

FAB – Fabric-Based Power Generation and Storage

Problem Statement

OBJECTIVE: The DOD relies on a diverse supply chain and a strong manufacturing industrial base to complement the organic defense industrial base. The department has a need to accelerate the transition of manufacturing technologies to ensure technological advantage for the warfighter.

DESCRIPTION: Many emerging technologies in textiles will require consistent, reliable, safe and potentially washable power sources. The development of energy delivery fabrics can greatly accelerate the delivery of new fabric technologies for applications from self-powered shelters to drop and charge fabrics. This topic produces a fabric system capable of generating, storing and/or supplying power to relevant, modern electronic systems.

Prepare a proposal to demonstrate useful charge/discharge rates and safe power cycles generation. Of interest are working prototype fabric-based systems, or systems that can be integrated with fabric-based-devices, that can generate energy through solar, triboelectric, thermoelectric, piezoelectric or other means with requisite electrical connections to supply power to a representative device. Safe, flexible battery sources that can be integrated into fabric systems and fabric antennae designs that can receive wireless power are also sought. ***The anticipated product form is a fabric swatch or equivalent that demonstrates the technological capability and justifies follow-on work in this area.***

For this exam, do not concern yourself with a specific end-product unless the end-use is fabric specific (for example: body heat will be harvested with some sort of clothing item). Instead, focus on developing a fabric sample that provides useful electrical energy using one or more modes of waste energy harvesting: motion, heat, photovoltaic, electromagnetic, etc. At a minimum, pick one mode and propose how to develop and demonstrate a fabric prototype that can reliably deliver and/or store useful energy while functioning as close to non-energy delivery fabrics as possible (for example: if the end application is a ‘shirt’ it should still be as comfortable as possible and non-intrusive to everyday life).

REFERENCES:

1. Liao, M. et al. “Printable Solid-State Lithium-Ion Batteries: A New Route toward Shape-Conformable Power Sources with Aesthetic Versatility for Flexible Electronics” Adv. Electron. Mater. 2019, 5, 1800456
2. Aktakka, E.E., Najafi, K. “A Micro Inertial Energy Harvesting Platform With Self-Supplied Power Management Circuit for Autonomous Wireless Sensor Nodes” IEEE Journal of Solid-State Electronics, 2014, 49, 2017
3. Lee, M., et al “Solar Power Wires Based on Organic Photovoltaic Materials” Science, 2009, 324, 232

KEYWORDS: Textiles, fabrics, fabric system, wearable fabrics, advanced functional fibers and fabrics manufacturing.

You are the Chief Technology Officer of a company that has specialized in creating low volume customized high reliability electronic systems for specific applications in demanding environments. Your CEO believes that the company’s expertise in micro to nanoscale materials, processing, and devices could provide a research and development path to meet DOD’s objectives in their solicitation. Your job is to define the research and development needed for new base technologies that would provide the platform for many future fabric based power generation and storage technologies, and perhaps even expansion into other harsh environment markets.

While meeting the DOD performance requirements are your priority, the cost of customized fabric-based power systems will always be very high as compared to off the shelf commercial systems. In order to have potential to be competitive in other market applications which value compact, high-

performance, it is desirable if your approach can be easily modified or adapted for lower price-point markets.

Your job as CTO is to deliver a complete proposal with your plan for the company to compete in this area to your CEO by your deadline.

YOUR DELIVERABLE

Your task is to write an internal proposal for your corporate officers describing your idea for research and development. The proposal should include the following:

- Executive summary (one page)
- Risk assessment roadmap form (one page)
- Full proposal (15 pages maximum)
- Appendix A: List of references (no page limit)
- Appendix B: Ranked list of intellectual property documents examined (no page limit)

Most Importantly – The significance and novelty of your creative solution, one that moves the boundaries of knowledge outward, will be the primary assessment focus of your review panel. The list below is just a minimum list of issues you might consider. There may be many more. The point is that your proposal *should contain the evidence* needed to make an effective and compelling case to your CEO in order to insure that she/he makes the right decision.

At a minimum, be sure you address all of the following:

Current Science and Technologies - What is already being done in this area by other researchers, companies and governmental institutions? Describe the current state-of-the-art for both the science and the implementation. Use diverse resources such as science literature, journals, conference proceedings, the internet, patents and other sources of existing public knowledge. **Cite all references you use and use quotes for any word-for-word transfer to your report.**

Your Design Approach – What is the basis for your design approach to the problem? Why is your technology better than existing technologies? What technology attribute(s) make it likely to be selected by DOD? Address scientific *and* engineering aspects of these questions. Where relevant, consider: device size, weight and power (SWAP) requirements; materials of construction; critical components and considerations that comprise the complete device-level or subsystem-level solution; and what are the required prototyping and/or production methods, tools and costs? ***Even if you are not an expert in all of the technological areas required to bring the end-product to fruition, you should at least be able to intelligently discuss the other critical components, considerations and R&D requirements.***

Research & Development Plan - Describe a set of tasks and/or tests you will complete to demonstrate that your approach is effective and that your implementation of the solution is meritorious of further R&D. ***This is essentially your design of experiments. What are your objectives? What are the tasks required to achieve those objectives?*** Where applicable answer the following:

- i) What are the key product specifications that you are targeting and how do they compare to the specifications of the existing solution(s) if any exist?
- ii) What mathematical models and/or simulation constructs will you use to validate your approach, especially if prototyping and test trials are costly?
- iii) What are the key dependent and independent variables that you must utilize and evaluate to confirm the proposed solution works?

Above all, be specific and detailed about the key tasks to confirm feasibility and validity of what you are proposing.

Cost Analysis – Identify cost and market issues that will impact the pricing strategy of the solution you have proposed. Identify Strengths, Weaknesses, Opportunities and Threats (SWOT) in the market place. If you are unfamiliar with the typical SWOT marketing analysis, I encourage you to ‘google it’. Consider such things as: the major cost items that would impact the implementation; which elements of your implementation solution would be handled in-house versus externally-sourced; major risk elements that could drive up costs if the primary path item fails; costs of IP

licensing needed, etc. Provide justification and/or reasoning behind your decisions. Estimate manufacturing cost for the total system as the technology reaches mature stage, so the marketing team can determine potential for penetrating other markets. Avoid subcontracting design, manufacture or assembly of any proprietary component outside the company, because the CEO is concerned with potential IP leakage.

Intellectual Property – In Appendix B, list in rank order of importance all commercial, academic, and governmental IP sources that were consulted while formulating the answer, including reference data. For instance, include the patent number; title; inventor name; and assignee name for a patent. Discuss the 3 most significant IP documents affecting your approach to your solution in the 15-page document. Compare strengths and weaknesses of these approaches relative to your own. Recommend how these IP threats should be handled.

Hint – Clearly state your hypothesized solution. Identify its innovation(s) and advantages relative to state of the art. Describe both existing data, and work needed to support each aspect of the hypothetical solution. Consider theoretical, fabrication, and characterization aspects: for each, identify software/equipment and methods to use, parameters to vary, anticipated outcomes, and possible alternatives in the event of unsatisfactory results. Discuss material, process, device, and systems aspects of your solution. *Refine* your hypothesized solution as you accumulate information and prepare the manuscript. **Remember:** clearly distinguish what is known from what is hypothesized or not known. What is needed to distinguish the important things to know?

Reference the 2020 PhD Candidacy Exam Guidelines document for general instructions.