Armadillo Aerospace and Purdue University Student Experiment Program.

Steven H. Collicott and Robert E. Manning

School of Aeronautics and Astronautics

Purdue University

NSRC February 2010

PURDUE
UNIVERSITY

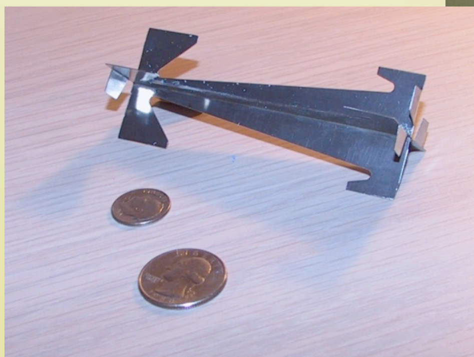
Purdue & Armadillo

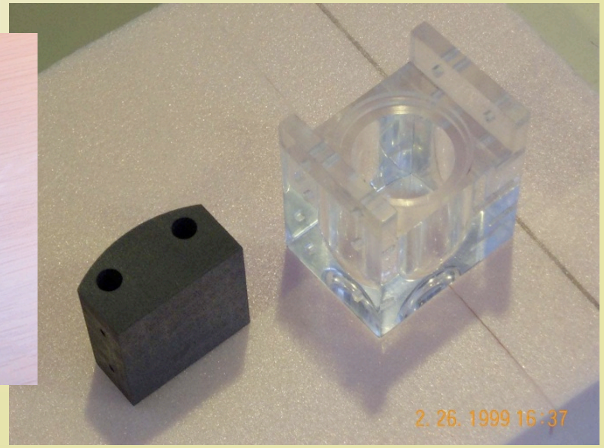
- Purdue University **School of Aeronautics and Astronautics** has
  - 600 undergrads
  - 300 grad students
  - 28 professors
- New *Neil Armstrong Hall of Engineering* with a new $1M student machine shop.
- NASA's *Reduced Gravity Student Flight Opportunity Program:*
  - Leader in student zero-g experiments
  - *42 successful flights over the last 13 years*
  - Purdue's 43rd and 44th student zero-g aircraft experiments are under construction now!

- **Armadillo Aerospace** is located east of Dallas, TX
- Flying successful rockets: Armadillo **won the first Lunar Lander Challenge** and was a very close #2 in the second challenge.
- A rarity: aerospace company without a Purdue alum as employee.
- A small company, easy to work with.

Purdue Student Zero-G History

NASA aircraft, high school sounding rocket, start-up rocket companies, drop tower experiments.





Our Collaboration

- SPEAR (Students from Purdue Experimenting on Armadillo Rockets)
- Fortunate to have received an invitation from Armadillo to launch a student-built science experiment on their rockets.
- Agreement reached in February 2009.
  - Self-contained
  - Shoe-box sized
  - 5kg or less
- Observed Armadillo operations in July 2009.
- First integration and launch December 18, 2009.

PURDUE UNIVERSITY

SPEAR Program Goals

1. **Science:**
   a. Image steady-state two-phase fluid.
   b. Video topology transitions for small Bond numbers (not necessarily μG).
   c. Complete original numerical modeling of the two-fluid capillary experiment.

2. **Engineering:**
   a. Automated capillary fluids experiment with video on a small budget.
   b. Integration and operations procedures with Armadillo for 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.

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 they succeed here at Purdue.

SPEAR Challenges

- Significantly different than cubesat, aircraft parabolic flights, sounding rockets, and ISS.
  - Paper-to-flight time is 3-5 months
  - Completely automated
  - Shoebox size

- Great learning experience for undergraduates
- Course contained within a single semester

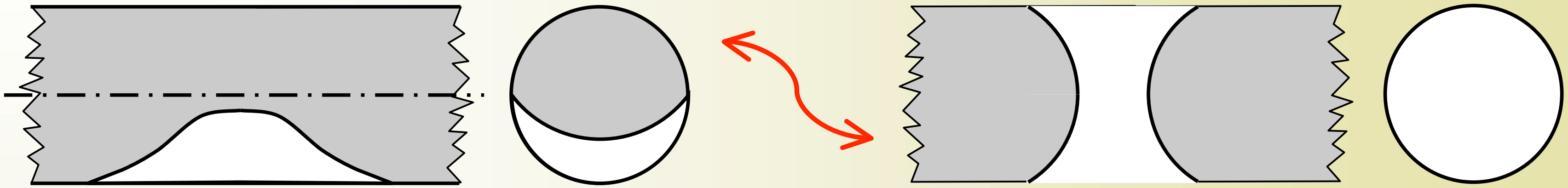
- Use COTS (commercial off-the-shelf hardware)

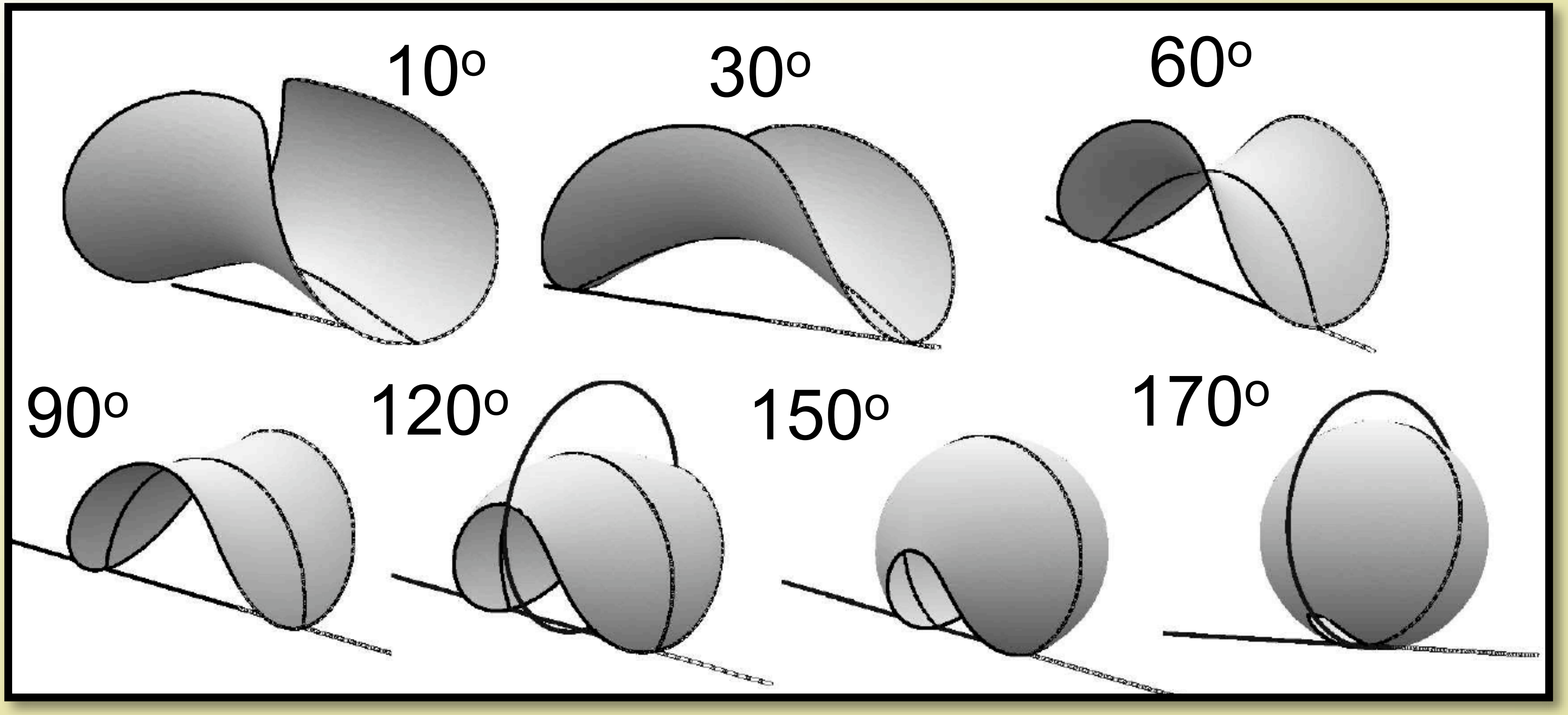
PURDUE UNIVERSITY

SPEAR-1 Goals

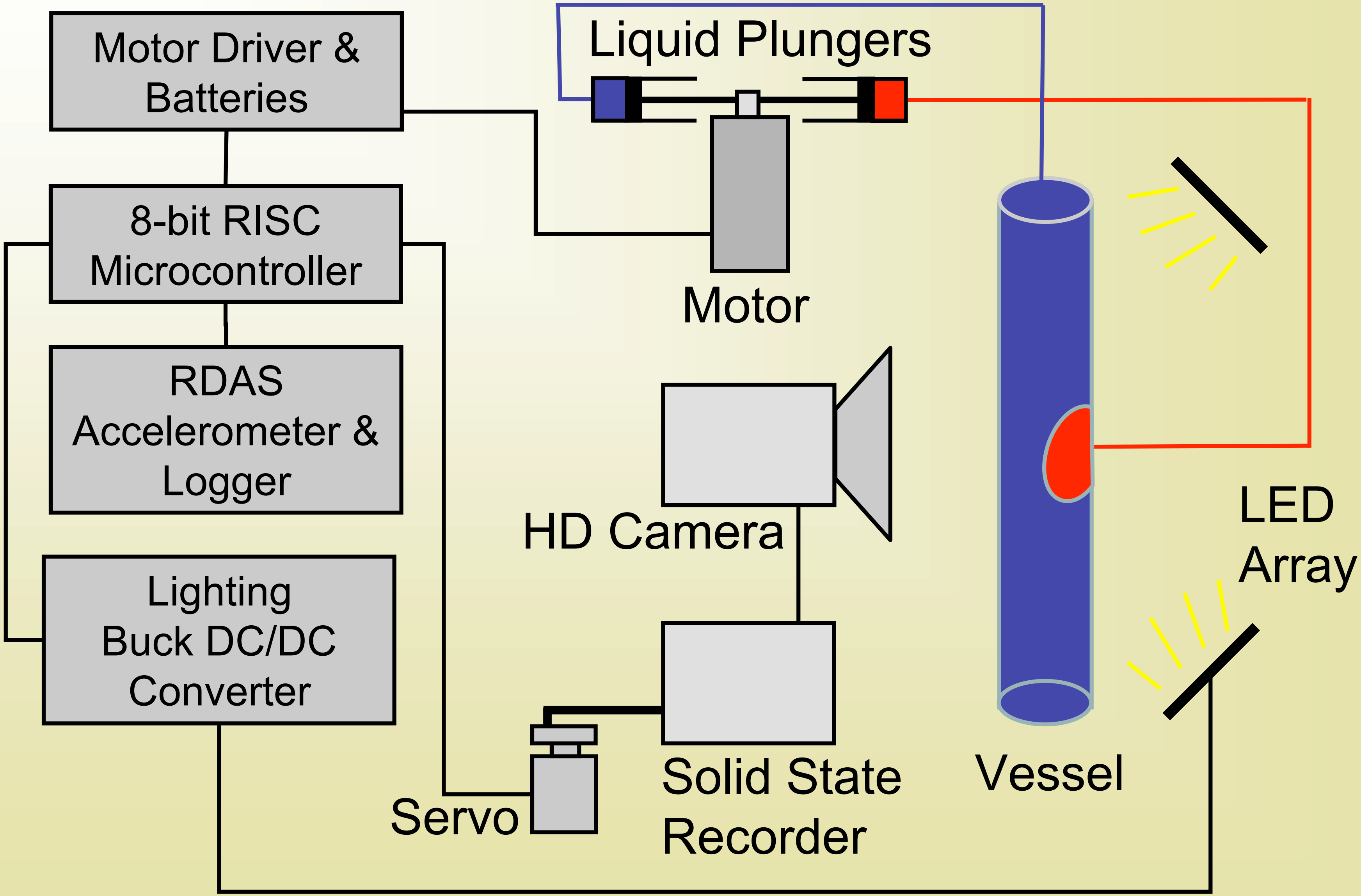
1. Integrate an automated experiment with Armadillos' rockets and operations.
2. Triggering of the experiment
3. Acquire image or video from single-injection liquid event in Martian gravity.
4. Learn for next time.

SPEAR-1 Fluids Science

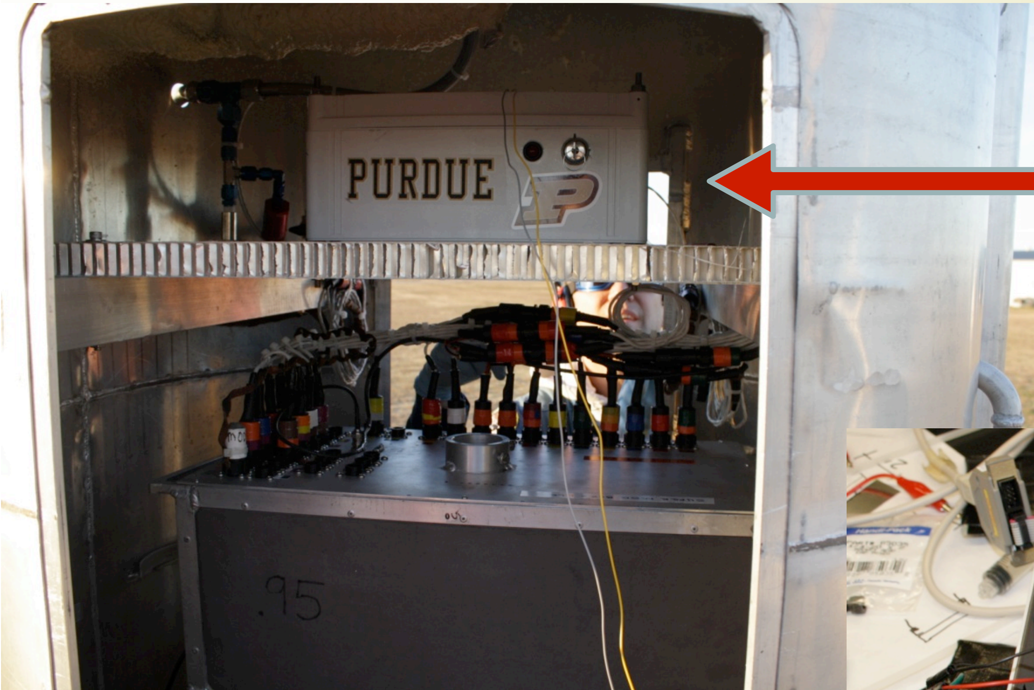


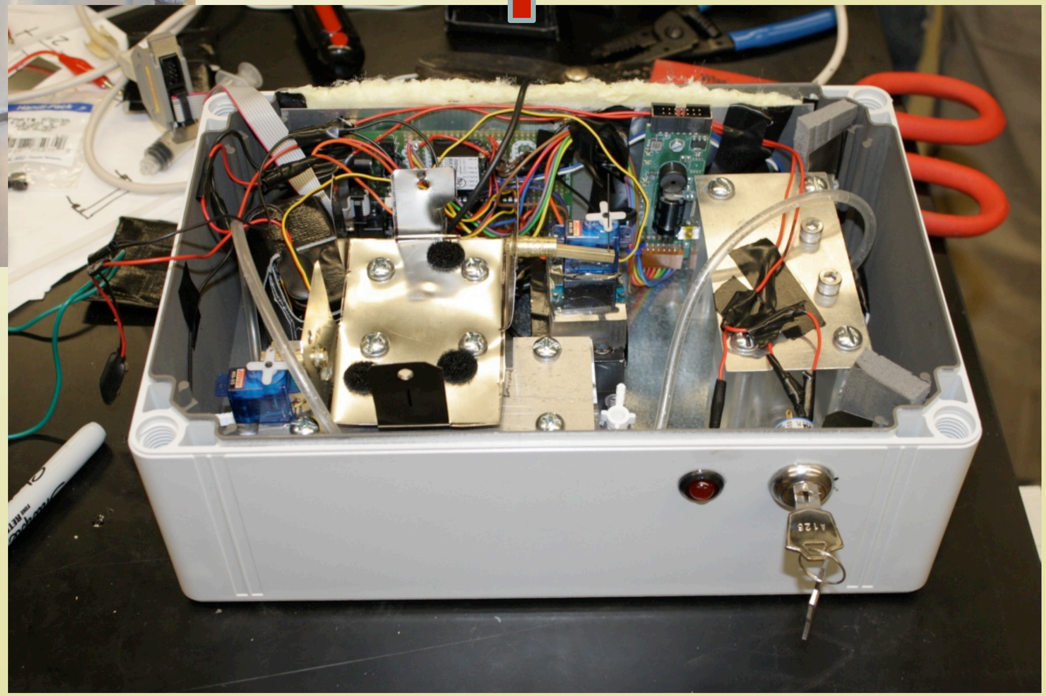


SPEAR-1 System Design



SPEAR-1 Operations





PURDUE
UNIVERSITY

Tethered Flight Tests

- Environment
- Mounting
- Operations
- Triggering
  - Due to low accelerations on ascent, RDAS Accelerometer may not trigger
  - Changed to trip-wire triggering

SPEAR-1 Conclusions

Continue to SPEAR-2 but simplify by reducing the number of active events – focus on trigger and video acquisition.

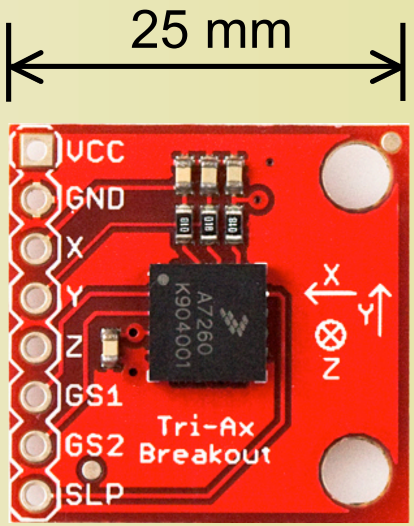
Experiment Re-design for SPEAR-2

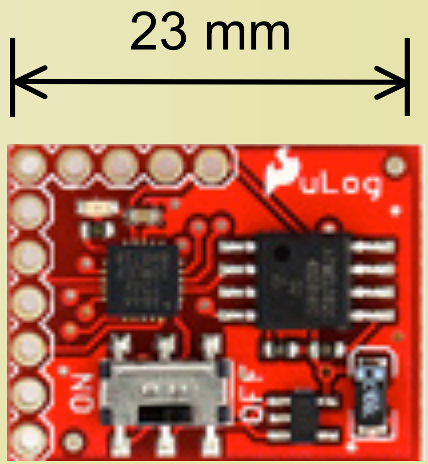
- Smaller camera / accelerometer / microcontroller
- Improved video capture
  - Prefer low-cost COTS based video camera
  - High definition video cameras are now common for extreme sports enthusiasts
  - Avoid electromechanical trigger
  - Avoid hacking / modifying camera
  - Use motion triggering
- Manual fluid injection before flight

PURDUE
UNIVERSITY

Tigger Re-design for SPEAR-2

- Have automated system
- Need accelerometer data
- MMA7260Q MEMS accelerometer
  - ±1.5, 2, 4, 6 G-levels
  - 1 kHz response frequency
  - < 0.01 G resolution
- COTS data-logger
  - 16 Mbit flash
  - 3 channels at 10 bits at >50 Hz
  - Reprogrammed to report launch event



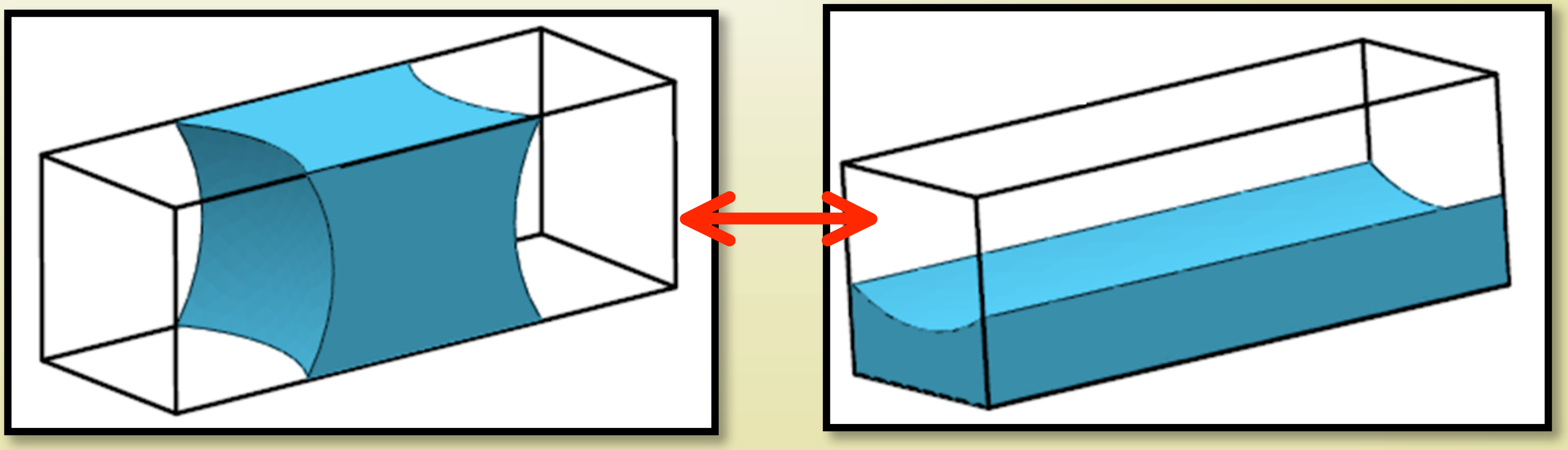


Courtesy of Sparkfun

Fluids Re-design for SPEAR-2

Simplification for mid-gravity levels:

- Change from an active injection process to passive.
- Liquid transitions from a pool to a plug at various G level
- Design from *Surface Evolver* models and modified Concus-Finn theory



Conclusions

- Undergrad design-build-test in emerging commercial spaceflight industry is feasible.
- Students said that this was their favorite class
- Students made connections with other classwork
- See Prof. Collicott to arrange Purdue involvement for new programs.
- Thanks to Armadillo!

PURDUE
UNIVERSITY

NSRC February 2010