

**Disruption Opportunity**  
**DARPA-PA-22-01-01**  
**Foundational Security for Food Systems (FS2)**

**I. Opportunity Description**

The Defense Advanced Research Projects Agency (DARPA) Defense Sciences Office (DSO) is issuing a Disruption Opportunity (DO), inviting submissions of innovative basic or applied research concepts in the technical domain of resilience in food systems. This DO is issued under the Program Announcement for Disruptioneering, DARPA-PA-22-01. All awards will be made in the form of an Other Transaction (OT) for prototype project. The total award value for the combined Phase 1 base (Feasibility Study) and Phase 2 option (Proof of Concept) is limited to \$1,000,000. This total award value includes Government funding and performer cost share, if required or if proposed.

To view the original DARPA Program Announcement for Disruptioneering, visit SAM.gov under solicitation number DARPA-PA-22-01:

<https://sam.gov/opp/d8f75aaf74ca4d18a8aaa2dd57e4c64d/view>

**A. Introduction**

The Foundational Security for Food Systems (FS2) program is focused on testing a pathway-based approach to develop advanced threat-detection and warning capabilities for U.S. cereal crops. Current capabilities to detect unusual, adverse effects to U.S. crops that may have a genetic origin require costly and time-consuming biochemical analysis to distinguish novel, concerning variations from the vast array of natural variations. Advances in nucleic acid sequencing have led to proposals for environmental, genetic sequencing observatories<sup>1</sup> to more quickly reveal the basis for anomalies of unknown origin in the wild. Both these sequence-based methods and traditional satellite-based remote crop-sensing approaches; however, are limited with respect to (1) the existence of measurable external signals; (2) unfavorable signal-to-noise/clutter ratio; (3) cost-effective techniques that can monitor large regions in real-time; and (4) the challenge of linking detected anomalies to definitive plant-level effects on timelines necessary to guide mitigating actions.

**B. Objective/Technical Scope**

The FS2 Disruption Opportunity will investigate the ability to create detection/warning protocols based on pathways with observable plant-level effects, including signatures that are detectable remotely. FS2 will address key tasks detailed in Section D with regard to defense of U.S. cereal crops, specifically rice and corn. The effort does not involve genetic modification of any organism. All research will be conducted in compliance with approved regulatory standards.

In rice (*Oryza sativa*), a complete gene-indexed mutant collection<sup>2</sup> allows the construction of a model of pathways (the program “reference set”) that link genetic variation in the rice plant to whole plant phenotype. Based on these models from rice and data from corn, inferences can be

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<sup>1</sup> Esvelt, K. 5 Aug 2021. A global nucleic acid observatory for biodefense and planetary health. arXiv.2108.0678v1. <https://doi.org/10.48550/arXiv.2108.02678>.

<sup>2</sup> e.g., Li et al. 2017. The sequences of 1504 rice mutants in the model rice variety Kitaake facilitate rapid functional genomic studies. Plant Cell 29(6):1218-1231 <https://doi.org/10.1105/tpc.17.00154>

constructed from rice to corn (*Zea mays*), another major species with a more complex genome in the same plant family. One key question in FS2 is the extent to which global models of pathways built in tractable, well-characterized species such as rice and corn may extend to other grasses such as wheat and other cereals. FS2 will use fungal rust disease as a well-characterized test challenge to crop health that relies on defined host pathways for symptom development or resistant responses. Although rice is not susceptible to fungal rust disease, many other important cereal crops are, including corn. Despite this type of phenotypic variation between cereal species, many key genetic and biochemical pathways are widely conserved across members of the grass family. Because of their economic impact, cereal rust diseases are monitored using plant and field-level data during the growing season through snapshot U.S. Department of Agriculture surveys and are scouted via cultivation and harvest equipment, drones, smartphones, and other devices with cameras or sensors. FS2 will develop validated models to systematically identify the earliest observable features of key “damage” pathways irrespective of the triggering agent.

Performers will establish the feasibility of linking genetic variation in crops to biochemical pathways to variant phenotypes in cereal crops by developing prototype rice/corn pathway models in Phase 1. These models will then be used for a proof of concept in Phase 2 to propose suites of pathways of major concern for crop defense (pathways by which major damage to the crop may occur) and additional potential observable effects associated with activation of those pathways. The goal of Phase 2 is to develop a new pathway-focused paradigm for detecting and interpreting field-level signals of a genetic event of concern.

## **Program Structure**

The FS2 Disruption Opportunity consists of two phases, Genetic Modeling (Phase 1) and Field-level Signal Detection and Interpretation (Phase 2). Each proposal must address both phases, structured with Phase 1 as a base period of performance with an option for Phase 2.

Proposals submitted to DARPA-PA-22-01-01 in response to this DO must be UNCLASSIFIED and must address two independent and sequential project phases (Phase 1 feasibility study (base) and Phase 2 proof of concept (option)). The periods of performance for these phases are ten (10) months for the Phase 1 base effort and eight (8) months for the Phase 2 option effort. Combined Phase 1 base and Phase 2 option efforts for this DO shall not exceed 18 months. The Phase 1 (base) award value for a single proposal is limited to \$500,000. The Phase 2 (option) award value, likewise, for each proposal is limited to \$500,000. Both Phase 1 and Phase 2 value limits include performer cost share, if required or proposed. The total award value for the combined Phase 1 and Phase 2 is limited to \$1,000,000. This total award value includes Government funding and performer cost share, if required or if proposed.

## **C. Program Description**

### *Phase 1: Genetic Modeling*

The goal of Phase 1 is to demonstrate that it is possible to link plant-level observable variation via actual and inferred pathways in corn.

In Phase 1, teams will execute the following Tasks:

**Task 1:** Construct a populated model of pathways in rice, e.g., cereal reactome database, that links genome-level variation to plant-level observable effects based on the complete rice gene-indexed mutant collection and delineate how such a model could be validated. Demonstrate that the rice pathways model is complete.

**Task 2:** Extend the rice pathways model from Task 1 to a corn pathways model, populated with corn genomic data and related corn phenotypes. Validate the corn pathways model to prove whether the model can consistently propose reasonable explanatory pathways linked to corn phenotypes from input genomic variation.

**Task 3:** Show whether a subset of explanatory pathways from Task 2 can be reliably and sufficiently characterized in corn field-level sensor data. Demonstrate that a subset of possible detection parameters will have a sufficiently strong and unique signal for large-scale commercial monitoring.

At the end of Phase 1, a proof of concept test will demonstrate whether the Phase 1 prototype corn pathways model can propose plant-level observable effects via pathways in response to unknown submissions of corn genomic sequence.

In Phase 1, teams will deliver the following Milestones:

**Milestone 1 (M1):** Presentation at one (1) day program kickoff meeting of all Principal Investigators (PIs) and key personnel.

**Milestone 2 (M2):** Populated model of pathways in rice, e.g., cereal reactome database, that links genome-level variation to plant-level observable effects based on the complete rice gene-indexed mutant collection and delineates how such a model could be validated. **(Should address Task 1:** Construct a populated model of pathways in rice, e.g., cereal reactome database, that links genome-level variation to plant-level observable effects based on the complete rice gene-indexed mutant collection and delineate how such a model could be validated. Demonstrate that the Rice Pathways Model is resilient and complete.)

**Milestone 3 (M3):** Host Program Manager Site Visit. Rice pathways model from Milestone 2 extended to a corn pathways model, populated with corn genomic data and related corn phenotypes. **(Should address Task 2:** Extend the rice pathways model from Task 1 to a corn pathways model, populated with corn genomic data and related corn phenotypes.)

**Milestone 4 (M4):** Attend PI Meeting. Corn pathways model validated using known and unknown model inputs to prove whether the model can consistently propose reasonable explanatory pathways linked to corn phenotypes from input genomic variation. **(Should address Task 2:** Validate the corn pathways model to prove whether the model can consistently propose reasonable explanatory pathways linked to corn phenotypes from input genomic variation.)

**Milestone 5 (M5):** Demonstration of whether a subset of explanatory pathways from Milestone 4 can be reliably and sufficiently characterized in corn field-level sensor data. **(Should address Task 3:** Show whether a subset of explanatory pathways from Task 2 can be reliably and sufficiently characterized in corn field-level sensor data.)

**Milestone 6 (M6):** Demonstrate that Phase 1 prototype corn pathways model can propose plant-level observable effects via pathways in response to unknown submissions of corn genomic sequence. Demonstrate that the rice/corn candidate explanatory pathways model can predict observable features and propose reasonable explanatory pathways when presented with previously untested adverse plant-level observed effects. **(Should address Task 3:** Demonstrate that a subset of possible detection parameters will have a sufficiently strong and unique signal for large-scale commercial monitoring.)

*Phase 2: Field-level Signal Detection and Interpretation*

The goal of Phase 2 is to demonstrate whether it is possible to build a candidate explanatory pathways model that can link adverse plant-level observations of unknown origin in corn to candidate explanatory pathways.

In Phase 2, teams will execute the following Tasks:

**Task 4:** Delineate as many detection parameters as possible for a comprehensive set of corn/corn rust plant-level observable effects, including the earliest observable manifestations of the disease process or resistance response. Construct a corn candidate explanatory pathways model to link observable plant-level parameters in corn related to the corn/corn rust interaction in real-world monitoring and historical time series data to possible explanatory pathways and validate with observable effects from corn/corn rust interactions.

**Task 5:** Populate rice/corn candidate explanatory pathways model with  $\geq 50$  theoretically possible observable adverse effects (e.g., unknown pathogen susceptibility, timed lethality or sterility, etc.), along with proposed candidate explanatory pathways.

**Task 6:** For cases where the pathway that accounts for a particular observable effect is not resolved uniquely, determine what additional data would be necessary to uniquely specify the correct explanatory pathway.

**Task 7:** Demonstrate that a subset of possible detection parameters will have a sufficiently strong and unique signal for large-scale commercial monitoring. Final Proof of Concept Test demonstrating if the rice/corn candidate explanatory pathways model can predict observable features and propose reasonable explanatory pathways when presented with previously untested adverse plant-level observed effects.

At the end of Phase 2, a final proof of concept test will demonstrate if the rice/corn candidate explanatory pathways model can predict observable features and propose reasonable explanatory pathways when presented with previously untested, unprecedented plant-level observed effects.

In Phase 2, teams will execute the following Milestones:

**Milestone 7 (M7):** Delineate as many detection parameters as possible for a comprehensive set of corn/corn rust plant-level observable effects, including the earliest observable manifestations of the disease process or resistance response. **(Should address Task 4:** Delineate as many detection parameters as possible for a comprehensive set of corn/corn rust plant-level observable effects including the earliest observable manifestations of the disease process or resistance response.)

**Milestone 8 (M8):** Host Program Manager for a site visit. Develop preliminary corn candidate explanatory pathways model to link observable plant-level parameters in corn related to the corn/corn rust interaction in real-world monitoring and historical time series data to possible explanatory pathways and validate with observable effects from corn/corn rust interactions. **(Should address Task 4:** Construct a corn candidate explanatory Pathways Model to link observable plant-level parameters in corn related to the corn/corn rust interaction in real world monitoring and historical time series data to possible explanatory pathways and validate with observable effects from corn/corn rust interactions.)

## Milestone 9 (M9):

- Milestone 9A. Rice/corn candidate explanatory pathways model constructed with  $\geq 50$  theoretically possible observable unprecedented effects (e.g., unknown pathogen susceptibility, timed lethality or sterility, etc.), along with proposed candidate explanatory pathways. **(Should address Task 5:** Populate rice/corn candidate explanatory pathways model with  $\geq 50$  theoretically possible observable adverse effects (e.g., unknown pathogen susceptibility, timed lethality or sterility, etc.), along with proposed candidate explanatory pathways.)
- Milestone 9B. Report documenting the determination of what additional data would be necessary to uniquely specify the correct explanatory pathway for cases where the pathway that accounts for a particular observable effect is not resolved uniquely. **(Should address Task 6:** For cases where the pathway that accounts for a particular observable effect is not resolved uniquely, determine what additional data would be necessary to uniquely specify the correct explanatory pathway.)

**Milestone 10 (M10):** Attend PI program closeout meeting. Demonstration that a subset of possible detection parameters will have a sufficiently strong and unique signal for large-scale commercial monitoring. The final proof of concept test demonstrating if the rice/corn candidate explanatory pathways model can predict observable features and propose reasonable explanatory pathways when presented with previously untested adverse plant-level observed effects. **(Should address Task 7:** Demonstrate that a subset of possible detection parameters will have a sufficiently strong and unique signal for large-scale commercial monitoring. Final Proof of Concept Test demonstrating if the rice/corn Candidate Explanatory Pathways model can predict observable features and propose reasonable explanatory pathways when presented with previously untested adverse plant-level observed effects.)

## D. Schedule/Milestones

Proposers must complete the “Schedule of Milestones and Payments” Excel spreadsheet attachment provided with this DO as part of submitting a complete proposal and fulfilling the requirements under Volume 2, Price Volume. If selected for award negotiation, the fixed payable milestones provided will be directly incorporated into Attachment 3 of the OT agreement (“Schedule of Milestones and Payments”). Proposers must use the Task Description Document template provided with the Program Announcement DARPA-PA-22-01, which will be Attachment 1 of the OT agreement.

Proposers must address in their proposals, at a minimum, each of the fixed payable milestones summarized in the Schedule of Milestones and Payments spreadsheet.

For planning and budgetary purposes, proposers should assume a program start date of **April 11, 2023**. Schedules will be synchronized across performers, as required, and monitored/revised as necessary throughout the program.

All proposals must include the following meetings and travel in the proposed schedule and costs:

- To foster collaboration between teams and disseminate program developments, two-day PI meetings will be held. For budgeting purposes, plan for travel to three two-day meetings over the course of 18 months: two meetings in the Washington, D.C., area and one meeting in the San Francisco, CA, area. The PI meeting in Month 6 will be conducted remotely and

will not require travel.

- Regular teleconference meetings will be scheduled with the Government team for progress reporting, as well as problem identification and mitigation. Proposers should also anticipate at least one site visit per phase by the DARPA Program Manager, during which they will have the opportunity to demonstrate progress towards agreed-upon milestones.

Performers will be expected to provide, at a minimum, the following deliverables:

Negotiated deliverables specific to the objectives of the individual efforts. These may include registered reports, experimental protocols, publications, intermediate and final versions of software libraries, code, and APIs (Application Programming Interface), including documentation and user manuals, and/or a comprehensive assemblage of design documents, models, modeling data and results, and model validation data.

## **II. Award Information**

Selected proposals that are successfully negotiated will result in the award of an OT for prototype project. See Section 3 of DARPA-PA-22-01 for information on awards that may result from proposals submitted in response to this notice.

Proposers must review the model OT for Prototype agreement provided as an attachment to DARPA-PA-22-01 prior to submitting a proposal. DARPA has provided the model OT in order to expedite the negotiation and award process and ensure DARPA achieves the goal of this Disruptioneering award format, which is to enable DARPA to initiate a new investment in less than 90 calendar days from idea inception. The model OT is representative of the terms and conditions that DARPA intends to award for all DO awards. The Task Description Document, Schedule of Milestones and Payments, and data rights assertions requested under Volumes 1, 2, and 3 will be included as attachments to the OT agreement upon negotiation and award.

Proposers may suggest edits to the model OT for consideration by DARPA and provide a copy of the model OT with track changes as part of their proposal package. DARPA may not accept suggested edits. The Government reserves the right to remove a proposal from award consideration should the parties fail to reach an agreement on OT award terms and conditions. If edits to the model OT are not provided as part of the proposal package, DARPA assumes that the proposer has reviewed and accepted the award terms and conditions to which they may have to adhere, and the model OT agreement provided as an attachment, indicating agreement (in principle) with the listed terms and conditions applicable to the specific award instrument.

To ensure DARPA achieves the Disruptioneering goal of award within 90 calendar days from the posting date (**January 12, 2023**) of this announcement, DARPA reserves the right to cease negotiations when an award is not executed by both parties (DARPA and the selected organization) on or before **April 11, 2023**.

## **III. Eligibility**

See Section 4 of DARPA-PA-22-01 for information on who may be eligible to respond to this notice.

## **IV. Disruption Opportunity Responses**

### **A. Proposal Content and Format**

All proposals submitted in response to this notice must comply with the content and format

instructions in Section 5 of DARPA-PA-22-01. All proposals must use the templates provided as Attachments to the PA and the “Schedule of Milestones and Payments” Excel attachment provided with this DO and follow the instructions therein.

Information not explicitly requested in DARPA-PA-22-01, its attachments, or this notice may not be evaluated.

## **B. Proposal Submission Instructions**

Responses to DARPA-PA-22-01-01 shall be submitted electronically to DARPA’s Broad Agency Announcement (BAA) Portal (<https://baa.darpa.mil>).

DARPA will acknowledge receipt of complete submissions via email and assign identifying numbers that should be used in all further correspondence regarding those submissions. If no confirmation is received within two (2) business days, please contact [fs2@darpa.mil](mailto:fs2@darpa.mil) to verify receipt.

When planning a response to this DO, proposers should take into account the submission time zone and that some parts of the submission process may take from one business day to one month to complete (e.g., registering for a SAM Unique Entity ID (UEI) number or Tax Identification Number (TIN)).

### **Electronic Upload**

First-time users of the DARPA BAA Portal must complete a two-step account creation process. The first step consists of registering for an extranet account by going to the URL listed above and selecting the “Account Request” link. Upon completion of the online form, proposers will receive two separate emails; one will contain a user name, and the second will provide a temporary password. Once both emails have been received, the second step requires proposers to go back to the submission website and log in using that user name and password. After accessing the extranet, proposers may then create a user account for the DARPA Submission website by selecting the “Register your Organization” link at the top of the page. Once the user account is created, proposers will be able to see a list of solicitations open for submissions, view submission instructions, and upload/finalize their proposal.

Proposers who already have an account on the DARPA BAA Portal may simply log in at <https://baa.darpa.mil>, select this solicitation from the list of open DARPA solicitations and proceed with their proposal submission. Note: proposers who have created a DARPA Submission website account to submit to another DARPA Technical Office’s solicitations do not need to create a new account to submit to this solicitation.

All full proposals submitted electronically through the DARPA Submission website must meet the following requirements: (1) uploaded as a zip file (.zip or .zipx extension); (2) only contain the document(s) requested herein; (3) only contain unclassified information; and (4) must not exceed 100 MB in size. Only one zip file will be accepted per full proposal. DARPA will reject full proposals not uploaded as zip files. Technical support for the DARPA Submission website is available during regular business hours, Monday – Friday, 9:00 a.m. – 5:00 p.m. Requests for technical support must be emailed to [BAAT\\_Support@darpa.mil](mailto:BAAT_Support@darpa.mil) with a copy to [fs2@darpa.mil](mailto:fs2@darpa.mil). Questions regarding submission contents, format, deadlines, etc., should be emailed to [fs2@darpa.mil](mailto:fs2@darpa.mil). Questions/requests for support sent to any other email address may result in delayed/no response.

Since proposers may encounter heavy traffic on the web server, DARPA discourages waiting until

the day proposals are due to request an account and/or upload the submission. Note: Proposers submitting a proposal via the DARPA Submission site MUST: (1) click the “Finalize” button in order for the submission to upload; AND (2) do so with sufficient time for the upload to complete prior to the deadline. Failure to do so will result in a late submission.

### **C. Proposal Due Date and Time**

Proposals in response to this notice are due no later than **4:00 p.m. February 10, 2023**. As described in Section 5 of DARPA-PA-22-01, full proposal packages must be submitted per the instructions outlined in this DO *and received by DARPA* no later than the above time and date. Proposals received after this time and date may not be reviewed.

Proposers are warned that the proposal deadline outlined herein is in Eastern Time and will be strictly enforced. When planning a response to this notice, proposers should take into account that some parts of the submission process may take from one (1) business day to one (1) month to complete.

### **V. Proposal Evaluation and Selection**

Proposals will be evaluated and selected in accordance with Section 6 of DARPA-PA-22-01. Proposers will be notified of the results of this process as described in Section 7.1 of DARPA-PA-22-01.

### **VI. Administrative and National Policy Requirements**

Section 7.2 of DARPA-PA-22-01 provides information on Administrative and National Policy Requirements that may be applicable for proposal submission as well as performance under an award.

### **VII. Point of Contact Information**

Molly Jahn, Program Manager, DARPA/DSO, [fs2@darpa.mil](mailto:fs2@darpa.mil).

### **VIII. Frequently Asked Questions (FAQs)**

All technical, contractual, and administrative questions regarding this notice must be emailed to [fs2@darpa.mil](mailto:fs2@darpa.mil). Emails sent directly to the Program Manager or any other address may result in delayed or no response.

All questions must be in English and must include the name, email address, and telephone number of a point of contact. DARPA will attempt to answer questions publicly in a timely manner; however, questions submitted within seven (7) calendar days of the proposal due date listed herein may not be answered.

DARPA will post an FAQ list under the DO on the DARPA/DSO Opportunities page at (<http://www.darpa.mil/work-with-us/opportunities>). The list will be updated on an ongoing basis until one (1) week prior to the proposal due date.