TPU
INK ON POLYESTER
INK ON KAPTON
NOVEL ELECTRICAL INTERCONNECT SOLUTIONS FOR FHE
OTHER UNIQUE FHE SOLUTIONS FOR HEATING ELEMENTS

Background on Related Work Performed:
Loomia has developed heating elements for a range of customers from Fortune 500 companies to Military clients– exposing us to a range of different specifications. We are well positioned to create a testing plan that is suitable for creating an objective benchmark that highlights key performance parameters related to a military grade FHE heating element.

About Loomia:
Loomia designs and manufacturers a soft, flexible circuit layer called the Loomia Electronic Layer (LEL). The LEL is an award-winning material covered by 6 patents. Our soft, flexible circuit technology is designed to integrate easily with textiles and can be used in a range of industries.

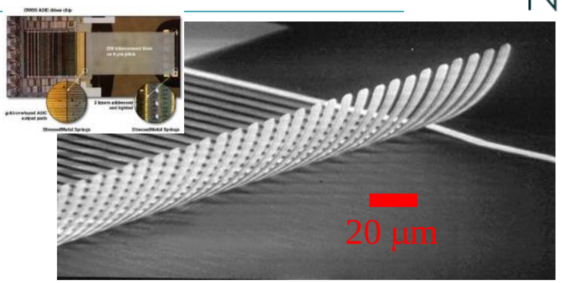
Example Past Customers:

ANALOG DEVICES
covestro
HYUNDAI CRADLE

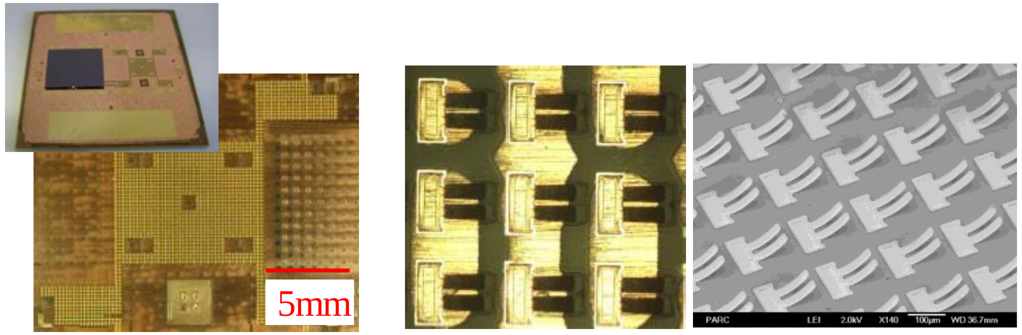
[1] Ref 1: Sustaining Health & Performance in Cold Weather Operations, DTIC ADA395745, TN/02-2, October 2001

PARC MICROSPRINGS

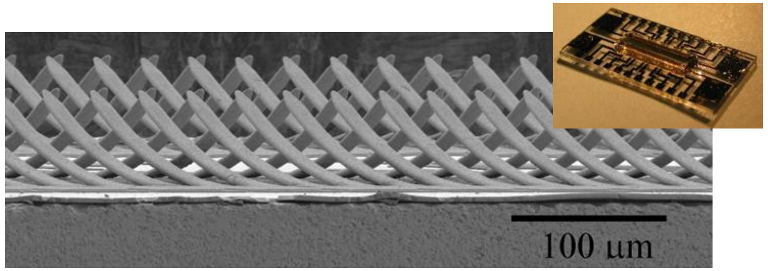
- Thin film lithographic defined pressure contact
- Reworkable flip chip interconnects
- Integrated test & package for lower cost known good module



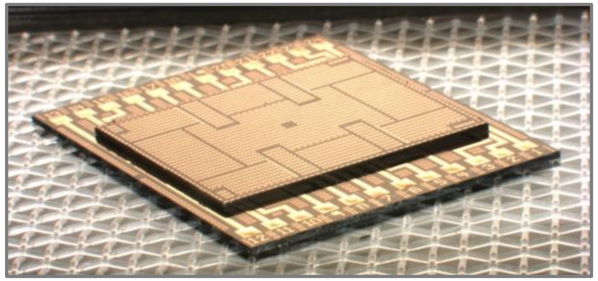
6um pitch linear array
(LED VCSEL bar)



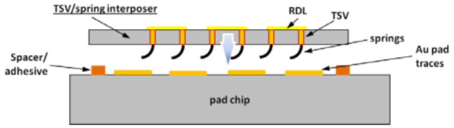
Organic substrate
(180x180um pitch, >2500 contacts, processors with Sun Microsystems)



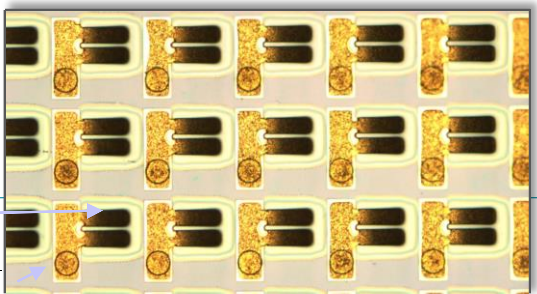
20um pitch linear arrays
(LCD driver array, 800 contacts)

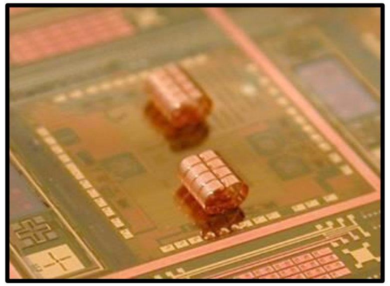


Silicon TSV (180x180um pitch)



springs
TSV

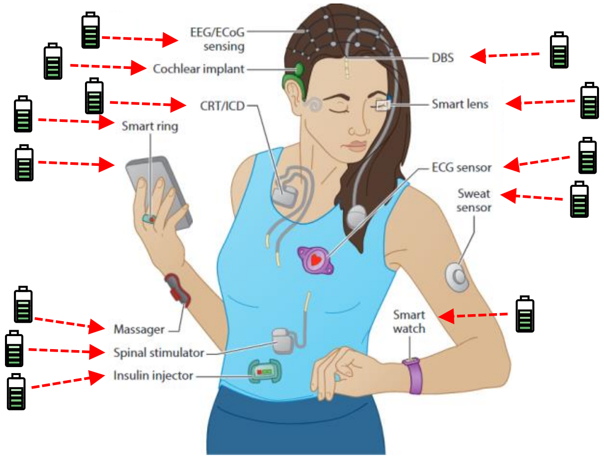




3D Coils on IC

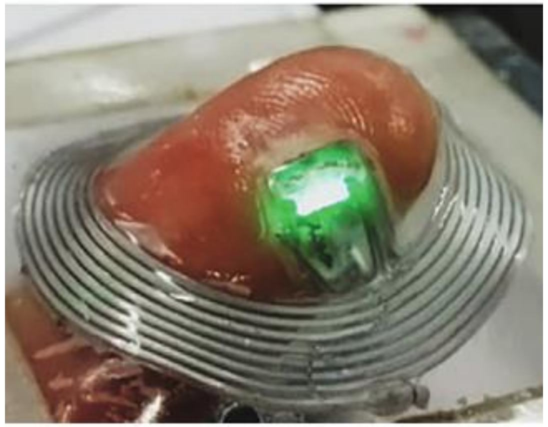
WEARABLE ANTENNA MOTIVATED BY KIRIGAMI

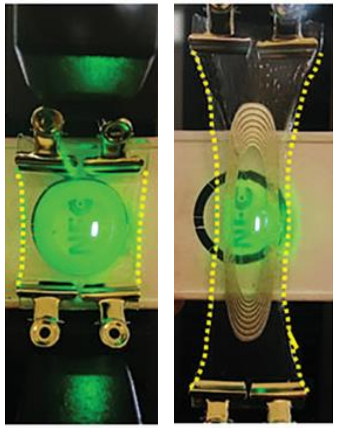
< Wearable Systems >



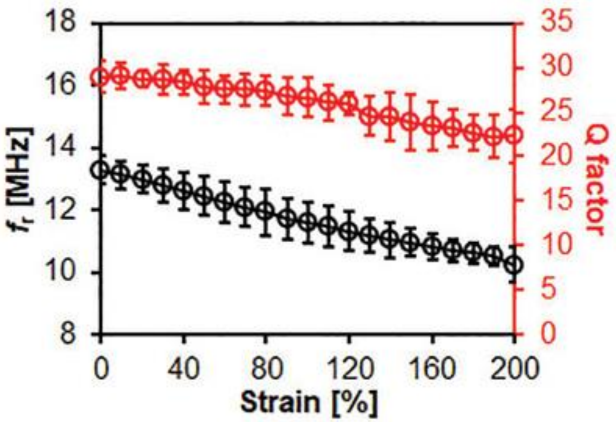
Annual review of chemical and biomolecular engineering 12 (2021)

< Wearable Antenna >





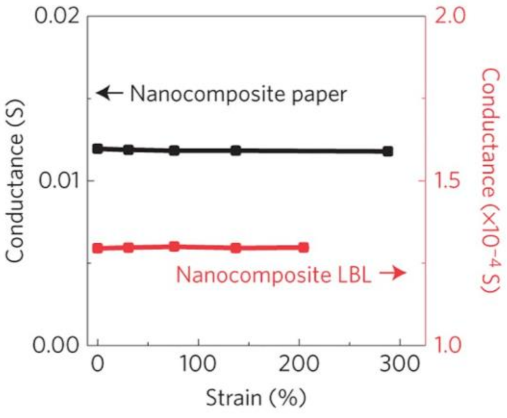
Undeformed Stretched



Advanced Materials 33 (2021)

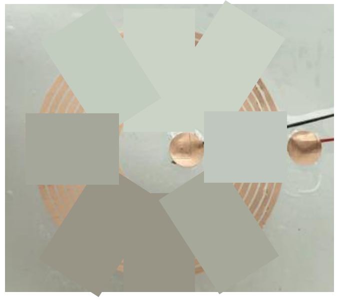
< Kirigami Structure >

Undeformed Stretched



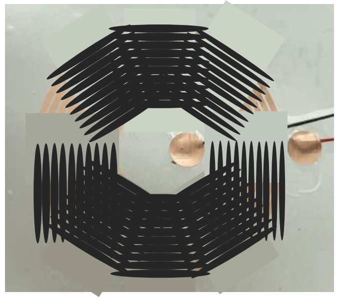
Nature Materials 14 (2015)

< Kirigami Liquid Metal Hinges >



Cut Antenna

Add LM at cut locations

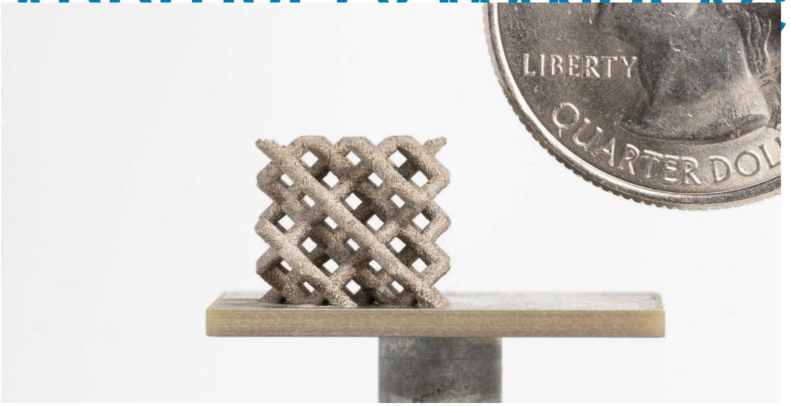


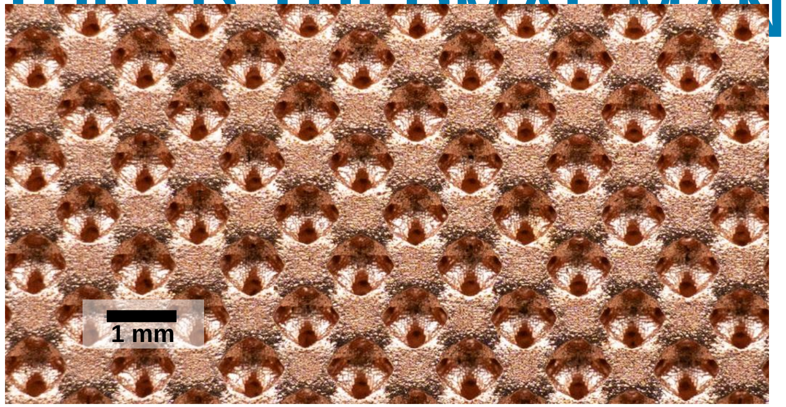
LM Hinge Antenna

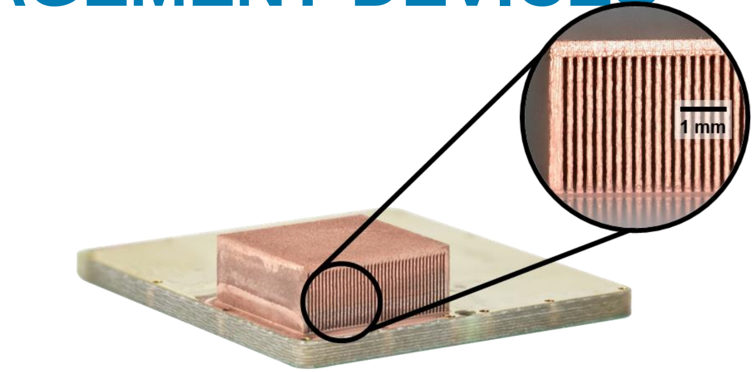
Increase:

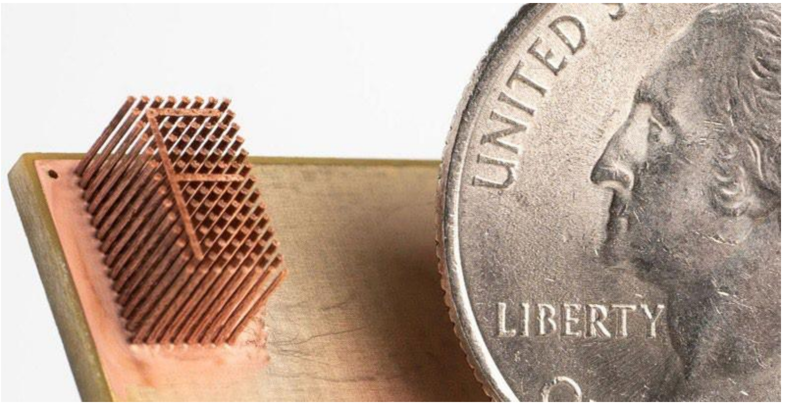
- Cut Size
- Stretchability
- Flexibility
- Electrical Conductivity

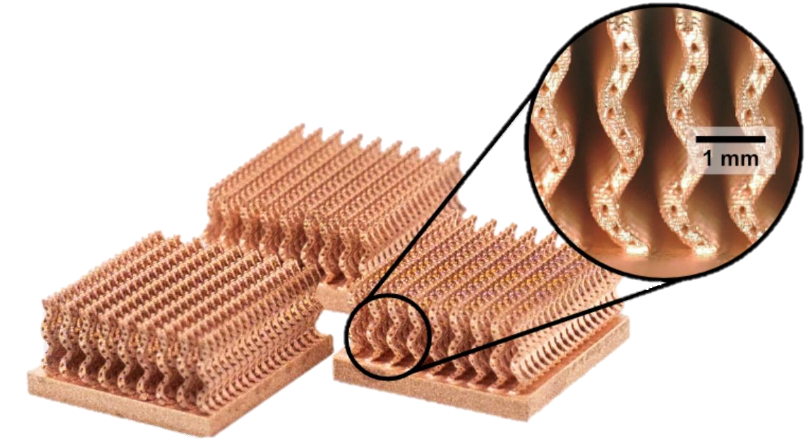
ELECTROCHEMICAL ADDITIVE MANUFACTURING (ECAM) FOR ADDITIVELY MANUFACTURED THERMAL MANAGEMENT DEVICES











ECAM: HIGH-QUALITY PARTS AS-PRINTED

Excellent Feature Resolution | Extreme Aspect Ratios
Low Surface Roughness | High Purity | Direct-Write to PCB/Silicon

POTENTIAL PROEJCT PARTNER CAPABILITIES

Component/System Design and Testing
Open to collaborating in all 8.0 categories

Ian Winfield – VP Product & Applications - ian.winfield@fabric8labs.com

TRL AND MRLS:
SUPPORTING THE NEXTFLEX PROJECT CALL 8.0

MR. MARK GORDON

NEXTFLEX LNO FOR OSD
OSD MANTECH / MFG STRATEGY

Outline

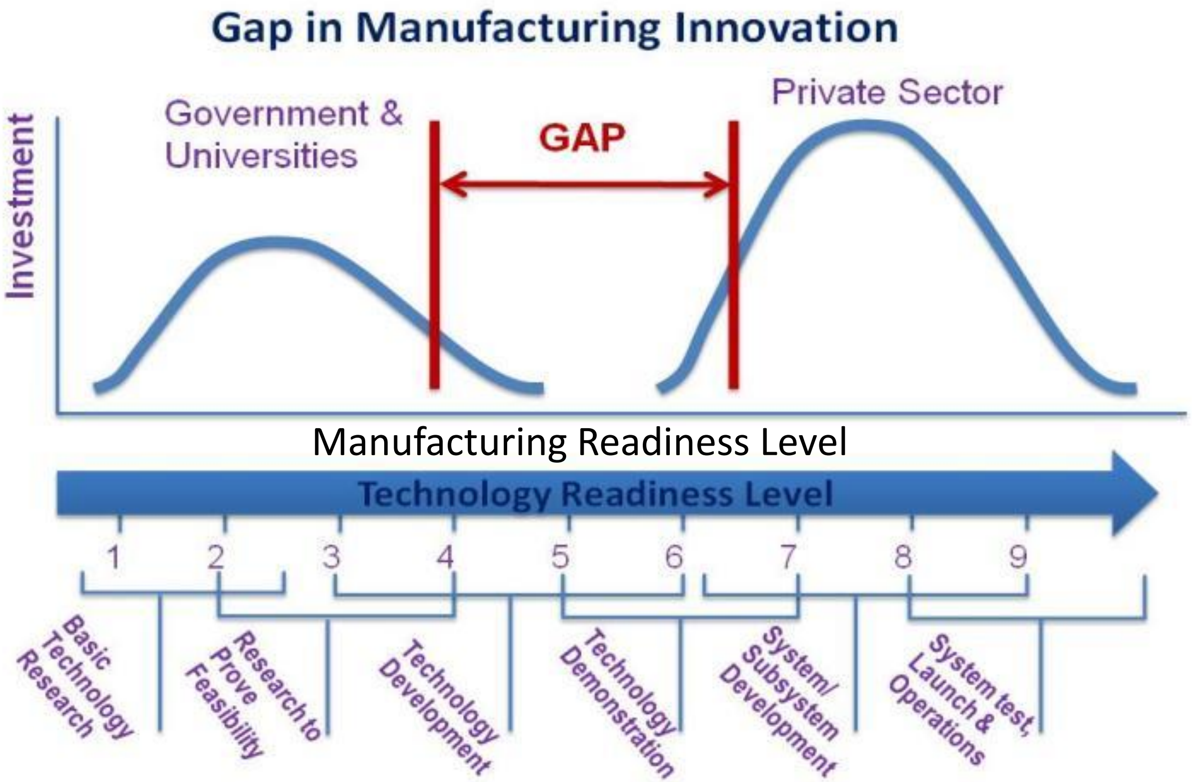
- Readiness Levels: Measures, Assessments, Process and Purpose
- Why MRLs are specifically applied within Institutes
- Technology Readiness Levels
  - As a Measure
  - Assessment Process
- Manufacturing Readiness Levels
  - As a Measure
  - Assessment Process
- Best Practice and Lessons Learned
- Questions?

READINESS LEVELS: MEASURES, ASSESSMENTS, PROCESS AND PURPOSE

- Technology Readiness Levels (and Manufacturing Readiness Levels) are a measurement scale, just like a ruler.
  - TRLs have definitions, documentation needs, and notes for use.
  - MRLs have definitions, 9 threads, 27 sub-threads, master matrix, documentation needs, examples situations, an interactive guide, and tools. (more comprehensive)
- Technology Readiness Assessment is a recommended process for how to determine critical technology elements, assess TRL level, and document results.
- Manufacturing Readiness Assessment is a recommended process for how to tailor MRL threads, apply criteria robustly, assess MRLs, document results, and recommend mitigation.
- The outcomes of utilizing TRLs and MRLs are to provide a common language and standard for *demonstrated* Tech and Mfg Maturity and for an estimate of risk in system acquisition (market success).

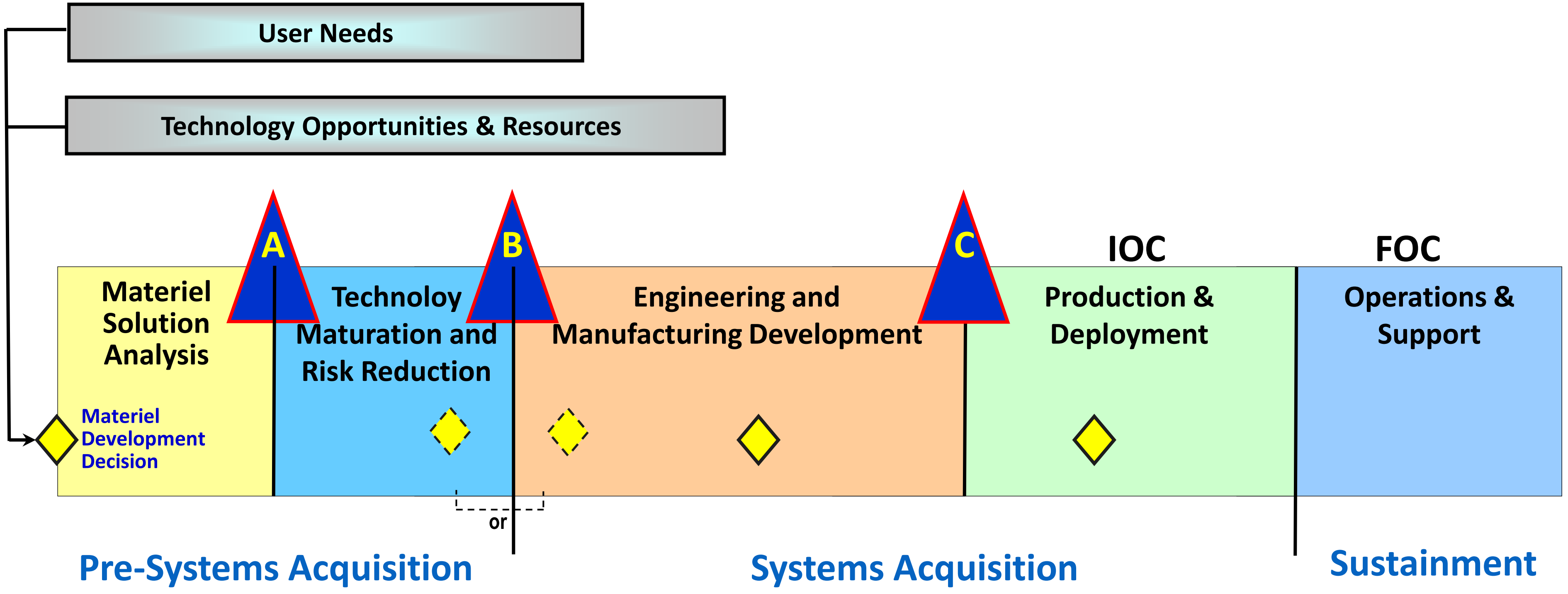
MFG INSTITUTES WERE CREATED TO FILL THE MISSING MIDDLE [MRL 4-7]

Common terms
The "valley of death"
The "missing Bell Labs"
The "industrial commons"



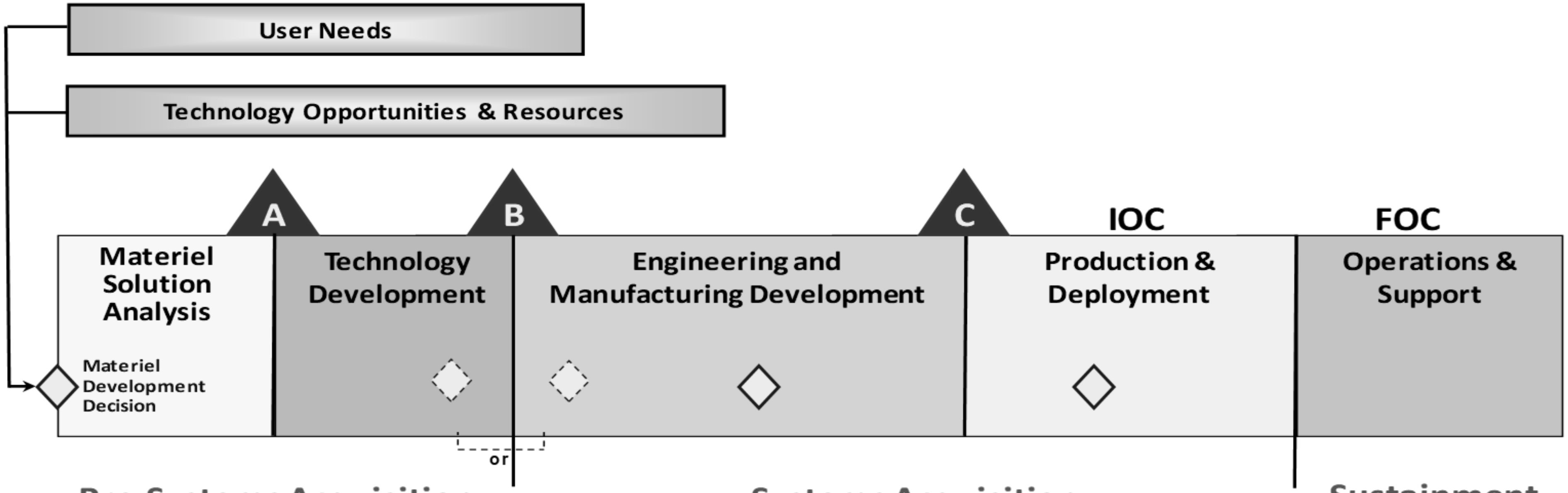
COMMON STARTING POINT

The Defense Acquisition Management Framework



COMMON STARTING POINT : COMMERCIAL PRODUCT DEVELOPMENT

NEXTFLEX



Research Opportunities Demand

Prototyping & Testbeds

Design & Manufacturing

Production & Certification

Launch Support

Ideation

Business Case

Product Development

Launch

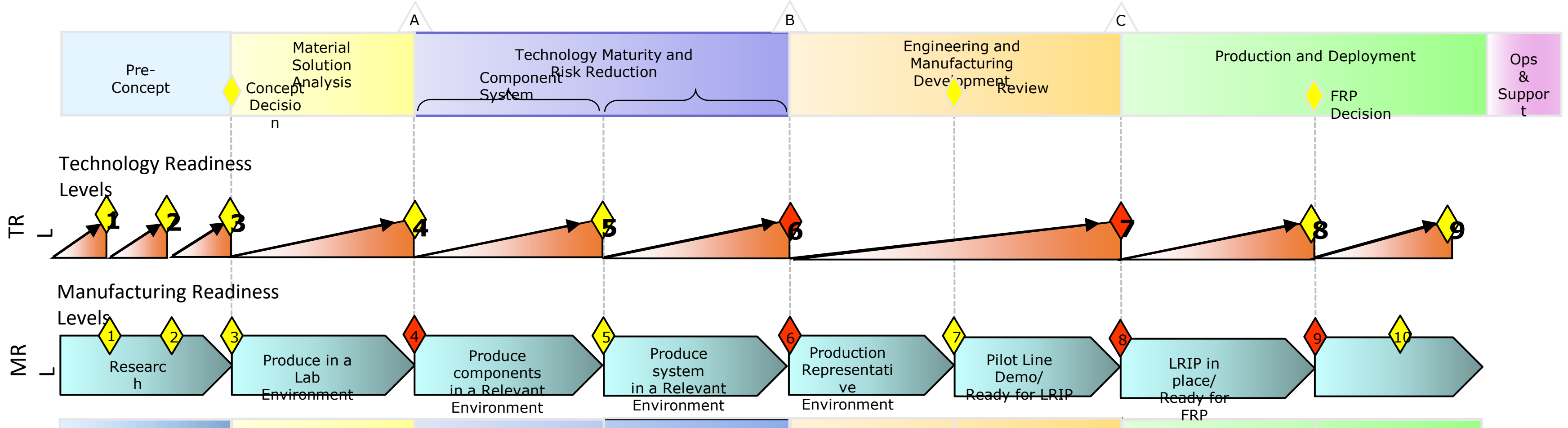
Preliminary Design Review

Critical Design Review

Production Decision

DEPARTMENT OF DEFENSE MANUFACTURING TECHNOLOGY PROGRAM INNOVATING MANUFACTURING

THE ENVIRONMENT FOR APPLYING READINESS LEVELS



Considerations

Manufacturing Concepts Identified *Basic Research* *Advanced Research* *Advanced Technology Development*	Mfg. Processes Identified Key Processes Identified Producibility Assessments Initiated	Mfg. Processes Emerging Producibility Assessments On-going Mfg. Cost Drivers Identified	Mfg. Processes Demonstrated in Relevant Env. Cost Drivers Analyzed Long Lead Items Identified Equipment in a Relevant Env.	Mfg. Processes in Development Producibility Improvement Underway Trade Studies Supply Chain Mgmt in place	Process Maturity Demonstrated All Materials Ready for LRIP Mfg. Processes Proven Supply Chain stable for LRIP	Mfg. Processes Operating at Target Quality, Cost and Performance Supply Chain Established and Meeting Lead Times	Lean/Six Sigma Production in Place Meeting or Exceeding Cost, Schedule and Performance Goals

MRL Exit Criteria

✓ Assess at TRL 1 – 3 ✓ Identify IB Sources ✓ Characterize Basic Materials for Mfg. ✓ Identify Material Concerns ✓ Identify Funding ✓ Identify Advanced ManTech Initiatives ✓ Coordinate with Technology Plan	✓ Assess at TRL 4 ✓ Identify IB Gaps ✓ Assess DFX ✓ Baseline Materials and Issues ✓ Funding/Budgeting for Trade Studies ✓ Identify ManTech or Other Initiatives ✓ Technology Development Strategy should include elements of Mfg/QA	✓ Assess at TRL 5 ✓ IB Analysis Finished ✓ KPPs Allocated ✓ Key Characteristics Identified ✓ SEP includes MFG/QA approach ✓ Funding to Meet Next Level ✓ ManTech Initiatives Initiated ✓ Early Supply Chain assessment	✓ Assess at TRL 6 ✓ IB Capability Assessment ✓ Initial Trade Studies ✓ Materials Matured Similar Lines ✓ Funding to Meet Next Level ✓ ManTech Solutions Developed in Relevant Env ✓ Acquisition Strategy includes Mfg/QA ✓ Quality Thresholds Established	✓ Assess at TRL 7 ✓ IB Monitored ✓ PEP Completed ✓ Materials Being Proven ✓ Funding to Meet Next Level ✓ ManTech Solutions Demonstrated ✓ Supply Chain being assessed ✓ BOM Identified ✓ QA data collected	✓ Assess at TRL 8 ✓ Est. Multi-sources ✓ Pilot Line Builds Validated ✓ Materials Proven ✓ Funding to Meet Next Level ✓ ManTech Solutions Validated ✓ Quality Characteristics Validated ✓ BOM Supports LRIP	✓ Assess at TRL 9 ✓ IB Supports Sched. ✓ Continuous Process Improvement is Ongoing ✓ Materials in Control ✓ Funding to Meet Next Level ✓ Quality Validated with LRIP Articles ✓ Make/Buy Supports FRP ✓ IB Capabilities Assessment	✓ Monitor and Manage all Key Characteristics at a Six Sigma Level ✓ Funding to Meet 6σ goals ✓ No Make/Buy Changes ✓ Key/Critical Suppliers all meet Six Sigma Goals

8 A Red Diamond indicates a Proposed Mandatory Review Point

TECHNOLOGY READINESS LEVELS

- Technology Readiness Levels were originally developed by NASA in the 1980s
- TRL are based on a scale from 1 to 9 with 9 being the most mature technology. A TRL of 6 is aligned with PDR.
- Technology Readiness Levels (TRL) are a method of estimating the technology maturity of program during the development process, and the readiness of the program to proceed to subsequent stages. (Assessment is limited to Critical Technology Elements (CTE) of Program)
- TRLs represent a logical procession of "DEMONSTRATED" capabilities, ranging from lab experiments to component prototypes to subsystems and systems. Demonstration also progress in terms of environment, from artificial to relevant to operational.
- TRLs are a measure of technology maturity through performance.

TECHNOLOGY READINESS LEVEL DEFINITIONS

Technology Readiness Level	Description
1. Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical function and/or characteristic proof of concept	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard **validation** in laboratory environment	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5. Component and/or breadboard **validation** in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.
6. System/subsystem model or prototype **demonstration** in a relevant environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7. System prototype **demonstration** in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space).
8. Actual system completed and qualified through t**est and demonstration.**	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system **proven** through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.

TECHNOLOGY READINESS ASSESSMENTS

- Well defined and rigorous process for assessing the technology maturity of a product or system using TRLs.
- DoD, NASA, and other organizations have processes.
- DoD TRA Deskbook (2011) is most widely used.
  - Establish a TRA Plan and Schedule
  - Form a SME Team
  - Identify Technologies To Be Assessed
  - Collect Evidence of Maturity
  - Assess Technology Maturity
    - SME team Assessment
    - Prepare, Coordinate, and Submit a TRA Report
    - Review and Evaluation
- In most cases, only Critical Technology Elements (CTEs) are assessed.
  - CTEs are those that directly related to system performance requirements or design critical.
  - CTEs should be identified in the context of the program's systems engineering process, based on a comprehensive review of the most current system performance and technical requirements and design

WHY AREN'T TECHNOLOGY READINESS LEVELS ENOUGH?

- TRL Definitions deal primarily with demonstration of performance.
  - Within increasingly realistic environments.
- Initially, during a 2000 manufacturing study of the FCS critical technologies, TRLs were rejected as a sole method of assessing readiness.
- TRLs do not encompass any production or sustainment attributes, and cannot answer questions such as:
  - **Is the prototype level of performance reproducible in items 2 - 1000?**
  - **What will these cost in production?**
  - **Can these be made in a production environment by someone without a PhD?**
  - **Is the acquisition schedule realistic**
  - **Are the key materials and components available?**
- So Manufacturing Readiness Levels were proposed, along with an initial scale and entrance criteria.
- MRLs measure the maturity (or readiness) of a technology for scale up and commercialization.

MANUFACTURING READINESS LEVELS

- Manufacturing Readiness Levels were originally developed by DoD ManTech starting in 2001
- MRLs are based on a scale from 1 to 10 with 10 being the most mature manufacturing capability. An MRL of 6 is aligned with PDR, and an MRL of 8 is aligned with a Production Decision.
- The MRL scale generally correlates with TRLs, with an additional level consisting of continuous improvement and lean practices.
- MRLs indicate the level of program risk – compared to an ideal progression of demonstrated knowledge- for meeting production goals (including cost, schedule, performance) based upon successful completion of manufacturing-related activities during development.
- Program maturity and readiness are compared to the “target” MRL based upon the product development phase.
- Assessment of “Level” is not based upon ‘Quick look,’ but instead based upon **substantiation**, usually in the form of supporting documents, tasks, or benchmarks. MRLs have a great deal more depth than TRLs in descriptions and criteria.

MANUFACTURING READINESS LEVEL DEFINITIONS

NEXTFLEX®

MRL	Definition
1	Manufacturing Feasibility Assessed
2	Manufacturing Concepts Defined
3	Manufacturing Concepts Developed
4	Capability to produce the technology in a laboratory environment.
5	Capability to produce prototype components in a production relevant environment.
6	Capability to produce a prototype system or subsystem in a production relevant environment.
7	Capability to produce systems, subsystems or components in a production representative environment.
8	Pilot line capability demonstrated. Ready to begin low rate production.
9	Low Rate Production demonstrated. Capability in place to begin Full Rate Production.
10	Full Rate Production demonstrated and lean production practices in place.

MRL- FURTHER DEFINITION OF TERMS

- **Production Relevant Environment** – An environment normally found during MRL 5 and 6 that contains key elements of production realism not normally found in the laboratory environment (e.g. uses production personnel, materials or equipment or tooling, or process steps, or work instructions, stated cycle time, etc.). *May occur in a laboratory or model shop if key elements or production realism are added.*
- **Production representative environment** – An environment normally found during MRL 7 (probably on the manufacturing floor) that contains most of the key elements (tooling, equipment, temperature, cleanliness, lighting, personnel skill levels, materials, work instructions, etc) that will be present in the shop floor production areas where low rate production will eventually take place.
- **Pilot line environment** – An environment normally found during MRL 8 in a manufacturing floor production area that incorporates all of the key elements (equipment, personnel skill levels, materials, components, work instructions, tooling, etc.) required to produce production configuration items, subsystems or systems that meet design requirements in low rate production. To the maximum extent practical, the pilot line should utilize rate production processes

MRL DESCRIPTIONS- DETAIL

MRL	Definition	Description	Phase
1	Manufacturing Feasibility Assessed	This is the lowest level of manufacturing readiness. The focus is on a top level assessment of feasibility and manufacturing shortfalls. Basic manufacturing principles are defined and observed. Begin basic re-search in the form of studies (i.e. 6.1 funds) to identify producibility and material solutions.	Pre Concept Refinement
2	Manufacturing Concepts Defined	This level is characterized by developing new manufacturing approaches or capabilities. Applied Research translates basic research into solutions for broadly defined military needs. Begin demonstrating the feasibility of producing a prototype product/component with very little data available. Typically this is applied research (i.e. 6.2) in the S&T environment and includes identification and study of material and process approaches, including modeling and simulation.	Pre Concept Refinement
3	Manufacturing Concepts Developed	This begins the first real demonstrations of the manufacturing concepts. This level of readiness is typical of technologies in the S&T funding categories of 6.2 and 6.3. Within these levels, identification of current manufacturing concepts or producibility has occurred and is based on laboratory studies. Materials have been characterized for manufacturability and avail-ability but further evaluation and demonstration is required. Models have been developed in a lab environment that may possess limited functionality.	Pre Concept Refinement
4	Capability to produce the technology in a laboratory environment.	Required investments, such as manufacturing technology development identified. Processes to ensure manufacturability, producibility and quality are in place and are sufficient to produce technology demonstrators. Manufacturing risks identified for prototype build. Manufacturing cost drivers identified. Producibility assessments of design concepts have been completed. Key Performance Parameters (KPP) identified. Special needs identified for tooling, facilities, material handling and skills.	Concept Refinement (CR) leading to a Milestone A decision.
5	Capability to produce prototype components in a production relevant environment.		Technology Development (TD) Phase.
6	Capability to produce a prototype system or subsystem in a production relevant environment.	Initial mfg approach developed. Majority of manufacturing processes have been defined and characterized, but there are still significant engineering/design changes. Preliminary design of critical components completed. Producibility assessments of key technologies complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on subsystems/ systems in a production relevant environment. Detailed cost analysis include design trades. Cost targets allocated. Producibility considerations shape system development plans. Long lead and key supply chain elements identified. Industrial Capabilities Assessment (ICA) for MS B completed.	Technology Development (TD) phase leading to a Milestone B decision.
			System Development & Demo (SDD) leading to Design Readiness Review (DRR).
			System Development & Demo leading to a Milestone C decision.
			Production & Deployment leading to a Full Rate Production (FRP) decision
			Full Rate Production/ Sustainment

Mfg strategy refined and integrated with Risk Mgt Plan. Identification of enabling/critical technologies and components is complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on components in a production relevant environment, but many manufacturing processes and procedures are still in development. Manufacturing technology development efforts initiated or ongoing. Producibility assessments of key technologies and components ongoing. Cost model based upon detailed end-to-end value stream map.

MRL IN DEPTH: NINE "THREADS"

- **Technology and the Industrial Base**: Requires an analysis of the capability of the national technology and industrial base to support the design, development, production, operation, and maintenance support of the system.
- **Design**: Requires an understanding of the maturity and stability of the evolving system design and any related impact on manufacturing readiness.
- **Cost and Funding**: Requires an analysis of the adequacy of funding to achieve target manufacturing maturity levels. Examines the risk associated with reaching manufacturing cost targets.
- **Materials:** Requires an analysis of the risks associated with materials (including basic/raw materials, components, semi-finished parts, and subassemblies).
- **Process Capability and Control:** Requires an analysis of the risks that the manufacturing processes are able to reflect the design intent (repeatability and affordability) of key characteristics.
- **Quality Management:** Requires an analysis of the risks and management efforts to control quality, and foster continuous improvement.
- **Manufacturing Workforce** (Engineering and Production): Requires an assessment of the required skills, availability, and required number of personnel to support the manufacturing effort.
- **Facilities:** Requires an analysis of the capabilities and capacity of key manufacturing facilities (prime, subcontractor, supplier, vendor, and maintenance/repair).
- **Manufacturing Management**: Requires an analysis of the orchestration of all elements needed to translate the design into an integrated and fielded system (meeting Program goals for affordability and availability).

MRL IN DETAIL- CRITERIA MATRIX

NEXTFLEX

MRL 1 to 10 →

Threads ↓

DoD Manufacturing Readiness Levels (MRLs)									
S&T Phase		6.1 - 6.2 SBIR	6.3 SBIR	6.3 / 6.4 / [illegible]	[illegible]	[illegible]	7.8	7.8	7.8 Title III
Acq Phase		Pre CR	CR - MS A	[illegible]	[illegible]	[illegible]	MS C	LRIP - FRP	FRP
Thread	Sub-Thread	MRL 1-3	MRL 4	[illegible]	[illegible]	[illegible]	MRL 8	MRL 9	MRL 10
Technology & Industrial Base	Technology Maturity	TRLs 1-3	Should be assessed at TRL [illegible]	[illegible]	[illegible]	[illegible]	...ld be assessed at TRL 8.	Should be assessed at TRL 9.	
	Technology Transition to Production	Potential manufacturing sources identified for technology needs. (Commercial/Government, Domestic/Foreign)	Industrial Base capabilities and gaps/risks identified for key technologies, components, and/or key processes.	Indus... identify potential ma... sources.	... completed. Industrial capability in place to support mfg of development articles. Plans to minimize sole/foreign sources complete. Need for sole/foreign sources justified. Potential alternative sources identified.	... been analyzed. Sole/foreign sources stability is assessed/monitored. Developing potential alternate sources as necessary.	Industrial Capability Assessment (ICA) for MS C has been completed. Industrial capability is in place to support LRIP. Sources are available, multi-sourcing where cost-effective or necessary to mitigate risk.	Industrial capability is in place to support start of FRP.	Industrial capability supports FRP. Industrial capability assessed to support mods, upgrades, surge and other potential manufacturing requirements.
	Manufacturing Technology Development	Mfg Science considered	Mfg Science & Advanced Mfg Technology requirements identified	Required manufacturing technology development efforts initiated.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production relevant environment.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production representative environment.	Manufacturing technology efforts continuing. Required manufacturing technology solutions validated on a pilot line.	Manufacturing technology efforts continuing. Manufacturing technology process improvements efforts initiated for FRP.	Manufacturing technology efforts continuing. Manufacturing technology continuous process improvements ongoing.
	P...ducibility ...m	Evaluate relevant materials/processes for manufacturability & producibility	Producibility & Manufacturability assessment of design concepts completed. Results guide selection of design concepts and key components/technologies for Technology Development Strategy. Manufacturing Processes assessed for capability to test and verify in production, and influence on O&S.	Producibility & Manufacturability assessments of key technologies and components initiated. Systems Engineering Plan (SEP) requires validation of design choices against manufacturing process and industrial base capability constraints.	Producibility assessments of key technologies/components and producibility trade studies (performance vs. producibility) completed. Results used to shape System Development Strategy and plans for SDD or technology insertion programs phase.	Detailed producibility trade studies using knowledge of key design characteristics and related manufacturing process capability completed. Producibility enhancement efforts (e.g. DFMA) initiated.	Producibility improvements implemented on system. Known producibility issues have been resolved and pose no significant risk for LRIP.	Prior producibility improvements analyzed for effectiveness during LRIP. Producibility issues/risks discovered in LRIP have been mitigated and pose no significant risk for FRP.	On-going producibility improvements analyzed for effectiveness. Producibility refinements continue. All mods, upgrades, DMSMS and other changes assessed for producibility.
	...ty	Evaluate product lifecyle requirements and product performance requirements.	Systems Engineering Plans and the Test and Evaluation Strategy recognize the need for the establishment/validation of manufacturing capability and management of manufacturing risk for the product lifecycle. Initial Key Performance Parameters (KPPs) identified.	Identification of enabling/critical technologies and components is complete and includes the product lifecycle. Evaluation of design Key Characteristics (KC) initiated.	Basic system design requirements defined. All enabling/critical technologies/components have been tested and validated. Product data required for prototype manufacturing released. A preliminary performance as well as focused logistics specification is in place. Key Characteristics and tolerances have been established.	Product requirements and features are well enough defined to support detailed systems design. All product data essential for manufacturing of component design demonstration released. Potential KC risk issues have been identified and mitigation plan is in place. Design change traffic may be significant.	Detailed design of product features and interfaces is complete. All product data essential for system manufacturing released. Major product design features are sufficiently stable such that key LRIP manufacturing processes will be representative of those used in FRP. Design change traffic does not significantly impact LRIP. Key characteristics are stable and have been demonstrated in SDD or technology insertion program.	Major product design features are stable and LRIP produced items are proven in product testing. Design change traffic is limited to minor configuration changes. All KC's are controlled in production to three sigma or other appropriate quality levels.	Product design is stable. Design changes are few and generally limited to those required for continuous improvement or in reaction to obsolescence. All KCs are controlled to six sigma or other appropriate quality levels.
Cost & F...	...t ...st	Technology cost models developed for new process steps and materials based on engineering details at MRL 1-2. High-level process chart cost models with major production steps identified at MRL 3.	Detailed process chart cost models driven by key characteristics and process variables. Manufacturing, material and specialized reqt. cost drivers identified.	Detailed end-to-end value stream map cost model for major system components includes Materials, Labor, Equipment, Tooling/STE, setup, yield/scrap/rework, WIP, and capability/capacity constraints. Component simulations drive cost models.	Cost model inputs include design requirements, material specifications, tolerances, integrated master schedule, results of system/subsystem simulations and production relevant demonstrations.	Cost models updated with detailed designs and features, collected quality data, plant layouts and designs, obsolescence solutions.	Engineering cost model driven by detailed design and validated with data from relevant environment.	Actual cost model developed for FRP environment. Variability experiments conducted to show FRP impact, potential for continuous improvement.	Cost model validated against actual FRP cost.
		Sensitivity, Pareto analysis to find cost drivers and production representative scenario analysis to focus S&T initiatives and address scale-up issues.	Material, manufacturing, and specialized reqt. costs identified for design concepts. Producibility cost risks assessed and manufacturing technology initiatives identified to reduce costs.	Current state analysis of cost of design choices, make/buy, capacity, process capability, sources, quality, key characteristics, yield/rate, and variability.	Cost analysis of mfg future states, design trades, supply chain/yield/rate/SDD/technology insertion plans. Allocate cost targets. Cost reduction and avoidance contract incentives identified.	Costs rolled up to system level and tracked against targets. Detailed trade studies and engineering change requests supported by cost estimates. Cost reduction efforts underway, incentives in place.	Cost analysis of proposed changes to requirements or configuration.	LRIP cost goals met, learning curve validated.	FRP cost goals met. Cost reduction initiatives ongoing.
	...ring ...t Budget	Program/ projects have budget estimates for reaching MRL of 4.	Program has budget estimate for reaching MRL 5. All Risk Mitigation Plans required to raise deficient elements to MRL of 4 are fully funded.	Program has budget estimate for reaching MRL 6 by MS B. Estimate includes capital investment for Production-representative equipment. All Risk Mitigation Plans required to raise deficient elements to MRL of 5 are fully funded.	Program has budget estimate for reaching MRL 7 by CDR. All Risk Mitigation Plans required to raise deficient elements to MRL of 6 are fully funded.	Program has budget estimate for reaching MRL 8 by MS C. Estimate includes investment for Low Rate Initial Production. All Risk Mitigation Plans required to raise deficient sub systems to MRL of 7 are fully funded.	Program has budget estimate for reaching MRL 9 by the FRP decision point. Estimate includes investment for Full Rate Production. All Risk Mitigation Plans required to raise deficient sub systems to MRL of 8 are fully funded.	Program has budget estimate for lean implementation during FRP. All Risk Mitigation Plans required to improve deficient subsystems to MRL of 9 during FRP are fully funded.	Production budgets sufficient for production at required rates and schedule.

DEPARTMENT OF DEFENSE MANUFACTURING TECHNOLOGY PROGRAM INNOVATING MANUFACTURING

MRL IN DETAIL- CRITERIA MATRIX

NEXTFLEX

DoD Manufacturing Readiness Levels (MRLs)

S&T Phase		**6.1 - 6.2 SBIR**	**6.3 SBIR**	**6.3 / 6.4 / 7**			**7.8**	**7.8**	**7.8 Title III**
Acq Phase		**Pre CR**	**CR - MS A**				**MS C**	**LRIP - FRP**	**FRP**
Thread	**Sub-Thread**	**MRL 1-3**	**MRL 4**				**MRL 8**	**MRL 9**	**MRL 10**
Technology & Industrial Base	**Technology Maturity**	TRLs 1-3	Should be assessed at TRL				…ld be assessed at TRL 8.	Should be assessed at TRL 9.	
	Technology Transition to Production	Potential manufacturing sources identified for technology needs. (Commercial/Government, Domestic/Foreign)	Industrial Base capabilities and gaps/risks identified for key technologies, components, and/or key processes.	Indus… identify potential manu… sources.	… completed. Industrial capability in place to support mfg of development articles. Plans to minimize sole/foreign sources complete. Need for sole/foreign sources justified. Potential alternative sources identified.	… been analyzed. Sole/foreign sources stability is assessed/monitored. Developing potential alternate sources as necessary.	Industrial Capability Assessment (ICA) for MS C has been completed. Industrial capability is in place to support LRIP. Sources are available, multi-sourcing where cost-effective or necessary to mitigate risk.	Industrial capability is in place to support start of FRP.	Industrial capability supports FRP. Industrial capability assessed to support mods, upgrades, surge and other potential manufacturing requirements.
	Manufacturing Technology Development	Mfg Science considered	Mfg Science & Advanced Mfg Technology requirements identified	Required manufacturing technology development efforts initiated.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production relevant environment.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production representative environment.	Manufacturing technology efforts continuing. Required manufacturing technology solutions validated on a pilot line.	Manufacturing technology efforts continuing. Manufacturing technology process improvements efforts initiated for FRP.	Manufacturing technology efforts continuing. Manufacturing technology continuous process improvements ongoing.
	…ducibility …m	Evaluate relevant materials/processes for manufacturability & producibility	Producibility & Manufacturability assessment of design concepts completed. Results guide selection of design concepts and key components/technologies for Technology Development Strategy. M…cturing …cesses assessed for capability to test and verify in production, and influence on O&S.	Producibility & Manufacturability assessments of key technologies and components initiated. Systems Engineer… …lan (SEP) requi… validation of design choices against manufacturing process and industrial base capability constraints.	Producibility assessments of key technologies/components and producibility trade studies (performance vs. producibility) completed. Results used to shape System Development Strategy and plans for SDD or technology insertion programs phase.	Detailed producibility trade studies using knowledge of key design characteristics and related manufacturing process capability completed. Producibility enhancement efforts (e.g. DFMA) initiated.	Producibility improvements implemented on system. Known producibility issues have been resolved and pose no significant risk for LRIP.	Prior producibility improvements analyzed for effectiveness during LRIP. Producibility issues/risks discovered in LRIP have been mitigated and pose no significant risk for FRP.	On-going producibility improvements analyzed for effectiveness. Producibility refinements continue. All mods, upgrades, DMSMS and other changes assessed for producibility.
					…gn …ed. All …onents ha…e …lidated. …red for …turing …nary …ll as foc…sed …on is in …ace. …s and …en	Product requirements and features are well enough defined to support detailed systems design. All product data essential for manufacturing of component design demonstration released. Potential KC risk issues have been identified and mitigation plan is in place. Design change traffic may be significant.	Detailed design of product features and interfaces is complete. All product data essential for system manufacturing released. Major product design features are sufficiently stable such that key LRIP manufacturing processes will be representative of those used in FRP. Design change traffic does not significantly impact LRIP. Key characteristics are stable and have been demonstrated in SDD or technology insertion program.	Major product design features are stable and LRIP produced items are proven in product testing. Design change traffic is limited to minor configuration changes. All KC's are controlled in production to three sigma or other appropriate quality levels.	Product design is stable. Design changes are few and generally limited to those required for continuous improvement or in reaction to obsolesence. All KCs are controlled to six sigma or other appropriate quality levels.
Cost & F…					…inclu…e design …erial …ranc…s, …sche…ule, …ubs…stem …odu…tion …atio…s.	Cost models updated with detailed designs and features, collected quality data, plant layouts and designs, obsolescence solutions.	Engineering cost model driven by detailed design and validated with data from relevant environment.	Actual cost model developed for FRP environment. Variability experiments conducted to show FRP impact, potential for continuous improvement.	Cost model validated against actual FRP cost.
					…fg…uture …es…supply …D…technology …l…cate cost …tion and …ncentives	Costs rolled up to system level and tracked against targets. Detailed trade studies and engineering change requests supported by cost estimates. Cost reduction efforts underway, incentives in place.	Cost analysis of proposed changes to requirements or configuration.	LRIP cost goals met, learning curve validated.	FRP cost goals met. Cost reduction initiatives ongoing.
	…t Budget	estimates for reaching MRL of 4.	reaching MRL 5. All Risk Mitigation Plans required to raise deficient elements to MRL of 4 are fully funded.	reaching MRL 6 by MS B. Estimate includes capital investment for Production-representative equipment. All Risk Mitigation Plans required to raise deficient elements to MRL of 5 are fully funded.	…t estimate for reaching MRL 7 by CDR. All Risk Mitigation Plans required to raise deficient elements to MRL of 6 are fully funded.	Program has budget estimate for reaching MRL 8 by MS C. Estimate includes investment for Low Rate Initial Production. All Risk Mitigation Plans required to raise deficient sub systems to MRL of 7 are fully funded.	Program has budget estimate for reaching MRL 9 by the FRP decision point. Estimate includes investment for Full Rate Production. All Risk Mitigation Plans required to raise deficient sub systems to MRL of 8 are fully funded.	Program has budget estimate for lean implementation during FRP. All Risk Mitigation Plans required to improve deficient subsystems to MRL of 9 during FRP are fully funded.	Production budgets sufficient for production at required rates and schedule.

MRL 1 to 10 →

Producibility assessments of key technologies /components and producibility trade studies completed. Results used to shape System Development Strategy and plans for EMD technology insertion.

DEPARTMENT OF DEFENSE MANUFACTURING TECHNOLOGY PROGRAM INNOVATING MANUFACTURING

MANUFACTURING READINESS ASSESSMENTS

- Well defined and rigorous process for assessing the status of a product or system against standard benchmarks using MRLs.
- Tailoring of the main matrix criteria is permitted based upon specific situations. MRLs are NOT limited to critical technology items.
- DoD has published an MRL Deskbook describing the MRA Process.
  - Determine Scope
  - Determine Assessment Taxonomy and Schedule
  - Form and Orient Assessment Team
  - Request Contractors Perform Self-Assessment
  - Set Agenda for Site Visits
  - Conduct the Assessment of Manufacturing Readiness
    - Start with MRL Benchmark, work backwards along Threads
    - Consider self assessment, use VSM, WBS, mfg flow and other techniques to understand and document process.
    - Discuss tooling and supply chain management, ask for evidence & Documentation
  - Prepare the Assessment Report and MMP

RESOURCES FOR MRLS AND MRAS

The MRLWG provides the following open-source documents and tools, which form the MRL BoK:

- DoD MRL Deskbook
- MRL User’s Guide (NOTE: macro-enabled MS Excel workbook)
- MRL Questionnaire.xlsx (included within the MRL User’s Guide file)
- MRL Criteria Matrix (included within the MRL User’s Guide file) or by separate download

http://www.dodmrl.org or http://www.dodmrl.com

MRL Bok Reference	Current Version	Previous Versions								
		2020	2018	2017	Early 2016	Mid 2015	Early 2015	2012	2011	2004-2009
MRL Deskbook	**2022**	2020	2018	2017	2016	Version 2.4	Version 2.3	Version 2.2.1	Version 2.0	Three earlier versions
Interactive Users Guide	**2022**	2020	2018	2016-2017	Version 12.6			Version 11.3		No earlier versions
Criteria Matrix	**2022**	2020	2018	Version 11.6		Version 11.5		Version 11.3	Version 11	No earlier versions
Printable Matriz	**2022**	2020	2018	Version 11.6		Version 11.5				No earlier versions

LESSONS LEARNED- BEST PRACTICES 1/ 2

- MRL is **limited** by TRL- If Technology or design is not sufficiently defined and demonstrated, how can manufacturing capability be proven. MRL may exceed TRL by one level in most cases.
- MRL is **NOT** about the number- focus on the meaning of each level, the number indicates progression and is used for communication
- MRL **cannot** be a 4.5 or 5.725- Levels represent stages, consider activities or milestones that will demonstrate maturity.
- MRLs are **not** an auditing mechanism- the descriptions, threads and criteria are mean to be adapted to the specific nature of a product under development. Provide reasoning for tailoring.
- The time, effort, and investment to progress from MRL 4 to 5 is **not** similar to MRL 6 to 7.

LESSONS LEARNED- BEST PRACTICES 2/2

- TRL or MRL is a contact sport- claims must be made based upon actual experience by team members, at team facilities, with known technology scope. One cannot claim a TRL or MRL of a 787 aircraft due to Boeing's experiences if one is not Boeing.
- In proposal planning, consider what steps would be necessary to progress through each MRL, and schedule milestones.
- Do NOT start with an MRL 4 and then magically have the project end at an MRL of 7. Describe progression of MRL 4 to 5, then 6, then 7. (if MRL 7 is indicated). Integrate with increasing TRL in program plan.
- Institute Project may involve limited demonstrations of Manufacturing Areas, or Technology Platform Demonstrations. If so, tailor the MRL matrix to focus on limited demonstration, but indicate what would be necessary to pursue commercialization.
- A formal MRA is not require for a pre-proposal or proposal.

HIGHLIGHTS OF DOD MRL REQUIREMENTS

LAW

- FY2012 NDAA – Public Law 112-81 (31 December 2011)

DoD

- DoDI 5000.02 Operation of the Adaptive Acquisition System
- CJCSI 3170-01I "Joint Capabilities Integration & Development System"
- Manual for the Operation of the JCIDS
- Defense Acquisition Guide (DAG)
- DoD Manufacturing Readiness Level Deskbook
- DoD Risk Management Guide for DoD Acquisition
- MIL-HDBK-896A Manufacturing Management Program Guide

Army, Navy & USAF

- Army Regulation 70-1 "Army Acquisition Policy"
- USAF AFI 63-101 "Integrated Life Cycle Management"
- USAF AFI 63-145 "Manufacturing and Quality Management "
- Navy Instruction 4355.19E "Systems Engr. Technical Review Process"