HOW DOES COFFEE DEVELOP THE ROCKETS OF THE FUTURE?

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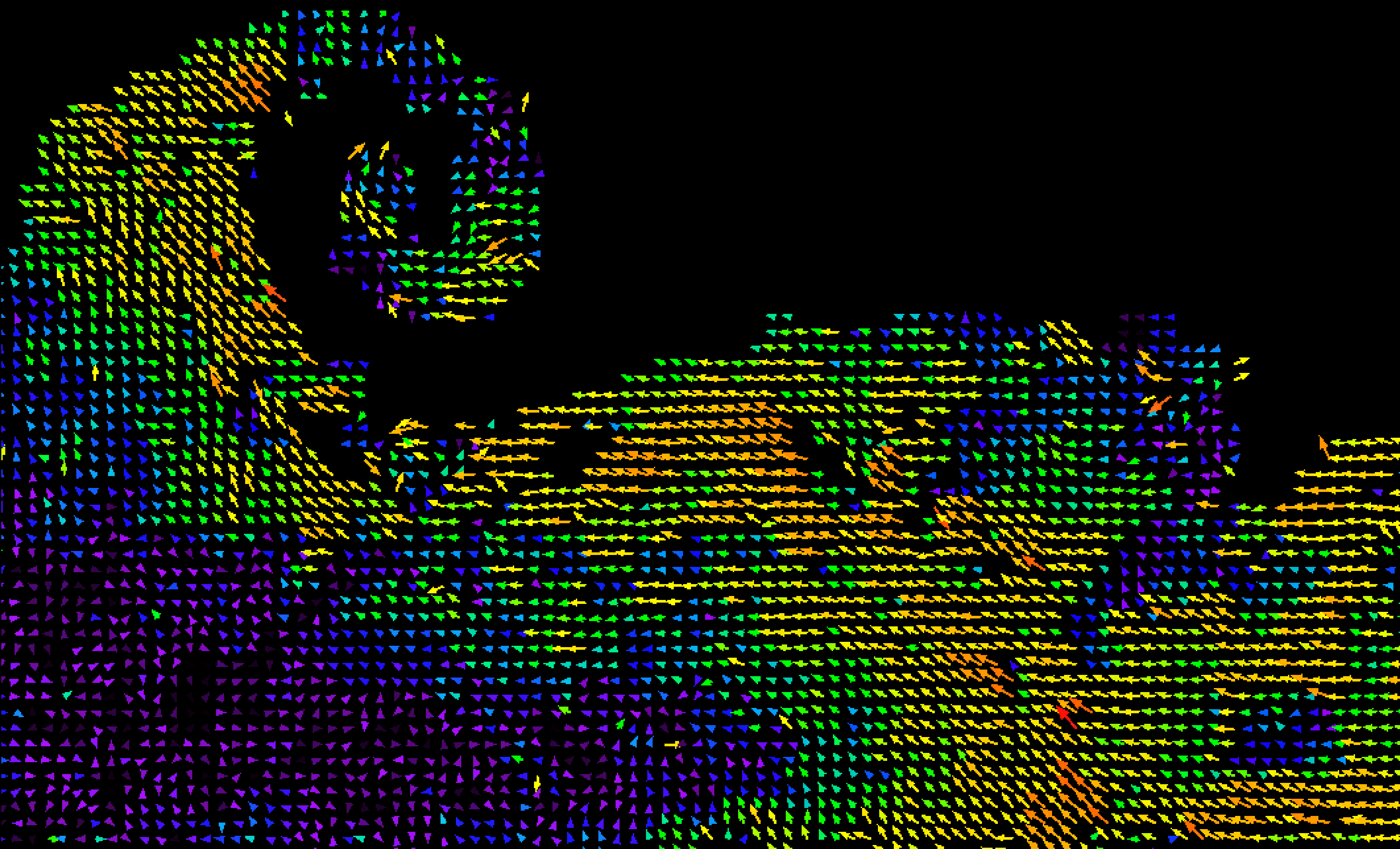


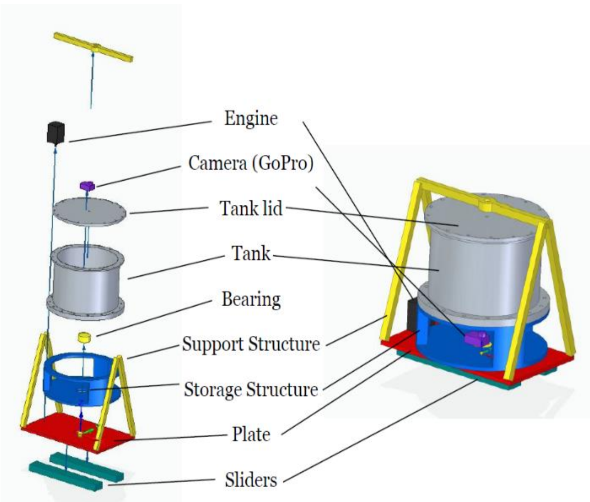
How Does Coffee Develop the Rockets of the Future?

For how long do you have to spin a coffee mug until you can send it in to space? The answer is around five minutes, if you use image analysis tools to track hydrogen bubbles submerged in a water tank. Lund University has together with the European Space Agency worked on a project to determine how instabilities develop in a rotating water tank. The data will used to design the new Ariane rocket, which is scheduled to have its first test-launch during 2020.

Ariane 5 together with the new design for Ariane 6

The space industry has during 21st century seen a dramatic development with new countries and private bussiness leading new innovation. This has forced the already established, governmental agencies to focus more on new technology to adapt market of safer and cheaper rocket launches.

The European Space Agency is developing the Ariane 6 rocket which will be safer and better for the environment than many of its competitors. The downside is that the rocket will be far more expensive which will be compensated for by launching several satellites at the same time. This will reduce the price for each launched satellite, as the voyage from the ground through the atmosphere consumes the most fuel. The launch of several satellites at the same time creates new challenges for the design of the rocket, one being the way fuel behaves as the upper stage starts and stops in a low gravity environment.



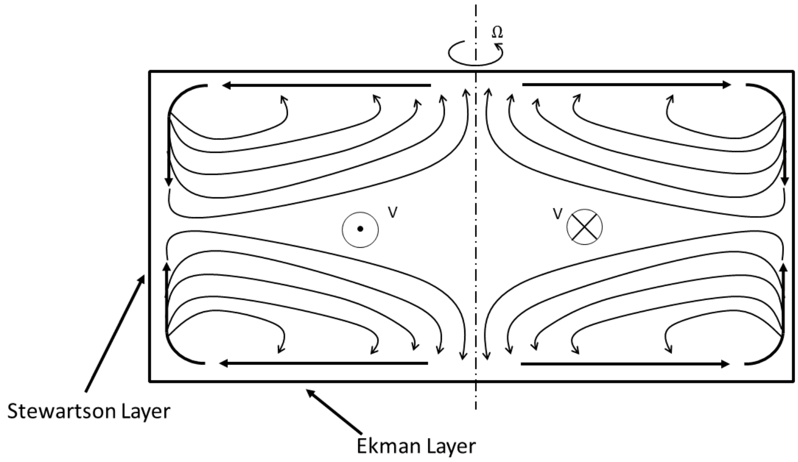
Experimental Setup

The satellites will require different orbits and different spins. This will require the upper stage to accelerate and decelerate to make sure every satellite has the right dynamics. When the rocket accelerates the fuel in the tank will move in reference to the rocket and cause dynamical instability in the vehicle. The movement of the fuel is called sloshing and can be found in an ordinary coffee mug as you walk to fast and the coffee easily spills over.

Another phenomenon that happens in the fuel tank can be found in the famous high school experiment known as the tea-leaf paradox. As the tea is stirred and the spoon is removed the leaves move to the middle of the mug. This is an example of Ekman pumping, a phenomenon discovered in 1902 by Vagn Walfrid Ekman, a Swedish Oceanographer. Ekman pumping affects the stability of the fuel in the tank. Ekman pumping only occurs for a limited amount of time and the rocket can be accelerated as Ekman pumping stops. Ekman pumping is known as secondary flow, since it is a different flow structure than the primary flow of the whirl caused by the stirring or rotation of the tank.

An experimental setup was built where a water tank was seeded with hydrogen bubbles. The flow was analyzed using image analysis. When the tank was half-filled the spin-up time until the flow is steady was found to be around 5 minutes, regardless of the rotational rate.

When the tank was completely filled two separate secondary eddies were created, one at the bottom and one at the top wall. The way these eddies interact affects the time until the flow reaches steady state. The time until steady state can be found in the figure below.



Tank completely filled seen from the side. Arrows indicate secondary flow.

This is the first time Sedney´s and Gerber´s theroretical model was verified using this technique. The experiments should be contiuned to find the transition velocity for when the Ekman layer becomes turbulent. The result can be used to design new fuel tanks for rockets and to develop new rocket manuevers. So next time you stirr you tea you can think that the leading space engineers are doing the same thing to design the rockets of tomorrow!