PROJECT IDEA SUBMISSION – *RESEARCH*

LABORATORY INFORMATION

Name: ___Warsinger Water Lab / Moran Lab_____________ **Date:** __9/8/2024___

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PROJECT NAME

Development of Apparatus to Measure (self-)Thermophoresis in Microgravity

GENERAL PROJECT DESCRIPTION

Purdue is part of a collaborative research project with George Mason University that is sending an experiment to the International Space Station (ISS) in 2025 to investigate the role of temperature gradients in transporting aerosols through air. Particle migration in temperature gradients is known as *thermophoresis*. The microgravity environment of the ISS is uniquely suited for these measurements, since the confounding influences of gravity and natural convection will be absent, allowing precise measurement of the thermophoretic migration speeds using the onboard optical microscope (known as KERMIT). The temperature gradients can be generated either by an external heat source or by the particles themselves. This knowledge will aid climate scientists by providing fundamental insights into the extent to which temperature gradients in the atmosphere drive the motion of aerosol particles (which exert an important, but incompletely understood, influence on the global climate).

WHAT IS THE MECHANICAL ENGINEERING PROBLEM (APPARATUS) YOU ARE WANTING SOLVED (BUILT)?

Prior to launch, the central task is to design, build, and validate the experimental apparatus the ISS crew members will use to run the experiments, as well as the cuvettes that will contain the aerosol particle samples. Owing to the unique setting for these experiments, there are several constraints that must be met. The aerosol particles must be visible under the optical microscope.

With the rise of climate change, and the increasing need for freshwater sources in drought and other crisis affected areas, the team will engineer a solution that can harness complex waveforms to accumulate a pressure gradient of at least 40-45 bars utilizing an energy accumulator. The primary goal is to create a solution that not only minimizes external energy and fossil fuel consumption, but also to harness complex and non-uniform wave activity by improving the wave energy converter itself.

WHY IS THIS PROBLEM (APPARATUS) WORTH SOLVING (BUILDING)? (Value Proposition)

Aerosols, which are produced by both natural events (such as volcanic eruptions) and human activity (such as burning fossil fuels), cause a great deal of uncertainty in climate models. The can either alleviate or exacerbate global warming, depending on their material composition and geographic location. For instance, some aerosols act as cloud condensation nuclei (CCN), which can sometimes exert an overall cooling effect by increasing the amount of sunlight that is reflected to space. In other instances, CCN can exert an overall warming effect; for example, a recent study found that sodium chloride aerosols over the North Pole act as CCN that overall accelerate the warming that is already taking place at an elevated rate in the Arctic. The mechanisms that are responsible for driving these aerosols to such a location remain the subject of debate.

There are reasons to believe that thermophoresis may play an outsized role in transporting atmospheric aerosols. Thermophoresis in air is known to be most important when the non-continuum nature of air begins to become important (more precisely, when the Knudsen number is between 0.1 and 10). The air pressure is lower at higher altitudes, so drag forces exerted by blowing wind are smaller in magnitude than close to sea level.

WHAT ARE THE MOST IMPORTANT FUNCTIONAL REQUIREMENTS AND SPECIFICATIONS FOR THIS PROJECT?

Req 1: The entire apparatus must fit into the KERMIT microscope currently on the ISS.

Req 2: The cuvettes must be airtight to avoid leakage of the aerosols into the ISS cabin, which would pose inhalation hazards to the crew members. This is especially true for pressures below atmospheric, which is of interest to the scientific objectives of the project (see Spec 2).

Req 3: The cuvette material must simultaneously be optically transparent, thin, and strong. Ideally, the crew members should be able to use the 60x objective to observe the particles' motion. (The working distance of both the 60x and 100x objectives is approximately 0.13 mm.)

Spec 1: The device must require as little assembly and parts as possible.

Spec 2: It should be possible to reduce the pressure of the air inside the cuvette to approximately 0.1 atmospheres. This can be accomplished, for example, by attaching a syringe to the apparatus and pulling the plunger out shortly before the experiment is to begin.

Spec 3: It should be possible to monitor the pressure of the air inside the cuvette to ensure it maintains a sub-atmospheric pressure.

WHAT DO YOU ANTICIPATE THE STUDENTS DESIGNING, ANALYZING, BUILDING/PROTOTYPING AND TESTING? BE AS SPECIFIC AS POSSIBLE.

Design:

The students will design and validate a system to apply a steady-state temperature gradient to a suspension of aerosol particles in air, contained in a transparent cuvette. The temperature gradient should be as one-dimensional as possible. The cuvette must be transparent enough and thin enough to permit observation of the particles' migration through an optical microscope (whose objectives have working distances on the order of millimeters). The system must fit into the KERMIT microscope currently on the ISS.

Analyze:

The team must analyze experimental and simulated temperature data to create a better design for a temperature gradient device that can impose 1-D temperature gradients. They must be able to attach a device (such as a syringe) to the cuvette to enable it to go to lower pressures, without drawing all the aerosol particles into the syringe itself (e.g., through adding a syringe filter). They must verify that the particles can be observed in the cuvette via optical microscopy using the Keyence Microscope like that on the ISS. The particles should not become trapped in the plunger/flange area of the syringe once the plunger is withdrawn.

Build:

Cuvettes that are sturdy and made from an optically transparent material (e.g., quartz, polystyrene, polycarbonate, etc.) that permits both visible and infrared light to pass through. A method to reduce the pressure in the cuvette such that the particles remain dispersed roughly uniformly throughout the container.

Test:

Verify in-focus observation of the particles through the cuvette walls on the optical microscope at Purdue that closely resembles the KERMIT microscope. Validation of the steady-state, 1-D nature of the applied temperature gradient.

WHAT IS YOU BEST ESTIMATE OF THE COST OF THE HARDWARE, COMPONENTS, MATERIALS, … OF THE PROPOSED PROTOTYPE?

Total $ 2500

Hardware Costs: 1500

Component Costs: 500

Material Costs: 500

HOW MUCH TIME AND EFFORT WOULD YOU EXPECT TO SPEND ON THIS PROJECT IF YOU WERE DOING IT INTERNALLY?

Calendar Months: 6-8 *Total Hours (Engineering, Shop, …): 6000-7000*

DO YOU BELIEVE THE PROJECT CAN BE COMPLETED WITH EXISTING TECHNOLOGY, IF NOT, ELABORATE ON NEEDED DEVELOPMENTS?

Yes, but some developments may be needed to determine the extent to which a temperature gradient may be induced across a Janus particle such as those in the self-thermophoresis experiments. The faculty advisors will assist the students with this portion of the project, and it is a lower priority than the development of the next-generation cuvettes.

CONCERNS OR OTHER RELATED INFORMATION ASSOCIATED TO THE PROPOSED PROJECT?

Concerns:

Other Info:

ATTACH ANY APPROPRIATE SKETCHES, DRAWINGS, STANDARDS, DATA, PHOTOS, … USEFUL IN JUDGING APPROPRIATENESS AND SCOPE OF PROPOSED PROJECT.

Attached is the final report from last year's capstone team, which produced the first working prototype of the device and cuvettes. Also attached are microscope images taken on a Keyence microscope nearly identical to the KERMIT, showing in-focus imaging of sodium chloride grains (~1 mm in size), and out-of-focus imaging of a 13-μm grain.

ARE YOU WORKING WITH ME SENIORS WHO YOU WOULD LIKE ON THIS PROPOSED PROJECT? YES/NO (If YES, provided what information you can.)

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Save this filled out .docx with the following naming nomenclature: “RESEARCH_*project name – student point of contact full name*.docx” where the *italic strings* get replaced with appropriate actual text strings.

If you have any questions concerning a proposed project or completing this form please contact Professor Greg Jensen.

To submit this document for consideration, please complete the survey using either the QR code or the link below.

https://purdue.ca1.qualtrics.com/jfe/form/SV_bkCjo7jyE5Wb7ro

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