



ALUMNI SPOTLIGHTS

These Purdue University alumni published articles in volume 1 (2011) of the *Journal of Purdue Undergraduate Research* during their time spent completing their baccalaureate degrees. Since graduation, they have moved into successful careers in industry and have pursued further educational opportunities.



NICOLE AROCKIAM

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What have you been doing since the publication of your article in *JPUR*, volume 1?

When the inaugural issue of *JPUR* was published, I had just graduated from Purdue with my BS in Aeronautical and Astronautical Engineering after spending my last semester studying abroad in France. After that, I went to the Georgia Institute of Technology for graduate school, joining the Aerospace Systems Design Laboratory as a research assistant, where I had the opportunity to work on a variety of research topics, ranging from unmanned aircraft systems to launch vehicles. My present research is on space systems architecting and is sponsored by the Advanced Concepts Office at

NASA's Marshall Space Flight Center, where I worked as a graduate intern last fall. I earned my MS in Aerospace Engineering in 2012, and I am currently working on my PhD.

What are your career goals?

Having worked on a wide variety of projects in academia, industry, and government, I have found that I can be quite flexible with my work topic and environment, and still find it highly fulfilling. Therefore, I have a fairly broad overall career goal, which is simply to work on challenging engineering problems, coming up with solutions that advance our knowledge and make the world a better place.

How did the research you did as an undergraduate at Purdue impact your current endeavors? What is the value of undergraduate research?

I decided to do undergraduate research at Purdue because I knew that I wanted to go to graduate school, and since research plays a key role there, I wanted to try it first at the undergraduate level. Through Purdue's Summer Undergraduate Research Fellowship (SURF) program and my subsequent work with my SURF faculty mentor, I learned that I did in fact enjoy research, and I was able to become more familiar with what graduate students do, thus confirming that I wanted to pursue an advanced degree.



THE FUTURE OF AEROSPACE PROPULSION: Visco-elastic non-Newtonian liquids

Nicole Arockiam, Aeronautical and Astronautical Engineering

Motivation

Many aerospace propulsion systems today operate by combusting liquid propellants. Before they can be combusted, these liquids must first be sprayed in a two-part process known as atomization. The first part, primary atomization, occurs when a liquid jet breaks up into large drops. The second part, known as secondary atomization, occurs after a drop is already formed but undergoes further breakup due to instability. This process determines final drop sizes, which affect the liquid's evaporation and mixing rates, ultimately impacting the efficiency of the combustor in which the liquid is used (Gaidenbecher, Lopez-Rivera, & Sojka, 2009). As the cost of using an aerospace vehicle is closely tied to its efficiency, the secondary atomization of propellants is of paramount importance.

Research problem

While much is known about the atomization of Newtonian liquids, such as water, very little is understood about the secondary atomization of non-Newtonian liquids, such as gels. Non-Newtonian liquids are increasingly being used as aerospace propellants for two reasons. First, they are more easily contained than Newtonian liquids, making them safer for humans to handle (Snyder, Arockiam, & Sojka, 2010). Second, they can be injected at varying rates, allowing for more control than solid propellants.

The aim of this study was to determine the breakup modes of visco-elastic non-Newtonian liquids, the conditions at which they occur, and the characteristic times of the atomization process. This is part of the overall goal to control the final droplet sizes, eventually enabling non-Newtonian liquids to be effectively used as propellants.

Theory

There are many non-dimensional parameters that can be used to describe secondary atomization. These include Weber number, Ohnesorge number, Deborah number, and Weissenberg number. Dimensionless initiation time is also a common parameter.

Weber number (We) measures the shear forces acting on a drop relative to its surface tension.

$$We = \frac{\rho_l v_{\infty} d_l^3}{\sigma}$$

ρ_l = density of liquid drop
 v_{∞} = velocity of surrounding fluid relative to drop
 d_l = drop diameter
 σ = liquid surface tension

Depending on the Weber number, a drop will exhibit different breakup modes, which result in different final droplet sizes. Newtonian liquids have five distinct breakup modes (Pich & Erdman, 1987), as illustrated in Figure 1.

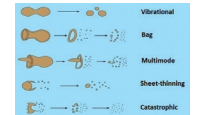


Figure 1. Newtonian liquid breakup modes. Pich & Erdman, 1987.

THE FUTURE OF AEROSPACE PROPULSION 3

Moreover, I gained valuable technical skills, such as setting up and running experiments, analyzing data, and drawing conclusions, as well as the experience of working in a research team where each person brings his or her own unique expertise to the table.

Additionally, I learned about new fields of study that I would never otherwise have been exposed to. I was an undergraduate student in the School of Aeronautics and Astronautics (AAE), but my mentors and the lab I worked in were in the School of Mechanical Engineering. Through my research, I learned about non-Newtonian liquids, sprays, rheology, and other topics that are not covered in a typical AAE undergraduate course load, thus enriching my education and broadening my horizons.

How did the faculty mentor relationship impact you during your time at Purdue?

The first impact that my faculty mentor had on me was increasing my self-confidence as an undergraduate. I had initially been hesitant to approach professors about research, but Dr. Paul Sojka's prompt and eager response soon showed me that I could contribute to his team.

I was certainly made to feel like a true part of the community, attending all the professional and social events in our research group. Dr. Sojka always made time for me, whether it was taking me personally around the lab, giving me valuable feedback on my technical work or presentation skills, or writing me recommendation letters for graduate school.

He also gave me some excellent general advice. When I was worried about the fact that I couldn't choose between aeronautics and astronautics as a career, he said something along the lines of, "You think that it's a bad thing that you don't know what you want to do. I see it as a good thing, that you could be happy doing a lot of things." He was absolutely right, as my subsequent experiences have shown, and this has stuck with me, impacting how I make decisions today.

How did the experience of publishing an article in JPUR benefit you? What advice would you give to other undergraduates at Purdue who are interested in contributing to the journal?

The experience of publishing an article in JPUR was an excellent opportunity for me to try to clearly communicate the work that I had done as an undergraduate researcher. It also was highly beneficial preparation for writing papers in graduate school.

As for advice I would give to other undergraduates, I encourage you to put yourself in your audience's shoes. Not everyone knows about your topic, so start with the basics, connecting your research to topics that everyone can relate to, and then work up to the more technical details.

What advice would you give to other undergraduates at Purdue who are interested in doing research?

Just do it! Don't be afraid to reach out to professors. There are so many that would be glad to have you as a part of their team. The experience is so valuable, no matter what you do later.

Arockiam, N. (2011). The future of aerospace propulsion: Visco-elastic non-Newtonian liquids. *The Journal of Purdue Undergraduate Research*, 1, 2–9. <http://dx.doi.org/10.5703/jpur.01.1.1>