

**High-Throughput Materials Discovery for Extreme Conditions
(HTMDEC)
Funding Opportunity Announcement (FOA)**

FUNDING OPPORTUNITY OVERVIEW	2
A. PROGRAM DESCRIPTION	3
B. FEDERAL AWARD INFORMATION	12
C. ELIGIBILITY INFORMATION	15
D. WHITEPAPER SUBMISSION INFORMATION	15
E. APPLICATION AND SUBMISSION INFORMATION	18
F. APPLICATION REVIEW/EVALUATION INFORMATION	28
G. AWARD ADMINISTRATION INFORMATION	31
H. AGENCY CONTACTS	34

FUNDING OPPORTUNITY OVERVIEW

1. Federal Awarding Agency Name

DEVCOM
U.S. Army Research Laboratory (ARL)
2800 Powder Mill Road
Adelphi, MD 20783-1197

Issuing Acquisition Office

U.S. Army Contracting Command – Aberdeen Proving Ground, Research Triangle Park (RTP)
Division, 800 Park Office Drive, Suite #4229, Research Triangle Park, NC 27709

2. Research Opportunity Title

High-Throughput Materials Discovery for Extreme Conditions (HTMDEC)

3. Announcement Type

Initial Funding Opportunity Announcement (FOA). This FOA seeks proposals from institutions of higher education, nonprofit organizations and for-profit organizations (i.e., large and small businesses) in the United States or its territories. Institutions of higher education are encouraged to propose.

4. Funding Opportunity Number

W911NF-21-S-0013

5. Catalog of Federal Domestic Assistance (CFDA) Number(s)

12.630 - "Basic, Applied, and Advanced Research in Science and Engineering"

6. HTMDEC Website: <https://www.arl.army.mil/HTMDEC>

7. FOA Request

This FOA is issued under 10 USC 2358 which provides the authority for issuing awards under this announcement for basic and applied research. This notice of funding availability constitutes a competitive mechanism by which to evaluate and select proposals for award, including a merit-based competition, as described in the Department of Defense Grants and Agreements Regulations (DoDGARS), 32 Code of Federal Regulations (CFR) 22.315 for the selection of proposals to be awarded. The definitions of basic and applied research may be found at 32 CFR 22.105. A formal Request for Proposals (RFP) or any other type of solicitation regarding this program will not be issued. ACC-APG RTP Division is soliciting proposals on the endeavor described herein.

8. Key Dates:

The following is a summary of the events and dates associated with the HTMDEC Funding Opportunity Announcement (FOA):

<u>EVENT</u>	<u>ESTIMATED DATE/TIMEFRAME</u>
Pre-Solicitation (Request for Comment)	June 2021
Opportunity released	July 2021
FOA Applicants' Workshop	July 29, 2021
Deadline for Questions on Funding Opportunity	August 2021
White papers Due	August 31, 2021
Invitations for Full Proposals	October 2021

High-Throughput Materials Discovery for Extreme Conditions
(HTMDEC)

A. PROGRAM DESCRIPTION

1. Background

Purpose: Within the Army science and technology enterprise, DEVCOM-ARL is chartered to conduct disruptive foundational research, engage as the Army's primary collaborative link to the scientific community, and interface to shape future fighting concepts. We crystalize these ideas and the impetus to perform these functions at the pace of innovation as 'Operationalize Science for Transformational Overmatch'. Simply put, we seek to accelerate discovery and transition breakthroughs to the Warfighter.

Rule-based artificial intelligence (AI) and machine learning (ML) tools present powerful avenues for exploring an information landscape in discovering novel materials for applications in extreme conditions (e.g. high-strain rate, high-g loading, high temperature). Such approaches present considerable opportunity in exploring new frontiers for materials used in protection and lethality applications, especially when coupled with new approaches that allow larger and richer datasets, computational tools, and data infrastructure for collaboration. Broadly, AI/ML can be used to augment individual steps in the synthesis-processing-characterization pipeline, be used for scale-bridging to draw greater information from more tractable experimental approaches, and be used to guide a broader research loop.

Advances in synthesis, modeling, and characterization will greatly advance our ability to exploit monolithic materials in extreme conditions. However, there is a need to contemplate how the capabilities of additive manufacturing and other processing techniques can be used to discover materials that exhibit spatial variations in composition, anisotropic characteristics, and contain interfaces between multiple materials. The parameter space expands exponentially as these variables compound the system inputs, but truly advanced materials performance will likely be dependent on an integrated systems-level approach to materials design.

ML toolsets coupled with advanced manufacturing and characterization is necessary to achieve accelerated discovery of new materials for application in extreme dynamic (impact, thermal, ablative) conditions. ML toolsets and software exist but may need to be adapted for the specific requirements of materials discovery and design. Full exploitation of the ML approach will certainly require extension and further development to focus on proof-of-concept for material classes of interest in Army applications. This could be achieved within a generalized and scalable framework that supports rapid, robust and trusted data exchange. New tools that consolidate/organize data and increase throughput throughout the workflow will require a specialized approach to be applied to ephemeral phenomena e.g. shocks, heating, localized deformation, and failure. ML models that incorporate these phenomena will critically rely on physics-based models that adequately capture the underlying driving mechanisms. Critical (targeted by ML approaches) physics models may require further development; ML offers opportunity to consolidate much of these physics into fast-running analytic frameworks compatible with the high-throughput approach and may be used to guide autonomous systems for high-

throughput characterization of transient phenomena.

To accelerate improvements in Army armor and weapon system performance, DEVCOM-ARL wants to leverage high-throughput methods in synthesis, processing, characterization, and modeling for materials used in these applications. Machine-learning techniques are in the nascent stage of integration with materials science but may present a path towards accelerated discovery, as these tools may uncover novel links between system performance and material science that have been previously underdeveloped or overlooked. DEVCOM-ARL seeks collaboration with external investigators to leverage (and train experts on) machine-learning techniques in the discovery of materials that perform in extreme environments, but machine-learning techniques require large volumes of quantifiable data in order to best reveal links between the materials science and system performance. High throughput characterization and manufacturing techniques may present a viable approach to satisfy the data volume requirements to bring machine-learning to bear.

In summary, the US Army Modernization Priorities require materials that survive and perform in extreme environments; harsh military environments of high-acceleration (e.g. projectile launch and flight), high-temperature and rapid ablation (e.g. hypersonic flight), and impacts at very high velocity (terminal ballistics). The totality of these environments and accumulating requirements on future materials drives the imperative to consider an increasingly large number of constituent elements, structure and properties. Discovery must now parse through billions of candidate materials to achieve highly specialized and transformational functions. This drives a data-driven approach; one that fuses high-throughput materials synthesis and characterization with machine learning algorithms and close-loop discovery automation.

The overarching goal of this program is to couple automation and machine learning techniques to material manufacturing and characterization to demonstrate new materials that withstand and perform under extreme conditions. The program will develop the necessary methodologies, models, algorithms, synthesis & processing techniques, and requisite characterization and testing to rapidly accelerate the discovery of novel materials through data-driven approaches. As such, it is expected the results of this program will be the above techniques as well as novel materials exhibiting unprecedented properties at the appropriate scales that have been developed utilizing all of the aforementioned tools which will be provided to DEVCOM-ARL for further analysis and testing.

Proposals may draw from any number of these thrusts but must focus on research that employs high-throughput data-driven techniques to close material design loops connecting material selection, synthesis, and processing to system performance.

In order to achieve this paradigm shift in materials discovery, significant advances are needed in the following “General Thrust” areas:

- **Data-driven Material Design** - a comprehensive term for all aspects of the material design phase of the material development cycle which are accelerated through the integration of data-driven methods.
- **High-Throughput Synthesis & Processing** – to include both modifying existing synthesis & processing methods to accommodate for high-throughput, as well as developing novel techniques.
- **High-Throughput Characterization** – to include implementation of automation for conventional techniques, and the development of surrogate tests to mimic techniques which are not amenable to automation, especially for experiments in extreme conditions (e.g. high

strain rate, high temperature).

- **ML-augmented Physics-Based Models** – the use of ML tools to identify the most crucial parameters and parametrization experiments for physics-based models is poised to be a tipping point in materials science. To date, nearly all ML algorithms have been developed for big data (e.g. image recognition). It is critical that we discontinue ‘repurposing’ these types of algorithms and begin developing ML algorithms specifically designed for materials discovery, and informed by physics.

The general thrust areas will be complemented by the following “Targeted Thrust” areas:

- **Program and Workflow Development** – optimizing workflow to achieve the best outcomes for the general thrust areas through improved teaming and program planning.
- **Data Handling and Management** – development and upkeep of a data platform used by all funding recipients and government collaborators.

HTMDEC has been developed in coordination with other related ARL-funded collaborative efforts (see descriptions of ARL collaborative alliances at <https://www.arl.army.mil/www/default.cfm?page=93>) and shares a common vision of highly collaborative academia-industry-government partnerships. However, HTMDEC will be executed with a program model different than previous ARL Collaborative Research/Technology Alliances. Specific components of the program are highlighted below:

- HTMDEC will be a two-step application process, consisting of a White paper stage and a Proposal stage.
- HTMDEC will be executed through an initial funding period (“Seedling” only), followed by subsequent funding periods involving both Seedling and “Center” awards. A Center will be an option period exercised from a seedling award. The only exception to this will be for the Targeted Thrust Area- Data Handling & Management. The Seedling selected for continuation for this particular thrust area will do so as a *recurring* Seedling for the duration of the HTMDEC program, and will support all of the Centers as the approved data platform for HTMDEC.
- A FOA Applicants’ workshop will be held to brief interested Applicants on the long term program goals of this FOA. In FY2022, only Seedling efforts will be awarded. The focus of these Seedlings will be to address either one or more of the General Thrust areas or an individual Targeted Thrust areas.
- White papers can address one or more of the General Thrust areas; thrust areas may change on an annual basis in order to reflect current interests. White papers for Targeted Thrusts can only address one Targeted Thrust area. The white paper should clearly state which thrust area(s) it is addressing on the cover page. White papers will be evaluated. Applicants with only the most highly rated white papers will receive an invitation from the Government to submit a Seedling Proposal.
- Invited Seedling Proposals can address one or more of the thrust areas. The Seedling Proposals can only address the thrust areas that were included in their corresponding white paper. Seedling Proposals will be evaluated and funding will be provided to those Recipients selected for award through a cooperative agreement (CA) or similar mechanism described as the Seedling award.
- Prior to the close of the Seedling award, the Seedling award Recipients are eligible to submit a proposal for consideration of a “Center” option period under the Seedling CA of up to 4 years. Since the Center proposal will need to address all four general thrust areas, Seedling Recipients will be encouraged to collaborate and combine during the Seedling option period of performance to develop the strongest possible Center proposal. Center proposals will be

evaluated and funding will be provided to those Recipients selected for the exercise of their Center option.

- Recipients for Center awards will also have the opportunity to request Graduate Student Fellowships for US citizens working in any of the Centers.
- Technical project reviews will be held annually, with the expectation that Seedling and Center award recipients present the results of their research and to foster collaboration between recipients.

White papers and Proposals that are in compliance with the requirements of the FOA will be evaluated in accordance with merit-based, competitive procedures. These procedures will include evaluation factors and an adjectival and color rating system. A review team, consisting of a qualified group of scientists and managers will evaluate the compliant proposals and provide the results of that evaluation to the decision-maker for the Government.

1. Technical Thrusts Areas

FY2022 Proposals will address one Targeted Thrust or one or more General Thrust as a seedling. Targeted Thrust areas for FY2022 will be: 1) Program & Workflow Development and 2) Data Handling & Management. General Thrust areas that are expected to endure are: 1) Data-driven Material Design, 2) High-Throughput Synthesis & Processing, 3) High-Throughput Characterization, and, 4) ML-augmented Physics-Based Models. Beyond FY2023, seedlings may address any active thrust area, while centers must address at least the four general thrusts to converge high-throughput and data-driven techniques to demonstrate material selection, synthesis, processing, and performance in a design-cycle manner.

Targeted Thrust Areas:

1. Program & Workflow Development

In FY2022 only, funding will be made available to allow for development of a comprehensive program plan, project workflow, and facilitate teaming among awardees and with government in anticipation of establishing a Center in FY2023. Seedlings funded in this specific Targeted Thrust area are encouraged to exercise proof-of-principle features of a rudimentary design cycle in order to expose shortcomings of existing methods and suggest research to close existing gaps. Project workflow should include determination of all of the required resources, including but not limited to: processes, facilities, personnel, etc. As Centers are expected to address all four of the primary thrust areas, proposals for this particular targeted thrust area should likewise address all four thrust areas.

2. Data Handling & Management

In FY2022 only, proposals may directly address data handling and management within the program. A common data handling and management schema must be established from the onset of the program that will be utilized by program participants throughout the life of the program. This schema should consider all aspects of data handling and management, including, but not limited to, data acquisition, data transfer and sharing protocols, tagging, data analysis, version control and safe/redundant/scalable data storage. The **FAIR** guiding principles for scientific data management and stewardship defined in 2016 in *Scientific Data*ⁱ shall be followed in order to improve the Findability, Accessibility, Interoperability, and Reuse of digital assets. Proposals must specifically address data sharing between

program awardees and government collaborators that have strictly regulated information systems (e.g. the DOD high performance computing system). Successful applicants will work alongside DEVCOM Army Research Laboratory subject matter experts to converge on a schema. Seedling Proposals for this particular task will only be accepted in FY2022, with the intent to down select the most promising proposals (selected on the basis of scientific merit and collaboration within the effort) for award throughout the duration of the program as the approved data handling and management platform for all of the award recipients moving forward.

General Thrust Areas:

1. Data-driven Material Design

For the purposes of this FOA, data-driven material design is meant to be a comprehensive term for all aspects of the material design phase of the material development cycle which are accelerated through the integration of data-driven methods. This includes, but is not limited to: data mining through literature sources and existing databases (from data sources such as density functional theory, thermodynamics databases such as Calphad, literature sources, etc.), use of adaptive learning or experimental optimization to predict or guide future experiments, and use of machine learning and artificial intelligence to parameterize the material property space for extreme conditions. Approaches that accelerate material design in multi-objective systems are of particular interest. A trained model is not a sufficient deliverable; a deliverable must include a toolset that can be used to design or discover new materials that offer an improvement in performance in Army application environments. Sub-areas within this thrust could include: data mining, adaptive learning approaches and ML/AI driven design, and uncertainty quantification:

- i. *Data mining* includes the use of machine learning algorithms for mining of material properties from various databases, repositories, and the open literature. This includes using conventional data science approaches on the larger data sets that currently exist, as well as using approaches such as natural language processing (NLP) to consolidate information that currently exists in an unorganized fashion in literature. While this type of data is sparse as compared to typical ‘big data’ sets, there is an opportunity to rapidly explore the compositional space of candidate materials as a first-order screening tool. This information can also be utilized to construct quantitative structure-property relationship (QSPR) models for predicting the properties of novel materials.
- ii. *Adaptive learning* is an AI approach to guide experimental steps for optimal value. Using various approaches, an active learning scheme can be used to target specific experimental parameters (e.g. composition and processing conditions) based on user-defined rules, such as targeting areas with maximum uncertainty in learned QSPR or targeting extrema in predicted materials performance. Such approaches can be critical in materials design and discovery of new candidate materials with strong application-specific performance. Integration of active learning schemes with experimental hardware offers the opportunity to automate or autonomize experimental steps and vastly accelerate the materials design process.

iii. *ML/AI driven design* involves use of ML/AI approaches to accelerate steps in the materials design and discovery process. This can include improvement of individual steps in the research pipeline (e.g. use of image recognition approaches in microscopy), connecting approaches together for improved connectivity (e.g. use of ML approaches to address scale bridging between computational models and tools), and use of these tools to learn a broader region of materials space and identify key regions of high performance. In all cases, emphasis of using these tools to design new materials at an accelerated rate is critical.

iv. *Uncertainty quantification* will play a prominent role in synthesis, characterization, and modeling for the materials design process. Understanding the scope of uncertainty during synthesis ensures that prototype materials contain desired structure. Analyzing uncertainty propagation in characterization experiments, based on uncertainties during synthesis and within the experiment itself, enables quantifiable estimates of confidence in collected data and enables informed design-of-experiments. Finally, modeling efforts stand to benefit from careful uncertainty quantification for model inputs to better identify the role of the most crucial parameters in the materials design space.

2. High-Throughput Synthesis & Processing

Emerging methodologies such as ICME and ‘Materials by Design’ have allowed scientists to rethink the early stages of a material’s development life cycle by integrating computational models and simulation into the material design phase. This allows researchers to very rapidly hone in on the most promising composition space, but is just the beginning of the material development cycle. In order to ensure high-throughput materials discovery, it is imperative that the accelerated pace continues through the synthesis, processing, and characterization phases. This poses significant challenges, as most existing R&D infrastructure is not designed for high-throughput and/or automated processes.

- i. *High-throughput synthesis* includes both modifying existing synthesis methods to accommodate for high-throughput, as well as developing novel techniques. Any technique developed should consider sample homogeneity and compositional control, as fluctuations could greatly impact uncertainty downstream. Characterization and testing of these samples will occur over many length scales, so it is imperative that the technologies proposed are amenable to the synthesis of bulk materials, and not solely applicable to thin films. Of particular interest is the integration of in situ diagnostics into the synthesis technique such that real time quality assurance (QA) could be achieved. Challenges to synthesis include a lack of available technologies demonstrated in a high throughput environment, e.g. combinatorial chemistry for metals and ceramics. Challenges also include a disparity across material classes, with polymers and metals being more amenable to high-throughput than ceramics and composites.
- ii. *High-throughput processing* involves all of the post-synthesis processing required before a material is ready for characterization, testing, or use in a relative environment. This includes, but is not limited to consolidation, heat-treatments, cold and hot working, machining, etc. Processing maps are often ill-explored and process models tend to be basic in nature. However, processing dictates microstructure evolution and

will be paramount to assuring consistency in material properties. Challenges in processing include the fact that there is no straightforward or unified way to represent/encode a material's processing history. In addition, processing techniques vary widely, and are sometimes proprietary and not based on industrial standards. Challenges also include the fact that many processing steps (e.g. sintering) are not easily adapted to high-throughput processes and could pose a rate-limiting bottleneck in the process.

- iii. *In situ diagnostic approaches and analysis* will play a critical role in any high-throughput process, including both synthesis and processing. Techniques are required that can monitor the quality of a material in real time such that uncertainty can be minimized. Items to be considered include, but are not limited to: homogeneity, presence of defects, texturing, crystallographic phase, etc.

3. High-Throughput Characterization

Characterization of materials suffers from being inherently slow. Equipment has been designed for conventional sample-by-sample handling, and very little has been done in the way of high-throughput and/or automation, especially in characterization experiments for extreme conditions or with higher fidelity technologies. Conducting high strain-rate or other extreme mechanical property testing with a high-throughput approach will always hold further challenges beyond those inherent to quasi-static testing. Methodologies to improve the throughput and/or automation of high-strain rate and high-temperature tests, which accurately mimic the extreme environments of the application space, are of significant interest. Modifications to techniques such as laser induced particle impact testing (LIPIT) and laser driven flyer plate experiments are examples of areas ripe for further exploration. High-fidelity characterization techniques (e.g. nano-indentation, scanning electron microscopy, etc.) have seen some limited levels of automation, but the majority of high-fidelity characterization techniques stand to benefit from further adaptations to achieve higher experimental throughput.

- i. *Surrogate test techniques* are required to enable evolution of materials in a relevant environment, but in a high-throughput or automated mode. The application space for the HTMDEC program places materials in extreme conditions such as at temperatures in excess of 1000s of degrees Celsius or at strain rates exceeding 10^4 per second with pressures in the tens of Gigapascals and rise-times in the nanoseconds. Achieving these conditions is nontrivial in conventional experiments, but these experiments tend to provide the most meaningful screening method for down-selection of the most promising candidate materials and systems. Surrogate experiments may need to focus on a single material property or mechanism that is the primary driver of the material or system response to extreme conditions in order to improve experimental throughput. These accelerated and/or automated surrogate experiments may also need to trade experimental fidelity for throughput, but the resulting larger datasets might guide further testing with slower, conventional higher fidelity traditional testing for extreme conditions (e.g. Kolsky bar, ballistic testing). Challenges include examining the trade-off space between experimental throughput and fidelity, as well as automating tests of considerable complexity. Ideally the surrogate experimental approach should interrogate system level

performance in as realistic of conditions as possible (i.e. experiments should reveal the role of multiple materials, their interfaces, and their geometries at the system level).

- ii. *Automated characterization techniques* are needed to rapidly accelerate what is often one of the slowest phases of material development. In addition to automating the actual techniques, data acquisition and analysis should also be automated and seamlessly fed into the appropriate ML data sets, it's anticipated that the greatest advances can be realized in lower fidelity, quasi-static techniques than in higher-fidelity, high-strain rate testing, especially in the near term. Challenges include the lack of automation in conventional characterization techniques, which were designed for sample by sample analysis. Challenges also include the fact that with high-throughput there will be increased uncertainty due to trade-offs between speed and accuracy.
- iii. *Novel diagnostic approaches and analysis* are required to maximize measurement resolution from single high-throughput characterization experiments to increase data fidelity and reduce error. Automated instrumentation methods (e.g. machine vision) may present an avenue to obtain more granular, full-field data from a single experiment than conventionally possible, both increasing the throughput of data and reducing experimental burden for individual characterization experiments. Coupling greater diagnostic depth to high-throughput experiments could then provide an even greater amount of experimental data than just the high-throughput experiment itself. ML trained analysis of characterization experiments may reduce experimental uncertainty requiring fewer experiments to make connections between processing and system performance.

4. ML-augmented Physics-Based Models

The ultimate goal of this research program is to link material processing and properties to system level performance. Numerical models offer an opportunity to design at the system level *in silico* but are completely reliant upon correctly identifying these links and developing models that faithfully and completely capture these links. Structural analysis of heterogeneous materials and systems using phenomenological constitutive models is often inaccurate without a connection to the material microstructure and underlying physics. Physics-based models that can accurately simulate the material response in the application environment are one way to attain this goal, but understanding the role of model inputs remains a challenge, and developing these materials models in realistic materials systems with fidelity to all behaviors across many length scales remains difficult or intractable. However, for many systems ML-augmented physics-based models represent a nascent catalogue of techniques that seek to improve upon the conventional models with respect to speed or fidelity, and overcome the limitations that result from lack of data required to employ more conventional data-driven learning. Approaches range from use of ML to optimize model parameters to learning the mathematical and physical models themselves or use of physics to constrain and guide an ML model. These approaches offer the opportunity to enhance computational approaches used to design and discover materials in a number of ways. Below are listed some examples of how a successful program might incorporate this thrust area:

- i. *Implementation of ML-augmented physics-based models* to study critical physics mechanisms. In particular, with respect to ballistics applications, it is difficult to study transient and highly-localized phenomena that occur in high-rate and ballistic events

(e.g. shocks, heating, deformation, and failure), especially for complex system-level geometries and interfaces. It is further difficult to incorporate these models into a wider workflow of research. Critical physics model development, coupled with ML approaches that can accelerate the runtime of these traditionally-slow models and allow their incorporation into a high-throughput and potentially autonomous workflow, are likely important to a successful program. Many of these behaviors are still modeled with approaches that cannot collect the full generalized behavior of these transient events with the required predictive accuracy for materials design requirements. In addition to developing models that offer improved speed in a workflow, developing models that can fill in critical gaps in behavioral understanding and quantitative prediction of these transient events is also a challenge that remains outstanding.

- ii. *Scale-bridging considerations* remain a challenging area in computational materials. The approaches used in Physics-driven ML models may offer solutions to bridge the scales from molecular interaction models developed in smaller scales up to the performance of a system in its application scale and environment. There are a great number of implementations possible that would benefit from accelerated queries for data from databases to accelerated physics models that can be called at runtime, among others. Developing an approach to streamline and accelerate multiscale materials research is likely critical to a broader program workflow.
- iii. *Training of ML models* as well as the ability to condense data into functions that can be queried quickly offers substantial opportunity in collaboration and handoff of information. By providing a solution that can relatively quickly provide a predicted system structure, property, or behavior, a broader automated or collaborative research loop for materials design and discovery can be improved. Development and handoff of such links in the chain are likely to be an important part of a successful program. Further, development of data sharing and data hand-off frameworks is necessary to a successful collaboration.
- iv. *Development of processing models* of materials remains an area of especial challenge in the development of a materials design and discovery approach. Though no less essential to development of new best-in-class materials than composition space, the wide range in category of degrees of freedom in sequential processing steps compared to composition creates a very grand challenge in representing and executing materials design and discovery through all but the simplest of processing chains. The development of a data science-ready physics-based processing model that can be executed to explore processing space in design of ballistic materials would be a major triumph. Challenges include representing or encoding an open-ended processing history, as well as predicting the composition-dependent changes such a processing chain would engender.
- v. *Development of an overarching methodology* will be required as multiple data sources are used (models/characterization/ML) to predict individual features, properties, or behaviors, the consolidation of these elements into a broader model that evaluates expected macroscopic properties becomes nontrivial. The use of some combination of ML and physics-based information will likely be critical in developing a final step that brings these elements together to predict a general system performance and/or learns the landscape of system performance as a function of these elements. The eventual goal of a successful

program includes design of materials with multi-objective requirements. Data will likely come from many sources, including data repositories, physics-based computational models, high-throughput our automated experiments, and ML models. The development of one over-arching umbrella that consolidates program information into a system performance model of materials will enable much greater success in discovering or designing materials with user-specified objectives.

Collaboration: HTMDEC addresses a critical objective within a broader Army goal- to accelerate discovery of materials for use in extreme conditions, for applications in Army armor and weapon systems, DEVCOM-ARL wants to leverage high-throughput methods in synthesis, processing, characterization, and modeling for materials used in these applications. This program has been developed in coordination with other related ARL-funded collaborative efforts (see descriptions of ARL collaborative alliances at <https://www.arl.army.mil/www/default.cfm?page=93>) and shares a common vision of highly collaborative academia-industry-government partnerships. However, with the rapid pace of technology development HTMDEC will implement a novel, synergistic approach/structure.

Option Proposal and Additional Fellowship Opportunity:

The goal of the Center option period will be progress in all four of the General Thrust areas. In addition to these thrust areas, a Recipient will also have the opportunity to request additional Graduate and Postdoctoral Fellowships for US citizens working in one of the four thrust areas, funded by the HTMDEC program. The purpose of these fellowships is to support talented US citizens in the fields of Physics, Materials Science, Machine Learning, and Data Science to feed into the ecosystem of researchers working on questions relative to the thrust areas in this FOA. Due to the scope of this program as noted in the Eligibility Information section and the sensitivity with applications of this research, the focus of these fellowships is US citizens only. Details on the submission and evaluation of the center option proposal, to include the Graduate and Postdoctoral Fellowships, will be provided to those Recipients who have received a seedling CA during the Center option proposal instructions.

B. FEDERAL AWARD INFORMATION

The intent is to award multiple seedling CAs from this FOA. The applicants selected for award will be notified by the Agreements Officer or his/her designee telephonically or via email. The CA award is not official until the Recipient has received the award signed by the Agreements Officer.

CAs for Institutions of Higher Education and nonprofit organizations are primarily governed by the following:

- Federal statutes
- Federal regulations
- 2 CFR Part 200, as modified and supplemented by DoD's interim implementation found at 2 CFR Part 1103

CAs for For-Profit Recipients are primarily governed by the following:

- Federal statutes
- Federal regulations
- 32 CFR Part 34

The following websites may be accessed to obtain an electronic copy of the governing regulations and guidance:

- FAR, DFARS, and AFARS: https://www.acquisition.gov/content/regulations_
- Code of Federal Regulations: <http://www.ecfr.gov>
- DoD Research and Development General Terms and Conditions JANUARY 2021
- ACC-APG-RTP Division Assistance, Research General Terms and Conditions dated DECEMBER 2020

The Government anticipates that this funding opportunity will run for 10 years, with anticipated available funding of approximately \$5M per year. Actual duration and funding levels may vary slightly. Multiple awards are anticipated from year-to-year, with all Seedlings in Year 1, and a mix of Seedlings and Centers in subsequent years, for example, on a per annum basis:

Year 1: – 10-12 Seedlings (approx. \$500K per Seedling)
Year 2+: 2 - 3 Centers (approx. \$1.5M-\$2.0M per Center per year)
2 - 3 Seedlings (approx. \$200K per Seedling per year)
At least 1 Seedling dedicated to data handling and management (approx. \$200-500K per year)

As Centers are more comprehensive and required to address all 4 thrust areas, these projects will be funded at higher levels than Seedling projects, which are allowed to focus on a single thrust area.

Award Instrument: This Funding Opportunity is expected to result in the award of multiple “seedling” cooperative agreements (CA) each year as defined at 31 U.S.C. 6305 for the execution of the program. The CA is used to enter into a relationship when:

- a. The principal purpose of which is to transfer a thing of value to the Recipient to carry out a public purpose of support or stimulation authorized by a law or the United States, rather than to acquire property or services for the Federal Government’s direct benefit or use.
- b. Substantial involvement is expected between the Federal Government and the Recipient when carrying out the activity contemplated by the CA.
- c. No fee or profit is allowed

Structure of Award: The CAs will consist of an initial 12-month Base award that will be executed and considered a “seedling” CA. The Recipients of a “seedling” CA are then eligible for consideration to receive funding for a single optional extension of up to 4 years at the conclusion of the “seedling” project. The period of the performance and funding amount of potential option periods will be based on the goals of the HTMDEC program, merits of the proposed optional research and potential impact to advancing the HTMDEC goals, and available funding.

Proposal Submission: This will be a two-step application process, consisting of a white paper stage and a proposal stage. The purpose of this two-step approach is to facilitate pre-screening of white papers by the U.S. Government such that detailed proposals are only sought from

applicants whose white papers demonstrate the most promise for award (this also helps to reduce unnecessary proposal preparation efforts). The government's decision to invite a proposal submission will be based upon the evaluation results of a timely and compliant white paper submission. Only the most highly rated white papers will receive an invitation from the government to submit a proposal. An applicant that does NOT submit a timely and compliant white paper, is NOT eligible to submit a proposal for consideration for funding. An applicant that does NOT receive an invitation from the Government to submit a proposal is NOT eligible to submit a proposal. An applicant invited to submit a proposal will receive feedback on their white paper.

Applicants should note there are page limitations and other requirements associated with the submission process. Submissions in connection with this FOA are due by the date and time specified below. The Government's decision to award a seedling CA will be based upon the evaluation results of the proposal submission. Center option proposals will be evaluated and funding provided to those Recipients selected for the exercise of their option.

Period of Performance: The CA Awards made as a result of this FOA will provide for a period of performance of 12 months, with the potential to exercise an option period for up to four additional years at the discretion of the Government. The Government reserves the right to negotiate with an Applicant to re-scope their proposal or optional proposal technical focus, period of performance, and associated costs in order to maximize the available program funding, balance of research topics across the program, and overall impact to the program.

Place of Performance:

There is no limitation on the place of performance although on-site collaboration at DEVCOM-ARL facilities and with DEVCOM-ARL researchers as well as with other Seedling Recipients is encouraged. It is mandatory that all Recipients participate at annual Program Review Workshops. These Workshops will likely be held virtually to start, and then will likely revert to in-person meetings in the vicinity of DEVCOM-ARL (Aberdeen Proving Ground, MD).

Funding: This FOA is issued subject to the availability of funds. Applicants are reminded this request is subject to Presidential, Congressional and Departmental approval. The Government will review and evaluate proposals in accordance with this FOA in order to make decisions on awards. Proposals are subject to available funding.

Profit/Fee: Profit/fee is not permitted under the CA.

Cost Sharing: Cost sharing is not required under this FOA.

FOA Applicants' Workshop (virtual): ARL will host a virtual FOA Applicants' Workshop on 29 July 2021. To sign up for this event, please visit:

<https://www.eventbrite.com/e/htmdec-applicants-day-2021-registration-162829949763>

. Additional information about this workshop can be found on the HTMDEC Program website at: <https://www.arl.army.mil/HTMDEC/>. This will be an opportunity for the Government to:

- Lay out its overall expectations for this FOA
- Discuss the white paper and proposal process
- Clearly explain the distinction between Seedlings and Centers
- Express the intent of Seedlings to work together and coalesce into Centers
- Highlight Government programs and technologies which will most likely be transition opportunities for these projects

Contact Information. Outside of questions posed at the FOA Applicants' Workshop, all questions or comments concerning this FOA shall be submitted to the Government through the HTMDEC Program website at <https://www.arl.army.mil/HTMDEC/>. Comments or questions submitted should be concise and to the point. In addition, the relevant part and paragraph of the FOA to which a comment or question pertains must be referenced in order to receive a response. Responses to non-proprietary questions received will be posted to the HTMDEC Program website under the "General Information/Questions & Answers" section for the benefit of all interested parties. All clearly identified and marked proprietary questions submitted will be responded to via an individual email response, not posted to the HTMDEC Program website. Applicants are encouraged to submit questions as early as possible. The deadline for submission of questions which will be answered under this FOA is listed in Event timeline above. Any answers provided to questions do not change the requirements of this FOA. Future amendments to this FOA, including new or modified topics, will be issued via an amended FOA posted in [grants.gov](https://www.grants.gov).

C. ELIGIBILITY INFORMATION

1. Eligible Applicants

Eligible applicants under this FOA include institutions of higher education, nonprofit organizations, and for-profit organizations (i.e. large and small businesses) in the United States or its territories. This eligibility criteria applies to all applicant institutions involved in the substantive efforts of a proposal (e.g., the Recipient). Recipient institution personnel need not be US citizens, though this FOA offers fellowships as incentives to employ and train US-citizen graduate students and postdoctoral fellows.

While the research to be conducted under this program is basic and fundamental in nature, the materials and technologies being developed are for use in applications under extreme conditions including, but not limited to: armor, kinetic energy penetrators, and hypersonics. These applications are sensitive in nature and on the military critical technology list. Based on the potential use of the research and development expected to come out of this program, the eligibility criteria is for United States applicants only.

2. Other

Pursuant to the policy of FAR 35.017 and supplements, Federally Funded Research and Development Centers (FFRDC) may propose as allowed by their sponsoring agency and in accordance with their sponsoring agency policy. Proposals may consist of teams from any combination of organizations (e.g., prime and subawardees), but this is not a requirement for

award and award will only be made to a single entity. Only those Applicants awarded a seedling CA will be eligible for consideration of a 4 year option period.

D. WHITE PAPER SUBMISSION INFORMATION

1. Overview

- a. White papers should focus on describing details of the proposed research, including how it is innovative, how it could substantially increase the scientific state of the art, Army/DOD relevance, and potential impact.
- b. White papers for Seedling Awards are limited to ten (10) total pages; eight (8) pages for white paper technical content, one (1) cover page and a one (1) page addendum as discussed below. Evaluators will only review the white paper cover page, up to eight white paper technical content pages, and the one-page addendum. In FY2023, white papers for Centers will be limited to six (6) total pages; four (4) pages for white paper technical content, one (1) cover page and a one (1) page addendum as discussed below. Evaluators will only review the white paper cover page, up to four white paper technical content pages, and the one-page addendum.
- c. White papers must be in the following format but do not require any special forms:
 - Page Size: 8 ½ x 11 inches
 - Margins – 1 inch
 - Spacing – single
 - Font – Times New Roman, 12 point
- d. Combine all files and forms into a single PDF before submitting.

2. Format and Content of White papers:

- a. COVER PAGE (not to exceed one page):

The white paper cover page shall include at a minimum: Title of the white paper, name and contact information of the individual and organization submitting the white paper, the Funding Period (Seedling Awards or Centers), the FOA number of this announcement, and the TPOC name, if known. If submitted under Seedlings, the Cover Page shall indicate which of the four (4) General technical thrusts the proposal will address. For FY2022, the additional option exists to submit Seedlings under the two (2) targeted thrusts, and the Cover Page for Seedling White Papers shall indicate which of the two (2) targeted thrusts the proposal will address. White Papers regarding the FY2022-only Targeted Thrusts must solely focus on that thrust area. Otherwise, white papers for General Thrusts may undertake multiple thrust areas.

- b. TECHNICAL CONTENT (Seedling Awards) (not to exceed eight pages):

- i. Scientific (max. 6 pages) - What is your basic idea? Why is it innovative? What are the technical challenges to this idea you will be focused on with your research? What are the scientific and technical approaches to overcome the

challenges?

- ii. Impact (max 1 page) - If successful, how will this work improve the capabilities (data driven material design, high throughput synthesis and processing, high throughput characterization, ML- augment physics based models) available to discover novel materials for extreme conditions? If for FY2022, the white paper may also address how this work improves the program workflow or data management for the HTMDEC program.
 - iii. Programmatic (max 1 page) – To the extent known at this point, provide details on the research team, timeline, deliverables, and estimated cost of the research. A teaming approach to include Seedling awards shall be presented. Brief descriptions per award year are an acceptable level of granularity (1 year for Seedlings, multiple years for Centers).
- c. TECHNICAL CONTENT (Centers) (not to exceed four pages):
- i. Scientific (max. 3 pages) - What is your basic idea? Why is it innovative? What are the technical challenges to this idea you will be focused on with your research? What are the scientific and technical approaches to overcome the challenges?
 - ii. Impact (max 0.5 page) - If successful, how will this work improve the capabilities (data driven material design, high throughput synthesis and processing, high throughput characterization, ML- augment physics based models) available to discover novel materials for extreme conditions?
 - iii. Programmatic (max 0.5 page) – To the extent known at this point, provide details on the research team (if more than one PI), timeline, deliverables, and estimated cost of the research. Brief per year descriptions are an acceptable level of granularity.
- d. ADDENDUM (Seedling Awards not to exceed 1 page; Centers not to exceed 1 page):
- i. Include biographical sketches of the all key personnel who will perform the research within one page, highlighting their relevant qualifications and experience.

3. Restrictive Markings on White papers:

- a. Any proprietary data that the applicant intends to be used only by the Government for evaluation purposes must be clearly marked. The applicant must also identify any technical data or computer software contained in the white paper that is to be treated by the Government as limited rights in technical data and restricted rights in computer software. In the absence of such identification, the Government will conclude there are no limitations or restrictions on technical data or computer software included in the white paper. Records or data bearing a restrictive legend may be included in the white paper. It is the intent of the Army to treat all white papers as procurement sensitive before award and to disclose their contents only for the purpose of evaluation.

Care must be exercised to ensure that classified, sensitive, and critical technologies are not included in a white paper. If such information is required, appropriate restrictive markings and procedures should be applied prior to submission of the white paper.

- b. Applicants are cautioned, however, that portions of the white papers may be subject to release under terms of the Freedom of Information Act, 5 U.S.C. 552, as amended.

4. Evaluation and Disposition of White Papers

- a. Evaluation Process: Applicants are advised that invitations for proposals will be made based on the white paper submission and the availability of funding. The white paper will be evaluated for the concept's scientific merit and relevance, research plan, plan for collaboration, experience and qualifications of the principle investigators, and potential contributions of the effort to the Army and DoD mission. Applicants whose white papers are evaluated as having the highest combined ratings across these factors may be invited to submit a full proposal. An applicant **may not** submit a proposal without submitting a white paper and receiving a proposal invite from the Government.
- b. Disposition Process: The applicant will be notified in writing (email) after completion of the evaluation. White papers will not be returned to applicants.

5. White paper Submission

White papers are due by 3:00PM (local time in North Carolina, USA) on 31 August 2021. All white papers must be emailed directly to the following email address:

usarmy.rtp.devcom-arl.mbx.baa3qa@mail.mil

In the email subject line, include the phrase "White paper Submission HTMDEC," the FOA number W911NF-21-S-0013, and the research thrust area from Section II.A.2 of this FOA. White papers submitted via email must be in a single PDF formatted file as an email attachment.

E. PROPOSAL APPLICATION AND SUBMISSION INFORMATION

The application process is a two-step process, a White paper and Proposal stage. Applicants will receive feedback on their White paper only if invited to submit a Proposal and feedback regarding their proposal **ONLY IF IT IS SELECTED FOR AWARD**, in order to improve the proposal and ensure alignment of the proposed research with Government goals. Applicants with **non-selected white papers and proposals will be notified of their non-selection, but will not receive feedback.**

1. Address to Request Application Package

This Funding Opportunity may be accessed from the following: Grants.gov (www.grants.gov). Amendments, if any, to this FOA will be posted to these websites when

they occur. Interested parties are encouraged to periodically check these websites for updates and amendments.

2. Content and Format of Application Submission

The following information is for those wishing to respond to the FOA:

Grants.gov Application Submission and Receipt Procedures

This section provides the application submission and receipt instructions for DoD program applications. Please read the following instructions carefully and completely.

DoD is participating in the Grants.gov initiative to provide the grant community with a single site to find and apply for grant funding opportunities. For this funding opportunity, DoD requires applicants to submit their applications online through Grants.gov. This funding opportunity may be found on Grants.gov by going to the Grants.gov Search Grants screen and entering the funding opportunity number for this FOA, W911NF-21-S-0013, in the Funding Opportunity search box. You can also search for the CFDA Number 12.630.

How to Register to Apply through Grants.gov

1. *Instructions:* Read the instructions below about registering to apply for DoD funds. Applicants should read the registration instructions carefully and prepare the information requested before beginning the registration process. Reviewing and assembling the required information before beginning the registration process will alleviate last-minute searches for required information.

Organizations must have a Data Universal Numbering System (DUNS) Number, active System for Award Management (SAM) registration, and Grants.gov account to apply for grants. Creating a Grants.gov account can be completed online in minutes, but DUNS and SAM registrations may take several weeks. Therefore, an organization's registration should be done in sufficient time to ensure it does not impact the entity's ability to meet required application submission deadlines.

Complete organization instructions can be found on Grants.gov here:

<https://www.grants.gov/web/grants/applicants/organization-registration.html>

- a. *Obtain a DUNS Number:* All entities applying for funding, including renewal funding, must have a DUNS Number from Dun & Bradstreet (D&B). Applicants must enter the DUNS Number in the data entry field labeled "Organizational DUNS" on the Standard Form (SF)-424 form. For more detailed instructions for obtaining a DUNS Number, refer to: <https://www.grants.gov/web/grants/applicants/organization-registration/step-1-obtain-duns-number.html>

- b. *Register with SAM:* All organizations applying online through Grants.gov must register with the System for Award Management (SAM). Failure to register with SAM will prevent your organization from applying through Grants.gov. SAM registration must be renewed annually. For more detailed instructions for registering with SAM, refer to: <https://www.grants.gov/web/grants/applicants/organization-registration/step-2-register-with-sam.html>
 - c. *Create a Grants.gov Account:* The next step is to register an account with Grants.gov. Follow the on-screen instructions or refer to the detailed instructions here: <https://www.grants.gov/web/grants/applicants/registration.html>
 - d. *Add a Profile to a Grants.gov Account:* A profile in Grants.gov corresponds to a single applicant organization the user represents (i.e., an applicant) or an individual applicant. If you work for or consult with multiple organizations and have a profile for each, you may log in to one Grants.gov account to access all of your grant applications. To add an organizational profile to your Grants.gov account, enter the DUNS Number for the organization in the DUNS field while adding a profile. For more detailed instructions about creating a profile on Grants.gov, refer to: <https://www.grants.gov/web/grants/applicants/registration/add-profile.html>
 - e. *EBiz POC Authorized Profile Roles:* After you register with Grants.gov and create an Organization Applicant Profile, the organization applicant's request for Grants.gov roles and access is sent to the EBiz POC. The EBiz POC will then log in to Grants.gov and authorize the appropriate roles, which may include the Authorized Organization Representative (CAM) role, thereby giving you permission to complete and submit applications on behalf of the organization. You will be able to submit your application online any time after you have been assigned the CAM role. For more detailed instructions about creating a profile on Grants.gov, refer to: <https://www.grants.gov/web/grants/applicants/registration/authorize-roles.html>
 - f. *Track Role Status:* To track your role request, refer to: <https://www.grants.gov/web/grants/applicants/registration/track-role-status.html>
2. *Electronic Signature:* When applications are submitted through Grants.gov, the name of the organization applicant with the CAM role that submitted the application is inserted into the signature line of the application, serving as the electronic signature. The EBiz POC **must** authorize people who are able to make legally binding commitments on behalf of the organization as a user with the CAM role; **this step is often missed, and it is crucial for valid and timely submissions.**

How to Submit an Application to DoD via Grants.gov

Grants.gov applicants can apply online using Workspace. Workspace is a shared, online environment where members of a grant team may simultaneously access and edit different webforms within an application. For each funding opportunity announcement (FOA), you can create individual instances of a workspace.

Below is an overview of applying on Grants.gov. For access to complete instructions on how to apply for opportunities, refer to:

<https://www.grants.gov/web/grants/applicants/workspace-overview.html>

- a. *Create a Workspace*: Creating a workspace allows you to complete it online and route it through your organization for review before submitting.
- b. *Complete a Workspace*: Add participants to the workspace to work on the application together, complete all the required forms online or by downloading PDF versions, and check for errors before submission. The Workspace progress bar will display the state of your application process as you apply. As you apply using Workspace, you may click the blue question mark icon near the upper-right corner of each page to access context-sensitive help.

- 1) *Adobe Reader*: If you decide not to apply by filling out webforms you can download individual PDF forms in Workspace. The individual PDF forms can be downloaded and saved to your local device storage, network drive(s), or external drives, then accessed through Adobe Reader.

NOTE: Visit the Adobe Software Compatibility page on Grants.gov to download the appropriate version of the software at: <https://www.grants.gov/web/grants/applicants/adobe-software-compatibility.html>

- 2) *Mandatory Fields in Forms*: In the forms, you will note fields marked with an asterisk and a different background color. These fields are mandatory fields that must be completed to successfully submit your application.
 - 3) *Complete SF-424 Fields First*: The forms are designed to fill in common required fields across other forms, such as the applicant name, address, and DUNS Number. Once it is completed, the information will transfer to the other forms.
- c. *Submit a Workspace*: An application may be submitted through workspace by clicking the Sign and Submit button on the Manage Workspace page, under the Forms tab. Grants.gov recommends submitting your application package **at least 24-48 hours prior to the close date** to provide you with time to correct any potential technical issues that may disrupt the application submission.
 - d. *Track a Workspace Submission*: After successfully submitting a workspace application, a Grants.gov Tracking Number (GRANTXXXXXXXX) is automatically assigned to the application. The number will be listed on the Confirmation page that is generated after submission. Using the tracking number, access the Track My Application page under the Applicants tab or the Details tab in the submitted workspace.

For additional training resources, including video tutorials, refer

to: <https://www.grants.gov/web/grants/applicants/applicant-training.html>

Applicant Support: Grants.gov provides applicants 24/7 support via the toll-free number 1-800- 518-4726 and email at support@grants.gov. For questions related to the specific grant opportunity, contact the number listed in the application package of the grant you are applying for.

If you are experiencing difficulties with your submission, it is best to call the Grants.gov Support Center and get a ticket number. The Support Center ticket number will assist the DoD with tracking your issue and understanding background information on the issue.

Application forms and instructions will be available at Grants.gov. To access these materials, go to <http://www.grants.gov>, select "Apply for Grants", and then select "Download an Application Package." Enter the FOA number, W911NF-21-S-0013.

Applicants must complete the mandatory forms and any optional forms (e.g., SF-LLL Disclosure of Lobbying Activities) in accordance with the instructions on the forms and the additional instructions below. The required fields should be completed in accordance with the “pop-up” instructions on the forms. To activate the instructions, turn on the “Help Mode” (icon with the pointer and question mark at the top of the form). Files that are attached to the forms must be in Adobe Portable Document Form (PDF) unless otherwise specified in this announcement.

The following formatting rules apply for the file attachments:

- Paper size when printed – 8.5 x 11 inch paper
- Margins – 1 inch
- Spacing – Single
- Font – No smaller than Times New Roman, 12 point

Form: SF 424 (R&R) (Mandatory) – Complete this form first to populate data in other forms. Authorized Organization Representative (CAM) usernames and passwords serve as “electronic signatures” when your organization submits applications through Grants.gov. By using the SF 424 (R&R), applicants are providing the certification required by 32 CFR Part 28 regarding lobbying.

Form: Research & Related Other Project Information - Complete questions 1 through 6 and attach files.

- **Project Summary/Abstract (Field 7 on the form)** - The Project Summary should be a brief summary of the content of the application. It shall include a title, the research team (include roles, expertise, affiliations), designation of Junior Investigator or Senior Investigator derivation, and a brief abstract articulating the project objectives. **The project summary/abstract must not exceed 1 page and will not be evaluated as it is primarily for documentation purposes.**
- **Project Narrative (Field 8 on the form)** - Chapters and Numbers of pages – Field 8 is to

contain the chapters set forth below and may not exceed the stipulated page counts for those chapters. Pages in excess of the page limits may be removed for the evaluation of the application. All chapters set forth below should be in a single PDF file. For those chapters with specified page limitations, any pages submitted beyond the specified amount for a chapter will not be reviewed or evaluation.

- Chapter 1: Technical Component. The pages included in Chapter 1 are to be numbered. Applicants are advised that Chapter 1 will not exceed 12 pages, utilizing one side of the page. Tables that extend beyond one page (fold out tables) will only count as one page.
 - Proposed Effort (approximately 6-8 pages): This section of Chapter 1 should include an overview of the research strategy to be employed to accelerate discovery of materials for extreme conditions; a short description and justification for annual research goals of the proposed effort; and a short technical discussion stating the background and objectives of the proposed research, and the overall technical approaches to be pursued. This technical discussion should include a proposed breakdown of research tasks and short description of the technical approaches for each task. The proposed effort should include the specific hypotheses to be tested, and what specific tasks will be performed by the research team to test them, as well as justification for why these are the appropriate measures.
 - Participant(s) roles, qualifications and bio-sketches (approximately 2 pages): Must include the names, primary role/availability, and brief biographies. Include plans for junior investigator development and mentorship of less experienced personnel (mentoring plan).
 - Proposed timeline (approximately 0.5-1 page): An estimated timeline of tasks to be completed during the proposed period of performance.
- **Chapter 2: Cost Component.** The pages included in Chapter 2 will be numbered and Chapter 2 does not have a page limitation. Cost Application must include a budget for the period of performance. The cost portion of the application will contain cost estimates sufficiently detailed for meaningful evaluation, to include Summit series participation. Budget justification may also be attached in this chapter. Before award it must be established that an approved accounting system and financial management system exist. Proposals should include itemized budgets per the instructions below for both the base seedling effort as well as potential options periods and must be commensurate with the technical level of effort proposed.

For all applications, the budget details should include:

- a. *Direct Labor*: Show the current and projected salary amounts in terms of man-hours, man- months, or annual salary to be charged by the personnel performing under this agreement either by personnel or position. State the number of man-hours used to calculate a man-month or man-year. For each person or position, provide the following information:

i. The basis for the direct labor hours or percentage of effort (e.g., historical hours or estimates);

ii. The basis for the direct labor rates or salaries. Labor costs should be predicted upon current labor rates or salaries. These rates may be adjusted upward for forecast salary or wage cost-of-living increases that will occur during the agreement period. The cost application should separately identify the rationale applied to base salary/wage for cost-of-living adjustments and merit increases. Each must be fully explained;

iii. The portion of time to be devoted to the requirements of the agreement;

iv. The total annual salary charged to the agreement; and

v. Any details that may affect the salary during the project, such as plans for leave and/or remuneration while on leave.

b. Fringe Benefits and Indirect Costs (Overhead, G&A, and Other): The most recent rates, dates of negotiation, the base(s) and periods to which the rates apply must be disclosed and a statement included identifying whether the proposed rates are provisional or fixed. If the rates have been negotiated by a Government agency, state when and by which agency. A copy of the negotiation memorandum should be provided. If negotiated forecast rates do not exist, applicants must provide sufficient detail to enable a determination to be made that the costs included in the forecast rate are allocable according to applicable cost provisions. Applicants' disclosure should be sufficient to permit a full understanding of the content of the rate(s) and how it was established. At a minimum, the submission should identify:

i. All individual cost elements included in the forecast rate(s);

ii. Basis used to prorate indirect expenses to cost pools, if any;

iii. How the rate(s) was calculated;

iv. Distribution basis of the developed rate(s);

v. Basis on which the overhead rate is calculated, such as "salaries and wages" or "total costs;" and

vi. The period of the applicant's FY.

c. Permanent Equipment: If facilities or equipment are required, a justification why this property should be purchased with Government funds must be submitted. State the organization's inability or unwillingness to furnish the facilities or equipment. Applicants must provide an itemized list of permanent equipment showing the cost for each item. Permanent equipment is any article or tangible nonexpendable property having a useful life of more than one year and an acquisition cost of \$5,000

or more per unit. The basis for the cost of each item of permanent equipment included in the budget must be disclosed, such as:

- i. Vendor Quote: Show name of vendor, number of quotes received and justification, if intended award is to other than lowest bidder.
- ii. Historical Cost: Identify vendor, date of purchase, and whether or not cost represents lowest bid. Include reason(s) for not soliciting current quotes.
- iii. Engineering Estimate: Include rationale for quote and reason for not soliciting current quotes.

If applicable, the following additional information shall be disclosed in the applicant's cost application:

- iv. Special test equipment to be fabricated by the Recipient for specific requirements in the agreement.
- v. Standard equipment to be acquired and modified to meet specific requirements, including acquisition and modification costs, listed separately.
- vi. Existing equipment to be modified to meet specific research requirements, including modification costs. Do not include equipment the organization will purchase with its funds if the equipment will be capitalized for Federal income tax purposes. Proposed permanent equipment purchases during the final year of an award shall be limited and fully justified.
- vii. Grants and cooperative agreements may convey title to an eligible institution for permanent equipment purchased with project funds. At the discretion of the Contracting/Agreements Officer, the agreement may provide for retention of the title by the Government or may impose conditions governing the equipment conveyed to the organization per the governing laws and regulations.

d. *Travel*: Forecasts of travel expenditures (domestic and foreign) that identify the destination (if known) and the various cost elements (airfare, mileage, per diem rates, etc.) must be submitted. The costs should be in sufficient detail to determine the reasonableness of such costs. Allowance for air travel normally will not exceed the cost of round-trip, economy air accommodations. Specify the type of travel and its relationship to the requirements of the agreement.

e. *Participant Support Costs*: This budget category refers to costs of transportation, per diem, stipends, and other related costs for participants or trainees (but not employees) in connection with DoD-sponsored conferences, meetings, symposia, training activities, and workshops. Generally, indirect costs are not allowed on

participant support costs. The number of participants to be supported should be entered in the parentheses on the budget form. These costs should also be justified in the budget justification page(s) attached to the cost application.

f. Materials, Supplies, and Consumables: A general description and total estimated cost of expendable equipment and supplies are required. The basis for developing the cost estimate (vendor quotes, invoice prices, engineering estimate, purchase order history, etc.) must be included. If possible, provide a material list.

g. Publication, Documentation, and Dissemination: The budget may request funds for the costs of preparing, publishing, or otherwise making available to others the findings and products of the work conducted under an agreement, including costs of reports, reprints, page charges, or other journal costs (except costs for prior or early publication); necessary illustrations, cleanup, documentation, storage, and indexing of data and databases; and development, documentation, and debugging of software.

h. Consultant Costs: Applicants normally are expected to utilize the services of their own staff to the maximum extent possible in managing and performing the project's effort. If the need for consultant services is anticipated, the nature of proposed consultant services should be justified and included in the technical application narrative. The cost application should include the names of consultant(s), primary organizational affiliation, each individual's expertise, daily compensation rate, number of days of expected service, and estimated travel and per diem costs.

i. Computer Services: The cost of computer services, including computer-based retrieval of scientific, technical, and educational information, may be requested. A justification/explanation based on the established computer service rates at the proposing organization should be included. The budget also may request costs, which must be shown to be reasonable, for leasing automatic data processing equipment. The purchase of computers or associated hardware and software should be requested as items of equipment.

j. Subawards (Subcontracts or Subgrants): A precise description of services or materials that are to be awarded by a subaward must be provided. For subawards totaling \$10,000 or more, provide the following specific information:

i. A clear description of the work to be performed;

ii. If known, the identification of the proposed subawardee and an explanation of why and how the subawardee was selected or will be selected;

iii. The identification of the type of award to be used

(cost reimbursement, fixed price, etc.);

iv. Whether or not the award will be competitive and, if noncompetitive, rationale to justify the absence of competition; and

v. A detailed cost summary.

k. *ODCs*: Itemize and provide the basis for proposed costs for other anticipated direct costs such as communications, transportation, insurance, and rental of equipment other than computer related items. Unusual or expensive items must be fully explained and justified.

1. *Profit/ Fee*: Profit/fee is not allowed for the Recipient of or subaward to an assistance instrument, where the principal purpose of the activity to be carried out is to stimulate or support a public purpose (i.e., to provide assistance), rather than acquisition (i.e., to acquire goods and services for the direct benefit of the Government). A subaward is an award of financial assistance in the form of money, or property in lieu of money, made under a DoD grant or cooperative agreement by a Recipient to an eligible subrecipient. The term includes financial assistance for substantive program performance by the Subrecipient of a portion of the program for which the DoD grant or cooperative agreement was made. It does not include the Recipient's procurement of goods and services needed to carry out the program.

- Bibliography and Reference Cited (Field 9 on the form)** – Attach a listing of applicable publications cited in above sections.
- Facilities and Other Resources (Field 10 on the form)** - The applicant is to provide a description of any facilities planned to be used for the project, whether at the home institution, a partner facility, or at DEVCOM-ARL in collaboration with DEVCOM-ARL researchers. A note of support guaranteeing access to these facilities on behalf of their primary management should also be included. Attach this information at Field 10.
- Equipment (Field 11 on the form)** - The applicant is to include a listing of equipment available to support the application. Any Government equipment necessary for performance is to be clearly identified. Attach this information at Field 11.
- Other Attachments (Field 12 on the form)** are as follows:
 1. Attached the completed certifications.
 2. **FORM: SF-424 Research & Related Senior/Key Person Profile (Expanded) (Mandatory)** – The Degree Type and Degree Year fields on the Research and Related Senior/Key Person Profile (Expanded) form will be used by DoD as the source for career information. In addition to the required fields on the form, applicants must complete these two fields for all individuals that are identified as having the project role of PD/PI or Co- PD/PI on the form. Additional senior/key persons can be added by selecting the “Next Person” button

3. **FORM: SF-424 (R&R) Personal Data (Mandatory)** - This form will be used by DoD as the source of demographic information, such as gender, race, ethnicity, and disability information for the Project Director/Principal Investigator and all other persons identified as Co-Project Director(s)/Co-Principal Investigator(s). Each application must include this form with the name fields of the Project Director/Principal Investigator and any Co-Project Director(s)/Co-Principal Investigator(s) completed; however, provision of the demographic information in the form is voluntary. If completing the form for multiple individuals, each Co-Project Director/Co-Principal Investigator can be added by selecting the "Next Person" button. The demographic information, if provided, will be used for statistical purposes only and will not be made available to merit reviewers. Applicants who do not wish to provide some or all of the information should check or select the "Do not wish to provide" option.
4. **SF-LLL – Disclosure of Lobbying Activities.** If applicable, attach a complete SF-LLL at Field 11 of the R&R Other Project Information form. Applicability: If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the cooperative agreement, you must complete and submit Standard Form - LLL, "Disclosure Form to Report Lobbying."
5. Complete the **Representations under DoD Assistance Agreements: Appropriations Provisions on Tax Delinquency and Felony Convictions** (this can be found under National Policy Requirements)

3. Submission Dates and Times

Proposals are due in grants.gov by 3:00pm (local time in North Carolina, USA) on **1 November 2021**. A grants.gov notification will be generated when your proposal has been received. Applications submitted after the closing date and time will not be considered or evaluated by the Government.

Application Receipt Notices

Grants.gov: After an application is submitted to Grants.gov, the CAM will receive a series of three emails from Grants.gov. The first two emails will be received within 24 to 48 hours after submission. The first email will confirm time of receipt of the application by the Grants.gov system and the second will indicate that the application has either been successfully validated by the system prior to transmission to the grantor agency or has been rejected due to errors. A third email will be received once the grantor agency has confirmed receipt of the application. Reference https://www.grants.gov/help/html/help/GetStarted/Get_Started.htm from the Grants.gov User Guide for information on how to track your application package.

For the purposes of this FOA, an applicant's application is not considered received by the Government until the CAM receives email #3.

F.APPLICATION REVIEW / EVALUATION CRITERIA INFORMATION

The following represents the evaluation criteria for this FOA:

Factor 1: Scientific Merit and Relevance: Evaluation of this factor will concentrate on the overall scientific and technical merit, creativity, innovation, and flexibility of the proposed research in addressing each of the HTMDEC thrust areas, and the expected outcomes based on the timeline of execution. The scientific merit will be evaluated with regard to the specific thrust area to be addressed in this Funding Opportunity. Evaluation of this factor will also concentrate on the long-term relevance of the proposed research and the likelihood that the proposed research will address scientific challenges and research barriers facing the Army and commercial sectors.

Factor 2: Research Plan and Plan for Collaboration: Evaluation of this factor will concentrate on the Applicant's strategies, plans and experience in fostering collaborative research and managing collaborative research programs as set forth in this FOA. Evaluation of this factor will include evidence of previous successful collaborative efforts, plans for participation at the HTMDEC Program Review Workshops, the Applicant's commitment and plans for collaboration within the program and the synergistic value of the collaborations among researchers and government scientists, as well as approaches to data/coding/model sharing and transition of products that create collaborative potential amongst government, academic, and industry partners. To maximize collaboration between seedling efforts towards forming centers featuring strong teaming, the number of seedlings proposing to become a center is a quantifiable evaluation criteria for effective collaboration.

Factor 3: Experience and Qualifications of Scientific Staff and Junior Investigator Development: Evaluation of this factor will concentrate on the qualifications, capabilities, availability, proposed level of effort, and experience of both the Applicant's key research personnel (individually and as a whole), their relevant past accomplishments, and their ability to achieve the proposed technical objectives. Key personnel are expected to be substantially and meaningfully engaged in the research and the proposed level of effort for key personnel reflected in the proposal should be commensurate with and demonstrate such engagement. The extent to which the Applicant's proposed facilities and equipment will contribute to the accomplishment of the proposed research will be evaluated, including the nature, quality, relevance, availability, and access to state-of-the-art research facilities and equipment.

Factor 4: Cost. While this area will not be weighted, evaluation of this area will consider cost realism, cost reasonableness, and affordability within funding constraints. The Government may make adjustments to the cost of the total proposed effort as deemed necessary to reflect what the effort should cost. These adjustments will consider the task undertaken and approach proposed. These adjustments may include upward or downward adjustments to proposed labor hours, labor rates, quantity of materials, price of materials, overhead rates and G&A, etc.

Proposal Review and Selection Process

All timely and compliant Proposal submissions will be evaluated in accordance with the evaluation criteria set forth in this FOA. Proposals are expected to be evaluated by a group of qualified scientists and managers from the Government.

No other material outside of a Proposal will be provided to those evaluating proposals. An initial review of the proposals will be conducted to ensure compliance with the requirements of this FOA. Failure to comply with the requirements of the FOA may result in a proposal not being evaluated and receiving no further consideration for award.

Proposals that are timely and in compliance with the requirements of the FOA will be evaluated in accordance with merit based, competitive procedures. These procedures will include evaluation factors that will be evaluated using an adjectival and color rating system as follows:

OUTSTANDING (blue): The proposal is evaluated as outstanding for this factor. The proposal includes one or more significant strengths that are not offset by weaknesses.

GOOD (purple): The proposal is evaluated as good for this factor. The proposal includes some strengths that are not offset by weaknesses.

ACCEPTABLE (green): The proposal is evaluated as acceptable for this factor. Any strengths and weaknesses in the proposal balance out.

MARGINAL (yellow): The proposal is evaluated as marginal for this factor. While the proposal may or may not contain some strengths, and strengths are more than offset by any weakness or weaknesses.

UNACCEPTABLE (red): The proposal is evaluated as unacceptable for this factor. While the proposal may or may not contain some strengths, and strengths are offset by any significant weakness or weaknesses.

A Review Team, consisting of a qualified group of scientists and managers, will evaluate the Proposals and provide the results of that evaluation to the decision maker for the Government. The decision maker will make decisions concerning award selection.

The Government will make award to the Applicant(s), whose proposal conforms to the Funding Opportunity that offers the most-favorably rated proposal(s) based on the evaluation criteria noted above. The Government reserves the right not to make an award should no acceptable Proposal be submitted. The Government also reserves the right to negotiate with an Applicant to re-scope their proposal or optional proposal technical focus, period of performance, and associated costs in order to maximize the available program funding, balance of research topics across the program, and overall impact to the program resulting in the development of an annual program plan to cover the optional research to be performed and the period of performance of that research.

Optional Period Review and Selection Process:

At the end of Year #1, the decision to exercise option periods of any seedling awards remains at the discretion of the Government. Details on the submission and evaluation of the option proposal will be provided to those Recipients who have received a seedling CA. The Government also reserves the right to negotiate with an Applicant to re-scope their proposal or optional proposal technical focus, period of performance, and associated costs in order to maximize the available program funding, balance of research topics across the program, and overall impact to the

program resulting in the development of an annual program plan to cover the optional research to be performed and the period of performance of that research.

Recipient Qualification

The Agreements Officer is responsible for determining a Recipient's qualification prior to award. In general, an Agreements Officer will award grants or CAs only to qualified Recipients that meet the standards at 32 CFR 22.415. To be qualified, a potential Recipient must:

- (1) Have the management capability and adequate financial and technical resources, given those that would be made available through the grant or cooperative agreement, to execute the program of activities envisioned under the grant or cooperative agreement;
- (2) Have a satisfactory record of executing such programs or activities (if a prior Recipient of an award);
- (3) Have a satisfactory record of integrity and business ethics; and
- (4) Be otherwise qualified and eligible to receive a grant or cooperative agreement under applicable laws and regulations (see 32 CFR 22.420(c)).

Applicants are requested to provide information with proposal submission to assist the Agreements Officer's evaluation of Recipient qualification.

In accordance with OMB guidance in parts 180 and 200 of Title 2, CFR, it is DoD policy that DoD Components must report and use integrity and performance information in the Federal Awardee Performance and Integrity Information System (FAPIIS), or any successor system designated by OMB, concerning grants, cooperative agreements, and TIAs as follows:

If the total Federal share will be greater than the simplified acquisition threshold on any Federal award under a notice of funding opportunity (see 2 CFR 200.88 Simplified Acquisition Threshold):

- (5) The Federal awarding agency, prior to making a Federal award with a total amount of Federal share greater than the simplified acquisition threshold, will review and consider any information about the applicant that is in the designated integrity and performance system accessible through SAM (currently FAPIIS) (see 41 U.S.C. 2313);
- (6) An applicant, at its option, may review information in the designated integrity and performance systems accessible through SAM and comment on any information about itself that a Federal awarding agency previously entered and is currently in the designated integrity and performance system accessible through SAM;
- (7) The Federal awarding agency will consider any comments by the applicant, in addition to the other information in the designated integrity and performance system, in making a judgment about the applicant's integrity, business ethics, and record of performance under Federal awards when completing the review of risk posed by applicants as described in 2

CFR 200.205 Federal awarding agency review of risk posed by applicants.

G. AWARD ADMINISTRATION INFORMATION

Award Notices

Should your Proposal be selected for award, you will be contacted telephonically or via email by the Agreements Officer or his/her representative to discuss additional information required for award. This may include representations and certifications, revised budgets or budget explanations, and other information as applicable to the proposed award. The anticipated start date will be determined at that time.

The award document signed by the Government Agreements Officer is the official and authorizing award instrument.

Administrative and National Policy Requirements

- a. Each award under this announcement will be governed by the general award terms and conditions in effect at the time of the award that conform to DoD's implementation of OMB guidance applicable to financial assistance in 2 CFR part 200, "Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards." The DoD Research and Development General Terms and Conditions (latest version, JULY 2018) are located at <https://www.onr.navy.mil/Contracts-Grants/submit-proposal/grants-proposal/grants-terms-conditions>. These terms and conditions are incorporated by reference in this announcement.
- b. You must comply with all applicable national policy requirements. The key national policy requirements that may relate to an award under this FOA are included in the terms and conditions specified in paragraph 2.a above.
- c. By electronically signing the SF-424, the applicant affirms its agreement with the following certification.

Certification Required for Grant and Cooperative Agreement Awards

The certification at Appendix A to 32 CFR Part 28 regarding lobbying is the only certification required at the time of application submission for a grant or cooperative agreement award. The certification is as follows:

"By signing and submitting an application that may result in the award of a grant exceeding \$100,000, the prospective awardee is certifying, to the best of his or her knowledge and belief that:

- (1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of an agency, a member of Congress in

connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

- (2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employ of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit SF-LLL, “Disclosure of Lobbying Activities” in accordance with its instructions.
- (3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, and loans, or cooperative agreements) and that all Subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails the required certification shall be subject to a civil penalty or not less than \$10,000.00 and not more than \$100,000.00 for each failure.

d. Representations Required for Grant and Cooperative Agreement Awards

Appropriations Provisions on Tax Delinquency and Felony Convictions

Check either “is” or “is not” for each of these two representations, as appropriate for the proposing institution, include the CAM signature and point of contact information, and attach the representation page to Field 12 of the SF-424 Research & Related Other Project Information form. The page for these representations is provided with the application materials that are available for download at Grants.gov. Representations:

The applicant is () is not () a “Corporation” meaning any entity, including any institution of higher education, other nonprofit organization, or for-profit entity that has filed articles of incorporation. If the applicant is a “Corporation” please complete the following representations:

- (1) The applicant represents that it is () or is not () a corporation that has any unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

(2) The applicant represents that it is () is not () a corporation that was convicted of a criminal violation under any Federal law within the preceding 24 months.

NOTE: If an applicant responds in the affirmative to either of the above representations, the applicant is ineligible to receive an award unless the agency suspension and debarment official (SDO) has considered suspension or debarment and determined that further action is not required to protect the Government's interests. The applicant therefore should provide information about its tax liability or conviction to the agency's SDO as soon as it can do so, to facilitate completion of the required considerations before award decisions are made.

OMB CONTROL NUMBER: 0704-0494

OMB EXPIRATION DATE: 11/30/2019

AGENCY DISCLOSURE NOTICE

The public reporting burden for this collection of information is estimated to average 5 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to the Department of Defense, Washington Headquarters Services, Executive Services Directorate, Directives Division, 4800 Mark Center Drive, East Tower, Suite 02G09, Alexandria, VA 22350-3100 [0704-0494]. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

Prohibition on Contracting with Entities that Require Certain Internal Confidentiality Agreements

Agreement with the representation below will be affirmed by checking the "I agree" box in block 17 of the SF-424 (R&R) as part of the electronic application submitted via Grants.gov. The representation reads as follows:

By submission of its application, the applicant represents that it does not require any of its employees, contractors, or Subrecipients seeking to report fraud, waste, or abuse to sign or comply with internal confidentiality agreements or statements prohibiting or otherwise restricting those employees, contractors, Subrecipients from lawfully reporting that waste, fraud, or abuse to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive such information

Note that: (1) the basis for this representation is a prohibition in Section 743 of the Financial Services and General Government Appropriations Act, 2015, Pub. L. 113-235) on provision of funds through grants and cooperative agreements to entities with certain internal confidentiality agreements or statements; and (2) Section 743

states that it does not contravene requirements applicable to SF-312, Form 4414, or any other form issued by a Federal department or agency governing the nondisclosure of classified information.

H. AGENCY CONTACTS

All questions or comments concerning this FOA should be submitted on or before the Deadline for Questions on Funding Opportunity date noted above (see Event timeline above). Questions and comments should be concise and to the point. In addition, the relevant part and paragraph of the FOA must be referenced. Responses to non-proprietary questions received by the specified date will be posted to the HTMDEC website (<https://www.arl.army.mil/HTMDEC>) for the benefit of all interested parties. Should an Applicant have questions they believe are of a proprietary nature, the Applicant must clearly state so and identify and mark the proprietary information in the question when submitted. Answers to questions of a proprietary nature will be provided via email directly to the requestor of the question and not posted on the HTMDEC website (<https://www.arl.army.mil/HTMDEC>).

ⁱ Wilkinson, M., Dumontier, M., Aalbersberg, I. *et al.* The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data* **3**, 160018 (2016). <https://doi.org/10.1038/sdata.2016.18>.