Armadillo Aerospace and Purdue University Student Experiment Program.

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Introduction: In 2009 undergraduate students in the School of Aeronautics and Astronautics at Purdue began designing and building a small, automated low-gravity fluid dynamics experiment. The enabling step was an agreement with Armadillo Aerospace that offered Purdue a ride on a test flight at no cost to Purdue.

Student effort is organized and led through the author's original and long-running class, *AAE 418 "Zero-Gravity Flight Experiments"*[1]. This class was created to maximize student benefits from participation in the annual NASA *Reduced Gravity Student Flight Opportunity Program* (RGSFOP) and, in fall semester of 2009, became the ideal vehicle with which to teach low-g experiment design for rocket launches.

The experiment is one that will explore interface topologies between a pair of immiscible liquids in a circular tube. This is motivated by 3-D computations performed by the author and a researcher at a CDC lab in West Virginia[2]. It is expected that an initial test-flight will not produce zero-gravity but rather something more like Lunar or Martian gravity. So the experiment is designed to explore the fluid physics in these partial gravities. Hopefully collaboration will persist until Armadillo is performing high-altitude zero-gravity flights. At present, Purdue and Armadillo are working through development of their respective hardware and expertise at the same time.

Goals: In this program we seek several goals in science, engineering, and education. Specifically:

1. Science:
   a. Acquire image data for steady-state configurations of low- and mid-Bond number two-phase fluid topologies in various cylinders. Specifically:
      i. Wall-bound droplets,
      ii. Plugs, and
      iii. The less common annular droplets
   b. Acquire video data of transitions between topologies in low- and mid-Bond number conditions. This is not possible in drop towers and aircraft flights are too noisy for this purpose.
   c. Complete an original numerical modeling effort in these two-fluid capillary problems that mix surface tension and gravitational effects. This will first support experiment sizing and will also produce specific hypotheses to test in the flight experiment.
2. Engineering:
   a. Create a functioning original automated single-injection event capillary fluids experiment with video data acquisition on a small budget.
   b. Develop integration and operations procedures with Armadillo for elaborate future experiments.
3. Education:
   a. Provide hands-on original design-build-test engineering education in a challenging, new, and exciting real-world application.
   b. Teach the basics of aerospace program management by immersing a small team of aerospace engineering students in a new spacecraft hardware program for flight testing.

Implicit in all of the above goals is the goal of making our students better prepared for, and hence more attractive to, the aerospace companies and agencies that they wish to go to work for after success at Purdue.

Hardware: Students are designing and fabricating the hardware necessary for this original experiment. Figure 1 shows a number of these parts. The complete experiment is 5kg or less and fits in a shoe-box sized volume. Video data acquisition is from a miniature digital video recorder and camera from the motorcycle helmet-cam market. White LEDs provide illumination. Triggering of the liquid injection event is by accelerometer board available in the high-power model rocketry market – that is, this experiment does not interface with the rocket. The hardware budget is around $1500.

Figure 1. Student-designed and built parts for the Purdue-Armadillo automated low-gravity experiment.

References:

[1] S. H. Collicott, "An Undergraduate Project Course for the NASA Reduced Gravity Student Flight Opportunities Program," *39th AIAA Aerosp. Sci. Mtg.*, Reno, NV, January 2001. AIAA-2001-0585

[2] S. H. Collicott, W. G. Lindsley, D. G. Frazer, "Zero-Gravity Liquid-Vapor Interfaces in Circular Cylinders," *Phy. of Fl.*, 18, No. 8, 8 pp., Aug.2006.