**Name:** _____

## Covariation in Thermal Systems

*Working in small groups (2 or 3 people), solve as many of the problems below as possible. Try to resolve questions within the group before asking for help. Each group member should then write up solutions in their own words.*

**Orient:** The surfaces represent measurements on a kilogram of water vapor in a piston (a graduated cylinder with a moveable top). The green surface is $U(S, V)$ and the red surface is $U(T, p)$. Each surface has a corresponding contour plot.

As you increase the temperature of the system, what happens to the internal energy of the water vapor?

Could you use the other surface? If so, how?

Does your answer depend on the initial state of the system?

Students may need guidance to recognize the meaning of the contour lines, and the fact that they can use either surface to answer this question.

Materials: $U_{T,p}$ and $U_{S,V}$ Surfaces.

**Explore:** As you increase the volume of the system, what happens to the internal energy of the water vapor?

Is the change in internal energy the same if you go in a different direction on the surface? A way that thermodynamics experts phrase this is, "What are you holding constant?"

If students know what the etched contour lines are, a good follow-up is "Can you use the other surface to determine the answer?"

**Coordinate:** Describe how $p, S, T, U$, and $V$ change if your system goes from the blue dot state (point A) to the green triangle state (point D).

Describe how each variable changes if your system goes from the blue dot state (point A) to the green triangle state (point D) to the red star state (point C) to the black square state (point B) and back to the blue dot state.

We want students to recognize that, after a complete cycle, there is no net change in any state variable. This definition of a state variable can be introduced or reinforced during the activity.

## Activity Evaluation

**What was the main point of this activity?**

**Describe one thing you understand as a result of this activity.**

**Describe one thing that is confusing after completing this activity.**