Fall 2026: AAE 518 Low-Gravity Fluid Dynamics

AAE518 is a three-credit in-person lecture-format theory and modeling class.
AAE518 is not more flight experiment projects as in AAE418.
Tuesdays and Thursdays 1:30 to 2:45pm

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Purpose

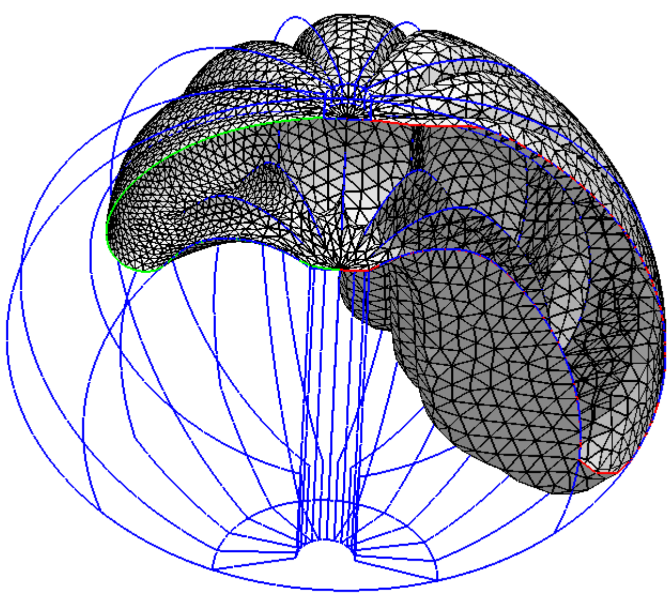
An in-person class to introduce students to a variety of fluids topics relevant to the use of liquids during the weightless periods of spaceflight. Capillary fluid physics, history of design and applications, current research topics, and terrestrial spin-offs are all likely topics in the semester. Because the field of zero-gravity fluids is such a small community, it is assumed that few if any of the students in AAE518 will have a career in zero-gravity fluids. Thus, the course seeks to teach fluid physics and the application of this knowledge to diversify fluids and propulsion specialists and to enhance the system-wide knowledge in our future engineers in spacecraft GN&C, life support systems, plant growth systems, and more. Numerical modeling in the class is not the common CFD but is rather the complementary, very fast, and mildly peculiar *Surface Evolver* code for capillary fluid statics and stability.

Introduction

An in-person class covering capillary-dominated fluid dynamics, which is not a topic generally taught in an aerospace engineering undergraduate curriculum. Thus, the semester begins with the fundamentals. A capillary dominated flow is one in which the surface tension and surface-wetting physics determine much of the behavior of the fluid flow. For flows on Earth, one often speaks of the ``capillary effects'' on the flow when gravity remains relevant. For example, gravity holds the soda pop in the cup, but the small vertical excursion of the liquid up the interior of the drinking straw is a capillary effect. The topic of capillary fluid *statics* has numerous unique issues in existence, uniqueness, and stability of solutions so considerable time is spent there. Solution methods, especially the *Surface Evolver* code, are taught.

Outline

The in-person course content often involves several current topics from spaceflight events during the semester, such as novel features of a propellant tank as large as SpaceX's Starship. And so the outline below is tentative.

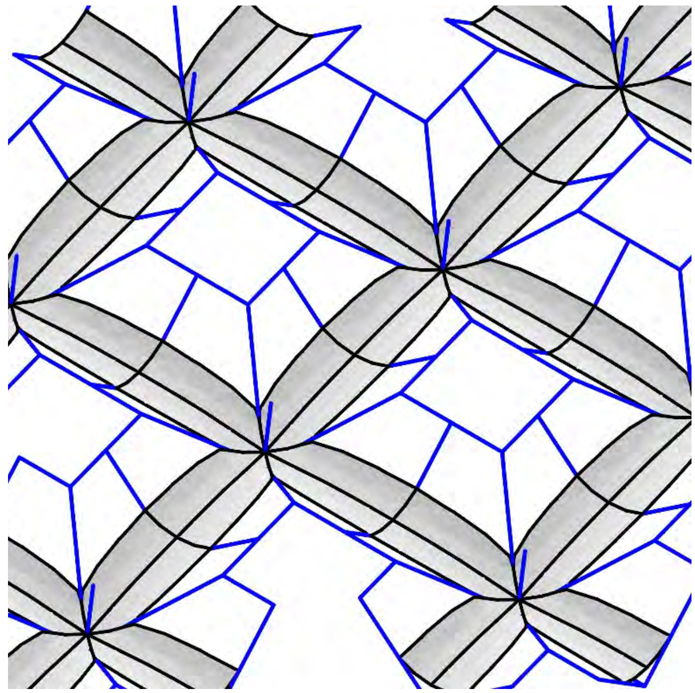


Surface Evolver modeling of propellant positioning in the Vented Tank Resupply Experiment, in the Space Shuttle.

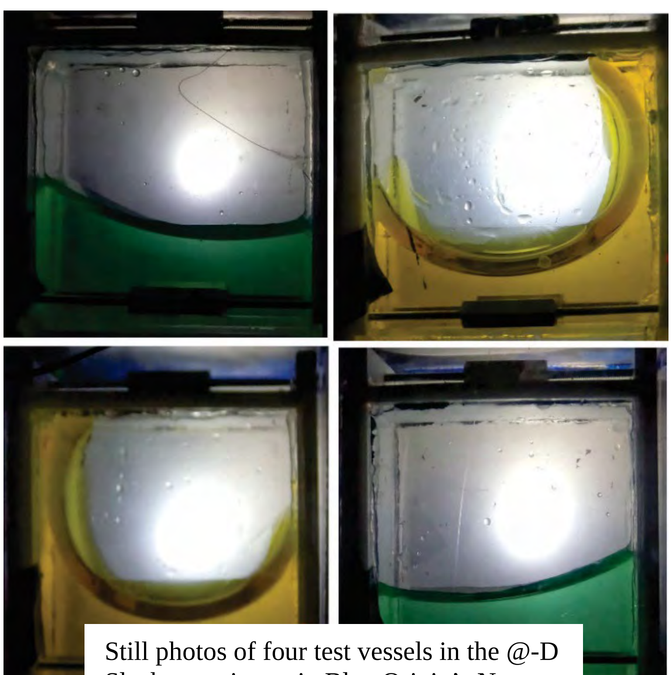
1. Examples of zero-gravity and zero-gravity basics.
    a. Physics review
    b. Orbits review
    c. What is zero-gravity, weightlessness, etc?
    d. Gravity gradient
2. Fluid properties, such as surface tension and contact angle
    a. Definitions and discussion
    b. Terrestrial examples
3. Energies in capillary fluids problems
    a. Physics
    b. Non-dimensionalization
    c. Scaling
4. Three-dimensional solutions: the *Surface Evolver* code.
    a. Demos
        i. Running the demos
        ii. "Cheat codes" for the vector calculus
    b. Defining your own geometries in *Surface Evolver.*

        i. Starting wisely
        ii. Defining clearly
        iii. Avoiding bugs and debugging effectively
        iv. Getting information out of the code and into real-world uses.

5. Capillary Stability:
    a. classical examples
    b. recent applications
6. Critical contact angle phenomena
    a. Examples and applications
    b. Concus-Finn analysis
    c. *Surface Evolver* use
7. Capillary-driven corner flows – imbibition
    a. Analysis
    b. Experiment
    c. Application
8. Conformal small-sat tanks
    a. Unique physics, new problems
9. Large tanks
    a. Unique physics, new problems
    b. Space-X Starship
    c. Blue Origin New Glenn
10. Experiment design
    a. Parabolic aircraft flight
    b. Blue Origin New Shepard
    c. Virgin Galactic
    d. Drop Towers
    e. Others
11. Projects
    a. Goals
    b. Topics
    c. Progress Reports
    d. Presentations



Surface Evolver modeling of a series of intersecting V-grooves on a solid surface.



Still photos of four test vessels in the @-D Slosh experiment in Blue Origin's New Shepard rocket,

Grading

Homework (often using *Surface Evolver*), one in-person mid-term, and a two-person project (see below) will combine for your semester grade. Each item counts for one third of the total.

Text

There is no textbook yet for the course but a draft of my book coming to the market in 2027 is provided in pdf format. Handouts, journal and conference papers, and at least one excellent old NASA report are also provided in pdf format.

Projects

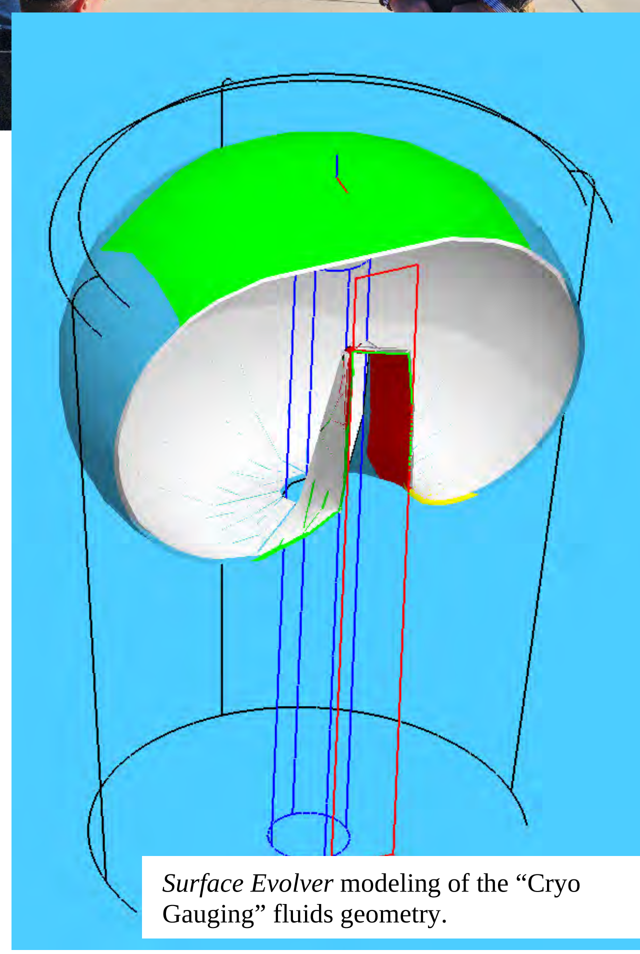
A two-person effort in performing *Surface Evolver* modeling in an original manner, reaching a solution, and explaining the solution approach and results in-person to the class. The simple drop tower experiments done by a few students in previous years are not feasible this semester because the tower is being modified.

Surface Evolver

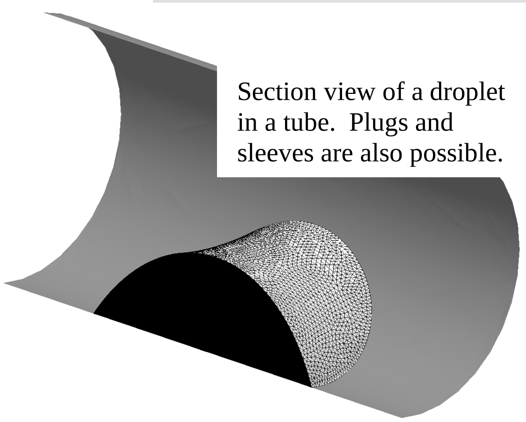
The *Surface Evolver* (SE) code was created in the late 1980s and 1990s on NSF Mathematics funding by Professor Ken Brakke, now retired from Susquehanna University. It is available for free to you for your computer from his website (https://kenbrakke.com/evolver/evolver.html). If you wish to run it on Purdue PCs such as in Armstrong Hall room 2106, run it there from a USB drive as *Surface Evolver* is a very small executable file by modern standards. I have been using Version 2.70, which is the latest version, on Windows PCs and it is running well in both 32-bit and 64-bit versions. *Surface Evolver* runs sufficiently well on a simple Windows notebook computer for all assignments in this class. The SE-FIT tool is not taught but the fundamental *Surface Evolver* knowledge that you need to be a smart SE-FIT user is taught.

Frame from a video of the "Vane Gap" experiment operating in ISS. Designed by Collicott using the *Surface Evolver* code.

Professor Collicott with VSS Unity after watching the Galactic-5 mission.



Surface Evolver modeling of the "Cryo Gauging" fluids geometry.



Section view of a droplet in a tube. Plugs and sleeves are also possible.