Normal Field Instability of a Ferrofluid in Microgravity

Brendan Krull, Tessa Rundle, Kevin LeCaptain, Amelia Gear, Justin Barhite, Kevin Crosby

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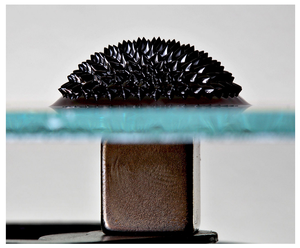
Introduction:

A ferrofluid, which is comprised of nanoscale iron particles suspended in a suspension liquid, deforms when subjected to an external magnetic field. The deformation of a ferrofluid and the onset of surface deformation (Normal Field Instability, NFI) is partially characterized by the strength of the gravitational field. We will examine this behavior and dependence in a sounding rocket payload.

Our payload incorporates a ferrofluid sample and a uniform magnetic field which can be varied across a discrete range of values. We will obtain video of the ferrofluid's behavior in microgravity and compare it to data taken in earth's gravity.



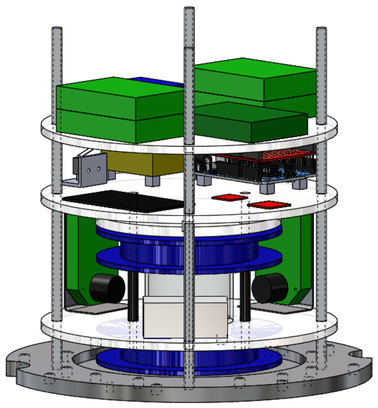
Ferrofluid experiencing NFI. Field applied by permanent magnet beneath glass.
Maxwell, Gregory. 2006. Wikipedia, Ferrofluid, 10-21-13.

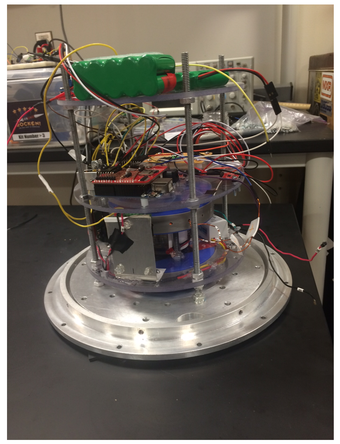
Research Objectives:

1. Observe the onset of NFI in a ferrofluid as a function of applied magnetic field.
2. Characterize the role of gravity in stabilizing the surface of the ferrofluid against deformation driven by magnetization.

Experiment Design:

Our payload centers around a ferrofluid capsule mounted between a pair of Helmholtz coils, which produce a uniform magnetic field in the region of the ferrofluid. A pair of cameras record video of the ferrofluid deformation.

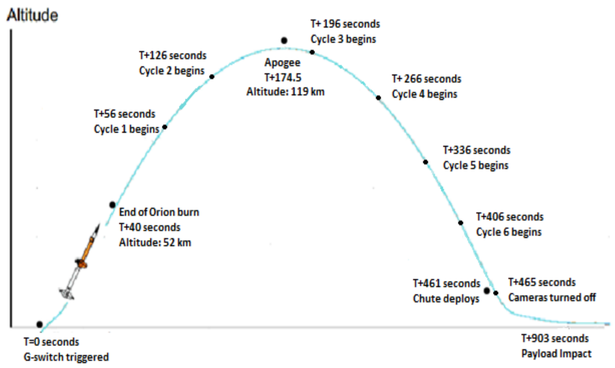




RockSat-C flight:

Terrior-Orion Rocket

Event	Time (sec)	Nom. Alt (Km)	Nom. Range (Km)	Nom. Vel. (m/s)
Rail Release	0.4	0.0	0.0	48.8
Terrier Mk 12 Burnout	5.2	1.9	0.2	720.8
Orion Ign.	15.0	7.7	1.0	482.4
Orion B-O	40.4	34.3	5.3	1295.5
Motor Separation	125.0	107.7	23.7	513.2
Apogee	174.5	119.2	34.1	213.4
Chute Deploy	461.2	6.3	68.1	292.7
Ballistic Impact	350.6	0.0	68.1	292.7
Payload Impact (zero wind)	902.8	0.0	68.1	10.4

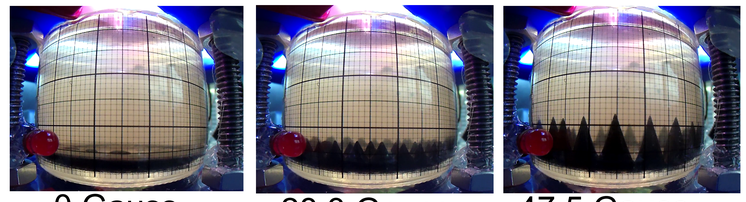


Build:

Payload size: 9.3 in diameter, 9.5 in height
Payload weight: 20±0.2 lbs
Center of Mass: 1x1x1in of center
Maximum G-load: 25g
Maximum payload temperature: 90°F
Spin Rate (Hz): 1.3-5.6
Fully autonomous

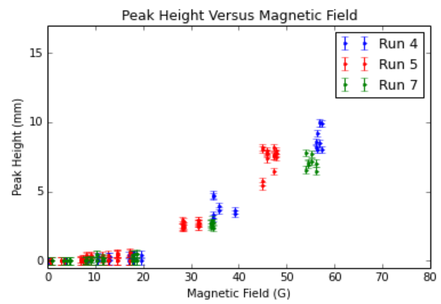
Rocket launched on June 26th, 2014

Ground Data Results:



0 Gauss 28.3 Gauss 47.5 Gauss

Above, we show image stills of our ferrofluid sample taken with a HackHD camera with different applied magnetic fields. Below, we show a plot of the measured peak heights versus the applied magnetic field, as well as a logarithmically-scaled plot of the peak height versus the applied magnetic field.



Based on our ground data, we find the onset of NFI to occur at approximately 15 Gauss. The calculated value for the onset of NFI is between 22.8 and 27.1 Gauss, which is close to, but does not correspond to, our experimental value.

Further Research:

Further research includes obtaining video of our ferrofluid in microgravity to determine the onset of NFI and its dependence on gravity. A continuously varying magnetic field is currently being implemented and undergoing ground testing in preparation for re-launch in June 2015. A continuously varying magnetic field will allow observers to more accurately determine the onset magnetic field in both 1- and 0-g.

In microgravity conditions, we expect the onset magnetic field to occur at less than 15 Gauss, the critical magnetic field in 1-g conditions.

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