

## TOPIC GENERATION

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**Topic#:** TARDEC-201-002

**DoD Topic#:**

This # will be assigned following the completion of DDR&E's Review

**Title:** Multifunctional Metamaterials for Novel Interaction with the Environment

**Organization:** TARDEC

**Status:** Accepted

**Solicitation:** 20.1

### AUTHOR INFO

Technical Point of Contact

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2nd Technical Point of Contact

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**Primary Technology Focus Teams (TFT)**

**Secondary TFT(s) (may select more than one)**

**Primary Systems Integration Domain (SID)**

**Secondary SID(s) (may select more than one)**

**Technical Director's Priority?** No (*Top 2 Topics from the RDEC*)

### PARTICIPATING ORGANIZATION CERTIFICATION

**Does This Topic Meet The [6 DoD Topic Criteria](#)?** Yes

**Rationale (if the answer is "no"):**

**Budget Activity:** Topic authors must select the most appropriate budget activity. If the topic falls in the [RDT&E budget activity 4 through 7](#), you must include a statement showing that the topic is soliciting R&D -i.e., projects involving a degree of technical risk - rather than procurement.

Budget Activity 3, Advanced Technology Development (ATD)

**Has this exact topic been submitted to the DoD Topic Review before?:** No

**If Yes, was it approved during the review process:**

**Has this exact topic appeared in prior DoD solicitation?:** No

**If Yes, under what topic number?:**

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**Was this topic generated following a private sector (e.g., small business, major defense prime vendor, academia) recommendation?** No

**Is this a University Affiliated Research Center (UARC) developed/partnered topic?** No

**If YES, which UARC?**

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## REVIEW STATUS

Reviewer	Role	Endorsement Status	Comments	Last Modified
<a href="#">Burnette, Thomas</a>	LogTech Lead	N/A		

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**[International Traffic in Arms Regulation \(ITAR\)](#):** No

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**Select the most relevant [DoD Tech Area](#):** 5 Materials/Processes

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**Select the most relevant [Army TAC](#):** A01 Advanced Materials and Manufacturing

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**Does this topic support the [Executive Order for Manufacturing](#) (i.e., does it relate to: (i) manufacturing processes, equipment and systems; or (ii) manufacturing workforce skills and protection):** No

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**6 Modernization Priorities** [6 Modernization Priorities](#)

1. Soldier Lethality
2. Next Generation Combat Vehicle
- 3.

**Warfighter Outcome (WFO) – Capabilities:**

- 1.
- 2.
- 3.

**Force Operating Capabilities (FOCs):**

- 1.
- 2.
- 3.

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**Army Technology Objectives (ATO)** [Explanation](#) [ATO Manager](#)

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**If no ATO linkage is appropriate, check off the Other box and clearly indicate the most likely transition path in the topic's Phase III description.** Other

**Does this topic support an Army ACAT I Program?** No

**Army ACAT I Programs** [Explanation](#):

- 1.
- 2.

**If other than Army ACAT I Program, list here:**

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*According to the 2 February 1999 directive from Dr. Jacques Gansler, at least 50% of the Army's topics must either:*

*Include, as an attachment, a brief (one or two paragraph) memorandum signed by the laboratory topic author and a DoD acquisition program official stating that if the technology is successful, the acquisition program would be interested in providing non-SBIR funding during or after phase II (either directly or through the prime contract) to integrate the technology into the program and describing the potential application **[PM/PEOs may insert this memo in the "Statement of Interest" section when they log into the Topic System]**; or*

*Be co-authored by an acquisition program official. The acquisition program's SBIR Liaison (or other point of contact, if not an ACAT 1 or 2 program) will be listed in the topic, along with phone, E-mail, and FAX number **[if a PM/PEO will be co-authoring this topic, the TPC will be able to add him/her above as the 2nd TPC]**.*

**Acquisition Program (PM/PEO)  
Program Endorsement:**

**2<sup>nd</sup> Acquisition Program (PM/PEO)  
Program Endorsement:**

**Program PC**

**2<sup>nd</sup> Program PC**

**Status:**

**Status:**

**Phone:**

**Phone:**

**Fax:**

**Fax:**

**Email:**

**Email:**

**Statement of Interest:**

**2<sup>nd</sup> Statement of Interest:**

**Objective:**

Develop multifunctional metamaterials (MFM) which exploit the electromagnetic (EM) spectrum or energy for novel environmental interactions. Novel environmental interactions include (but are not limited to) EM wave guidance, absorption, negative permittivity, negative permeability, and EM stimulated mechanical resonance or oscillation.

**Description:**

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Multifunctional Metamaterials (MFM) can harness, direct and control the propagation and transmission of certain aspects of the EM spectrum. There is a need for novel materials that can manipulate the paths traversed by visible light and other frequencies of the EM spectrum, including infrared (IR) and microwaves, alter their reflection and refraction, and enhance material properties for combat applications. MFMs are defined as artificially structured organic, metallic, ceramic, or composites of many materials which interact with the EM spectrum and exhibit behaviors that do not readily occur in nature. The proposers should demonstrate MFMs that control EM radiation by absorbing or guiding an incident wave around an object, without being affected and/or reflected by the object. Metamaterials should be engineered with arbitrarily assigned positive or negative values of permittivity and permeability, which can also be independently varied at will. The proposers should demonstrate the capability to build metamaterial based devices, adaptable to a broad spectrum of radiated light. The proposers should demonstrate materials and techniques that produce strong scattering suppression in all directions and over a broad bandwidth of operation.

#### **Phase I:**

Phase I should demonstrate the innovation, the scientific and technical merit, the feasibility, and commercial merit of selected concepts. The proposers should identify and explore novel multifunctional metamaterials with one or many of the attributes such as negative reflective and refractive index across the electromagnetic spectrum, wave absorption, wave guidance, which enhance vehicle protection and performance. Metrics of interest for Phase 1 include percentage of EM energy absorbed, reflected, refracted at visible light frequencies and other frequencies of the EM spectrum, including infrared (IR) and microwaves; and measureable changes in MFM physical properties when under EM radiation and when not. Prototype samples, modeling and simulation (M&S), or other rigorous and scientifically sound methods should be used to demonstrate MFM performance along the stated metrics of interest. Prototype samples, models and data are an expected deliverable and include mathematical formulae and/or scientific M&S results.

#### **Phase II:**

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Phase II should culminate in well-defined deliverable prototype(s) (technologies or materials) which meet the requirements of the original solicitation topic. Prototype(s) should manipulate the paths traversed by light and other EM frequencies, alter their reflection and refraction, and/or create effects which enhance material properties for combat applications. Deliverables should include technical drawings and specifications, mathematical formulas, M&S and test results, and prototype(s) of MFMs. The measurable metrics of the metamaterials' performance should include the changes in refraction, reflection index and scattering. The first prototype should be delivered at the end of the first year of Phase II SBIR. The second prototype should achieve a significant performance improvement of the first year's prototype. The second prototype should be delivered at the end of the second year of Phase II SBIR and also include recommendations for large-scale manufacturing. Improved life cycle and performance models from Phase I are also expected deliverables. Testing of the Phase II designs should include benchtop testing of Phase II prototypes. Testing of the Phase II designs should also include system level testing of prototypes at Ground Vehicle Systems Center (GVSC) of Combat Capabilities Development Command (CCDC). Phase 2 performance metrics of interest include, but are not limited to a prototype MFM sample with the claimed environmental interactions from Phase 1 (% EM refractivity, % EM reflectivity, % EM absorption, etc.), MFM-mass cost at scale (i.e. \$/kg or \$/ton), areal cost at scale (i.e. \$/sqft or \$/m<sup>2</sup>).

**TRL:** (Technology Readiness Level) [TRL Explanation Biomedical TRL Explanation](#)  
TRL 6 - System/subsystem model or prototype demonstration in a relevant environment

**Phase III:** Proposers could partner with the industry to build and implement novel materials and manufacturing techniques which make vehicles more or less visible on the road. These are all commercially viable benefits of this topic. Possible applications include: road safety, law enforcement, intelligence, rescue and training aids. This is a dual-use technology applicable for government and private industry use.

**References:**

- 1: Shalaev, V. M. (2008) "PHYSICS: Transforming Light". Science. 322 (5900): 384-386.
- 2: Pendry, J.B.; Schurig, D.; Smith, D. R. (2006). "Controlling Electromagnetic Fields", Science, 312 (5514): 1780-1782
- 3: Chen, Huanyang; C. T. Chan, C.T. and Sheng, Ping (April 23, 2010). "Transformation optics and metamaterials". Nature Materials, 9 (5): 387-396
- 4: Smith, D. R.; Padilla, Willie; Vier, D.; Nemat-Nasser, S.; Schultz, S. (2000). "Composite Medium with Simultaneously Negative Permeability and Permittivity", Physical Review Letters, 84 (18): 4184-7.
- 5: Padilla, Willie J.; Smith, David R.; Basov, Dimitri N. (2006-03-01). "Spectroscopy of metamaterials from infrared to optical frequencies" (PDF). JOSA B. 23 (3): 404-414.
- 6: S. Pais, "Craft using an inertial mass reduction device", Patent No.: US 10,144,532 B2, Dec. 4, 2018.

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7: M. Gao, Z. Wu, Z. Wen, Effective Negative Mass Nonlinear Acoustic Metamaterial with Pure Cubic Oscillator, Advances in Civil Engineering, Vol. 2018, Article ID 3081783, 15 pp.

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Legacy

Format:

**Keywords:**

metamaterials, transformation optics, negative permeability, negative permittivity, negative refraction index, scattering, invisibility, inertial mass reduction, mechanical resonance or oscillation

**Background:**

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This topic is linked to Army Research Development, Test and Evaluation Budget Activity 3, Appropriation: 2040, Program Element: PE 0603462A, Next Generation Combat Vehicle Advanced Technology BG7, Ground Systems Active Defense (GSAD) Advanced Technology. This topic is also linked to ARL Manufacturing Technology Budget Activity 7, Next Generation Combat Vehicle Advanced Technology, Metamaterial Electronic Scanning Array APS Radar.

This topic would benefit Product Management (PdM) Office, Vehicle Protection Systems (VPS). This topic would benefit VPS, because the MFM properties described can greatly enhance combat vehicle protection by reducing armor inertia and enhancing vehicle camouflage, concealment, deception and obscurity. PdM VPS, under PEO Ground Combat Systems (GCS) and PM Stryker, are the ultimate transition partner for ground combat vehicle protection capabilities. This SBIR topic received a Letter of Endorsement from Daniel Ramos, LTC, USA, Product Manager, VPS on 4/3/19.

This topic is a collaborative effort distributed among multiple research centers and product management offices:

- Combat Capability Development Command C5ISR Center, Nahid Kabir, FCDD-IST-AM, , S&TD, Office: 443-395-7925, Nahid.n.kabir.civ@mail.mil
- PEO-Ground Combat Systems, PdM Vehicle Protection Systems, Eric Hodges, SFAE-GCS-SVP, APM CCDO, Office: 586-282-1537, eric.w.hodges.civ@mail.mil

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## COMMENT LOG

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