Test Equipment Data Package

Soybean Sugar Extraction Through Innovative Blending Design

Topic: Food Processing in Microgravity

Team CyMix

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Date: May 28, 2004

Change Record:

No changes have been made to this document as of May 28, 2004.

Quick Reference Data Sheet:

Principal Investigator:	David Chipman
Contact Information:	1407 Georgia Avenue Apt. #2 Ames, IA 50014 Cell: (515) 291-9964
Experiment Title:	Soybean Sugar Extraction Through Innovative Blending Design
Flight Dates:	July 8 – July 17
Overall Assembly Weight:	286.84 lbs.
Assembly Dimensions:	24 in. x 43 in. x 41.5in.
Equipment Orientation Requests:	The team requests that the long length dimension be aligned with the aft-forward direction (see **Figure 3**).
Proposed Floor Mounting Strategy:	Bolts
Gas Cylinder Requests:	No cylinders will be used.
Overboard Vent Requests:	No overboard venting will be required.
Power Requirement:	115VAC 60Hz
Free Float Experiment:	No free floating parts are in this experiment.

Flyer Names for Each Proposed Flight Day:

Jonathan Gettler	July15
David Chipman	July15
Clayton Neumann	July16
Dustin Lunde	July 16
Alternate-	None

Camera Pole or Video Support:	The team requests one hard mount camera pole to be located on the left side of the experiment setup (see **Figure 3**)

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1. Flight Manifest

Day one flyers:	Jonathan Gettler David Chipman
Day two flyers:	Clayton Neumann Dustin Lunde
Alternate flyer:	None
Journalist:	None (NASA TV- Destination Tomorrow is using video from our flight on their television show)
Flight Request:	Thursday/Friday (July 15/July 16)
Ground Crew:	Kevin Schroeder Cheryll Reitmeier

No flyers have previous flight experience on the KC-135.

2. Experiment Background

In future long term space flights and on planetary outposts, there will be a need to process hydroponically and zeoponically grown foods for human consumption (Bourland 2003, Perchonok 2003). A blender, used in many food processing devices, could be a solution to this need. By designing a blender that will work in both microgravity and 1-g, it will likely work in the gravitational conditions found on lunar or Mars outposts.

The purpose of this experiment is to test the function of a specially designed blender in a microgravity environment. The objective of this research is to explore the effects of microgravity on blending and food processing through the use of an innovative blending technique. The device will blend soybeans in microgravity over a varied number of passes under a blending wheel during flight. Soybeans were chosen as our test specimen for their ability to be made into a wide variety of products (i.e. tofu, soymilk, etc.) and because their growth has been extensively studied in space (Watkins 2003). Post flight, the success of each test will be evaluated by measuring the concentration of sugar content of each test trial and by comparing the results to those obtained from ground experiments of the same protocol. Data collected from this experiment should provide information about the effects of gravity on the dynamics of the transformation of solid particles (soybeans) to a slurry mash (blended soybeans) and basic food processing techniques. Microgravity is required for this experiment because it is unknown how the beans will behave as they are transformed from a solid to a semi-fluid state in a microgravity environment. The KC-135 will provide an excellent test bed for evaluating our experiment.

This experiment is not a follow-up to a previous experiment nor is it directly related to a space flight experiment. Although this device may not be a final solution to food processing in space, we feel that the concept of our design may be useful in future space applications. Depending on the results of and the interest in this experiment, this may be considered a preliminary step to a future experiment.

The results generated by this experiment will hopefully guide future research in the development of food processing devices for space applications. This device would be useful for long-term space missions during which hydroponic and zeoponic foods will be grown and harvested.

This experiment is supported in part by the NASA Food Technology Commercial Space Center at Iowa State University, Iowa Space Grant Consortium, ISU Departments of Mechanical and Electric Engineering, ISU College of LAS, Iowa State University Foundation, and a USDA Honors Grant.

2.1 Technical References

Bourland, C. Consultant NASA FTCSC. Personal Interview. 16 April 2003.

Perchonok, M. Advanced Food Technology Workshop Report – Volumes 1 & 2: Space and Life Sciences Directorate, Habitability and Environmental Factors Division. http://jsc-web-pub.jsc.nasa.gov/hefo/hhfo/aft/documents.asp 10 March 2003. National Air and Space Administration

Watkins, C. 2003. Space age dining. *Inform*. 14: 60-61.

3. Experiment Description

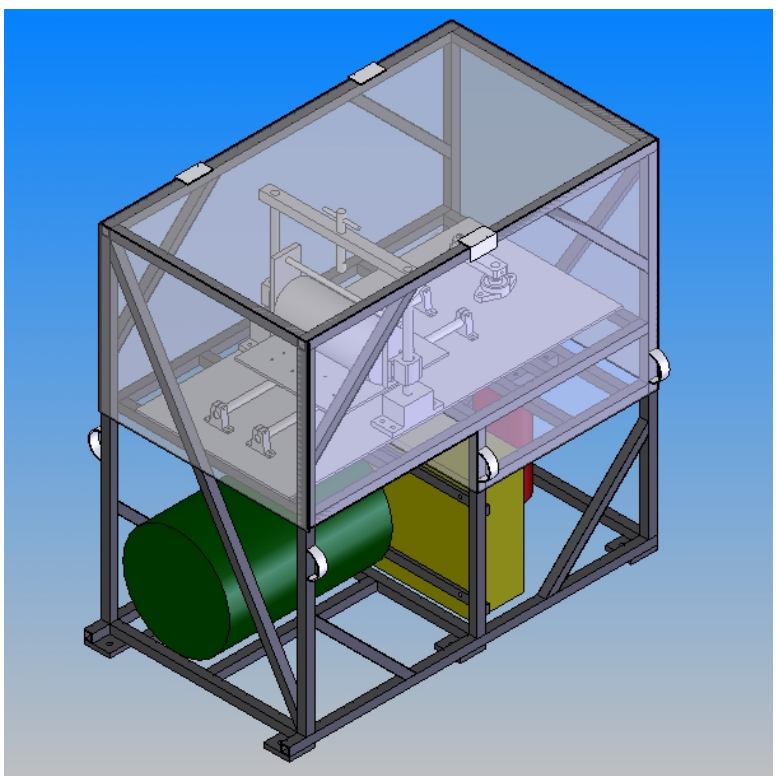

Figure 1. Isometric view of the experiment assembly. See **Figure 2** for more details.

In a microgravity environment, a device will be used to blend previously prepared soybeans. The soybeans, which are one fixed variable, will be prepared by first soaking them in water for eight hours, boiling them for ten minutes, and then vacuum sealing 6 oz portions of the drained, prepared beans into 3.2 mil polyethylene 10 in. x 15 in. food grade plastic bags. This process will be completed before flight and off campus from JSC/Ellington. Upon return to Iowa State University, an identical protocol will be used for ground testing. The soybeans are prepared in this way to facilitate the extraction of the proteins and sugars, which are important for use in soybean derived food products and are the quantitative values that will be measured in this experiment (Reitmeier 2003).

Blending events will require two parabolas. The first parabola will be used for setup, and the second parabola will be used for testing. Setup will include removing, storing, and replacing the bag from the previous parabola. Testing will include running the blender at varying number of passes.

During the experimental trials, the soybean sample size, bag size, the blending wheel speed, and the pressure of the blending wheel on the blending plate will all be controlled. The experimental variables are the number of passes underneath the blending wheel and the presence or absence of gravity. Four different blending pass settings (40 pass setting, 30 pass setting, 20 pass setting, and 10 pass setting) will be repeated 8 times (each pass setting tested over 8 parabolas each flight day). Four bags of control beans will remain in the storage container during each flight day. Four extra bags of soybeans will act as spares. The second flight day will be an exact replica of the first with appropriate changes after evaluation of the first flight day. Post flight, the sugar concentration in °Brix will be measured for each pass interval.

Testing the experiment in microgravity is important because the effects of the gravitational contributions to fluid and mass flow within the bag and its contribution to blending are unknown. Although fluid behavior in microgravity is not the focus of this experiment, it is important to address this unknown due to its possible effect on the blending effectiveness on the experimental device.

One hour after the flight (or as soon as possible after that time period), data from experimental trials will be analyzed on the ground in the following manner. The top of each bag will be cut open and 16 oz.fl. of water will be added to the bag to dissolve the extracted sugars and proteins from the mashed soybeans. After soaking the beans for five minutes, a refractometer reading of the solution will be taken (Reitmeier 2003). The data will be recorded and analyzed. Graphs of sugar concentration per pass interval for the flight experiments will be generated. Ground results will be computed in an identical manner and compared to the flight results. Our goal is to obtain sugar concentrations of 5 °Brix/solid in both the flight and ground tests. This is the required concentration in soymilk for further processing into the soy product, tofu (Reitmeier 2003). We expect that the flight results will closely resemble ground results.

4. Equipment Description

4.1 Flight Equipment

4.1.1 Blending Mechanism

The blending mechanism (**Figure 2A**) is constructed of 24 individual components. The size and weight of each individual component of the blending mechanism is listed in **Table 1**. The dimensions of the blending mechanism are 18 in. x 39 in. x 17.25 in., and its weight is approximately 85 lbs.

4.1.2 Experiment Assembly

The experiment assembly is shown in **Figure 2B**. The dimensions of the experiment assembly are 24in. x 43in. x 41.5in., and the total weight is approximately 285 lbs. See **Table 1** for a complete list of components and component weights.

4.1.3 Support Structure

The support structure is made of 1" square mild steel tubing, 1/8" thickness. The dimensions of the support structure are 24in. x 43 in. x 41.5 in., and the total weight is approximately 130 lbs. The joints are mig or tig welded by a certified welder depending on joint location (see **Appendix I**). The top half of the support structure is completely encased in Plexiglas and sealed with silicone and foam gaskets. A 2" diameter hole is drilled into the Plexiglas and covered with filter paper in order to prevent a pressure difference build up between the inside of the compartment and the cabin atmosphere. The filter paper acts as a barrier for any fluid that may enter the blending compartment. The top Plexiglas cover is hinged and serves as an access point to the blending mechanism. The access door is secured with Velcro straps. The top section acts as the second portion of double containment in the unlikely event that a bag bursts during flight. The Plexiglas also serves to shield the motor/clutch/drive axle connection as well as the crank arm/drive link/blending plate connection. All exposed corners and edges will be covered with foam.

4.1.4 Soybean Blending Bag Storage Container

The soybean blending bag storage container is a modified 5 gallon water cooler (**Figure 2B** #42). The cooler is used to keep the soybeans thermally isolated from cabin temperature fluctuations as well as to serve as double containment for the stored blending bags. Inside, the cooler is divided into two sections separating the used and unused blending bags. The water spigot is removed and a filter is placed over the hole to prevent a pressure difference build up between the inside of the storage container and the cabin atmosphere. The soybean blending bag storage container has a radius of 14.5" and is 19" long. The approximate weight of the container loaded with soybeans is 30 lbs. The storage container is used to transport the soybean blending bags to and from the aircraft. It is restrained in the aircraft with straps fastened to the support structure.

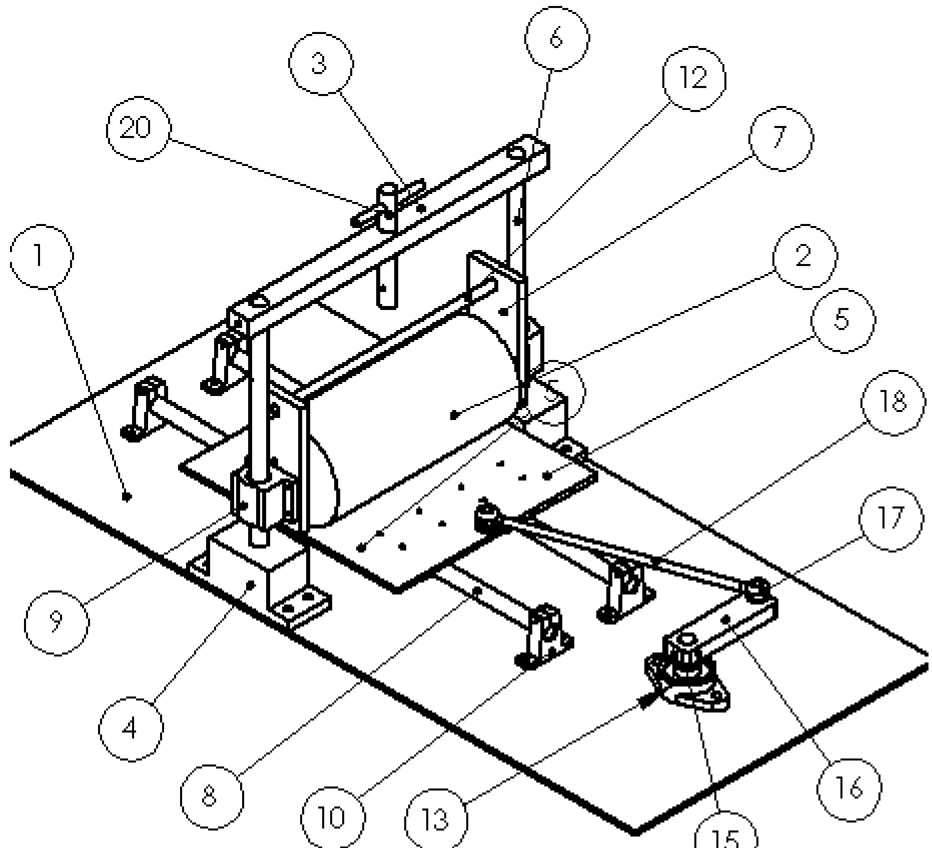

Figure 2A. Isometric view of the microgravity blender. See **Table 1** for reference key and component descriptions.

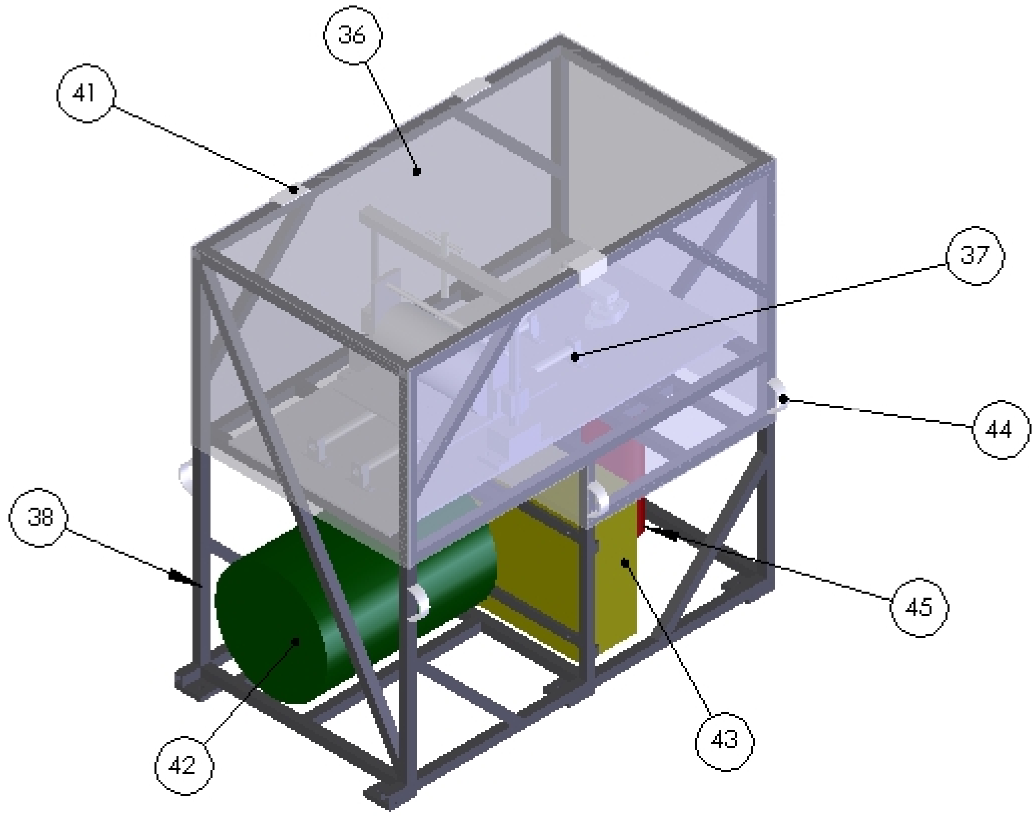

Figure 2B. Isometric view of experiment assembly. See **Table 1** for reference key and component descriptions.

Table 1. Blender and experiment assembly figure key and component weight chart.

REF. #	**BLENDER PART(S)** (function/description)	**QUANTITY**	**MATERIAL**	**Approximate Weight (lbm)**	**Approximate OVERALL Weight (lbm)**
1	**Base Plate** (serves as base for mounting components)	1	Aluminum 6061	17.59	17.59
2	**Blending Wheel** (spins on axle attached to bearings on bearing adapter plate; acts to crush soybeans)	1	Aluminum 6061	5.03	5.03
3	**Support Bar** (holds vertical support shafts in place; serves as mounting point for crank lift)	1	Aluminum 6061	2.11	2.11
4	**Vertical Support Shaft Mount** (holds vertical support shafts in place; mounts blending wheel assembly to base plate)	2	Aluminum 6061	2.32	4.64
5	**Blending Plate** (serves as mounting surface for blending bags; passes back and forth underneath blending wheel along guide rods; attached to guide	1	Aluminum 6061	3.81	3.81

	rods with four linear bearings underneath blending plate (not shown))				
6	**Vertical Support Shaft** (supports blending wheel assembly; allows blending wheel assembly to travel; secured with set screws and whistle stops)	2	Hardened Precision Steel Shaft	1.88	3.76
7	**Bearing Adapter Plate** (allows sealed roller bearings to attach to blending wheel axle; serves as attachment point for linear bearings; serves as attachment point for lift bar)	2	Aluminum 6061	0.82	1.63
8	**Guide Rod** (allows blending plate to pass back and forth; linear bearings from underneath the blending plate slide along these guide rods)	2	Hardened Precision Steel Shaft	3.04	6.09
9	**Linear Bearings** (slide along vertical support shafts and along guide rods)	6	Aluminum 6061	0.59	3.51
10	**Guide Rod Mount** (serves as mount points for guide rods)	4	Aluminum 6061	0.18	0.74
12	**Lift Bar** (allows blending wheel assembly to be raised and lowered by the crank lift)	1	Mild Steel	0.64	0.64
13	**Drive Bearing** (keeps drive axle stable and in place; second drive bearing mounted underneath base plate (not shown))	2	Cast Iron Steel	0.52	1.05
14	**Shaft Encoder Spacer** (allows space for mounting shaft encoder to drive axle (not shown))	1	Aluminum 6061	0.58	0.58
15	**Drive Axle** (connects clutch (not shown, underneath base plate) with crank arm; secured with set screws and whistle stops)	1	Hardened Precision Steel Shaft	0.85	0.85
16	**Crank Arm** (attaches to and rotates with the drive axle; attaches to drive link and drives blending plate back and forth; stroke translates into 8.5" blending plate travel)	1	Aluminum 6061	0.56	0.56
17	**Spherical Rod Bearing** (serves to attach drive link to crank arm and the drive link to the blending plate; increases range of motion of drive link connection points)	2	Mild Steel	0.14	0.28
18	**Drive Link** (connects drive plate to crank arm; allows rotational motion of drive crank to be converted into linear motion of blending plate)	1	Mild Steel	0.38	0.38
20	**Crank Lift** (consists of a threaded shaft with a handle; allows	1	Mild Steel	0.85	0.85

	blending wheel assembly to be raised and lowered using a screwing action; linked to lift bar with cable (not shown))				
not shown	**Bungee Cord** (wraps around lift bar and attaches to support frame; serves to apply a constant force on the blending bag during blending)	2	Nylon, Rubber, Steel	0.25	.5
not shown	**Shaft Encoder** (mounted underneath base plate in between base plate, shaft encoder spacer, and drive bearing; attaches to drive shaft and counts revolutions of drive shaft)	1	Plastic, Aluminum	.25	.25
not shown	**Electromagnetic Clutch** (attaches to motor shaft; when signaled, the electromagnetic engages the drive axle)	1	Steel, Aluminum	5.00	5.00
45	**Motor** (attaches to support frame and clutch underneath the base plate; drives drive axle when the clutch is engaged)	1	Steel, Copper	25.00	25.00
				Approximate Total Blender Weight	**84.83**

REF. #	**FULL ASSEMBLY PART (S)** (function/description)	QUANTITY	MATERIAL	Approximate Weight (lbm)	Approximate OVERALL Weight (lbm)
36	**Plexiglas** (serves dual function as secondary containment and safety shielding; encloses blender compartment and shields motor/clutch/drive axle connection; serves as access hatch on top compartment; contains vent hole with filter to avoid a pressure difference between inside and aircraft cabin (not shown))	1	Plexiglas	20.00	20.00
37	**Blender** (housed in top enclosed compartment; blends soybeans contained in soybean blending bags; contains parts listed in above section)	1	See above	84.83	84.83
38	**Support Structure** (serves as attachment structure to KC-135 using bolts; serves as attachment structure for flight equipment including blender, blending bag storage container, NEMA 4X enclosure, motor, and Plexiglas	1	1 square inch Mild Steel Square Tubing, 1/8 inch thick	130.76	130.76

	shielding/containment panels)				
41	**Access Hatch Hinge** (serves to attach Plexiglas access hatch to support structure)	2	Steele	.25	.5
42	**Soybean Blending Bag Storage Container** (serves to store unblended and blended soybean blending bags during flight; it is a modified 5 gallon water cooler with the inside divided into two sections by netting; access to the container is achieved by unscrewing the lid; serves as secondary containment for blending bags; contains filtered vent hole to prevent a pressure difference between the inside and the aircraft cabin; restrained by strapping with to support structure with nylon straps (not shown))	1	Plastic, Nylon, Soybeans (in individual blending bags)	30.00 (with soybeans)	30.00
43	**NEMA 4X Enclosure** (contains all electronic components; side panel facing outward serves as control panel)	1	Plastic	20.00	20.00
44	**Nylon Lift Handle** (bolted to support structure; allows manipulation of structure when not attached to aircraft)	6	Nylon	.13	0.75
				Approximate Total Full Assembly Weight	**286.84**

4.1.5 Other Flight Equipment

Flight equipment that is not a direct component to the experiment will include the items shown in **Table 2**. This equipment will be stowed with the team members or properly secured to the support structure during take off and landing.

Table 2. Other Flight Equipment

Other Flight Equipment (function/description)	**Approximate Weight (lbm)**
Absorbent Paper (used to clean up any fluid spills in the unlikely event of a bag rupture)	1.00
24 Zip Locking Bags (used to contain a ruptured bag in the unlikely event of a bag rupture)	1.00
Sharpie Marker Pen (used to label used blending bags; secure to structure with Velcro and string)	0.125
Personal Video Camera (used to document team members' flight experience)	3.00
Personal Camera (used to document team members' flight experience)	3.00
Iowa State University Flag (mounted to KC-135 wall near the experiment assembly; used to show Cyclone Pride!)	0.50
Approximate Total Other Flight Equipment Weight	**8.63**

4.2 Ground Equipment

The ground equipment will include tools, a toolbox, and a cooler. All tools will be labeled with the owner's name, and the tool box will be labeled with the owner's identification. The cooler will be appropriately labeled with its contents and marked with the owner's identification.

4.3 Equipment Layout

We propose to place our experimental setup in fuselage stations 760-800 (see **Figure 3**). We request that the experiment setup be oriented so that the motor is aft and the storage container is forward. Restraints for the experimenters should be placed on the right side of the experiment setup (see **Figure 3**). The position of the experiment setup will not change for take off, landing, or during the parabolas. Experimenters will take their appropriate positions around the experiment setup only during the parabolic portions of the flight.

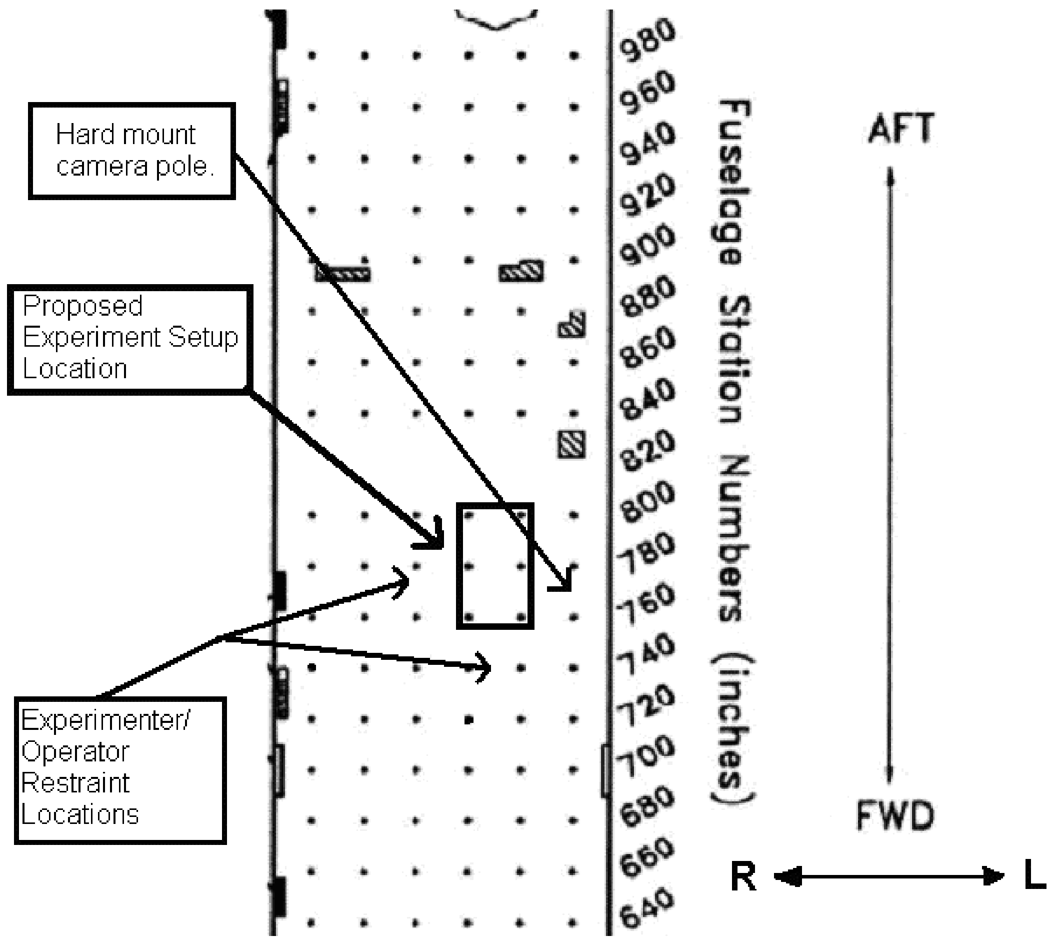

Figure 3. This figure shows the proposed placement of the experiment setup and experimenter/operator restraint locations. The experiment setup is 40 inches from the left wall of the fuselage and spans Fuselage Station Numbers 760-800. The experiment/operator restraints are located on the right and front sides of the experiment setup. A hard mount camera pole is requested on the left side of the experiment assembly.

4.4 Lasers

No lasers will be used for this experiment.

4.5 Fluids

The soybeans used in the experiment will be specially prepared off of the JSC/Ellington Field campus. This preparation, similar to the first steps in making soymilk, includes soaking the soybeans in water for 8 hours followed by cooking the beans in boiling water for 10 minutes. After cooking, the beans will be drained, measured into 6 oz portions, and vacuum sealed into custom plastic bags.

After blending, the beans will be partially liquefied. The viscous blended slurry with the residual water from soaking and boiling constitutes the fluid component of our experiment. The blended beans will be stored in a storage container beneath the blending mechanism (see **Figure 2B** #42). The amount of liquefied beans per bag after blending is estimated at approximately 6 fl oz which meets the requirement for not needing double containment (AOD 33897 section 2.12). However, the team is keeping all bags in a secondary containment as an extra precautionary method. Absorbent material will also be present in the blending portion of the experiment assembly.

Twenty-four zip locking bags (one for each blending bag) will be brought along on the flight for the unlikely scenario of a bag rupture. If a bag rupture occurs during a zero g portion of the flight, cleanup will wait until the parabola is complete. Once gravity is present, the containment will be broken, the ruptured bag will be sealed in a zip locking bag, stored in the storage container, and the containment area will be wiped with absorbent paper.

4.6 Chemicals

No chemicals will be used for this experiment.

4.7 Pressure Vessels

Pressure vessels for this experiment consists of 24 vacuum sealed 3.2 ml polyethylene 10 in. x15 in. bags (each containing 6 oz of pre-prepared soybeans).

4.8 Special Requirements

No ground based or flight based special requirements are needed for this experiment.

4.9 Free Float

This experiment will not free float.

5. Structural Analysis

The structural analysis of the design was completed using several different methods due to the various structural situations presented by the design. Finite element analysis using the computer program Cosmos was utilized to confirm the structural integrity of the support structure and pull testing was utilized to verify the structural integrity of the blender.

5.1 Free Body Diagrams

Free body diagrams were used to estimate loads applied by each component attached to the support structure for each load case. These estimates were entered into Cosmos to complete the structural analysis using finite element analysis (see section 5.3).

5.1.1 9 g Forward Load

Shown below are the free body diagrams and accompanying calculations used to obtain the approximate structural loads for the 9g forward load case.

5.1.1.1 NEMA 4X Enclosure

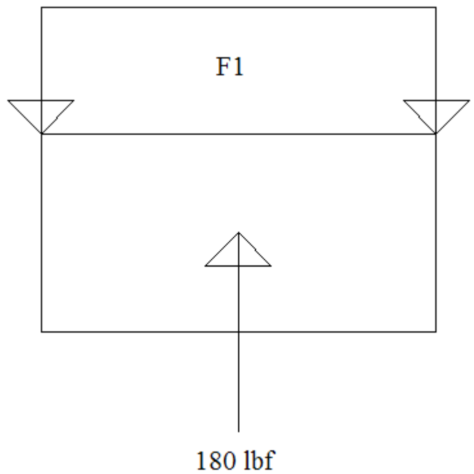

Figure 4. 9 g forward NEMA 4X enclosure FBD.

The approximate weight of the NEMA 4X enclosure is 20 lbs and its center of mass is approximated to be at its geometric center.

The force applied to the center of mass of the enclosure is:

20 lbf * 9 = 180 lbf

Summing forces for the enclosure yields:

$\sum F = 180 \text{ lbf} - F1 = 0$

Solving yields: F1 = 180 lbf

180 lbf / (2 * 24 in) = 3.75 lbf / in^2

This force is applied over the area of the metal support straps

5.1.1.2 Blender

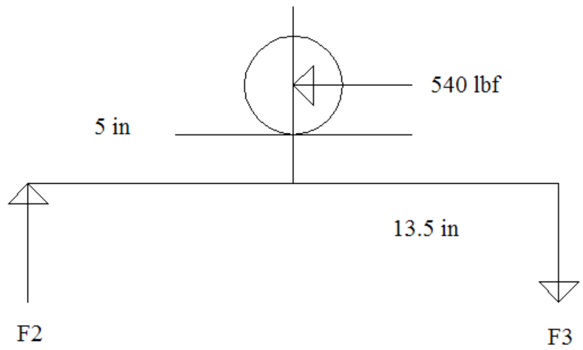

Figure 5. 9g forward blender FBD.

The approximate weight of the blender without the motor is 60 lbs. The assembled blender's center of mass is approximated to be at the center of the blending wheel.

The force applied at the center of mass of the blender is:

60 lbf * 9 = 540 lbf

Summing forces and moments for the blender yields:

$\sum F = F2 - F3 = 0$

$\sum M = F2 * 13.5 \text{ in} + F3 * 13.5 \text{ in} - 540 \text{ lbf} * 5 \text{ in} = 0$

Solving yields: F2 = F3 = 100 lbf

The forces due to the moment applied by the 9g forward load are applied to surface of the blender support rack bars and the faces of the twenty bolt holes that fasten the blender to the support structure.

100 lbf / (2 * 22 in) = 2.27 lbf / in^2

540 lbf / 20 = 27.0 lbf / hole

5.1.1.3 Motor and Drive Components

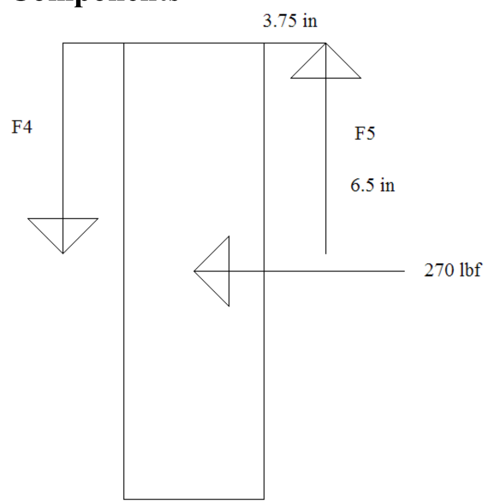

Figure 6. 9 g forward motor and drive components FBD.

The approximate weight of the motor and corresponding drive components is 30 lbs. The center of mass of the motor and drive components is approximated as the center of the motor.

The forces applied at the center of mass of the motor is:

30 lbf * 9 = 270 lbf

Summing forces and moments for the motor yields:

∑ F = F4 – F5 = 0

∑ M = F4 * 3.75 in + F5 * 3.75 in – 270 lbf * 6.5 in

Solving yields: F4 = F5= 234 lbf

The forces due to the moment applied by the 9 g forward load on the motor are applied to the faces of the motor support rack bars and the faces of the eight bolt holes which fasten the motor and drive components to the support structure.

234 lbf / 22 in = 10.6 lbf / in^2 270 lbf / 8 = 33.8 lbf / hole

5.1.1.4 Soybean Blending Bag Storage container

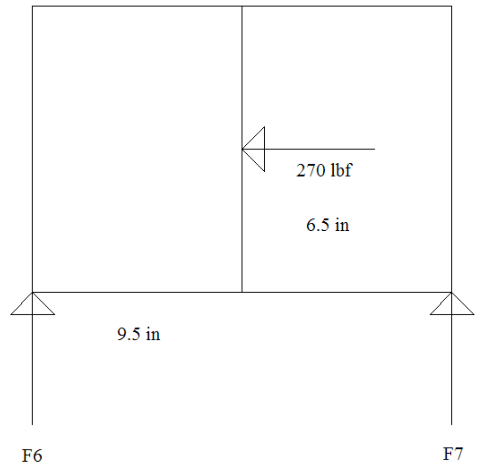

Figure 7. 9 g forward storage container FBD.

The weight of the soybean blending bag storage container with soybeans is approximately 30 lbs. The forces applied by the ratchet straps, which will hold the container inside the frame, are approximated as point forces applied to the four vertices of the two attachments on each container support bar. The center of mass of the container is approximated at its geometric center.

The force applied at the center of gravity of the storage container is:

30 lbf * 9 = 270 lbf

Summing forces and moments for the container yields:

$\sum F = F6 - F7 = 0$

$\sum M = F6 * 9.5 \text{ in} + F7 - 270 \text{ lbf} * 6.5 \text{ in} = 0$

Solving yields: F6 = F7 = 92.4 lbf

The forces applied to the vertices of the support bars are:

92.4 lbf / 4 =23.09 lbf / vertex

5.1.2 6 g Down Load

Shown below are the free body diagrams and corresponding calculations used to determine the approximate structural loading for the 6 g down load case.

5.1.2.1 NEMA 4X Enclosure

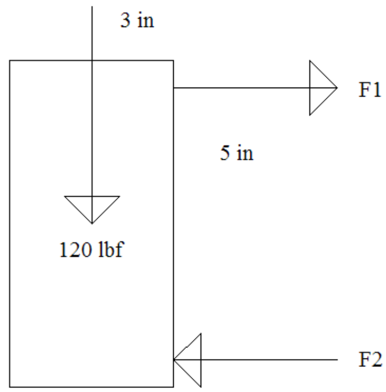

Figure 8. 6 g down NEMA 4X enclosure FBD.

The approximate weight of the NEMA 4X enclosure is 20 lbs and its center of mass is approximated to be at its geometric center.

The force applied to the center of mass of the motor is:

20 lbf * 6 = 120 lbf

Summing forces and moments for the electrical panel yields:

$\sum F = F1 - F2 = 0$

$\sum M = F1 * 5\text{ in} + F2 - 120\text{ lbf} * 3\text{ in} = 0$

Solving yields: F1 = F2 = 36.0 lbf

The forces due to the 6 g downward load are applied to the surface of the two electrical panel mounting straps and the faces of the four bolt holes (which fasten the panel to the structure).

36.0 lbf / 24 in = 1.50 lbf / in^2 120 lbf / 4 = 30 lbf / hole

5.1.2.2 Blender

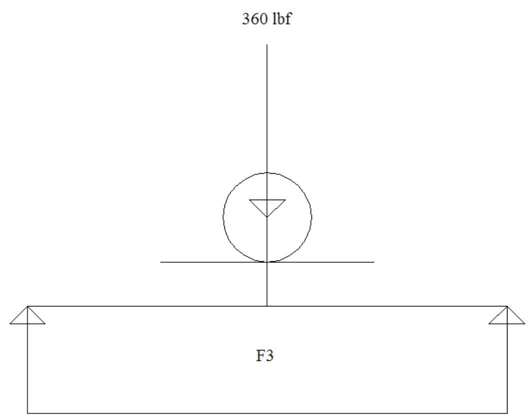

Figure 9. 6 g down blender FBD.

The approximate weight of the blender without the motor is 60 lbs. The forces are applied over the five blender mounting bars.

60 lbf * 6 = 360 lbf

Summing forces yields: $\sum F = F3 - 360 \text{ lbf} = 0$

Solving yields: F3 = 360 lbf

The force is applied over the area of the blender mounting rack.

360 lbf / (5 * 22 in) = 3.27 lbf / in^2

5.1.2.3 Motor and Drive Components

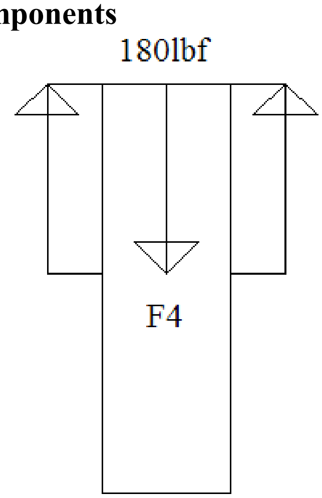

Figure 10. 6 g down motor and drive components FBD.

The approximate weight of the motor and corresponding drive components is 30 lbs. The forces due to the 6 g downward load are applied over the two bars of the motor mounting rack.

The force applied at the center of mass of the motor is:

30 lbf * 6 = 180 lbf

Summing forces yields:

$\sum F = 180 \text{ lbf} - F4 = 0$

Solving yields: F4 = 180 lbf

The force is applied over the area of the motor mounting rack.

180 lbf / (2 5.5 in) = 16.4 lbf / in^2

5.1.2.4 Soybean Blending Bag Storage Container

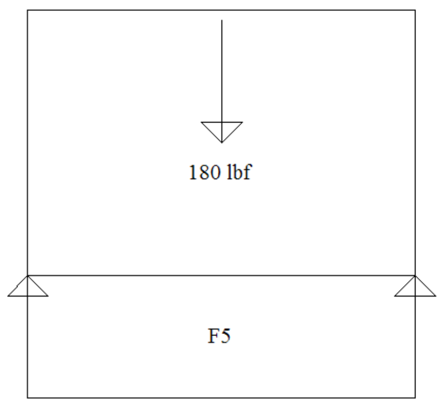

Figure 11. 6 g down storage container FBD.

The weight of the soybean blending bag storage container with soybeans is approximately 30 lbs. The force applied by the container on the structure by the 6 g downward load is applied over the two bars of the container support rack. The center of mass of the container is approximated at its geometric center.

The force applied to the center of mass by the 6g downward load is:

30 lbf * 6 = 180 lbf

Summing forces yields:

$\sum F = F5 - 180 \text{ lbf} = 0$

Solving yields: F5 = 180 lbf

The force is applied over the area of the bars of the container support rack.

180 lbf / (2* 19 in) = 4.74 lbf / in^2

5.1.3 2 g Lateral Load

Shown below are the free body diagrams and calculations associated with the loads applied to the support structure by the 2 g lateral loading situation.

5.1.3.1 NEMA 4X Enclosure

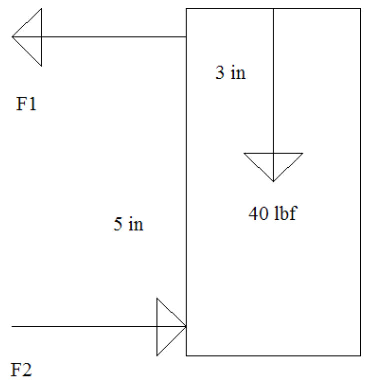

Figure 12. 2 g lateral NEMA 4X enclosure FBD.

The approximate weight of the NEMA 4X enclosure is 20 lbs and its center of mass is approximated to be at its geometric center

The force applied to the center of mass of the enclosure is:

20 lbf * 2 = 40 lbf

Summing forces and moments yields:

$\sum F = - F1 + F2 = 0$

$\sum M = F1 * 5 \text{ in} + F2 * 5 \text{ in} + 40 \text{ lbf} * 3 \text{ in} = 0$

Solving yields: F1 = F2 = 12 lbf

The forces generated by the 2 g lateral load are applied over the surface and the faces of the bolt holes of the NEMA 4X enclosure support rack.

12 lbf / 24 in = .500 lbf / in^2 40 lbf / 4 = 10 lbf / hole

5.1.3.2 Blender

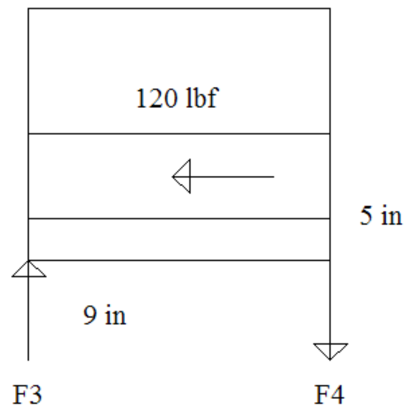

Figure 13. 2 g lateral blender FBD.

The approximate weight of the blender without the motor is 60 lbs. The center of mass of the blender is approximated at the center of the blending wheel.

The force applied to the center of mass of the blender is:

60 lbf * 2 = 120 lbf

Summing and forces and moments for the blender yields:

$\sum F = F3 - F4 = 0$

$\sum M = F3 * 9 \text{ in} + F4 * 9 \text{ in} - 120 \text{ lbf} * 5 \text{ in} = 0$

Solving yields: F3 = F4 = 33.3 lbf

The force applied to the center of the blender is applied to the surface of the blender support rack and the faces of the bolt holes in the blender support rack.

$33.3 \text{ lbf} / (39 \text{ in} * 1 \text{ in}) = .846 \text{ lbf} / \text{in}^2$ 120 lbf / 20 = 6 lbf / hole

5.1.3.3 Motor and Drive Components

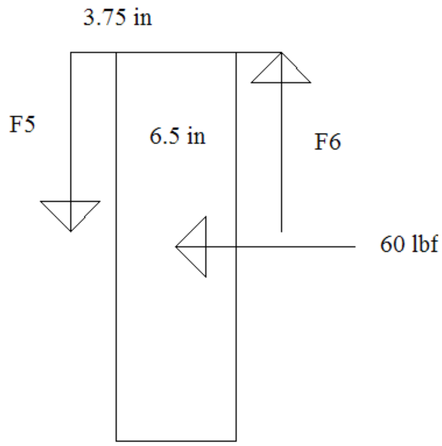

Figure 14. 2 g lateral motor and drive components FBD.

The approximate weight of the motor and corresponding drive components is 30 lbs. The center of mass of the motor is approximated as the geometric center of the motor.

The force applied at the center of mass is:

30 lbf * 2 = 60 lbf

Summing forces and moments yields:

$\sum F = F6 - F5 = 0$

$\sum M = F6 * 9 \text{ in} + F5 * 9 \text{ in} - 60 \text{ lbf} * 6.5 \text{ in} = 0$

Solving yields: F5 = F6 = 52.0 lbf

The forces applied to the structure by the 2g horizontal load are applied over the surface of the motor support rack and the faces of eight bolt holes in the support rack.

52.0 lbf / (5.5 in) = 9.45 lbf / in^2 60 lbf / 8 = 7.50 lbf / hole

5.1.3.4 Soybean Blending Bag Storage Container

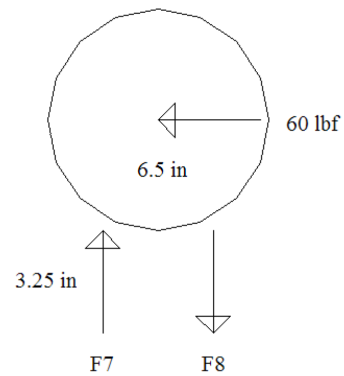

Figure 15. 2 g lateral storage container FBD.

The weight of the soybean blending bag storage container with soybeans is approximately 30 lbs. The center of mass of the container is approximated to be at its geometric center.

The force applied to the center of gravity of the storage container is:

30 lbf * 2 = 60 lbf

Summing forces and moments yields:

$\sum F = F7 - F8 = 0$

$\sum M = F7 * 3.25\text{ in} + F8 * 3.25\text{ in} - 60\text{ lbf} * 6.5\text{ in} = 0$

Solving yields: F7 = F8 = 60 lbf

The forces applied by the storage container are distributed over the container support rack.

$60\text{ lbf} / (19\text{ in} * 1\text{ in}) = 3.16\text{ lbf} / \text{in}^2$

5.1.4 2 g Up Load/3 g Aft Load

Due to the relative symmetry of the both the support structure and the components attached to the support structure during the experiment and in the interest of brevity the calculations and free body diagrams for both the 2g up and 3g aft loads have been omitted. The approximate loads applied to the support structure by the attached equipment are listed in the tables below:

Table 3. 2g Up Load.

Equipment	Force at CM	Surface Area	Bolt Holes	lbf / in^2	lbf / hole
Electrical Panel	40 lbf	24 in^2	4	.500	10.0
Blender	120 lbf	110 in^2	20	NA	6.00
Motor	60 lbf	11.0 in^2	8	NA	7.50
Bean Storage Container	60 lbf	19 in^2	0	1.59	NA

Table 4. 3g Aft Load.

Equipment	Force at CM	Surface Area	Bolt Holes	lbf / in^2	lbf / hole
Electrical Panel	60 lbf	24 in^2	4	NA	15.0
Blender	180 lbf	44 in^2	20	.758	9.00
Motor	90 lbf	22 in^2	8	3.55	11.3
Bean Storage Container	90 lbf	19 in^2	NA	NA	7.70 lbf / vertex

5.2 Component/ Assembly Weight

See **Table 1**.

5.3 Support Frame Analysis

The information from the free body diagrams (see section 5.1 above) was entered into Cosmos to simulate the g load cases on the SolidWorks model of the experiment support structure. The structure is modeled and constructed with 1 inch square mild carbon steel tubing that has a wall thickness of 1/8 inch. All joints will have been tig or mig welded by a certified welder (see Appendix I) depending on the specific requirement/geometry of each joint. A brief explanation of each structural inquiry is shown below.

The 9g forward load was obviously the most strenuous of the loading scenarios and was the only test that did not yield a factor of safety above 2 (the as tested factor of safety was 1.1). The reason for this low factor of safety was the fact that washers, which will be used to fasten the support structure to the plane, were not taken into account in the model. This produced unreasonably high stress concentrations around the six aircraft attachment bolt holes. The bolt holes were the only areas where the factor of safety was below 2 (see **Figure 18**). All other tests revealed minimum factors of safety well above 2. The results of all the tests are shown in the figures below and are also summarized in **Table 5**.

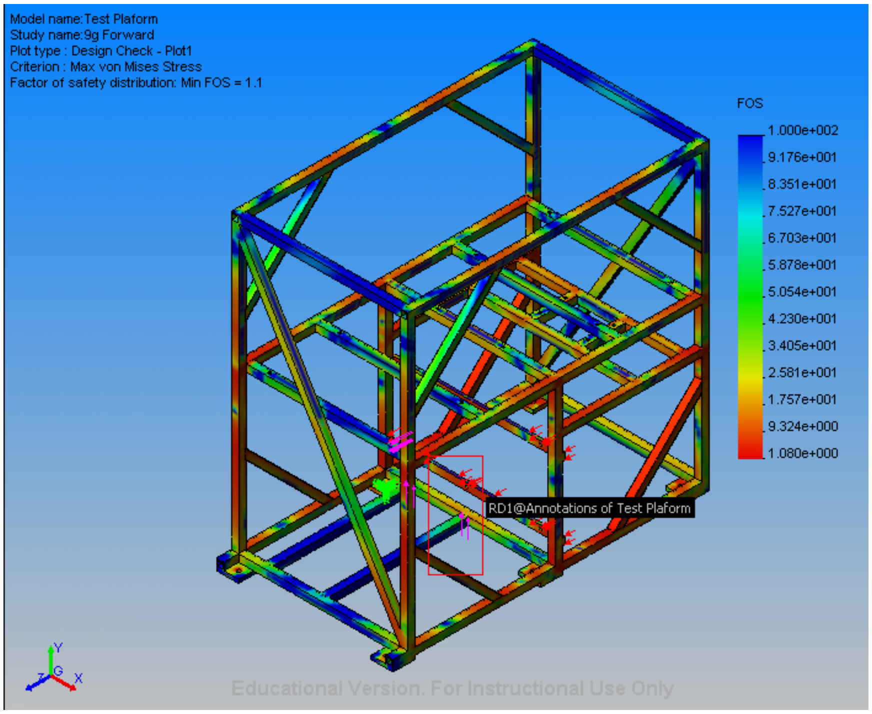

Figure 16. 9 g Forward Load factor of safety distribution.

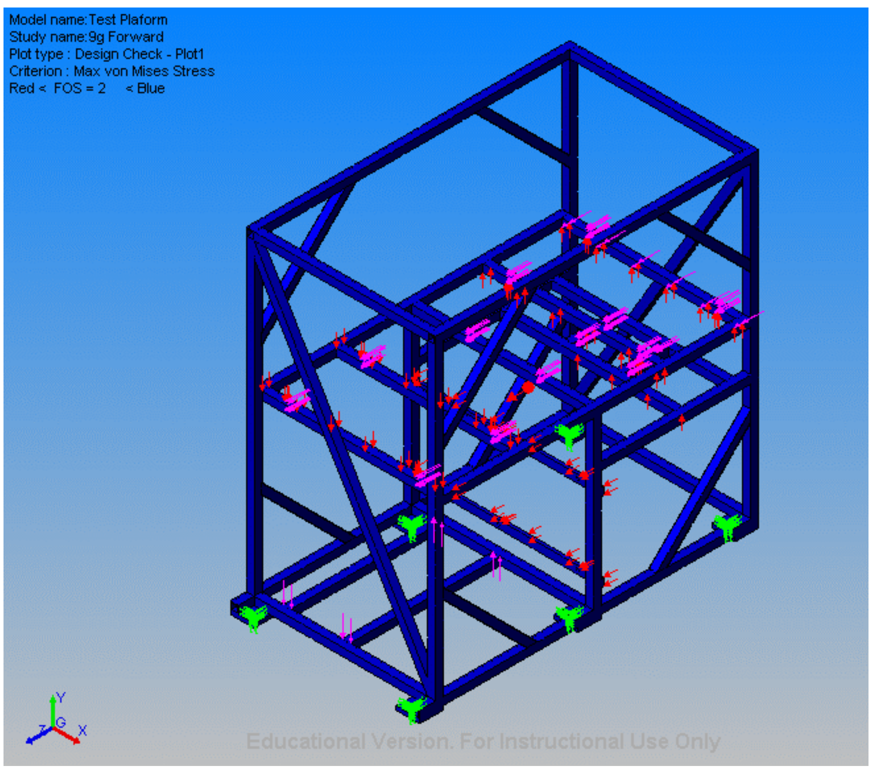

Figure 17. 9 g Forward Load support frame loading case.

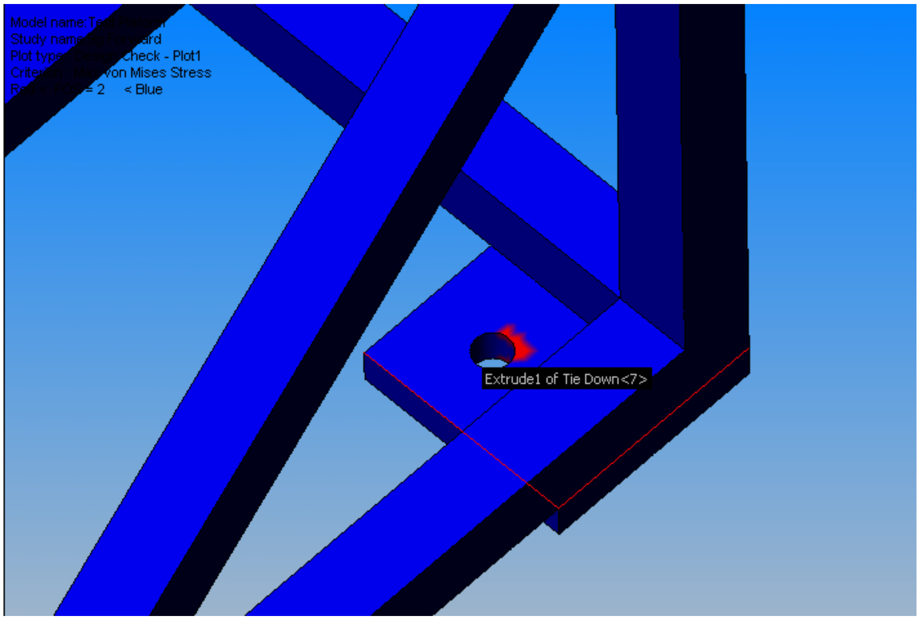

Figure 18. Bolt hole displaying (red) area that has a factor of safety less than 2 (9 g Forward Load).

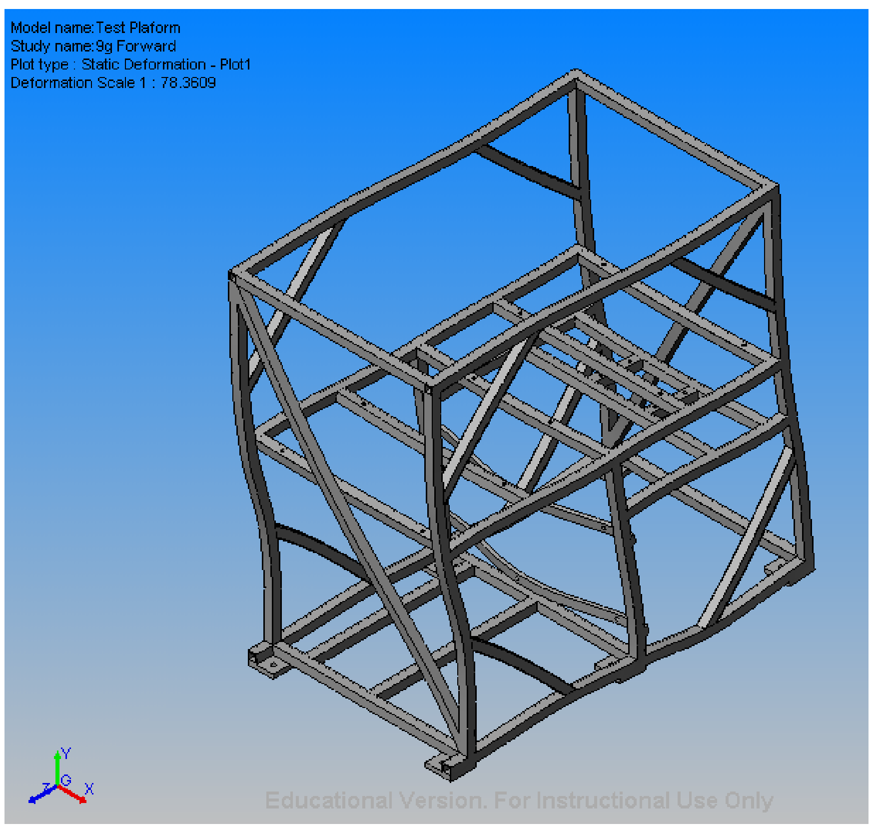

Figure 19. 9 g Forward Load vastly exaggerated support frame deformation.

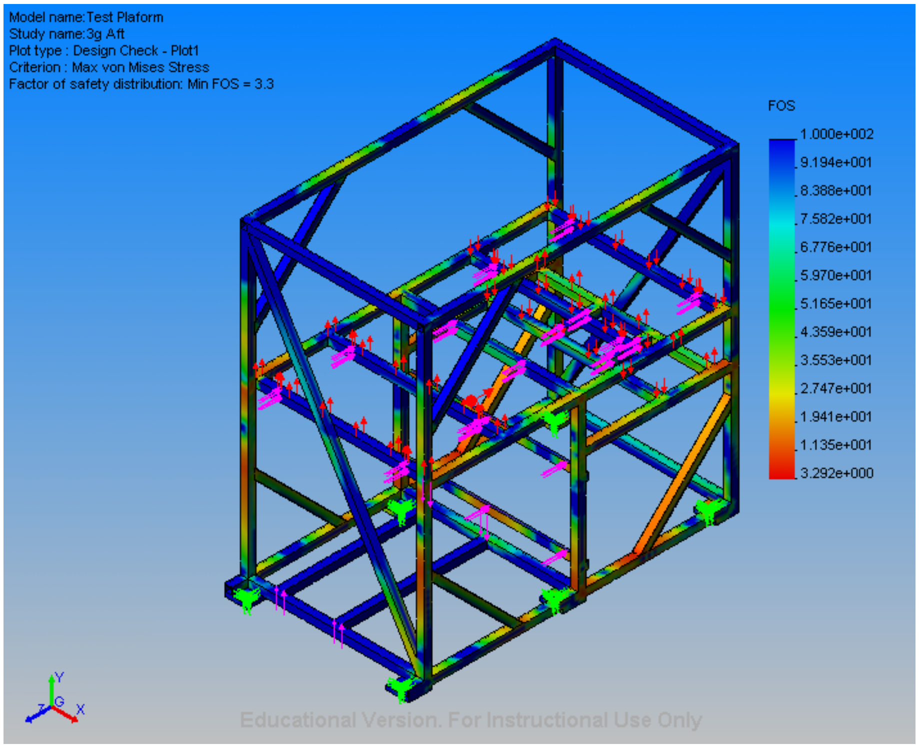

Figure 20. 3 g Aft factor of safety distribution.

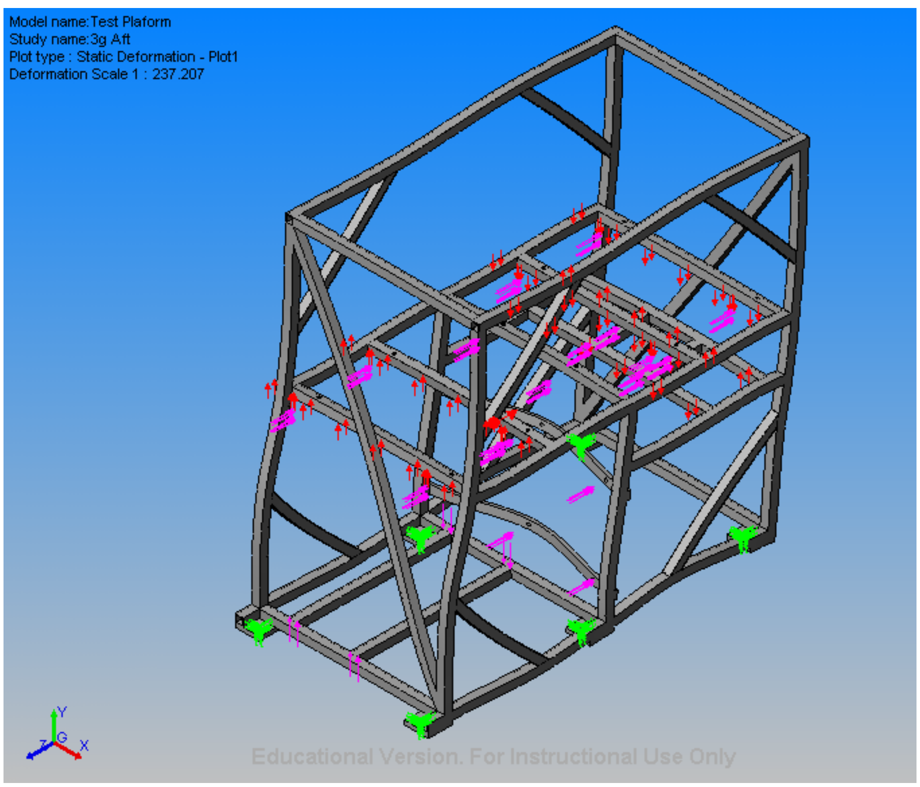

Figure 21. 3 g Aft vastly exaggerated deformation of support frame.

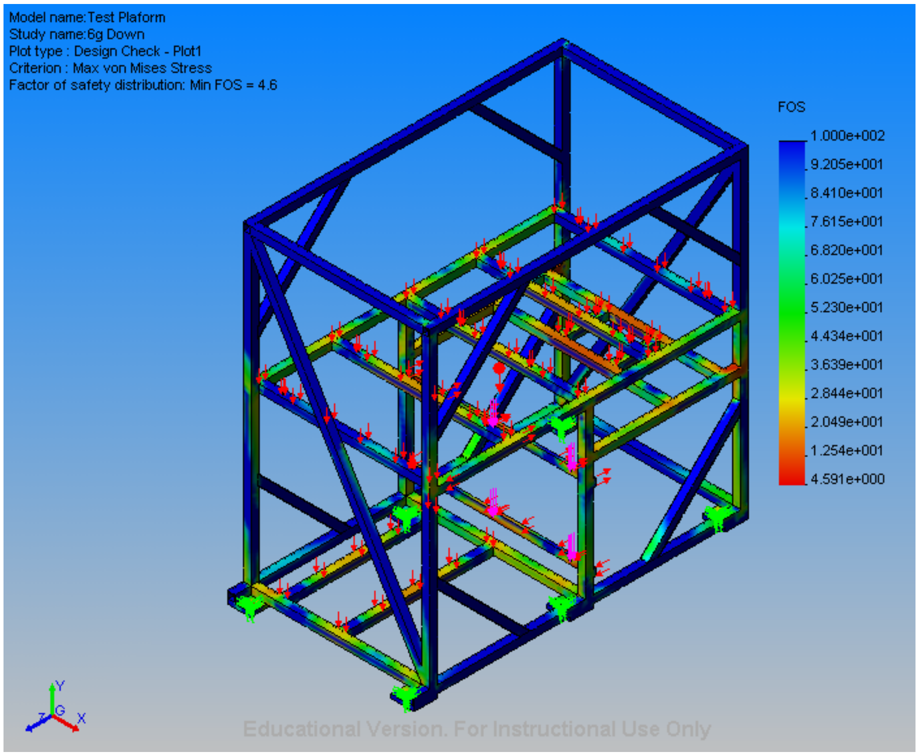

Figure 22. 6 g Down factor of safety distribution.

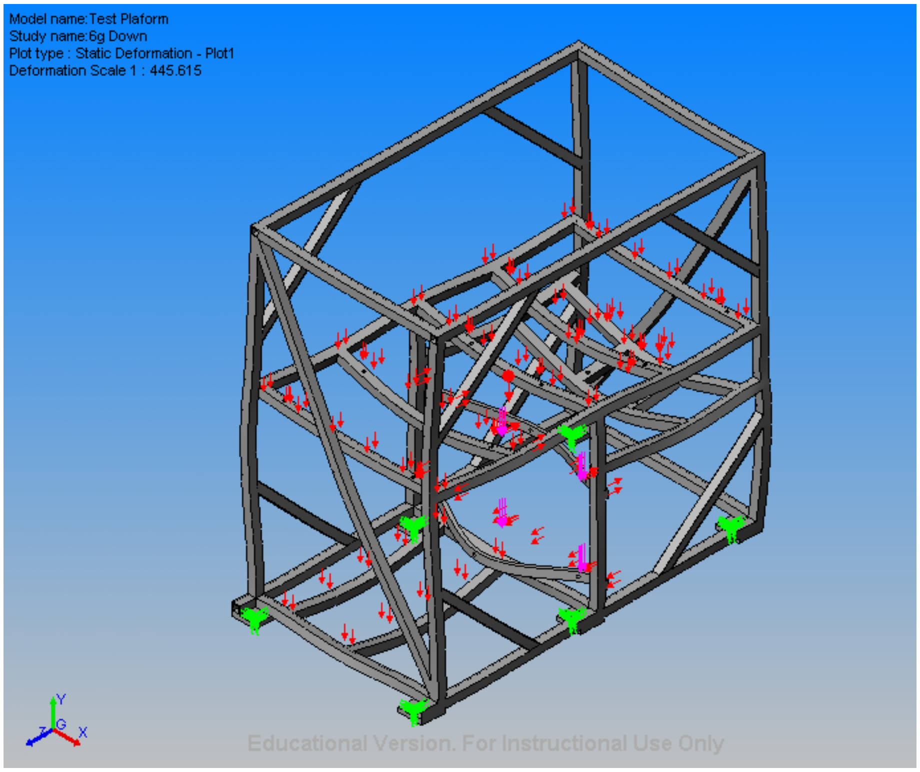

Figure 23. 6 g Down vastly exaggerated deformation.

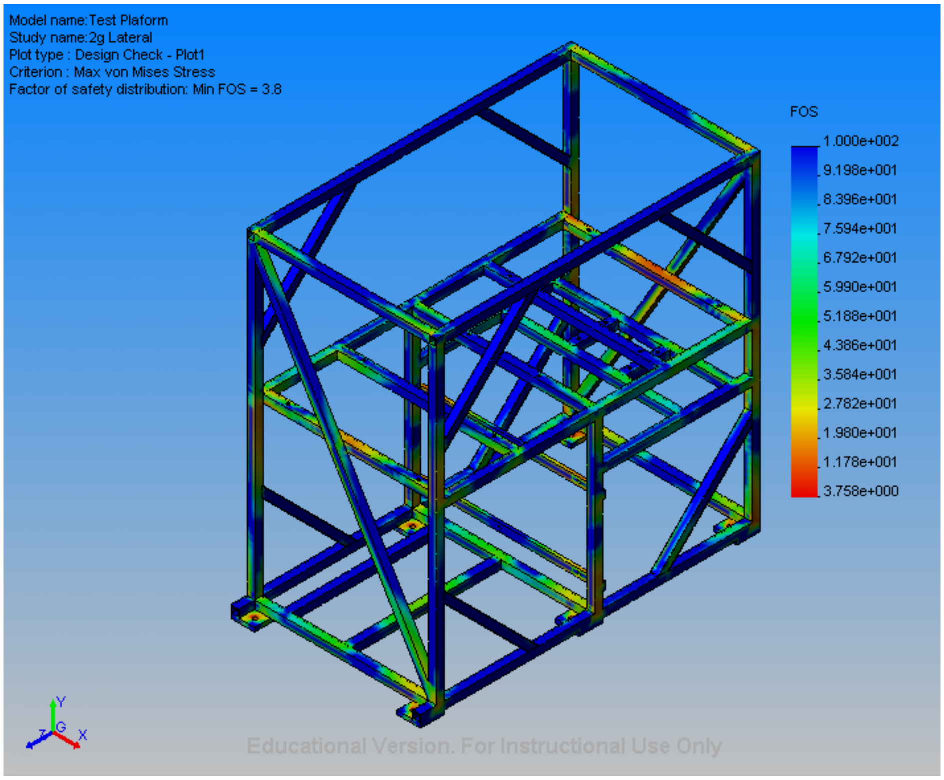

Figure 24. 2 g lateral factor of safety distribution.

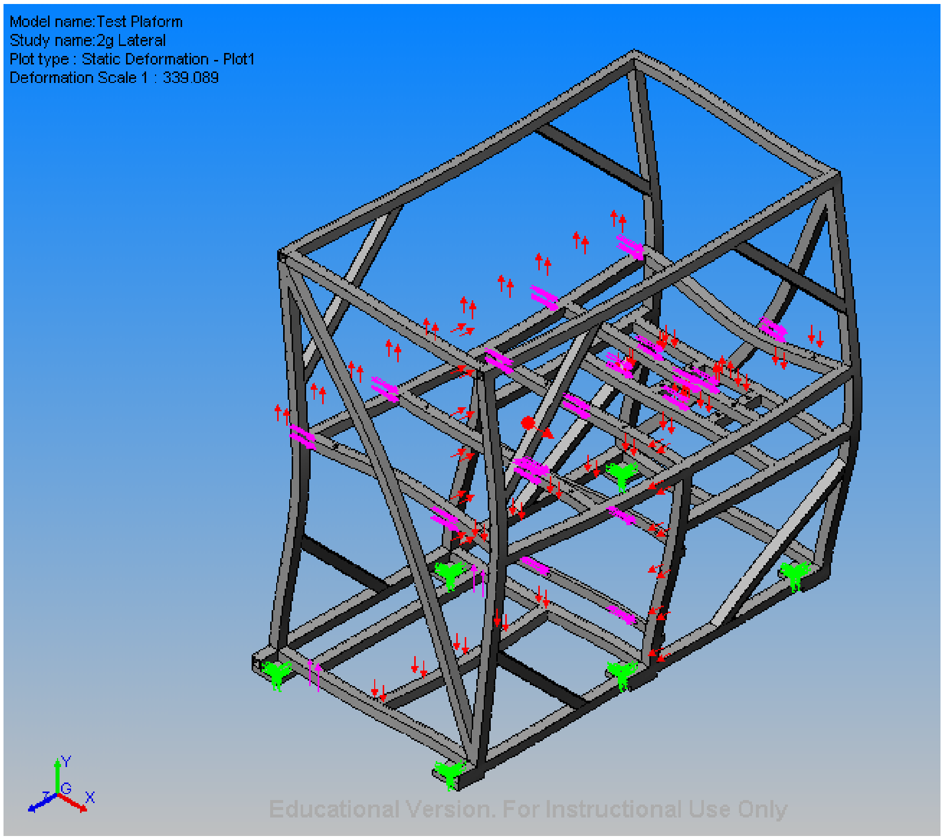

Figure 25. 2 g lateral vastly exaggerated deformation.

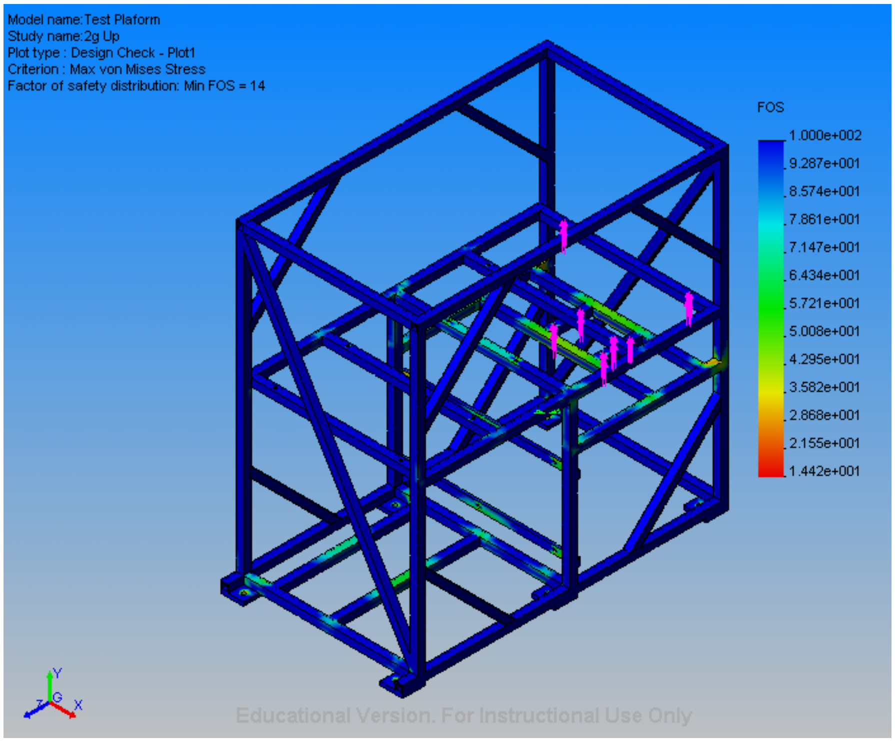

Figure 26. 2 g Up factor of safety distribution.

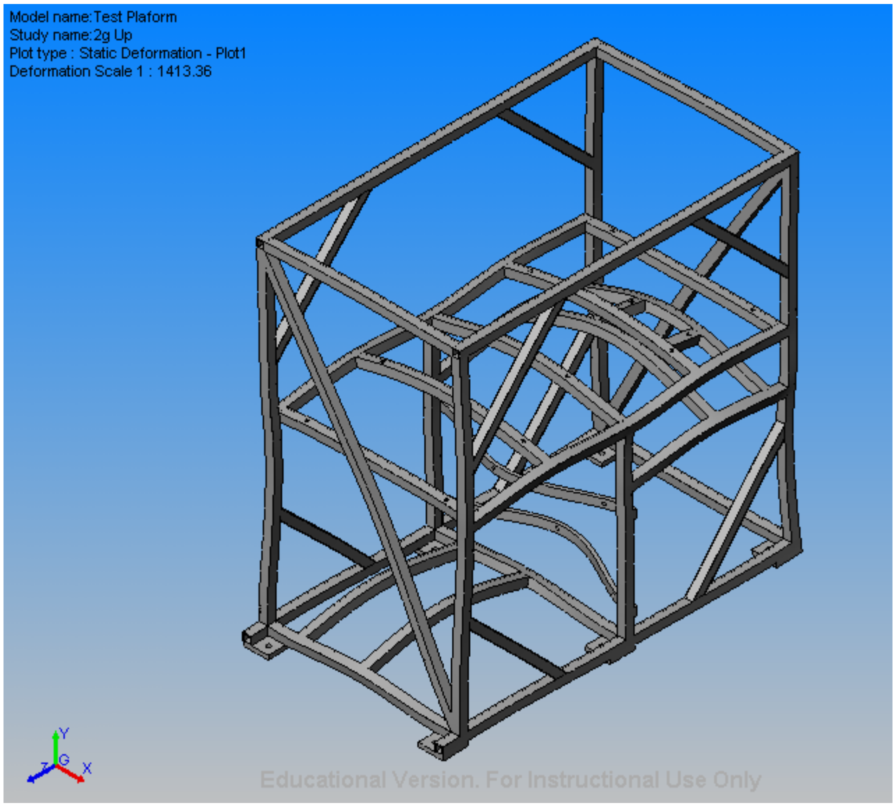

Figure 27. 2 g Up vastly exaggerated deformation

Table 5. Minimum Factor of Safety.

Loading Situation	Minimum Factor of Safety
9g Forward	1.1
3g Aft	3.3
6g Down	4.6
2g Lateral	3.8
2g Up	14

5.4 Pull Test

Pull testing was performed on components of the blender and focused on attachment points. G-loads were simulated by first calculating the component weight, multiplying by the appropriate g factor, and hanging weights of the same or greater magnitude from the component's approximate center of gravity. Labeled weights were used to hang from the components. The component was given a "Pass" rating if no joint failures or component deformations were observed. Each component pull test was documented with a digital photograph of the test. Pull testing was performed on May 23, 2004 by team members David Chipman and Kevin Schroeder.

5.4.1 Assumptions

Since the parts tested are symmetrical, it is assumed that parts able to pass the 9 g forward load are also able to pass the 3 g aft load. Therefore, 3 g aft load tests are not shown.

5.4.2 Results

Table 6. Pull test results.

Component Tested	Weight of Component (lbs)	g load	Calculated Load of Hanging Mass (lbs)	Actual Load Applied for Test (lbs)	Pass/ No Pass	Figure Reference
Lift Bar	0.64	9 g fwd	5.75	9.78	Pass	**Figure 28**
		6 g down	3.83	4.89	Pass	
	9.31* (blending wheel axle assembly, 2 bearing adapter plates with bearings, and lift bar)	2 g lat *	18.62	19.56	Pass	
		2 g up	1.28	4.89	Pass	
Support Bar	2.10	9 g fwd	18.90	19.56	Pass	
		6 g down	12.60	14.67	Pass	
	9.31*	2 g lat *	18.62	19.56	Pass	

	(blending wheel axle assembly, 2 bearing adapter plates with bearings, and lift bar)				
	1.88* (vertical support shaft)	2 g lat *	3.76	4.89	Pass
		2 g up	4.20	4.89	Pass
Blending wheel axle assembly (blending wheel and axle)	5.03	9 g fwd	45.43	50.00	Pass
		6 g down	30.18	34.45	Pass
	9.31* (blending wheel axle assembly, 2 bearing adapter plates with bearings, and lift bar)	2 g lat *	18.62	19.56	9.31
		2 g up	10.05	14.70	Pass
Blending plate and 4 bearings	6.15	9 g fwd	55.35	55.00	Pass
		6 g down	36.90	39.45	Pass
		2 g lat	12.30	14.67	Pass
		2 g up	12.30	14.67	Pass
Guide rods and holders	8.20	9 g fwd **	36.4	39.45	Pass
		6 g down	49.20	50.00	Pass
		2 g lat *** (on 1 rod)	8.20	9.87	Pass
		2 g up	16.40	19.56	Pass

*Hanging the weight from the components' center of gravity for the lateral 2 g pull test was not always possible to do. In these cases (for the lift bar, support bar, and blending wheel axle assembly), hanging from the center of gravity would require destroying the component (drilling into rods, etc.). Therefore similar lateral 2 g tests were performed at locations that stressed the connection points of the components in question.

**For the guide rods and holders 9 g forward test, the weight could not be hung from the center of mass without drilling into and destroying the guide rods. Therefore, to test these components, we simulated a 9 g forward load on 2 of the 4 holders using the weight of 2 holders and 1 guide rod (2 half lengths of the guide rods) to calculate the load.

***For the guide rods and holders 2 g lateral test, the 2 g load was applied to one guide rod due to test apparatus limitations.

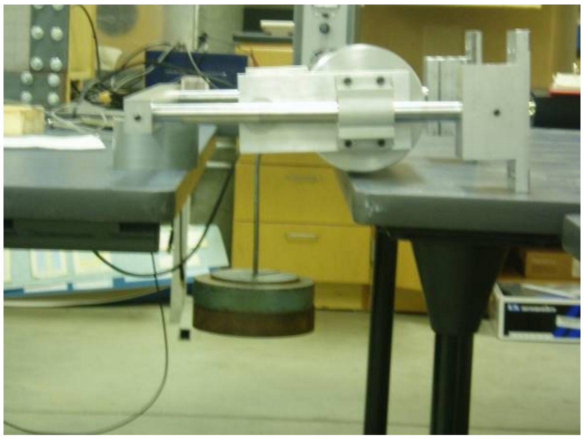

Figure 28. Lift bar 9 g's forward.

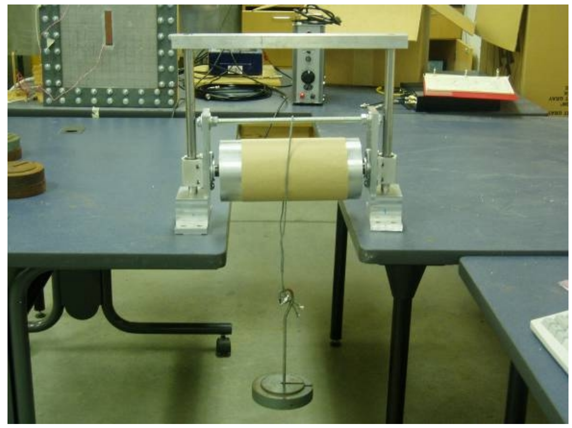

Figure 29. Lift bar 6 g's down.

Figure 30. Lift bar 2 g's up.

Figure 31. Support bar 9 g's forward.

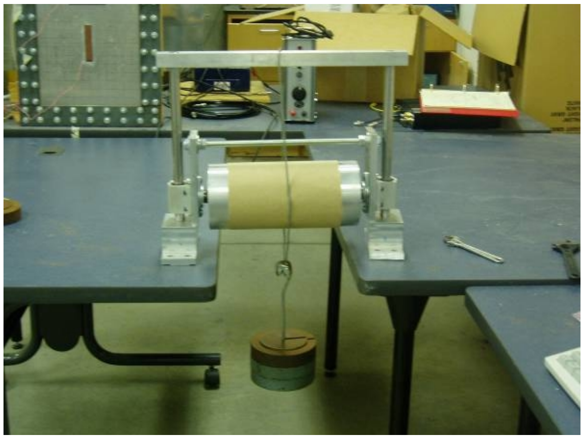

Figure 32. Support bar 6 g's down.

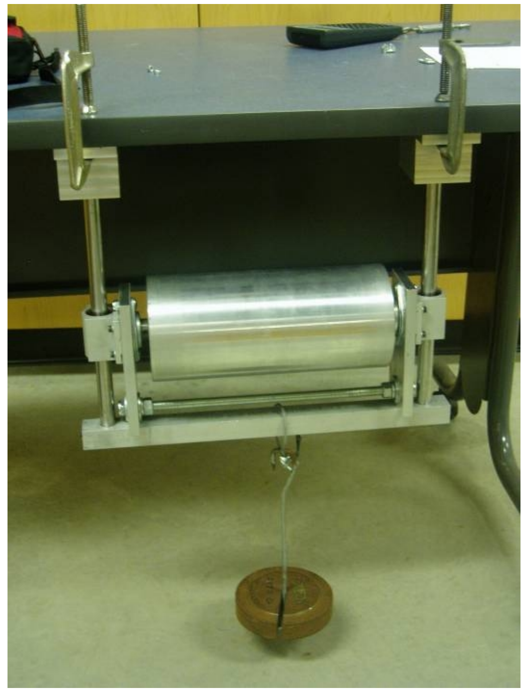

Figure 33. Support bar 2 g's up.

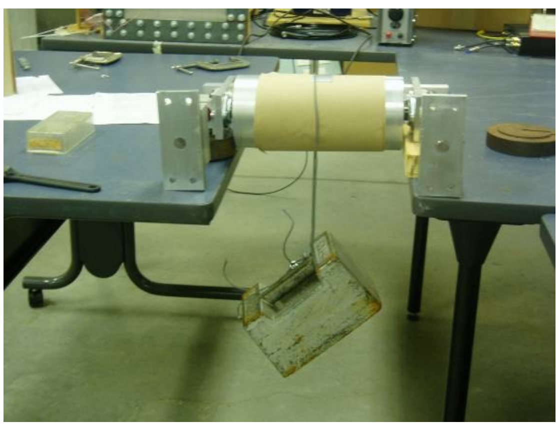

Figure 34. Blending wheel axle assembly 9 g's forward.

Figure 35. Blending wheel axle assembly 6 g's down.

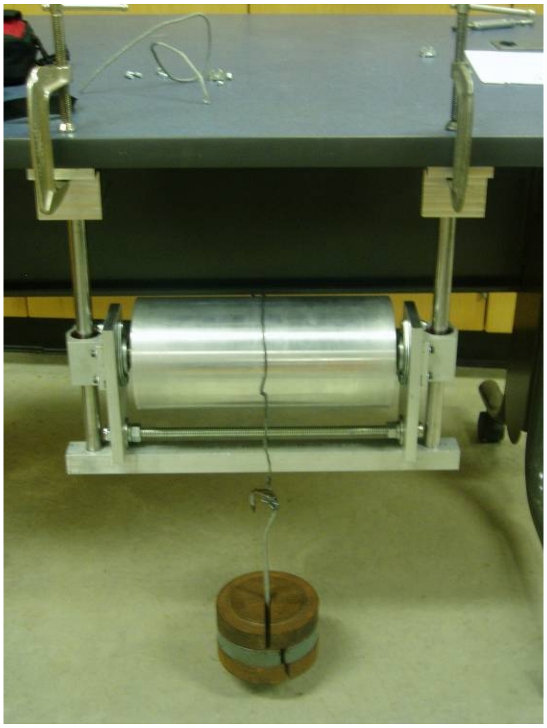

Figure 36. Blending wheel axle assembly 2 g's up.

Figure 37. Blending plate and bearings 9 g's forward.

Figure 38. Blending plate and bearings 6 g's down.

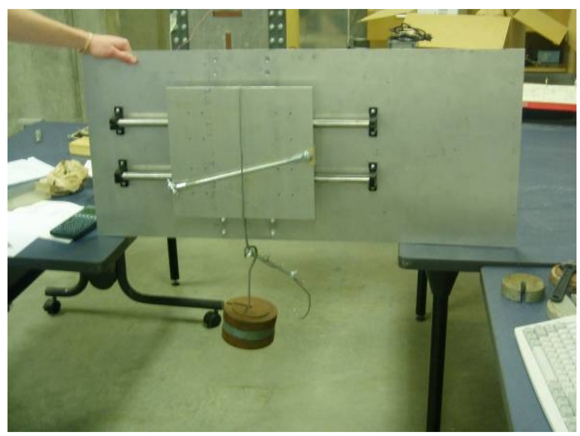

Figure 39. Blending plate and bearings 2 g's lateral.

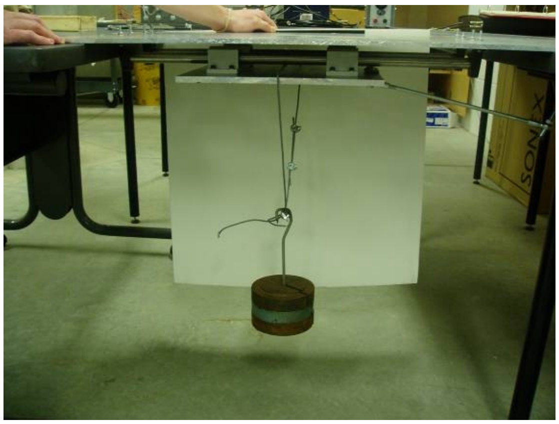

Figure 40. Blending plate and bearings 2 g's up.

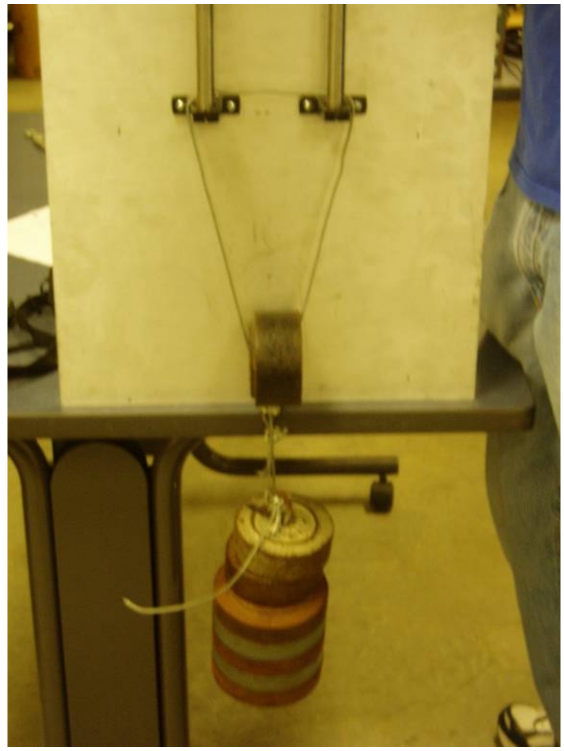

Figure 41. Guide rods and holders 9 g's forward. To prevent drilling into the guide rods, the load was applied to two holders.

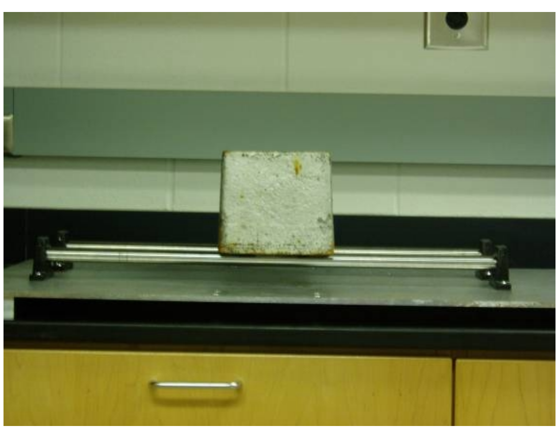

Figure 42. Guide rods and holders 6 g's down.

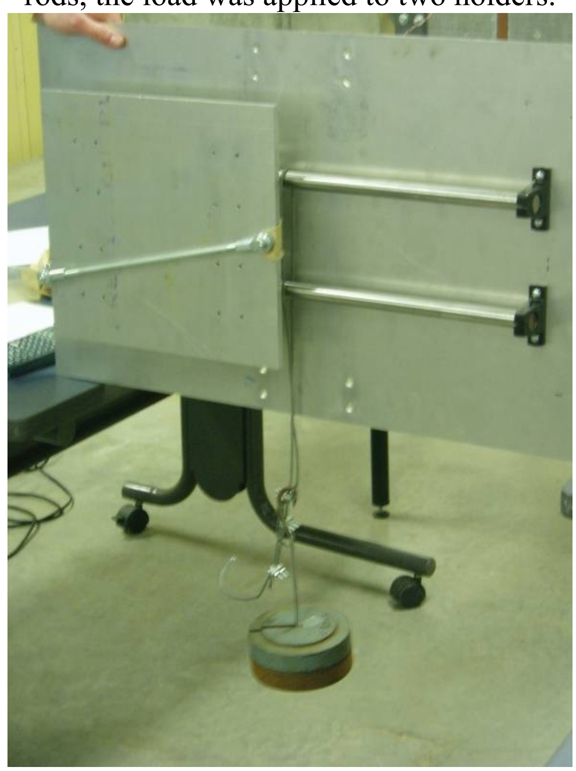

Figure 43. Guide rods and holders 2 g's lateral. The load was applied to one guide rod due to test limitations.

Figure 44. Guide rods and holders 2 g's up.

Figure 45. Modified 2 g's lateral test for lift bar, support bar, and blending wheel axle assembly.

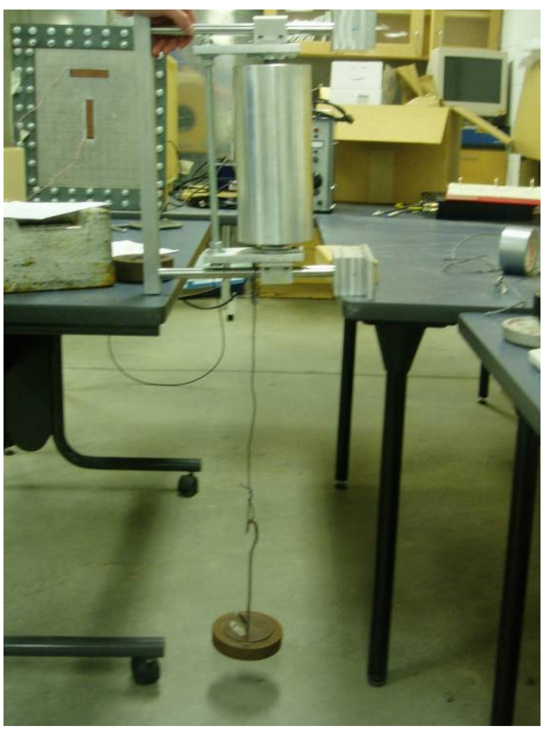

Figure 46. Modified 2 g's lateral test for lift bar, support bar, and blending wheel axle assembly.

6. Electrical Analysis

6.1 Schematic

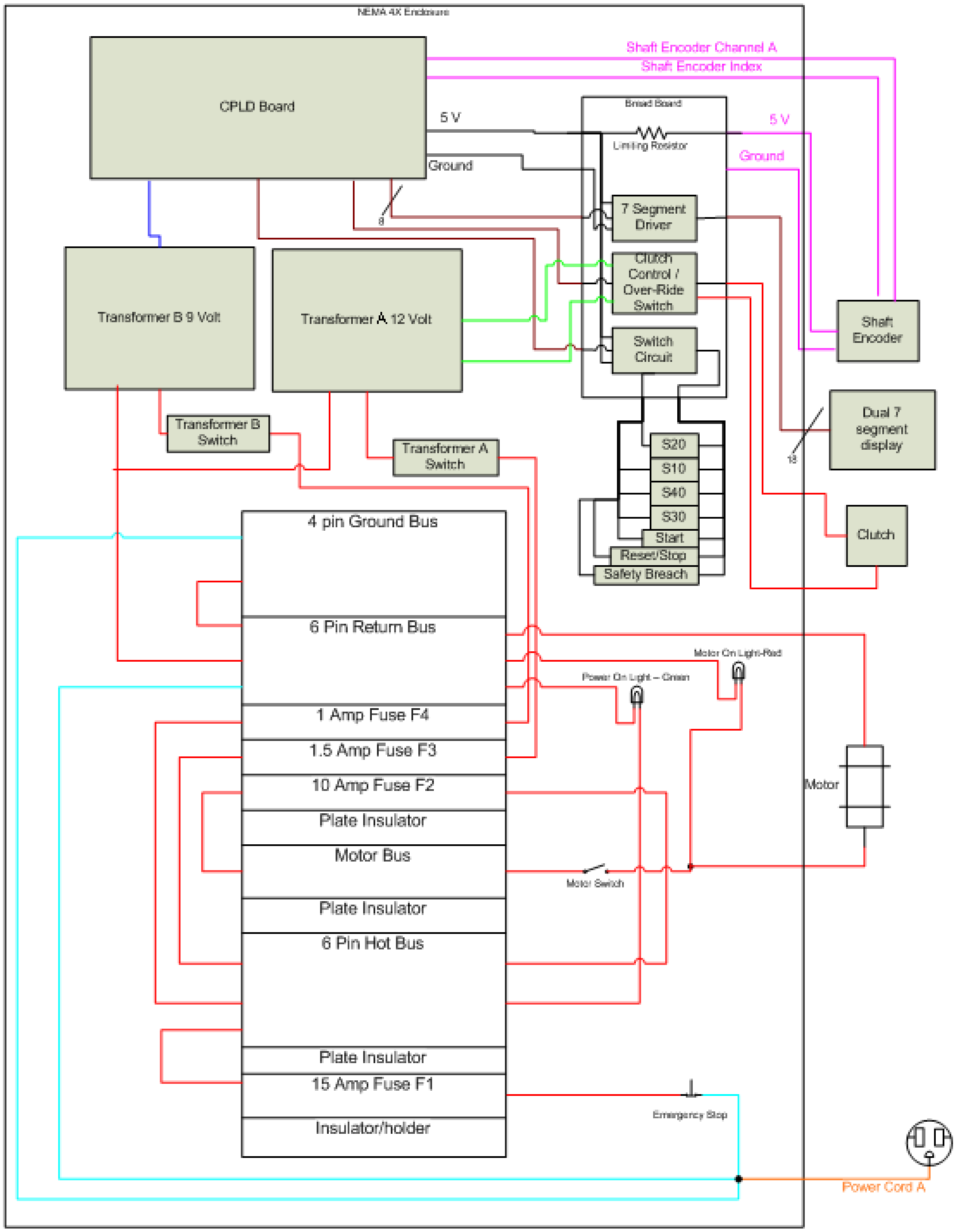

Figure 47. This figure shows the top level electrical schematic.

The electrical circuit will have partial control of the experiment during operation. The circuit will control the clutch activation as well as stop the experiment if the double containment is entered. The circuit will count revolutions using the shaft encoder and engage/disengage the clutch as needed. The circuit will also drive a dual 7 segment LED display to indicate the number of passes left during a trial.

The electrical components of the experiment will be connected following the JSC Safety and Health Handbook as well as the National Electric Code. The circuit has been designed to fail to a safe configuration during an unexpected power outage or emergency shut down. The kill switch will remove all power from the experiment allowing the clutch to immediately disengage and the motor to spin down to a stop. The programmable chip will reboot to its current state when recovering from a power outage. The reset/stop button will allow the chip to be reset upon start up. Components located outside of the NEMA 4X enclosure will not be exposed to the double containment area. The top level components have been described below.

Commercial Off The Shelf (COTS)

- Fuse/Breaker Bus
- Regulated 12 VDC Transformer (115VAC to 12VDC)
- 9 VDC Transformer (115VAC to 9 VDC)
- Baldor ½ HP 115VAC 60Hz Gear Motor
- US Digital Shaft Encoder
- DynaCorp Electromagnetic Clutch
- Altera Student Version Circuit Board Model PLDT-2 (CPLD Board)
- Switches
    - Toggle Switches (SPDT, SPST, DPDT)
    - Push Buttons (Momentary On)
    - Emergency Stop
- Dual 7 Segment Display/Driver
- Resistors/Transistors
- Personal Video Camera
- Personal Camera

Custom Components:

- Bread Board
- Current Limiting Circuits
- Clutch Control/ Over-Ride Circuit

Custom components will be simple circuits, mostly resistors, to ensure proper current will flow through devices. The clutch control/override circuit will consist of an npn transistor to open or close the circuit. A DPDT toggle switch will be located on the front panel to override this circuit if it were to fail during the experiment. Refer to **Figure 48** for the location of the switches. The actual components of this circuit will be COTS although custom current limiting circuits must be constructed to ensure a reliable control system. The Altera board is equipped with a 5 volt power supply; this will be used to drive some of the components on the bread board, other components on the bread board will receive power from the 12 VDC transformer.

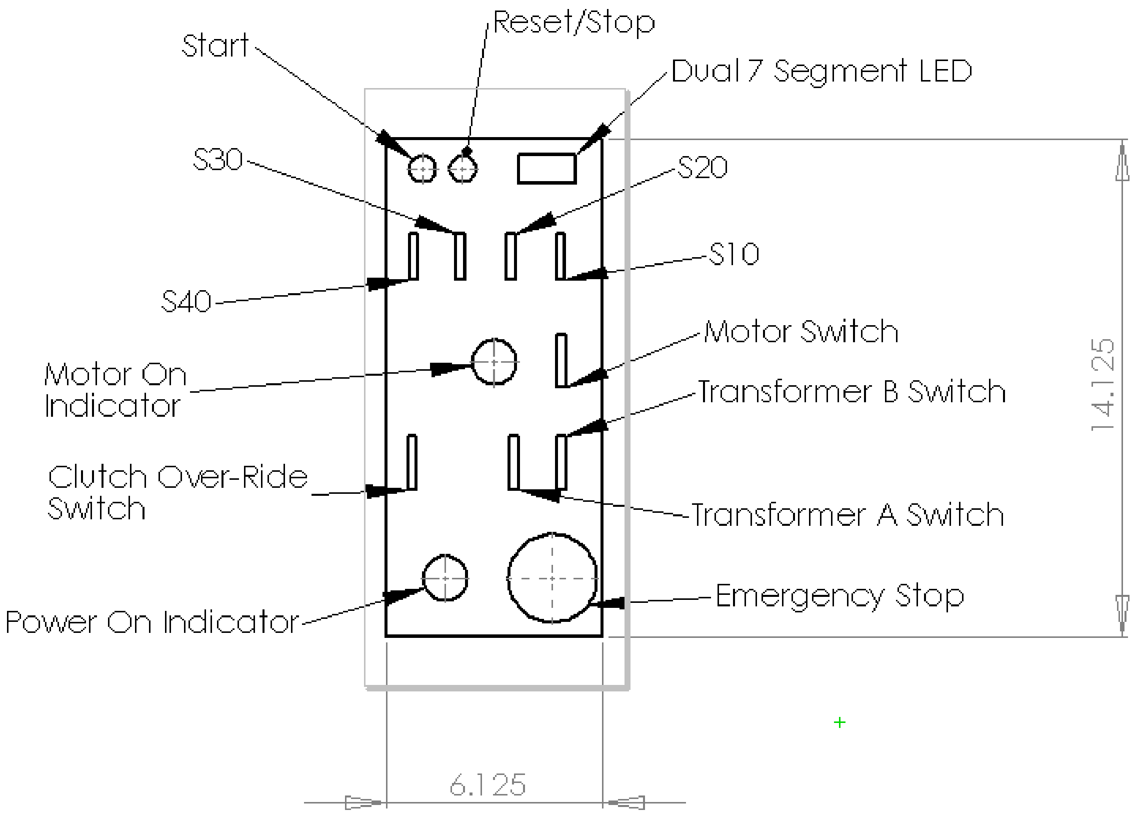

Figure 48. Control panel switch locations.

Components will be mounted securely to an aluminum mounting panel enclosed in the NEMA 4X enclosure. Components will be grounded to the aluminum panel which will have a separate ground cable that will be bolted to the structure enclosing the blender. The steel structure will be mounted securely to the plane providing a good ground between the experiment and the plane. Wire size will be appropriately chosen for the peak currents between components. Refer to **Table 7** for conductor gauge and type.

Table 7. Conductor gauge, type, nominal and peak current. Colors refer to **Figure 47**.

Device Name	AWG	Nominal Amps	Peak Amps	Conductor Type
Power Cord A	12	7.15	15	3 Conductor stranded, water resistant insulator
Power Cord A (separated)	12	7.15	15	1 Conductor stranded, insulated
Adapter A (12V) (separated)	22	.934	1.5	1 Conductor stranded, insulated
Adapter B (9V)	22	0.787	1	2 Conductor stranded, insulated
Motor Wiring	14	3.43	6.82	1 Conductor stranded, insulated
Clutch Wiring	14	1	1.5	1 Conductor stranded, insulated
Shaft Encoder Cables	24	0.017	0.040	1 Conductor shielded round twisted pair, insulated
Bus Jumpers	14	1, 1.5, 3.43	15	1 Conductor solid, insulated
Ribbon Cables	28	.005, .020	0.025	30 Conductor stranded, 9 mil PVC insulation
Bread Board Jumpers	22	.005, .025	0.03	1 Conductor solid, insulated
Where possible, wire will be bundled using plastic 1/2" (OD) spiral wire wrap				

Current limiting devices have been placed throughout the circuit. Current limiting resistors will be placed on the bread board to ensure proper operation of the CPLD with the external components. Fuses have been placed on the 3 portions of the circuit to ensure that an over current will not occur. Refer to the schematic, **Figure 47**, for fuse ratings.

The experiment will have one 20 foot, 12 AWG power cord leading to the power distribution panel located on the plane from the NEMA 4X polyester enclosure. The power cord will be identified with a tag labeled "CyMix-A".

Experiment requirements and requests:

- 115 Volt AC 60 Hz Power
- 1 GFCI Outlet on Bus A or Bus B
- Fuselage Station #770 is Requested for Power
- Nominal Current Draw 7.15 Amps
- Expected Peak Current Draw 11.32 Amps
- Peak Current Draw 15 Amps (fuse rating)

6.2 Load Tables

A personal video camera and a personal camera will be used to document the team's experience during the flight. These devices will use manufacturer supplied batteries. The CDTS items have not been modified.

The following load table displays the nominal and expected peak load on every power supply and transformer. Fuses have been chosen to withstand the peak current present on each component as well as protect the circuit from damage if the current is too great.

Table 8. Load table.

Power Source Details			Nominal Load Analysis (Amps)			Peak Load Analysis (Amps)		
Name	:	Power Cord A	Transformer A (12V)	:	.934	Transformer A (12V)	:	1.5
Voltage	:	115 VAC, 60 Hz	Transformer B (9V)	:	0.787	Transformer B (9V)	:	1
Wire Gauge	:	12 AWG	Gear Motor/Other	:	5.43	Gear Motor/Other	:	8.82
Max Outlet Current	:	15 Amps	Total Current Draw	:	7.15	Total Current Draw	:	11.32
Name	:	Transformer A (12V)	Clutch	:	0.934	Clutch	:	0.934
Voltage	:	115 VAC, 60 Hz to 12 VDC						
Wire Gauge	:	22 AWG						
Max Current Draw	:	1.5 Amps	Total Current Draw	:	0.934	Total Current Draw	:	0.934
Name	:	Transformer B (9V)	Altera Board	:	0.787	Altera Board	:	1
Voltage	:	115 VAC, 60 Hz to 9 VDC						
Wire Gauge	:	22 AWG						
Max Current Draw	:	1 Amp	Total Current Draw	:	0.787	Total Current Draw	:	1

6.3 Stored Energy

There will be no large capacitors in this experiment. There will be wire coils present on the ½ horsepower electric gear motor used to power the experiment. The motor will run on 115 VAC power. The start up current is rated at 6.82 Amps and the synchronous speed current is rated at 3.43 Amps. This electric energy will be dissipated through the spinning rotor creating mechanical energy, discharging any electric field that may be created during operation of the experiment.

6.4 Electrical Kill Switch

The Electrical Kill Switch is located on the front lower right corner of the control panel (see **Figure 48**). The Electrical Kill Switch is a clearly labeled 50 mm red mushroom push button. Power to the system is indicated by a green light. During the unlikely event of a malfunction or an emergency, the Electrical Kill Switch is depressed and cuts power from the plane to the experiment.

6.5 Loss of Electrical Power

In the event that the plane experiences a loss of electrical power the experiment will fail to a safe configuration. When power is lost, the clutch disengages, the crank arm will no longer spin, and the motor shaft will spin down to a stop. For the experiment to be powered up again, the Reset/Stop button must be pushed again to reset the CPLD. Ideally, all switches should be in the off position before power is restored to the experiment. If the experiment experiences a small power glitch and power is lost momentarily, the experiment will restore to its current position when the power is returned.

7. Pressure Vessel Certification

The pressure vessels in the experiment are categorized below.

The 24 3.2 ml polyethylene 10 in. x 15 in. vacuum sealed bags are categorized as Category E. The custom prepared bags will contain 6 oz of cooked soybeans. We discussed the classification of our custom made plastic bags with Mr. John Yaniec (Yaniec 2004). He stated that the energy stored in these vessels is of small enough quantity that the bags were of small risk.

8. Laser Certification

No lasers will be used in this experiment.

9. Parabola Details and Crew Assistance

No partial g levels are required for this experiment. Testing will require two parabolas for each blending event. The first parabola of the blending event sets up the experiment for function in the next parabola (see sections "**18.6.3 During Parabola**" for bag change procedures). Crew assistance is not required unless team members become incapacitated due to motion sickness.

Below is a table describing what will occur during the parabolas for the two flight days.

Table 9. Parabola details.

Parabola #	**Team Activity**
1-3	Adapt/Familiarize with microgravity
4-11	Blender run at 40 blending plate passes (4 blending events consisting of 4 setup parabolas and 4 testing parabolas)
12-19	Blender run at 30 blending plate passes (4 blending events consisting of 4 setup parabolas and 4 testing parabolas)
20-27	Blender run at 20 blending plate passes (4 blending events consisting of 4 setup parabolas and 4 testing parabolas)
28-35	Blender run at 10 blending plate passes (4 blending events consisting of 4 setup parabolas and 4 testing parabolas)
36-40	Stow final blending bag/ Repeats if necessary/ Outreach photos

10. Institutional Review Board

Institutional Review Board Approval is not required for this experiment.

11. Hazard Analysis Report

Table 10. Hazard source checklist.

n/a	Flammable/combustible material, fluid (liquid, vapor, or gas)
n/a	Toxic/noxious/corrosive/hot/cold material, fluid (liquid, vapor, or gas)
n/a	High pressure system (static or dynamic)
I	Evacuated container (implosion)
II	Fragile material
n/a	Stress corrosion susceptible material
n/a	Inadequate structural design (i.e., low safety factor)
n/a	High intensity light source (including laser)
n/a	Ionizing/electromagnetic radiation
III	Rotating device
IV	Extendible/deployable/articulating experiment element (collision)
V	Stowage restraint failure
VI	Stored energy device (i.e., mechanical spring under compression)
n/a	Vacuum vent failure (i.e., loss of pressure/atmosphere)
n/a	Heat transfer (habitable area over temperature)
n/a	Over-temperature explosive rupture (including electrical battery)
n/a	High/Low touch temperature
n/a	Hardware cooling/heating loss (i.e., loss of thermal control)
n/a	Pyrotechnic/explosive device
n/a	Propulsion system (pressurized gas or liquid/solid propellant)
n/a	High acoustic levels
n/a	Toxic off-gassing material
n/a	Mercury/mercury compound
n/a	Other JSC 11123, Section 3.8 hazardous material
n/a	Organic/microbiological contamination source
VII	Sharp corner/edge/protrusion/protuberance
VIII	Flammable/combustible material, fluid ignition source (i.e., short circuit; undersized wiring/fuse/circuit breaker)
IX	High voltage (electrical shock)
n/a	High static electrical discharge producer
X	Software error or compute fault
n/a	Carcinogenic material
XI	Other: Pinch Points

Hazard number: I

Title: Soybean Blending Bag Implosion/ Tear

Hazard Description:

It is possible that the soybean blending bag may tear or implode on itself during the experiment resulting in floating debris.

Hazard Cause(s):

- Improper seal on the soybean blending bag
- Rough surfaces on the blending plate or wheel
- Improper care of the soybean blending bags while transporting

Hazard Control(s):

- Immediately push the Stop/Reset button on the control panel
- Do not enter the double containment area during zero gravity
- When in non zero gravity remove a zip locking bag from it's location and place the broken soybean blending bag inside
- Use absorbent paper to soak up any water/particles present.
- Place the destroyed soybean bag inside the storage compartment.
- Continue experiment as accordingly

Hazard number: II

Title: Proper Handling of Soybean Blending Bags

Hazard Description:

Soybean blending bags may tear if not handled with care while transporting them from the storage area to the double containment area. A torn soybean blending bag will result in floating particles.

Hazard Cause(s):

- Sharp corners, hard surfaces could decrease the strength of the bag
- Improper handling of the soybean blending bags

Hazard Control(s):

- Use care while transporting soybean blending bags from the storage container to the experiment area
- Carefully remove the soybean blending bag from the storage container using care not to damage other bags
- Exercise close attention to sharp corners while handling bags
- Cover all sharp edges and corners with foam
- Inspect blending bags before flight

Hazard number: III

Title: Rotating Crank Arm Failure

Hazard Description:

The rotating crank arm will be affixed using a whistle stop on the shaft and a set screw to lock it into the correct position. It is possible that this component may work itself loose and become a projectile. This component is hazardous for the simple reason that it is spinning.

Hazard Cause(s):

- Sheared set screw
- Loose set screw
- Improper guarding

Hazard Control(s):

- Check the set screws before the experiment is loaded and periodically throughout the trials to ensure that it is not becoming loose
- Do not enter the double containment without letting the crank arm come to a complete stop. The door to enter the containment will remove power from the crank arm, although the crank arm will still spin until its momentum is expended.
- Pay close attention to sharp edges on the crank arm
- Depress Emergency Kill switch

Hazard number: III

Title: Clutch/Motor Coupling Failure

Hazard Description:

The clutch attaches to the motor shaft using set screws and a whistle stop on the motor shaft. If the drive axle becomes unstable from a large mechanical load while the clutch is engaged, the clutch/motor coupling could be stressed to a breaking point. This break up could result in a projectile.

Hazard Cause(s):

- Large mechanical load on drive axle while clutch is engaged
- Unstable coupling
- Sheared set screw
- Loose set screw
- Improper guarding

Hazard Control(s):

- Manually disengaging clutch if drive axle becomes unstable
- Manually switch off power to motor
- Install drive bearings to stabilize drive axle
- Visually check set screws before, during, and after experiment trial
- Install Plexiglas guarding around clutch/motor coupling area
- Depress Emergency Kill switch

Hazard number: IV

Title: Blending Plate Guide Rod Supports Failure

Hazard Description:

During operation, the blending plate oscillates linearly along fixed guide rods. If the guide supports failed, the blending plate could be derailed from the guide rods and flop about on the base plate and potentially move outside the bounds of the support structure.

Hazard Cause(s):

- Loose guide rod set screw compounded with jerky motion of blending plate

Hazard Control(s):

- Manually disengage clutch and switch off motor
- Check guide rod set screws prior to operation and flight
- Clean guide rods and blending plate linear bearings of any debris to ensure smooth motion
- Install Plexiglas guarding around bender enclosure
- Depress Emergency Kill switch

Hazard number: IV

Title: Drive Link Failure

Hazard Description:

During operation, the drive link transfers the circular motion of the crank arm to the linear motion of blending plate. If the bolts securing the drive link or the drive link itself failed, the drive link could whip about in the blender compartment

Hazard Cause(s):

- Loose attachment bolts
- Weak metal

Hazard Control(s):

- Inspect bolts prior to operation
- Check drive link periodically for signs of metal fatigue
- Install Plexiglas guarding around bender compartment
- Depress Emergency Kill switch

Hazard number: IV

Title: Lift Crank/Blending Compartment Access Hatch Collision

Hazard Description:

When changing the blending bag, the blending compartment access hatch must be opened and the lift crank must be cranked up to raise the blending wheel assembly. If the lift crank is not returned to its default position after bag change, a collision could occur with the blending compartment access hatch causing damage to the Plexiglas containment/guarding.

Hazard Cause(s):

- User error

Hazard Control(s):

- Team members must be familiar with blending bag procedures
- Team members should double check the lift crank position before closing the access hatch

Hazard number: V

Title: Soybean Blending Bag Storage Restraint Failure

Hazard Description:

The storage container for the soybean blending bags will have a removable lid that will unscrew. It is possible that this lid, if not properly handled, could cause injury.

Hazard Cause(s):

- Improper lid opening or closing
- Care not used while handling the lid when unscrewed

Hazard Control(s):

- Familiarize oneself with the operation of the storage container before it is necessary to open the storage container
- Make sure other people are not in the way of the lid when opening the storage container

Hazard number: VI

Title: Bungee Cord Failure

Hazard Description:

The experiment will have stored mechanical energy in the form of two bungee cords. It is possible that these bungee cords may unhook or break causing injury. The bungee cords also introduce exacerbate pinch points on the experiment.

Hazard Cause(s):

- Faulty bungee cords
- Improper soybean bag loading procedure followed
- Carelessness of an experimenter while inside the double containment

Hazard Control(s):

- Inspect bungee cords before the experiment is started
- Follow the soybean bag loading procedure
- Pay close attention to pinch points that may be caused by the bungee cords.
- Always secure the blending wheel with the crank lift apparatus when fingers are near the wheel

Hazard number: VII

Title: Injury from Colliding with Sharp Corners/Edges

Hazard Description:

The support structure is made from steel tubing. At the joints sharp edges and corners could be present. Colliding into these during microgravity could cause serious injury.

Hazard Cause(s):

- Sharp edges and corners on support structure
- Uncontrolled movement in microgravity

Hazard Control(s):

- All edges and corners will be covered with foam
- Use foot restraints during microgravity portions of the flight

Hazard number: VII

Title: Premature Blending Compartment Access Hatch Closure

Hazard Description:

The access hatch is made of Plexiglas and attached to the support structure with hinges. During a blending bag change, the door must be held open while the bag change takes place. If the door was closed prematurely, it could potentially injure whoever is still working in the blending compartment. Conversely, if the hatch is carelessly left open, a collision with the hatch could damage to the hatch and the hinges as well as whoever collided into the hatch.

Hazard Cause(s):

- Mental lapse on part of team member
- Sweaty hands/ poor grip
- Person unaware of surroundings

Hazard Control(s):

- Pay attention to task especially when the hatch is open
- Dry hands on flight suit before gripping hatch
- Add grip to hatch if there is insufficient friction
- Possibly secure hatch open by temporarily securing hatch to aircraft wall
- Double check surrounds before sudden movements

Hazard number: VIII

Title: Electrical System Failure Resulting in Fire

Hazard Description:

If improper wiring or the wrong fuses were used, a fire could develop in during a circuit overload.

Hazard Cause(s):

- Poor wiring
- Wrong wire gage
- Wrong fuse usage

Hazard Control(s):

- Double check wiring
- Double check fuse settings
- Test fuses prior to operation
- Have Electrical and Computer Engineers in charge of circuit design
- Depress Emergency Kill switch

Hazard number: IX

Title: Electrical Shock

Hazard Description:

It is possible that electrical shock will result if there is not a good ground contact between the plane and the structure.

Hazard Cause(s):

- Faulty contact between the plan and the structure
- Loose grounding contact between the structure and the NEMA 4X enclosure

Hazard Control(s):

- Inspect ground connections in the preflight inspection
- If the static electrical shock is too much, remove power from the experiment by pushing the Kill Switch, which will be insulated from the rest of the structure to ensure there will be no electrical shock when pushing the switch.

Hazard number: X

Title: Complex Programmable Logic Device (CPLD) Failure

Hazard Description:

It is possible that the CPLD may not work properly under certain extreme conditions. Due to the nature of the semiconductor the chip is made from, it is static sensitive and may become unusable if a large static field were to build up on the plane for an unknown reason. In the case of a large static build up, it is possible that the CPLD will not disengage the clutch properly. In this case it is necessary to use the override controls located on the control panel.

Hazard Cause(s):

- Extreme static charge build up
- Under voltage causing the chip to not work properly

Hazard Control(s):

- If the clutch does not disengage as expected push the Stop/Reset button located on the control panel
- If the clutch is still not disengaged activate the Clutch Over-Ride switch located on the panel
- If the experiment continues to improperly disengage the clutch it will be necessary to use the override controls to perform the entire experiment. An experimenter will need to count the number of passes and manually flip the clutch override switch on or off.

Hazard number: XI

Title: Blending Wheel/Base Plate Pinch Point

Hazard Description:

The microgravity blender functions by rolling a bag full of material between the blending wheel and the base plate. If someone was to put a hand in the blending compartment during operation, injury could result.

Hazard Cause(s):

- Moving parts
- Improper guarding

Hazard Control(s):

- Completely enclose blending compartment in Plexiglas during operation
- Install clutch disengage switch to access hatch (this will disengage the clutch and stop the motion when the access hatch is opened
- Keep hands out of blending compartment until blending plate has come to a complete stop

Hazard number: XI

Title: Blending Wheel/Base Plate Pinch Point Part 2

Hazard Description:

During a blending bag change, the blending wheel assembly must be raised using the lift crank in order to remove the blending bag. If the lift crank is lowered while someone's fingers are near the blending wheel the person's fingers could be pinched.

Hazard Cause(s):

- Mental lapse on part of team member
- Lift crank failure
- Carelessness

Hazard Control(s):

- Pay close attention when changing blending bag
- Follow the procedures for changing the blending bags
- Check lift crank prior to flight
- Use caution when working in the blending compartment

12. Tool Requirements

12.1 Ground Tools

Ground tools will include: socket set, pliers, allen wrench set, Phillips and flat head screw drivers, crescent wrench, and other non-motorized hand tools used for assembling the equipment. On flight days, a properly marked cooler containing the soybeans sealed in blending bags will be present.

12.2 Flight Tools

No tools will be taken aboard the KC-135.

12.3 Tool Storage

The tools will be housed in a toolbox.

12.4 Tool Identification

All tools will be labeled with its appropriate owner. The toolbox will be marked clearly with the owner's identification. The cooler will be labeled with its contents and the owner's identification.

13. Photo Requirements

A still photographer and a videographer are requested to document the crew experience during flight operations. The team requests one hard mount camera pole to be located on the left side of the experiment setup (see **Figure 3**).

14. Aircraft Loading

14.1 Ground Manipulation

The team will need a cart or loading device capable of transporting the experiment assembly from the hanger/team storage area to the aircraft. Once at the base of the aircraft, the experiment assembly will placed onto a lifting pallet and lifted into the aircraft.

14.2 KC-135 Test Cabin Manipulation

Once in the KC-135 test cabin, the experiment assembly will be manipulated using nylon lifting handles. There are 6 lifting handles, and the load to each person is 47.5 lbs.

14.3 Experiment Assembly Securing

The experiment assembly to be loaded onto the aircraft weighs approximately 285 lbs and has a base plate area of 7.2 (43 in. x 24 in.) square feet. The load placed on the aircraft floor is 39.6 psf. The experiment assembly is secured to the aircraft with 6 bolt holes, resulting in a force of 47.5 lbs per bolt hole.

An important consideration is the attachment hardware that will be used to attach all components to the experiment assembly. The NEMA 4X enclosure, blender, and motor will be attached to the structure with Grade 5 3/8 inch diameter course thread bolts (tensile strength 9,888 lbf and shear strength 8280 lbf). The blending storage container will be secured using a 1 inch wide nylon ratchet straps. After an initial review of the loads applied by all of these components, the most massive being the blender, the loads placed on most of these fasteners will be well below their yield strength.

15. Ground Support Requirements

Two 120 VAC 15-Amp outlets will be needed on the ground for testing research equipment. No pressurized gas is needed for the experiment. No chemicals that are toxic and/or corrosive will need to be mixed or stored. Access to building 993 is not needed after hours other than normal business hours.

The team requests a cart or loading device capable of handing our experiment assembly on the ground to and from the hanger/team storage area and the aircraft.

16. Hazardous Materials

The experiment does not require and will not be using any toxic, corrosive, explosive or flammable materials.

17. Material Safety Data Sheets

No material safety data sheets are needed for this experiment.

18. Experiment Procedures Documentation

18.1 Equipment Shipment to Ellington Field

All equipment for the experiment will be brought to Ellington Field by the team when the team arrives (morning of July 8). A 100 sq. ft area (10 ft X 10 ft) will be needed to safely store our hardware and allow space for assembly.

18.2 Ground Operations

One 120 VAC 15-Amp outlet will be need for the equipment to operate at the TRR prior to flight. All other equipment and tools will be supplied by the team. Procedures to set up and operate our equipment on the ground at Ellington Field are as follows:

1. Check equipment and attachment points for disturbance from shipping
2. Check all electrical connections
3. Plug in equipment to 120 VAC 15-Amp outlet
4. Pull out Electrical Kill Switch
5. Test electronics and motor
6. Open top compartment hatch to test disengage switch
7. Test Electrical Kill Switch
8. Make necessary adjustments
9. Operate equipment using procedures from section **18.6** for Test Readiness Review

18.3 Loading

The experiment assembly will be prepared for loading by double checking hardware attachments. Once the check is complete, aircraft loading will be completed by following the procedures found in section "**14. Aircraft Loading.**"

18.4 Pre-Flight

All personal video cameras, photographic equipment, and personal items will be stowed in the aircraft prior to flight.

To prevent spoilage and to save time, the soybean blending bags will be prepared off campus of Ellington Field the night before each flight. Prior to boarding the aircraft, the prepared blending bags will be loaded into the unused section of the storage container.

18.5 Take-off/Landing

The storage container will be carried onto the aircraft with the team members and properly secured in its restraint straps located in the support structure before take off. All equipment will remain powered down until five minutes prior to the first parabola. For the landing, the equipment will remain powered down from the in flight shutdown after the last parabola.

18.6 In-Flight

18.6.1 Power Up

Five minutes prior to the first parabola, power up procedures will begin.

1. Set switches to default positions
2. Pull out Electrical Kill Switch
3. Switch Power Supply A to the on position
4. Switch Power Supply B to the on position

18.6.2 Prior to Parabola

Prior to the parabolas, team members will remain in foot restraints.

18.6.3 During Parabola

Testing will require two parabolas for each blending event. The first parabola of the blending event sets up the experiment for testing in the next parabola. The procedures for the first parabola of a blending event are as follows:

1. Team Member 1: Open top compartment hatch
2. Team Member 2: Raise blending wheel using the blending wheel crank
3. Both Team Members: Unclamp soybean blending bag from blending plate (this step is not necessary for the first blending event of the flight)
4. Team Member 2: Store blending bag in the used section of the storage container (not necessary for the first blending event of the flight) and obtain one soybean blending bag from unused section of storage container

5. Both Team Members: Clamp soybean blending bag to blending plate
6. Team Member 2: Lower blending wheel using the blending wheel crank
7. Team Member 2: Close and secure top compartment hatch
8. Team Member 1: Select desired number of blending plate passes using appropriately labeled toggle switch (each pass setting will be repeated 4 times over the course of the flight)
9. Team Member 1: Switch the motor to the on position

The procedure for the second parabola of a blending event is as follows:

1. When the aircraft microgravity indicator light turns on, press start button (the clutch will automatically disengage when the selected number of passes is reached)

18.6.4 After Parabola

After the second parabola of a blending event, the following procedure is followed.

1. Switch the motor to the off position.

After any other parabola, the team members will remain in foot restraints.

18.6.5 Standard Shutdown

After each pass setting/blending event has been repeated 4 times (32 parabolas), the equipment is shut off and prepared for landing.

1. Switch motor to the off position.
2. Team Member 1: Open top compartment hatch
3. Team Member 2: Raise blending wheel using the blending wheel crank
4. Both Team Members: Unclamp final soybean blending bag from blending plate
5. Team Member 1: Store final blending bag in the used section of the storage container
6. Team Member 2: Lower blending wheel using the blending wheel crank
7. Team Member 2: Close and secure top compartment hatch
8. Switch Power Supply A to the off position
9. Switch Power Supply B to the off position
10. Depress Electrical Kill Switch

18.6.6 Emergency Shutdown

In the event of an equipment failure or flight emergency, the follow Emergency Shutdown procedure will be used.

1. Depress Electrical Kill Switch (this will kill all electrical power to the equipment)
2. Secure top compartment hatch and storage container (if they are already not secured)
3. Take appropriate action to address the problem as soon as possible.

18.7 Post-Flight

After landing, the blending bag storage container will be removed and carried off of the aircraft. The contents of the storage container will be transferred to a cooler. Blending bags for the next day's flight will be prepared off campus that night.

18.8 Off-Loading

No special procedures are required for off-loading the equipment from the KC-135, and the same procedures as used for aircraft loading will be used. All team equipment will leave with the team.

19. Bibliography

AOD Form 71, Hazard Source Checklist
AOD Form 72, Quick Reference Data Sheet
AOD 33897, Experiment Design Requirements and Guidelines
Reitmeier, C. Professor, Food Science and Human Nutrition, Iowa State University. Personal Interview. 16 April 2003.
Yaniec, John. Personal communication. 26 March 2004. 4:40 PM CST.

20. Exceptions

After talking to John Yaniec and discussing the pressure classification of our blending bags, a pressure relief valve is not required for the blending bags. He stated that the energy stored in these vessels is of small enough quantity that the bags were of small risk (Yaniec 2004).

Appendix I

See attached weld certification document.