DuraMAT "Reliability Forecasting" Lab Core and Spark Projects Request for Proposals (RFP)

Submit proposals adhering to the template and page limits to DuraMAT@nrel.gov by:
11:59 pm MT, Thursday, June 20th, 2024
Additional information about the DuraMAT Consortium can be found at: https://www.duramat.org/

DURAMAT BACKGROUND

The DuraMAT Consortium brings together DOE national lab and university research capabilities with the photovoltaic (PV) and supply-chain industries to accelerate a sustainable, just, and equitable transition to zero-carbon electricity generation by 2035 through our five core objectives: development of a central data resource for PV modules, multi-scale and multi-physics modeling, disruptive acceleration science, forensic tools for fielded modules, and materials solutions for more durable, reliable, and resilient modules. DuraMAT leverages the decades of experience, expertise, and world-class facilities at the national laboratories to create a "one-stop-shop" for timely solutions to critical barriers limiting module reliability and durability. In its first five years, DuraMAT has become a trusted partner for the US industry.
The core objectives have been defined in partnership with DuraMAT's Industry Advisory Board (IAB) along with long-term research objectives that are expected to continue through DuraMAT 2.0 (see www.duramat.org).

The program's core objectives are focused on ***the DuraMAT goal of accelerating a sustainable, just, and equitable transition to zero-carbon electricity generation by 2035*** *by addressing these two questions:*

1. *Which materials and module designs will enable sustainable, high-energy yield 50-year modules, and how do we ensure that these new modules are not going to fail prematurely?*
2. *What triggers wear out, defined as a rapid increase in degradation at end of life, and what are the characteristics, rates, and mechanisms of long-term degradation in PV modules?*

The DuraMAT Consortium is currently divided into five core objective areas: Central Data Resource, Multi-Scale, Multi-Physics Modeling, Fielded Module Forensics, Disruptive Acceleration Science, and Materials Solutions. Descriptions of these core objectives are available at https://www.duramat.org/core-objectives.html.

TECHNICAL BACKGROUND FOR THIS CALL

This call is for two types of proposals for projects and capabilities that support the DuraMAT goal above. Full projects are intended to be 2 - 3 year efforts, starting October 2024 and ending by the end of September 2027. DuraMAT expects to fund between 2 and 4 full proposals. "Spark" proposals are for shorter projects with a 6 - 9 month time frame. More information on budget period and expected award amounts for each type of proposal can be found later in this document.

The core objectives have been defined in partnership with DuraMAT's Industry Advisory Board (IAB) and are long term research objectives that are expected to continue through DuraMAT 2.0. Selection and funding of specific projects however are dynamic, allowing the consortium the flexibility to address the most current and pressing industry concerns. DuraMAT funding supports research projects through a number of different competitive processes described on the website. All the core objectives are focused on the DuraMAT goal of accelerating a sustainable, just and equitable transition to zero carbon electricity generation by 2035 by addressing these two questions:

1. Which materials and module designs will enable sustainable, high-energy yield 50-year modules, and how do we ensure that these new modules are not going to fail prematurely?

2. What triggers wear out, defined as a rapid increase in degradation at end of life, and what are the characteristics, rates, and mechanisms of long-term degradation in PV modules?

In close collaboration with the IAB, DuraMAT 2 has identified understanding which materials and packaging designs will enable high energy yield modules with the potential for 50-year lifetimes and identifying long term degradation mechanisms and wear out failures as our highest priorities. Building confidence in 50-year modules requires an understanding of early failures and end of life wear out. Our planned work in DuraMAT 2 includes:

- De-risking high yield modules and screening them for weaknesses that lead to early failure.
- Identifying the triggers and dominant contributors to wear out failures.
- Understanding the role of polymeric materials in wear out and long term degradation.
- Continued study of bifacial modules, glass-glass packaging, thinner glasses, and impacts of high energy yield module design.
- Continued development of new accelerated testing methods, modeling approaches, and scalable forensics.
- Development of materials solutions and designs to enable new applications and address known risks.
- Development of data science tools and methods to quickly identify trends in reliability and technologies.
- Developing technoeconomic, sustainability, and other analysis capabilities that support the DuraMAT goal.

DuraMAT specifically excludes pre-commercial cell technologies like perovskites and cell efficiency or device physics research. Cells can be used as a sensor to test packaging or interconnect technologies.

DuraMAT employs two main approaches to understanding reliability. The first is a "physics of failure" approach based on individual degradation mechanisms, material properties, interfacial properties, climate-relevant stresses, mass transport, and chemical reactions that can be used to build reliability forecasting capabilities. The second is a probabilistic approach where large scale data analysis enables insights into reliability and performance based on field and accelerated test data and predictive models. DuraMAT is aiming to build mechanistic rather than phenomenological measurements and models of degradation to predict degradation rates, failure rates, and wear out.

DuraMAT requires a set of interconnected testing, modeling, characterization, and analysis capabilities. Individual experiments or models may focus on one or several physical, chemical, or degradation mechanisms. Interconnection of the experiments and models allows for the prediction of failure modes and their implication on module performance and/or lifetime. For example, a testing and characterization project focused on metallization corrosion may consist of experiments that are capable of measuring moisture ingress, reactant transport, reactant formation, corrosion reactions, and eventual metallization failure mechanisms. A complementary project may focus on modeling these processes at different time and length scales. Experimental and modeling results could then be validated with "top-down" approaches by comparing the prediction results with field observations, modeled predictions, and other data. DuraMAT expects a mixture of "top-down" studies and "bottom-up" studies in the portfolio. Each can focus on either a specific stressor, material or interface property, mechanism, or failure mode, but when incorporated into the portfolio needs to contribute to a more complete understanding of degradation and failure rates over time.

DuraMAT is not requesting complete service life prediction models under this budget and timeline. Instead, we are requesting proposals for accelerated testing, materials and module forensics, advanced data analytics, and/or models that can be integrated with model chains to leverage work done by multiple groups and institutions to collaboratively advance our understanding of long-term degradation and wear-out. The proposed projects may follow the "model chain" approach used for Predictive Modeling[1] where individual mechanism-based models are linked in a larger modeling framework for a holistic assessment of PV module reliability.

Individual mechanistic studies can be difficult and time-consuming; therefore, it is essential to develop such capabilities in parallel and to include methods to effectively collaborate and share results between projects so that they can be interconnected in the future. More specifically, proposers should describe how their work addresses a key question in reliability that is currently missing from standards and existing tests, establishes or develops a capability for reliability research, provides and leverages predictive modeling data, or contributes to material, stress, or mechanistic property libraries. This does not mean that projects must use the same experimental, modeling, or analysis approach, but it does encourage researchers to develop connections between projects where useful.

Proposed work should drive toward understanding of failures and long term wear out in modern module technologies. Proposals including foundational DuraMAT capabilities supporting the core objectives are encouraged. Proposed work may also include equipment design/development, forensics technique development, software to make data publicly available and human readable, and creation of publicly accessible dashboards or calculations tools or open-source software.

PROPOSAL SCOPE AND AIMS

DuraMAT is open to studies at different scales as shown in Figure 1 which shows the range of samples that could be relevant and some of the scaling relationships between different sample/test article types that could be used for experimental studies, modeling, and validation. Material coupons may be used to study bulk degradation rates under individual or combined stresses. Coupon testing has very high throughput at low cost, but the data can have low fidelity or direct relevance to fielded module performance. Some mechanisms may require custom test structures (e.g. a solder bump test)[2] to get field

[1] https://doi.org/10.1002/pip.3645
[2] M. Kempe, T. Lockman, J. Morse, "Development of Testing Methods to Predict Cracking in Photovoltaic Backsheets," Proc. of the IEEE PVSC 46, 2019

relevant combinations of stresses and interfaces. Single encapsulated cells or mini-modules can be used for studies that use cells as "sensors" of degradation or of complex heterogeneous reactions. Increasing sample complexity to mini-modules and full-size modules increases the fidelity of the test results to commercial product performance, but at higher cost and much lower throughput. All of this can be done before commercialization and purchase/deployment. At the opposite extreme, huge PV system and fleet datasets are available, occasionally with additional imaging and characterization. However, learning from these complex and noisy datasets is challenging, requiring the development of analysis tools for "top-down" insights into degradation and reliability. **Proposals under this call should focus on degradation mechanisms leading to wear out and/or investigating potential reliability risks and packaging needs of new commercial technologies before large scale deployment**.

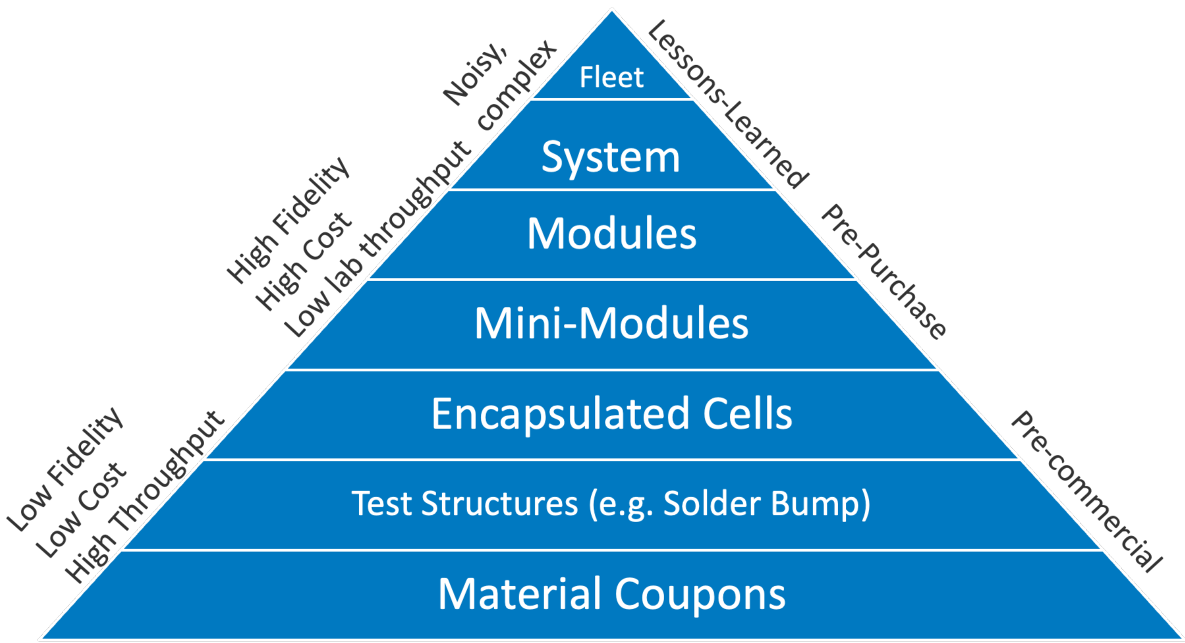

Figure 1: Scaling relationships between sample sets used in reliability studies. Sample sets can vary from isolated material coupons to packaged devices and mini-modules to commercial products and systems. Forward looking work is concentrated towards the lower portion of the pyramid. .

Successful proposals will identify relevant modes and mechanisms that can result in degradation and describe which mechanisms, physical/chemical properties, or stresses will be studied. They should describe how the proposed work will result in an improvement in our abilities to predict degradation and failure indicators, including the onset of wear out, or indicators that materials, designs, or modules will be reliable in the field. Proposals should describe how results could eventually be used to address the DuraMAT goal and key questions on page 1 – include existing and missing pieces. They will also include a plan to use the DataHUB to store and share data.

PROPOSAL ELEMENTS (see proposal template for formatting details and page limits)

PROPOSAL TYPE

DuraMAT is soliciting two types of proposals during this call: full project proposals (2 – 3 year efforts, up to $1.5M total) and "Spark" projects (6 – 9 month efforts - $65k each). The Spark projects are expected to have a well-defined final project deliverable. These efforts are expected to support the larger DuraMAT goals, but they may address the topic tangentially. Examples of Spark projects include, but are not limited to:

- Building a publicly accessible web, DuraMAT data hub (https://datahub.duramat.org), or Github-based tool from an existing study that is currently proprietary or inaccessible (*e.g.*, exists only in a desktop spreadsheet).
- Creating a simple material, stress, or reaction model that is needed quickly.
- Experimental or data driven validation work.
- Extending an existing model, test, or characterization approach to include a new material, stress, interface, etc.

PROBLEM STATEMENT

- Define your project in terms of the specific reliability problem or capability your work will address or develop. Briefly describe the system, data, model, module, materials, stresses, and/or tools involved, and be specific about which will be addressed in your project.
- Document the relevance of this problem or capability in current and emerging commercial modules. DuraMAT prioritizes research on issues relevant to high energy yield modules for utility commercial, and residential applications.
- Describe the effect of the problem or capability on future fielded performance, including the risk factors that make modules susceptible to this mechanism, probability or frequency of occurrence, ability to detect, and impact on performance. DuraMAT prefers proposals that address specific degradation rates or failure probabilities and show how the study improves our ability to quantify lifetime, degradation, or failure more quickly.

TECHNICAL APPROACH

- Clearly describe the experimental, modeling, and/or characterization aspects of the work and how they will add to our understanding of lifetime and degradation.
- Describe how your approach addresses your problem statement or key research question.
- Document the expected results – Is this a new test, a new tool, a material model, reaction mechanism, validation study, etc.? How can the results be used?
- Document available input data from other projects and how your output data could be used in a future lifetime prediction effort. Include references to complementary or related work.
- Describe the specific mechanisms under investigation and the relevance current and emerging commercial modules. How can your work be leveraged for future technologies?
- Describe why you have chosen your test samples/system, testing, or characterization approach and how they are relevant to current and emerging module technologies. Does this experiment answer your research questions?
- Describe how you will make your results publicly available including material, mechanism, or stress libraries, test data, or documented code libraries and APIs if applicable.
- Describe the data that will be included in the datahub.
- Describe how your work will help DuraMAT meet its goal of developing confidence in 50-year modules by forecasting early failure, useful life, degradation, or the onset of wear out related to the phenomena you study.

DATA SHARING

All project proposals are required to include a plan to submit FAIR-compliant data to the DuraMAT datahub[3]. Periodic data submissions to the data hub are a requirement for DuraMAT funding. Proposals for development of new software tools must include open-source development and release with full documentation and an example or demonstration data set for use. Modeling aspects of proposals relying on proprietary or commercial software packages must commit to sharing methods, input data, boundary conditions, output data, *etc.* so their work can be replicated using alternative software packages to the extent permitted by license conditions. For example, projects using commercial finite element analysis software may opt to use tools such COMSOL Application Builder, PyAnsys, or similar packages.

EXTENSIBILITY/DISSEMINATION PLAN

Successful proposals will be expected to have a mid- to long-term impact on addressing the DuraMAT goals by answering the DuraMAT questions, leveraging the results and capabilities of DuraMAT to date, and creating effective links between core objectives at the national laboratories. The proposed approach and problem statement should be clearly justified (e.g. how/why was this problem chosen). A dissemination plan for the project should be described in the proposal, including a description of how others can use your work, model, or data without working with you. Studies are expected to be foundational with a clear path for next steps. Proposals must have a well-defined work plan with clear yearly milestones and deliverables. Proposals are encouraged to include industry participation and should address problems or challenges identified as longer-term research needs by the PV industry.

Proposals should include a short description of how their work could be used in a larger lifetime prediction effort or combined with other work to study more complicated questions requiring sequential or combined stresses, validated material models, or additional degradation models.

CURRENT STATE OF THE ART & DURAMAT CONTEXT

Describe the current state of the art in the area of your proposed work and the current state of this field in DuraMAT. Is this a new area for the consortium or is it a continuation of or complement to existing work? Describe how the proposal will leverage the DuraMAT Network, the strengths of your project team, and how feedback from workshops or the IAB have informed the proposal.

If applicable, describe how this proposed effort is differentiated from the research in other current or past SETO-funded projects (e.g. SETO Lab Call/Core, PVRD, PREDICTS, etc.). Does this build on an existing capability or establish a new one? Does it use a capability in a new way or solve an emerging problem?

Eligibility

Proposals must have a National Lab PI from a DuraMAT core partner lab (NREL, Sandia, or LBNL) or core participant lab (SLAC) and are strongly encouraged to consider partnerships with DuraMAT core participant Universities (Stanford University (SU) and Arizona State University (ASU)). Proposals may include team members from industry, national labs, academia, etc. as subcontracts, but at least 70% of the funding must stay within the DOE national laboratories. More information on working with DuraMAT can be found at https://www.duramat.org/working-with-us.html. Cost share is encouraged, but not

[3] FAIR Principles at GO FAIR https://www.go-fair.org/fair-principles/

required for this proposal call. Collaboration or coordination with other SETO programs (e.g. reliability core, PV proving grounds) is encouraged.

Proposal Format

Proposals must be submitted using the appropriate Word and 3-slide summary templates attached to this email and available at www.duramat.org.

Full Proposals:

Full proposals are **strictly limited to six pages, not including the cover pages and appendix, plus a 3-slide summary using the attached templates**. The first four pages should describe the project goals, approach, dissemination plan, and impact on the current state of the art. The final two pages should include the technical workplan, milestones, and industrial relevance. All proposals should have an appendix that includes references, 3-page resumes, letters of support, which do not count towards the page limit. **No technical or project information outside of the page limit will be considered. Any proposal content in excess of the page limit will be removed before the proposals are sent to review**.

Spark proposals:

These abbreviated proposals are strictly limited to 3 pages (including references), plus a 3-slide summary using the attached templates. No additional supporting documentation is required (e.g., please do NOT include separate references, 3-page resumes, letters of support).

Proposal Evaluation

Submitted proposals will be screened for adherence to the above guidelines and relevance to the targeted DuraMAT critical outcomes. Proposals that meet these criteria will be reviewed by technical experts on the DuraMAT Industry Advisory Board using the following criteria. Any members involved in a proposal will recuse themselves. Each proposal will be considered based on the following metrics:

TECHNICAL MERIT (70%)

- How effectively does the proposal address the **DuraMAT goal** of *accelerating the transition to zero carbon electricity generation by 2035* by answering one or both of these questions:
    - Which materials and module designs will enable sustainable, high-energy yield 50 year modules, and how do we ensure that these new modules are not going to fail prematurely?
    - What triggers wear out, defined as a rapid increase in degradation at end of life, and what does long term degradation look like in PV modules?
- What is the potential impact of this work on the **DuraMAT Goal** identified above if it is successful?
- Which reliability problem does the proposal address or what capability does it build, and what is the relevance of the potential work for understanding reliability of high energy yield modules?
- Does the proposal clearly identify a research question or problem statement and its relevance?
- Does the proposal clearly identify a method to address that research question or problem statement and expected results?
- Does the proposal improve our ability to quantify degradation rates, failure probabilities, or identify "successes" in the form of more durable or reliable modules?
- Does the proposal clearly describe the current and future field relevance of the work?
- How will the results be made publicly accessible? Is this sufficient for industry adoption?
- Which public data sets or tools will be made publicly available?

- What is the likelihood that this research would be effectively leveraged by DuraMAT collaborators in the solar industry?
- What is the plan for stakeholder engagement to use this research or build on the results from this work?
- If the proposed work is unsuccessful, what can DuraMAT or the PV community learn?

ORGANIZATION AND EXECUTION (30%)

- Is the work plan clearly articulated and effective in achieving the goals of the project?
- Are the milestones and deliverables clearly articulated and appropriate?
- Does the proposal describe how the project leverages or engages ongoing or previous work and progress towards the DuraMAT goals? How does it fit into the DuraMAT ecosystem?
- Does the proposal include a data plan that includes providing data meeting FAIR standards (www.go-fair.org/fair-principles/) to provide data sets and/or analysis tools to the DuraMAT datahub?
- Does the proposal include an effective dissemination plan to ensure that the results reach appropriate stakeholders?
- What is the likelihood of the proposed work to succeed based on the budget and work period proposed?
- Does the team have the skills and resources necessary to build this capability?
- For proposals including characterization does the proposal provide a clear plan for obtaining relevant samples. This might include a plan to fabricate samples from available materials, in-kind partnerships, or sourcing commercial modules or materials.
- Does the proposal complement current DuraMAT work? How is it differentiated from existing SETO projects and how does it compare to the current state of the art?

Proposal Selection

The DuraMAT industry advisory board (with additional technical experts approved by SETO if needed) will review proposals according to the merit criteria above. The DuraMAT Leadership Team will make programmatic recommendations based on those rankings to SETO, and the DOE SETO program manager will have final selection authority. DuraMAT anticipates making selections in Summer 2024 for work starting in October FY25.

Total Award Funding is up to $3,100,000 for 2-4 full projects and 1 – 3 Spark projects.

Estimated project funding: Full projects: up to $500,000 per year for up to 3 years. Spark projects: $65,000 for up to 9 months.

If selected for award, PIs will be responsible for submitting a budget package, completed website template, and at the selection team’s discretion, a current & pending support document.

Reporting requirements include quarterly reporting slides, quarterly milestone/accomplishments tracking, reporting of data and/or analysis tools to the DuraMAT datahub, and participation in one (for spark projects) and two (for full projects) DuraMAT workshops per year for the duration of the project. Travel to the two annual workshops is required for full proposals. Travel to workshop is required for sparks. All projects are required to upload data to the DuraMAT DataHub and work with the data team to ensure full compliance with open data requirements. Please plan for these requirements in your budget.