

Opportunity Title: Scientific Computing Software: Air Force Research Laboratory Summer Internship
Opportunity Reference Code: ERDC-ITL-2023-0036

Organization U.S. Department of Defense (DOD)

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How to Apply Click on *Apply* now to start your application.

Description The composites performance team at the Air Force Research Laboratory Materials and Manufacturing Directorate uses a combination of novel and high-impact experiments, in-house high-fidelity HPC simulation software, and machine learning to characterize and predict the performance of current and emerging materials.

Project: Scientific simulation often requires finding the solution to large, sparse systems of linear equations. However, the solution method must consider additional linear constraints in some situations, including the enforcement of periodic boundary conditions or existence of hanging nodes. This project explores methods and develops an implementation for enforcing linear equality constraints during matrix-vector operations when a matrix-free method is used.

What will I be doing?

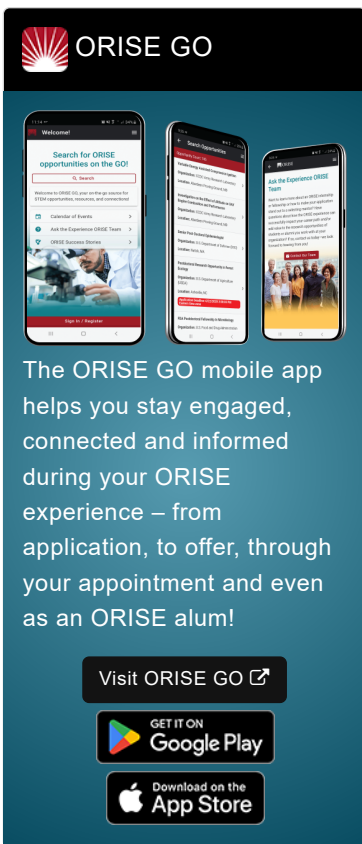
The Scientific Computing Institute at the University of Utah has developed a C++ template library for matrix-free linear algebra operators that implements an interface compatible with PETSc, which currently supports simple constraints (Dirichlet). The library stores the collection of element-level matrices that compose the system of equations and uses them to perform global matrix-vector multiplication operations (using either a multi-threaded, vectorized kernel for CPUs or a CUDA kernel for NVidia GPUs) within an iterative solver available in PETSc. Simple constraints are enforced by simply zeroing any entries in the element-level matrices corresponding to rows and columns to the constrained degrees of freedom (adding any resulting nonzero terms to the right-hand side vector). In the more general case, linear equality constraints can be expressed as another matrix, C , and the matrix-vector multiplication involving the original matrix, K , becomes three operations: $(C^T * (K * (C * \text{vector})))$. The goal of this project is to extend the matrix-free matrix-vector operator to pre/post-multiply the vector by constraint-level matrices (one matrix per a linear constraint), following the same matrix-free philosophy.

Under the guidance of a mentor, you will perform a range of activities typical of a research scientist and developer of scientific computing software.

- Build familiarity with the existing library and linear equality constraints, which are essentially additional equations that are linear combinations of degrees of freedom.
- Implement a serial CPU kernel for performing the pre/post-multiplication for the rectangular constraint matrices, using the existing matrix-vector kernels as an example.
- Implement a multi-threaded, vectorized CPU kernel for performing the constraint matrix operation.
- Document and implement unit-tests for any new code.
- Benchmark the results on a DoD HPC system and compare the performance to our existing implementation for assembled systems of equations, which enforces linear equality constraints through an in-place elimination method. It is expected that at some point between 10 million and 100 million equations, the matrix-free method will be faster.
- Write internship project report and give a scientific presentation to the research team at AFRL that summarizes the effort and its findings.

Why should I apply?

This fellowship provides the opportunity to independently utilize your skills and engage with



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experts in innovative ideas to move the proposed research forward.

Where will I be located? AFRL/RXNP Wright-Patterson AFB, OH

What is the anticipated start date? June 2023

Exact start dates will be determined at the time of selection and in coordination with the selected candidate.

What is the appointment length?

This appointment is a summer research appointment. Appointments may be extended depending on funding availability, project assignment, program rules, and availability of the participant.

What are the benefits?

You will receive a stipend to be determined by the sponsor. Stipends are typically based on a participant's academic standing, discipline, experience, and research facility location.

Other benefits may include the following:

- Health Insurance Supplement (*Participants are eligible to purchase health insurance through ORISE*)
- Relocation Allowance
- Training and Travel Allowance

About ORISE

This program, administered by Oak Ridge Associated Universities (ORAU) through its contract with the U.S. Department of Energy (DOE) to manage the Oak Ridge Institute for Science and Education (ORISE), was established through an interagency agreement between DOE and DoD. Participants do not enter into an employee/employer relationship with ORISE, ORAU, DoD or any other office or agency. Instead, you will be affiliated with ORISE for the administration of the appointment through the ORISE appointment letter and Terms of Appointment. Proof of health insurance is required for participation in this program. Health insurance can be obtained through ORISE. For more information, visit the [ORISE Research Participation Program at the U.S. Department of Defense](#).

Qualifications The candidate should:

- Have completed at least one year of a Bachelor's degree
- Have some prior experience in technical communication and software development (including school projects)
- Be proficient in C++ (at least familiar with template programming)
- Have an ongoing interest in high-performance computing (HPC) and motivation to learn HPC concepts

An understanding of MPI, distributed algorithms, threading, and vectorization are helpful but certainly not a requirement.

Security Investigation: Applicants should be able to pass a National Agency Check and Inquiries (NACI) security investigation should they be selected and accept the internship offer.

Application Requirements

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A complete application consists of:

- Zintellect Profile
- Educational and Employment History
- Essay Questions (goals, experiences, and skills relevant to the opportunity)
- Resume (PDF)
- Transcripts/Academic Records - For this opportunity, an official transcript or copy of the student academic records printed by the applicant or by academic advisors from internal institution systems may be submitted. [Click here for detailed information about acceptable transcripts.](#)
- One recommendation. Your application will be considered incomplete and will not be reviewed until one recommendation is submitted. We encourage you to contact your recommender(s) as soon as you start your application to ensure they are able to complete the recommendation form and to let them know to expect a message from Zintellect. Recommenders will be asked to rate your scientific capabilities, personal characteristics, and describe how they know you. You can always log back in to your Zintellect account and check the status of your application.

Submitted documents must have all social security numbers, student identification numbers, and/or dates of birth removed (blacked out, blackened out, made illegible, etc.) prior to uploading into the application system. All documents must be in English or include an official English translation. If you have questions, send an email to USACE@orise.orau.gov. Please list the reference code of this opportunity in the subject line of the email. Please understand that ORISE does not review applications or select applicants; selections are made by the sponsoring agency identified on this opportunity. All application materials should be submitted via the "Apply" button at the bottom of this opportunity listing. Please do not send application materials to the email address above.

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**Eligibility
Requirements**

- **Citizenship:** U.S. Citizen Only
- **Degree:** Associate's Degree, Bachelor's Degree, Master's Degree, or Doctoral Degree received within the last 60 months or currently pursuing.
- **Overall GPA:** 3.00
- **Discipline(s):**
 - **Computer, Information, and Data Sciences** ([17](#) )
 - **Engineering** ([27](#) )
 - **Mathematics and Statistics** ([11](#) )
 - **Physics** ([16](#) )
- **Age:** Must be 18 years of age
- **Veteran Status:** Veterans Preference, degree received within the last 120 month(s).