DEPARTMENT OF AEROSPACE ENGINEERING AND MECHANICS

UNIVERSITY OF MINNESOTA
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Microgravity Study of a Gas Vortex in a Liquid
Topic Area: Fluid Mechanics
Team Name: Spinning Gophers

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Faculty signature for proposal endorsement:__________________________________________
Quick Reference Sheet

Principal Investigator: Ellen K. Longmire, Ph.D.
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Experiment Title: Microgravity Study of a Gas Vortex in a Liquid

Proposed Flight Date(s): March 16-25, 2006 (1st Choice)
March 30 – April 8, 2006 (2nd Choice)
March 2-11, 2006 (3rd Choice)

Overall Assembly Weight: 284.5 lbs

Assembly Dimensions (L x W x H [in]): 30 x 14.5 x 60

Equipment Orientation Requests: We request the length of the assembly (30 inches) be parallel with the fuselage of the plane.

Proposed Floor Mounting Strategy (Bolts/Studs or Straps): Bolts

Gas Cylinder Requests (Type and Quantity): NONE

Overboard Vent Requests (Yes or No): No

Power Requirements: 110 VAC, 60 Hz, 6.35 Amps

Flyer Names for Each Proposal Flight Days:

Day 1 - Matt Bartkowicz
Brandon Huelman

Day 2 - Matt Otterstatter
Nick Schrampfer
Microgravity Study of Gas Vortex Rings in a Liquid, University of Minnesota Twin Cities

Table of Contents

TECHNICAL DESCRIPTION.................................................................................. 5

1.1 Flight Week Preference .................................................................................. 6
1.2 Mentor Request ............................................................................................. 6
1.3 Abstract .......................................................................................................... 6
1.4 Test Objectives .............................................................................................. 7
1.5 Hypothesis ...................................................................................................... 7
1.6 Test Description ............................................................................................. 7
1.7 Justification for Follow-Up Flight ................................................................. 10
1.8 References / Bibliography ............................................................................. 10

EXPERIMENT SAFETY EVALUATION ............................................................ 11

2.1 Flight Manifest .............................................................................................. 12
2.2 Experiment Background ................................................................................ 12
2.3 Equipment Description .................................................................................. 14
2.4 Structural Design .......................................................................................... 15
2.5 Electrical System .......................................................................................... 17
2.6 Pressure / Vacuum System .......................................................................... 17
2.7 Laser System ................................................................................................ 17
2.8 Crew Assistance Requirements ..................................................................... 18
2.9 Institutional Review Board .......................................................................... 18
2.10 Hazard Analysis ........................................................................................... 19
2.11 Tool Requirements ...................................................................................... 20
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.12</td>
<td>Ground Support Requirements</td>
<td>20</td>
</tr>
<tr>
<td>2.13</td>
<td>Hazardous Materials</td>
<td>20</td>
</tr>
<tr>
<td>2.14</td>
<td>Procedures</td>
<td>20</td>
</tr>
<tr>
<td>2.14.1</td>
<td>Ground Operation</td>
<td>20</td>
</tr>
<tr>
<td>2.14.2</td>
<td>Pre-Flight</td>
<td>20</td>
</tr>
<tr>
<td>2.14.3</td>
<td>In-Flight</td>
<td>21</td>
</tr>
<tr>
<td>2.14.4</td>
<td>Post-Flight</td>
<td>21</td>
</tr>
<tr>
<td>3.1</td>
<td>Outreach Overview</td>
<td>23</td>
</tr>
<tr>
<td>3.2</td>
<td>School Visits</td>
<td>23</td>
</tr>
<tr>
<td>3.3</td>
<td>University Community</td>
<td>24</td>
</tr>
<tr>
<td>3.4</td>
<td>Media Plan</td>
<td>24</td>
</tr>
<tr>
<td>3.5</td>
<td>Museum Presentations</td>
<td>24</td>
</tr>
<tr>
<td>3.6</td>
<td>Team Website</td>
<td>25</td>
</tr>
<tr>
<td>4.1</td>
<td>Institution’s Letter of Endorsement</td>
<td>27</td>
</tr>
<tr>
<td>4.2</td>
<td>Statement of Supervising Faculty</td>
<td>27</td>
</tr>
<tr>
<td>4.3</td>
<td>Funding / Budget Statement</td>
<td>27</td>
</tr>
<tr>
<td>4.4</td>
<td>Institutional Review Board (IRB)</td>
<td>27</td>
</tr>
<tr>
<td>4.5</td>
<td>NASA / JSC Human Research Consent Form</td>
<td>27</td>
</tr>
<tr>
<td>4.6</td>
<td>Institutional Animal Care and Use Committee</td>
<td>27</td>
</tr>
<tr>
<td>4.7</td>
<td>Parental Consent Forms</td>
<td>28</td>
</tr>
</tbody>
</table>
Section 1

Technical Description
1.1 Flight Week Preference

Our preference for flight weeks is given below.

- March 16-25, 2006 (1st Choice)
- March 30 – April 8, 2006 (2nd Choice)
- March 2-11, 2006 (3rd Choice)

Proposed schedule of flyers:

- Day 1 - Matt Bartkowicz
  Brandon Huelman
- Day 2 - Matt Otterstatter
  Nick Schrampfer

None of the team members has participated in the NASA Reduced Gravity Student Flight Opportunities Program prior to this year.

1.2 Mentor Request

The assistance of a JSC scientist or engineer is not requested for our team and experiment.

1.3 Abstract

Vortices are very important to fluid dynamics and engineering because of their presence in many kinds of flows including jets and flow over airfoils. Vortex rings are generated when a slug, a volume of fluid in a cylinder, is given momentum to be injected into a tank of ambient fluid. In most experiments the slug and ambient fluid have similar densities to avoid buoyancy effects. Rarely is a gas/liquid experiment done because the buoyant force on the gas is so large relative to the mass of the gas slug that it dominates all other phenomena one might attempt to observe. In microgravity this buoyant force becomes very small and it would be possible to observe a non-buoyant gas vortex ring. Also, we must consider the effects of surface tension because we are using a gas in a liquid. This would be a factor in our analysis because it could inhibit the formation of the Vortex Ring.

It is under these conditions that we will test the slug model of vortex rings. This will be done using a piston/cylinder assembly to drive the slug of air into a tank of water. To measure the necessary quantities of the vortex ring, we will record each test run with 2 video cameras placed at different angles. We expect to see minor, but measurable differences to the slug model based on the added effect of surface tension and the different fluid properties.
After the experiment, we will begin an outreach program to explain our experiment to the general public and to inspire the scientists of tomorrow. This plan is detailed in the following sections.

1.4 Test Objectives

The overall objective of this test is to observe the formation and propagation of an air vortex ring in water under the conditions of microgravity. As part of this objective we intend to:

- test the accuracy of the slug model under the conditions of our experiment. This includes testing the predicted translational velocity, energy, circulation, and impulse of the vortex ring of a low density, non-buoyant fluid. We will vary the stroke ratio and the maximum piston velocity to ensure that our data will be meaningful.

- observe the decay length and time of the vortex ring under the conditions of our experiment. Should the apparatus not be able to accommodate this length, then the behavior of the vortex ring will be recorded when it impacts the bottom of the test section.

By running this experiment, we hope to make a contribution to the data already compiled in the scientific community on vortex rings. The ability to study fluids of such different densities without considering buoyant forces should prove to be an interesting addition.

1.5 Hypothesis

We expect to see minor, but measurable variations between our experimental results and those predicted by current vortex ring theory. These discrepancies are due to the difference in properties between the slug and ambient fluids and also due to the effect of surface tension.

1.6 Test Description

We intend to perform this experiment within a Plexiglas tank filled with water. On one end of the tank will be an opening with a cylinder extending outside the tank as shown in Figure 1. This cylinder will have a piston inside that will be operated with a motor. As the piston is driven down the cylinder, the slug will be driven into the tank. To drive air into water, the piston will need to form a seal against the side of the cylinder. The bellows added to the top of the tank will accommodate the change in volume needed when the slug is injected into the tank. In microgravity, the vortex ring will move toward the bottom of the tank until it breaks down or collides with the wall. To document our tests, we will mount two cameras, one to record the translational motion of the vortex ring and a second to accurately record the structural properties such as ring radius and core radius. This footage will be saved and filed on the computer along with the quantities measured from the various sensors on the apparatus, such as the velocity profile of the piston and the fluid properties during the test. During the period of flight where gravity is at or above terrestrial gravity, the air will return to the surface and
reenter the cylinder for the next cycle. In the event that air is trapped in the bellows, relief valves will be installed on the tops of the bellows to release any unwanted air.

As a first objective, we will test the slug model by considering two variables that will be tested individually, slug length (L) and maximum piston velocity (U_{p,max}). The slug model describes the ideal properties of a vortex ring and is based on these two variables. In each case the Reynolds’ number will change, but more so when we vary the maximum piston velocity. For vortex rings the Reynolds’ number is the circulation (\Gamma) divided by kinematic viscosity (\nu), or

\[
Re = \frac{\Gamma}{\nu}.
\]  (1)

Using this parameter, we will be able to relate our experiment to others to see how it compares with normal gravitational conditions. In our experiment, we will be looking at a range of Reynolds’ numbers from 100 to 2000.

The stroke ratio is a comparison of the slug length to its diameter (L/D). To simplify our design, we will maintain a constant diameter of two inches throughout the experiment and vary the slug length. Because we are not using a single fluid and will not have a reservoir from which to draw air, we will install a valve in the side of the cylinder to be able to draw or expel air as necessary to change the slug length. We intend to vary

Figure 1: A 2-Dimensional diagram of the test tank.
the slug length by one inch for each test series, through a range of six to ten inches. This will allow us to approximate the stroke ratio minimum for forming multiple vortex rings. This is called a formation number and is described in Gharib et al\textsuperscript{3}. To measure the slug length during the experiment, we will attach an LVDT on the piston shaft to measure the displacement of the piston.

![Diagram](image)

Figure 2: A diagram describing the stroke ratio (L/D)

After testing the variations of stroke ratios, we will vary the power to the motor to attain different maximum piston velocities ($U_{p,\text{max}}$). The velocity profile we intend to use will be a fast ramp. The fast ramp profile implies that the piston will be quickly accelerated to a maximum velocity, which will be held until the slug has fully been expelled. The equations in the slug model use only a constant velocity profile, but this can be accounted for by taking a time average of the piston velocity. We will measure the displacement on the LVDT and the time on our computer and use a central differencing approximation to determine the piston velocity. We intend to use a range about 0.5 to 12 inches per second, corresponding to the Reynolds’ number range.

![Graph](image)

Figure 3: A fast-ramp piston velocity profile. The time axis is time over the total run time of the piston. The velocity axis is the piston velocity over the maximum piston velocity.
Throughout all of these tests we will be able to observe the vortex decay or impact the bottom of the tank. Should the vortex decay, it would be due to the shedding of vorticity on the outer edges of the ring, caused by the shear forces generated at the interface. We expect that a gas vortex ring will go further than in other experiments due the smaller viscosity of a gas (Weigand and Gharib\textsuperscript{7}). Should the vortex ring impinge on the bottom surface of the tank, we expect to ring to bounce off the wall. We also expect that the ring will expand and eventually decay.

To ensure that our experiment is feasible, we will also perform a number of tests on the ground. This will tell us if the equipment can handle our specifications and allow us to work out instrumentation problems. We will also be able to record the formation of a gas vortex ring under terrestrial gravity. We expect that buoyancy forces will dominate during the ring’s formation demonstrating the need for microgravity.

1.7 Justification for Follow-Up Flight

Not Applicable to this experiment.

1.8 References / Bibliography


SECTION 2

EXPERIMENT SAFETY EVALUATION
2.1 Flight Manifest

Flight Crew Members:
   1. Matt Bartkowicz
   2. Brandon Huelman
   3. Matt Otterstatter
   4. Nick Schrampfer

Alternate Flight Crew:
   1. Ross Wagnild

Proposed Flight Dates:

- March 16-25, 2006 (1st Choice)
- March 30 – April 8, 2006 (2nd Choice)
- March 2-11, 2006 (3rd Choice)

Flyer Names for each proposed Flight Day:

- **Day 1**
  - Matt Bartkowicz
  - Brandon Huelman

- **Day 2**
  - Matt Otterstatter
  - Nick Schrampfer

None of the team members have participated in the NASA Reduced Gravity Student Flight Opportunities Program prior to this year.

2.2 Experiment Background

People have studied vortex rings and their formation for many years, starting with Lord Kelvin in 1880. Since then, there has been much progress in understanding and predicting the various properties of vortex rings. However, vortex rings maintain their mystery and intrigue for many scientists in fluid mechanics today. Many applications exist that require a thorough understanding of vortex rings, including the fields of geophysics, biology, and aerodynamics. Studies of gas vortex rings in a liquid are rare because the buoyant force overpowers the inertial force in terrestrial gravity. In microgravity this buoyant force becomes very small and it would be possible to observe a non-buoyant gas vortex ring.

To prove this relationship, we should consider the ratio of inertial forces to buoyancy forces. These are as follows:
where \( \rho_i \) is the density of fluid \( i \), \( W \) is the translational velocity of the vortex ring, and \( V \) is the volume of the vortex ring. We can approximate the volume by a characteristic length of the vortex ring cubed, which we could relate to the diameter of the slug \( D_o \). We can also approximate the translational velocity by the piston velocity \( U_p \). The formula becomes

\[
\frac{\text{Inertia}}{\text{Buoyancy}} = \frac{\rho_{air} W^2 V^{2/3}}{(\rho_{water} - \rho_{air}) g V},
\]

where \( \rho_{air} \) is the density of air, \( W \) is the translational velocity of the vortex ring, and \( V \) is the volume of the vortex ring. We can approximate the volume by a characteristic length of the vortex ring cubed, which we could relate to the diameter of the slug \( D_o \). We can also approximate the translational velocity by the piston velocity \( U_p \). The formula becomes

\[
\frac{\text{Inertia}}{\text{Buoyancy}} = \frac{\rho_{air} U_p^2 D_o^2}{(\rho_{water} - \rho_{air}) g D_o^3} = \frac{\rho_{air} U_p^2}{(\rho_{water} - \rho_{air}) g D_o}. \quad (3)
\]

This ratio is often called the Froude number. It shows that the Froude number changes inversely with gravity. Should the gravitational term reduces by a 6 orders of magnitude, the ratio would increase by 6 orders of magnitude.

The slug model gives us a way to calculate the ideal properties of a vortex ring. After running our experiment, we will compare our data against the predicted values calculated from this model. Important quantities that we can calculate from the slug model are circulation \( (\Gamma) \), impulse \( (I) \), and energy \( (E) \). These equations are as follows:

\[
\Gamma = \frac{U_p^2 * T}{2} = \frac{L * U_p}{2}, \quad (4)
\]

\[
I = \frac{\pi D_o^2 \rho L U_p}{4}, \quad (5)
\]

\[
E = \frac{\pi D_o^2 \rho L U_p^2}{8}. \quad (6)
\]

The slug model also gives us an equation for the translational velocity. From Schusser and Gharib\(^5\), this equation is:

\[
W = \frac{\Gamma}{4\pi R} \left[ \ln \frac{8}{\varepsilon} - \frac{1}{4} + \frac{3\varepsilon^2}{8} \left( \frac{5}{4} - \ln \frac{8}{\varepsilon} \right) \right], \quad (8)
\]

where

\[
\varepsilon = \frac{a}{R}. \quad (9)
\]

For our experiment, we will easily be able to record the ring’s radius \( R \), the ring’s core radius \( a \), and the ring’s translational velocity \( (W) \). It is these values that we will compare in our experiment.
2.3 **Equipment Description**

The main elements of our experimental apparatus are as follows:

**Experiment:**

**Plexiglas Tank:** The sides of the tank, with dimensions 30 inches by 10 inches, will be constructed of ½” Plexiglas. The bottom, with dimensions 10 inches by 10 inches, will also be made of Plexiglas. A lid will be made out of aluminum and will have the piston mechanism integrated into it. The lid will be sealed to the sides with an o-ring and fastening screws. Its function will be to help hold the sides of the tank together. Other seals on the tank will be made with GE Silicone II Household Sealant and Glue. The container will hold distilled water.

**Bellows:** Bellows will be integrated into the lid of the tank to provide an expansion chamber to accommodate the increased volume from the air added. This will prevent pressure buildup inside the tank.

**Piston:** A piston will be used to drive the air volume into the water. It will be driven by an electric motor.

**Frame:** Aluminum angle stock will be used to construct the frame. The frame will support our experiment and instruments. Sharp edges will be padded to reduce the risk of personal injury.

**Fluid:** The test fluid used will be distilled water.

**Control & Supply:**

**Motor:** An AC electric motor will be used to drive the piston.

**System Control Mux:** The mux will allow us to supply the correct amount of power to the motor and relay the data from the LVDT and Accelerometer.

**Power Supply:** A power supply will be used to provide power to the motor, the motor controller, and the velocity sensor.

**Instrumentation:**

**Velocity Sensor:** An LVDT (Linear Variable Differential Transformer) will be used to measure the displacement of the piston. We will obtain the velocity profile by comparing the position versus time.

**Accelerometer:** An accelerometer will be used to record variations in the value of the gravitational force and correlated with our data to ensure accuracy.
Data Acquisition:

**Laptop Computer:** A laptop computer will be mounted on the aluminum frame, and will be interfaced with the system control mux. Data from the experiments will be stored on the computer’s hard drive.

**Video Camera:** Image sequences will be recorded on tape. After the flights, the tapes will be downloaded to a PC for analysis.

Experiment Operation:

A brief summary of how we expect our experiment to operate is outlined below:

1) By opening a valve, a chamber of air will be created between the piston and a gate. The valve will then be closed.
2) Once Microgravity occurs, the gate will be opened and the piston will drive the air into the water.
3) Video cameras will record the vortex ring created by the air slug.
4) Because of the increased volume of air added to the tank the bellows may enlarge slightly to accommodate the displaced water.
5) After the microgravity phase is over the air in the tank will rise to the top in either the bellows or the original air chamber.
6) The gate of the air chamber will be closed
7) Valves in the bellows will be opened to release any air contained in them.
8) This process is then repeated.
9) After five or six successful runs the stroke length will be adjusted. Once a suitable amount of data has been recorded for stroke length variations, we will vary the maximum speed of the piston.

2.4 Structural Design

The main frame will be two rectangles composed of 2 x 2 inch aluminum beams. These will be separated by 10.5 inches and will have cross beams at each corner. We intend to mount the frame to the floor of the plane by bolts. The tank, as described above, will be reinforced around the corners by using aluminum angle-irons. It will be resting on two 2 x 2 inch beams that run the length of the frame. This will support the weight of the tank and the force of the water on the bottom piece of Plexiglas during periods of increased gravity. These two beams will be mounted so that the top of the beam is ten inches off the ground. This will allow for one of the cameras to be mounted on a plate underneath the tank. These two beams will also be the base of the electronics box. This will be made of aluminum, will be bolted to the beams, and will house the power supply and system control mux. Our second camera will be mounted on top of this electronics box. This will allow enough distance between the tank and the camera lens so that it can view the entire tank.

Two similar beams will run along the top of tank to fix its position at the vertical
and the support it during periods of upward force. The laptop will be mounted to a plate that is bolted to these two beams.

The ends of both pairs of beams will be bolted into the four vertical beams of the main frame. Two of the angle-irons of the tank will be bolted to two of the vertical beams, making the tank fixed to one side of the frame. For added support two more vertical beams will be added for mounting the other two angle-irons.

The AC motor will be mounted on an aluminum plate that is fixed to the two horizontal beams on the top of the frame. This will allow the motor enough room to operate the piston at our maximum slug length of ten inches.

![Figure 4: Diagram of proposed structural design.](image)

Here is a summary of components and their weights.

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight (lbs)</th>
<th>Dimension (in. L x W x H)</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cameras</td>
<td>2 lb*2 cameras = 4 lb</td>
<td>5.25 x 3 x 4</td>
<td>Aluminum Mounting Plate</td>
</tr>
<tr>
<td>Frame</td>
<td>100 lb</td>
<td>30 x 14.5 x 60</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Tank and Fluids</td>
<td>140 lb</td>
<td>10 x 10 x 30</td>
<td>Plexiglas, Aluminum Mounting Plate</td>
</tr>
<tr>
<td>Electronics</td>
<td>22.5 lb</td>
<td>6 x 12 x 13</td>
<td>Various Materials</td>
</tr>
<tr>
<td>Laptop Computer</td>
<td>9 lb</td>
<td>16 x 10 x 10</td>
<td>Various Materials</td>
</tr>
<tr>
<td>Other</td>
<td>10 lb</td>
<td>N/A</td>
<td>Various Materials</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>284.5 lb</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The formal TEDP will include a thorough force and load analysis of all of the components (frame, tank, mounting brackets, and bolts) on the experimental apparatus.

### 2.5 Electrical System

The electrical equipment needed for our experiment, as described above, will require the following input voltages and currents.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Voltage</th>
<th>Frequency</th>
<th>Current</th>
<th>Type</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laptop Computer</td>
<td>110</td>
<td>60 Hz</td>
<td>1.2 A</td>
<td>1 Outlet</td>
<td>9 lb</td>
</tr>
<tr>
<td>Power Supply</td>
<td>110</td>
<td>60 Hz</td>
<td>1.15 A</td>
<td>1 Outlet</td>
<td>7.5 lb</td>
</tr>
<tr>
<td>Motor</td>
<td>110</td>
<td>60 Hz</td>
<td>3 A</td>
<td>1 Outlet</td>
<td>10 lb</td>
</tr>
<tr>
<td>System Control Mux</td>
<td>110</td>
<td>60 Hz</td>
<td>1 A</td>
<td>1 Outlet</td>
<td>5 lb</td>
</tr>
<tr>
<td>Video Cameras</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Int. Batteries</td>
<td>4 lb</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>110</td>
<td>60 Hz</td>
<td>6.35 A</td>
<td>4 Outlets</td>
<td>35.5 lb</td>
</tr>
</tbody>
</table>

A power strip/surge protector will be used to power all of the electrical equipment. One 110 VAC, 60 Hz power outlet will be required for the surge protector. The Power Supply will provide power for the LVDT and the Accelerometer.

### 2.6 Pressure / Vacuum System

When the air slug is shot into the tank the pressure increases. In order to maintain a safe operating environment, a bellows system will be integrated on top of the tank. Thus, the variable volume will offset the effects from the addition of the air slug, and a safe pressure level will be maintained.

![Bellows System](image)

The bellows system will be placed on the top of the tank so that all of the fluid will remain in a vertical column. Consequently, regardless of whether the tank is experiencing microgravity or 2g forces, none of the distilled water will be isolated. Furthermore, if any of the water goes into the bellows as a result of microgravity, it will be pulled back into the tank when experiencing increased gravity levels.

### 2.7 Laser System

Lasers will not be used in this experiment.
2.8 Crew Assistance Requirements

We do not expect to need assistance from the crew after our experiment is loaded onboard the C-9 aircraft.

2.9 Institutional Review Board

Not Applicable to this experiment.
## 2.10 Hazard Analysis

<table>
<thead>
<tr>
<th>Event</th>
<th>Cause</th>
<th>Repercussions</th>
<th>Precautions Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water escapes the test chamber</td>
<td>- Failure of bellows</td>
<td>- Other objects in the aircraft could get wet</td>
<td>- The primary test chamber will be situated within a secondary chamber. The secondary chamber will then contain any escaped fluid.</td>
</tr>
<tr>
<td></td>
<td>- Failure of test chamber structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Failure of test chamber seals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor stops working</td>
<td>- Overheating</td>
<td>- Experiment would no longer run</td>
<td>- The motor controller will control the current to the motor. Power can be shut down manually</td>
</tr>
<tr>
<td></td>
<td>- The piston jams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piston jams</td>
<td>- Alignment of the piston in the tube becomes off center</td>
<td>- Experiment would no longer run</td>
<td>- The mechanism will be tested thoroughly to insure smooth operation</td>
</tr>
<tr>
<td>Fracture of Plexiglas® tanks</td>
<td>- Impact by free-floating object</td>
<td>- Injury to experimenters/flight crew</td>
<td>- The structural analysis performed indicates high factors of safety, thus rendering this scenario highly unlikely.</td>
</tr>
<tr>
<td></td>
<td>- Excessive stresses due to flight conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Damage to cabin</td>
<td></td>
</tr>
<tr>
<td>Impact with sharp edge/corner</td>
<td>- Sharp edges or corners</td>
<td>- Bodily harm</td>
<td>- All sharp edges and corners will be covered in padding</td>
</tr>
<tr>
<td>Stowage Restraint Failure</td>
<td>- Failure of tie-down straps</td>
<td>- Bodily harm</td>
<td>- Load analysis will be performed to ensure that straps can support the maximum potential load.</td>
</tr>
<tr>
<td>Electrocutition</td>
<td>- Contact with bare wires</td>
<td>- Incapacitation</td>
<td>- All wires will be insulated. Circuit components will be placed in electronics boxes. The circuitry and experiment will be designed in such a way that no direct interaction with wires will be necessary.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Electric burns</td>
<td></td>
</tr>
</tbody>
</table>
2.11 Tool Requirements

To keep the experiment safe during shipping it is likely that minor assembly will be required once the experimental setup has reached its destination. The following tools will be required for assembly. These tools will not be brought aboard the aircraft.

- 1 Ratchet and socket set
- 1 Set of box-end wrenches
- 1 Set of screwdrivers
- 1 Extra cargo strap

Each tool will be marked with our team and school name, and a team member will be responsible for them.

2.12 Ground Support Requirements

Assistance will be needed to load and unload our experiment into the C-9 aircraft. There is no anticipation of further assistance.

2.13 Hazardous Materials

The test fluids used in this experiment are air and distilled water; therefore, no hazardous materials are used in this research.

2.14 Procedures

2.14.1 Ground Operation

Prior to shipping our experimental equipment to Ellington Field, we will have completely assembled and tested the apparatus. We will then ship the experiment to Ellington Field after disassembling part of it. Our team will provide tools necessary to reassemble the setup, once on location. After the experimental set up is rebuilt, we will load the water into the tank and ready the electronics. Different tests will be conducted to verify the apparatus is in working condition prior to boarding the aircraft.

2.14.2 Pre-Flight

We will need assistance loading our experiment into the C-9 aircraft. Before take-off, we will secure the setup, connect the electrical wires properly, and setup the camera. We will make sure that our equipment is functional and working properly before the first flight. After this equipment check we will power down the electrical equipment in preparation for take-off.
2.14.3 In-Flight

Once the C-9 aircraft has reached the proper altitude, the experiment electronics will be powered up and the bellows activated. For a given configuration we will run the experiment 5 or 6 times. Our configuration will change because the stroke ratio (L/D) will be varied during the flight. This is done so we can see how vortex ring formation changes as a function of the stroke length.

At the end of the parabola set, the electrical equipment will be powered down to prepare for landing.

2.14.4 Post-Flight

After the flight, the electrical components will be disconnected from the C-9 power source. Assistance will be needed to unload the experiment from the aircraft. Video camera feed will be backed up by transferring it to the computer. The first flight crew will discuss with the second flight crew any issues that arose during the first flight, and all of the equipment will be inspected prior to the second flight.

After completion of both flights, the experimental apparatus will be drained of the fluid (distilled water). The setup will then be disassembled and shipped back to the University of Minnesota.
SECTION 3

Outreach Program
### 3.1 Outreach Overview

We plan to reach out to the Twin Cities community in many ways, reaching a diverse range of people. Because we are targeting several different audiences, we will have different goals for each audience level. We believe that the main purpose of this outreach is to facilitate the “passing of the torch” to the next generation of explorers, researchers, scientists, and engineers. Our primary goal is to inspire those who would not otherwise be aware of such exciting and interesting scientific projects.

We plan to target a younger student audience, including elementary and high school students. Our goal for these young people is not necessarily to recruit microgravity researchers; rather, we want to boost the interest and excitement of science, engineering, and NASA in general. This approach will have a special impact on the students already interested in science, giving them a broader landscape of career choices. Our primary means of interaction with the younger students will be through school visits. It is probable that some intrigued children will also take their parents to the other outreach activities geared toward the general public.

Although our target audience is primarily the young students who have not yet established career objectives, we also want to reach the undergraduates at our own school. Hopefully, we can inspire other students to participate in this excellent opportunity again next year, continuing what has become a tradition at the University of Minnesota. The specific details of our plan concerning the university community will be discussed in a later section.

In addition to student-minded programs, we will have outreach events dedicated toward the general public. This form of outreach will be accomplished in two main ways, the media and museum exhibits. Our media exposure will be covered through local newspaper articles and TV reports. The team website will also have content aimed at the masses. In these presentations it would not be sensible to focus on science careers and research options because the majority of the audience will have already formed their careers. Instead, our goal is to demonstrate the kind of research done at the University of Minnesota, emphasizing that we are actively participating in NASA programs. We will also provide a general overview of our research topic with a basic education on the fundamental scientific principles we are investigating.

Throughout all of our outreach efforts we will advertise our team website. This website will serve as the central point of information, listing future activities in the community. While being tailored to various education levels, it will also be very detailed and comprehensive to provide much more information than we could give in a short presentation.

### 3.2 School Visits

In an effort to reach out to all ages of students, we are planning on visiting various schools of different education levels. Our combined visits will encompass grades K-12, requiring several visits to elementary schools, middle schools, and high schools.

Fitting with our goal of reaching out to those who have never thought about scientific careers, we will focus our efforts on the schools that contain large numbers of people that are under-represented in the sciences. For example, the demographics of schools in the inner city are very diverse, offering us the opportunity to reach out to a
wide range of minorities. Specifically we have already been approved to visit a high school in West Saint Paul and an elementary school in Minneapolis. Many more visits will be scheduled in the future, as we are planning on contacting more than 20 schools in the metro area, including the suburbs.

The school visits will most likely be made in April or May after all of our research is complete. This would allow our group time to create a display with information and photos from our experiment in Houston. We could also process our experimental data and present our results in various levels of detail depending on the audience.

### 3.3 University Community

We plan on making several classroom visits to reach out to the undergraduates. These will be brief talks before class, and perhaps longer if the professor allows. We just want to explain what the program is, tell them how to get involved, and point them to more resources.

Besides these classroom visits, we will create a display to set up in the main hall of the aerospace engineering building, Akerman Hall. Several teams have done this in the past, and we would likely update their permanent exhibit. The effects of this plan would be long lasting, as engineering students for years to come will see information about the microgravity project as they pass through the building.

Finally, we will give a joint presentation with our student chapter of the American Institute of Aeronautics and Astronautics (AIAA). This outreach effort could be the most effective, because the student members of the AIAA are all very passionate about NASA and its missions.

### 3.4 Media Plan

For as long as our university has been involved with the microgravity project our school newspaper, The Minnesota Daily, has provided coverage of our experiments. We have contacted them this year and they are again excited to write about our experiment and flight. This school newspaper is consistently rated as one of the top in the nation, and it reaches out very successfully to the students at our university.

In addition to The Minnesota Daily, we have contacted other local newspapers to expand our coverage. Companies such as the Star Tribune and the Pioneer Press have worked with past microgravity groups from the University of Minnesota. They have agreed to help in educating our community about our project.

Using other forms of media, we have contacted local television stations. Specifically we are working with WCCO (channel 4), KMSP (channel 9), and KARE (channel 11). TV coverage is not guaranteed; however, the agencies are at least interested enough at this time to ask for more information.

### 3.5 Museum Presentations

Located in Saint Paul, the Science Museum of Minnesota is the largest science museum in the state. It drew 1.3 million visitors last year, attributing much of this success to the relatively new facilities that house the museum. The Science Museum often hosts private presentations for large audiences. They have worked with past
Microgravity research teams from the University of Minnesota and would like to continue this trend. This museum is a perfect environment for hosting a display of our microgravity research project.

We plan to have a large display set up in the engineering exhibit at the museum. This exhibit will contain the essential information about our experiment along with diagrams and pictures of our tests. The display could possibly include the experimental apparatus as well.

We propose that our museum presentations will take place after our school visits. This timing would allow us to use a professional display as part of our traveling presentation to the schools. After the school presentations, the exhibit could be setup in the museum along with our apparatus. The display would remain in the museum throughout the summer months. At the beginning of the next school year, we will transfer our exhibit to the University of Minnesota, where it will be visible during the school year for the undergraduates in our department.

3.6 Team Website

The focal point of our outreach efforts will be the team website. The internet is accessible by everyone at all times of the day, removing the obstacle of coordinating our class schedules with our presentations. Not only is a website convenient, but it is comprehensive, allowing the curious person as much information as they choose to digest. Digital technology also allows us the freedom of displaying rich media.

When finished, our website will be hosted on the server of the Department of Aerospace Engineering and Mechanics at the University of Minnesota. The site will be accessible through a dedicated NASA Microgravity projects page on the undergraduate site, at http://www.aem.umn.edu/proj-prog/sfo/. Links guiding visitors to our website will be available on all presentation materials we develop for our outreach program, making the website our primary and most permanent source of information to our target audiences.

Our team website will present all stages of our project with photographs, illustrations, diagrams, and videos. This will include discussions on our brainstorming process, advisor contact, testing, research, and outreach. By talking about these topics in a simple and logical manner, we will dissuade the belief in younger students that large research projects are intimidating. We hope to show that science can be fun and educational at the same time, further pushing our central message to the young students. The outline of our project will also provide insight for next year’s batch of microgravity students.

Structurally, the website will be built to match the style of the official University of Minnesota website. This will be accomplished through basic HTML and cascading style sheets (CSS), allowing every major internet browser to properly display our website.
Section 4

Administrative Requirements
4.1 Institution’s Letter of Endorsement

See Attachment.

4.2 Statement of Supervising Faculty

See Attachment.

4.3 Funding / Budget Statement

Our team will receive funding from the Aerospace Engineering and Mechanics Department at the University of Minnesota. Additional funding has been applied for through the University's Undergraduate Research Opportunity Program (UROP). An itemized list of expected expenses is included below.

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>Expected Cost</th>
<th>Source of Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shop Time</td>
<td>$500</td>
<td>UROP</td>
</tr>
<tr>
<td>Copying and Printing</td>
<td>$25</td>
<td>UROP</td>
</tr>
<tr>
<td>Phone</td>
<td>$25</td>
<td>UROP</td>
</tr>
<tr>
<td>Assembly Materials</td>
<td>$250/$150</td>
<td>UROP/AEM Department</td>
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<tr>
<td>Shipping</td>
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<td>Electronics</td>
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<tr>
<td>Airfare</td>
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<td>AEM Department</td>
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<tr>
<td>Accommodations</td>
<td>$2000</td>
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</tr>
<tr>
<td>Food</td>
<td>$800</td>
<td>AEM Department</td>
</tr>
</tbody>
</table>

Total $6350

4.4 Institutional Review Board (IRB)

Not Applicable to this experiment.

4.5 NASA / JSC Human Research Consent Form

Not Applicable to this experiment.

4.6 Institutional Animal Care and Use Committee

Not Applicable to this experiment.
4.7 Parental Consent Forms

Not Applicable to this experiment, all of the team members are over the age of 18.