

Packing the PLSS

Spacesuit Life Support Design for Future Space Exploration



Introduction/Background

NASA Engineers design spacesuits for ultimate protection and functionality in the extreme environment of space. The spacesuit is often referred to as a “personal spacecraft” because it provides the astronaut with everything he or she needs to survive and work in space outside of the vehicle or habitat.

The systems within the spacesuit include the pressure garment system (PGS), the Portable Life Support System (PLSS), and the power, avionics, and software (PAS) system. These elements are necessary to protect crewmembers and allow them to work effectively in the pressure and temperature extremes of space environments. Development of the spacesuit system is necessary to support future human extravehicular exploration activities to Lunar, Martian, microgravity, and possibly other space destinations.

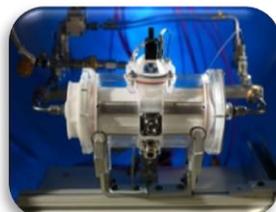
Although all the systems that make up the space suit are important, the PLSS is one of the most complex. The PLSS provides the life support needed by the astronaut and consists of the oxygen (O₂) subsystem, ventilation subsystem, and thermal control subsystem. Within each subsystem, there are many different components, a few of which are explained as follows. The oxygen tanks hold the oxygen that the crewmember uses to breathe and pressurizes the suit. The primary oxygen tank is responsible during normal operations and the secondary oxygen tank kicks on in the case of an emergency. The Rapid Cycle Amine (RCA) canister is used to remove the carbon dioxide (CO₂) and extra humidity in the crewmember’s ventilation/breathing gas. The fan moves the oxygen around the suit. Suit Water Membrane Evaporator (SWME) is used within the thermal control loop to cool the water that is used to maintain a comfortable temperature for both the crew member and the other equipment inside the suit. Another component is the battery, which supplies the power needed to operate all these and the many other pieces. The battery is one of the biggest and heaviest components within the PLSS. These are just a few of the components that encompass the PLSS. Each component has a weight and a certain volume that the NASA Engineers must take into account when building the PLSS, because the weight and volumes affect the crewmembers center of gravity (CG). [See the Notes Section for the link to an Apollo video that demonstrates the issues some of the crewmembers had picking up tools and dealing with center of gravity/tools on the surface of the Moon.] In this activity, students will simulate engineering design techniques that NASA Engineers and Designers are currently implementing to configuring the components within the PLSS. Through testing, students will consider the comfort, mobility, and center of gravity for their test subjects and how that changes after adjusting the placement of their simulated PLSS components



Primary and Secondary Oxygen Tanks



Rapid Cycle Amine (RCA)



Suit Water Membrane Evaporator (SWME)



Fan



Battery

Objectives

1. To teach students the basic concepts used in packaging the life support components within the PLSS.
2. To teach students the importance of center of gravity as a key element in the design of a spacesuit life support system.

Materials needed for each group

- Standard backpack \geq 1800 cubic inches
- Packing materials (bubble wrap or newspaper)
- 2 liter bottle to represent Primary Oxygen Tank
- 48 oz ground coffee container to represent Secondary Oxygen Tank
- 24 oz juice container to represent Rapid Cycle Amine (RCA)
- 18 oz instant oatmeal container to represent Suit Water Membrane Evaporator (SWME)
- 20 oz water bottle to represent Fan
- Shoebox to represent Battery
- ~5 lbs sand to weight out each component (see Table 1 for specific amounts)
- Hammer or other tool
- Name tags to identify each team members role (test conductor, test subject, safety lead, test engineer, and data collector)
- 2 clipboards (one for test conductor and one for data collector)
- 2 pencils (one for test conductor and one for data collector)

Table 1: Weights for Each Simulated Item

Components	NASA's Goal Weight (lbs)	Classroom Weight (lbs)	Lunar Weight (lbs)	Martian Weight (lbs)
Primary Oxygen Tank	4.70	0.47	0.78	1.57
Secondary Oxygen Tank	6.70	0.67	1.12	2.23
Rapid Cycle Amine (RCA)	6.00	0.60	1.00	2.00
Suit Water Membrane Evaporator (SWME)	4.20	0.42	0.70	1.40
Fan	2.00	0.20	0.33	0.67
Battery	20.00	2.00	3.33	6.67
Total for these components	43.60	4.36	7.26	14.54

Team Roles & Responsibilities

Just as each person on a NASA team has a special and important role, each student plays a unique role in this test.

Safety Lead

- Responsible for overall safety of the test and Test Subject.
- Assists test subject with putting on and taking off hardware (backpack).
- Verifies that the test subject is ready prior to each test point.

Test Conductor

- Responsible for conducting the overall test procedure using the checklist. This includes directing the test team through each test point.

Test Engineer

- Closely observe all testing to improve component location in the backpack.
- Responsible for “packing the PLSS” by configuring the backpack in the weighted tests.
- Works directly with Data Collector to make sure configurations are documented correctly.

Test Subject

- Responsible for wearing the backpack and conducting test point movements as directed by the Test Conductor.
- Responsible for sharing feedback when requested by Safety Lead, Data Collector, and Test Conductor.

Data Collector

- Responsible for accurately tracking all data collection from start to finish of the activity.
- Responsible for taking notes and drawing correct packing configuration for the weighted tests.

Glossary of Terms

CG: Center of Gravity – the location of the average of the mass that makes up an object.

EVA: Extra Vehicular Activity – (also known as a “spacewalk”) this is an activity that takes place outside of the spacecraft.

Life Support: the system and components used to keep humans alive.

PAS: Power Avionics and Software – power and control system of the spacesuit.

PGS: Pressure Garment System – the combined materials & bearings of the spacesuit.

PLSS: Portable Life Support System – the life support system worn on the back of the spacesuit. It contains the oxygen, carbon dioxide removal system, water temperature control, battery, and many other components.

RCA: Rapid Cycle Amine – controls carbon dioxide (CO₂) and humidity levels in the spacesuit.

Shirtsleeve: is the unweighted/unsuited test series performed by NASA engineers at the beginning of a test to create a baseline for the testing

SWME: Suit Water Membrane Evaporator – controls the temperature of the water inside the spacesuit.

Procedure

Getting ready for the experiment-

- Gather supplies for each group
- Fill each container with sand, based on the values given in Table 1
- Label each container with PLSS component name
- Make team member name tags with role/responsibility and group (optional)
- Make copies of handouts needed for the experiment
 - Test Conductors Checklist (one for each group)
 - Data Collection Sheet and Backpack Layout Sheet [front and back] (one for each group)

The class period before the experiment-

- Give student background of importance of this experiment and overview of how the experiment will work [See Background and Notes sections for additional information]
- Assign team member roles and groups [Each role is described in the Team Roles and Responsibilities section]

The day of the experiment [*students steps are italicized*]-

- Move materials on to each groups table
- Once students arrive, have them move to their specific group
- Begin by demonstrating the Shirtsleeve phase of the test, with a few volunteers (2 is suggested) demo steps 1 – 5.
 - Showing students the importance of specific feedback from the test subject, not just “it feels ok”.
 - Remind students that this is not a race to be the first complete and that it is more important to get a good experiment.
 - Have students stop after completing the Shirtsleeve phase in their groups up to step 5.

Step 1: The Safety Lead will assist the Test Subject in putting on the empty backpack.

Safety Lead: Verify Test Subject is OK to test.

Safety Lead: Inform Test Conductor that you and the Test Subject are “go” for testing.

Test Conductor: Verify remaining team members are “go” to test.

Test Conductor: Announce “everyone quiet in the test area.”

Step 2: The Test Subject stands in place and assesses the feel of the backpack, considering overall comfort and how his/her center of gravity/balance is affected.

Test Conductor/Data Collector: Ask for direct feedback from the Test Subject and write all observations on the Data Collection Sheet.

Step 3: The Test Subject walks in a straight line 10 paces, turns around, and returns to the starting location.

Test Conductor/Data Collector: Ask for direct feedback from Test Subject and write all observations on the Data Collection Sheet.

Step 4: The Test Subject bends down and picks up the tool.

Test Conductor/Data Collector: Ask for direct feedback from Test Subject and write all observations on the Data Collection Sheet.

Step 5: Safety Lead removes the backpack from the Test Subject.

- **At this point, explain the weighted configurations and let the students work straight through the 1st and 2nd configurations**
- **Remind the students that they have to use only the main compartment of the backpack, all PLSS components must be included in the backpack, and the zipper must close.**
- **Packing material is available if the teams want it**

Step 6: The Test Engineer arranges each of the containers that represent the oxygen tanks, Rapid Cycle Amine (RCA), Suit Water Membrane Evaporator (SWME), fan and battery into the backpack. The Data Collector documents the location of each container on the Backpack Layout Sheet under the 1st Weighed Test, for both the back and side views.

Step 7: Repeat steps 1-5 with the 1st weighted configuration. After completion of Step 7, the Test Engineer unloads the containers from the backpack and then reloads the backpack with the 2nd container configuration. The Test Engineer documents the location of each container on the Backpack Sheet under the 2nd Weighed Test, for both the back and side views.

Step 8: Repeat steps 1-5 for the 2nd weighted configuration.

Test Conductor/Data Collector: Ask for general feedback from the team following completion of Step 8 and record on the Data Collection Sheet.

Step 9: Each group completes the Assessment questions and then discusses as a class.

Assessment

1. How did the center of gravity change for each test (i.e. the shirtsleeve vs the weighted and the 1st weighted vs the 2nd weighted)?
2. Which configuration had the most noticeable center of gravity issue? Why was this?
3. Compare your results with what might happen to astronauts when they are in a reduced gravity environment.
4. Based on your findings, what would you suggest to NASA Spacesuit Designers/Engineers to improve the center of gravity of the spacesuit?

NOTES:

Wear comfortable clothing for this experiment

Educators may adapt the activity to their individual classrooms as needed

Apollo Video: www.hq.nasa.gov/alsj/a16/a16v.1464941.mov

Extension

- Have students weight out components prior to activity themselves.
- Change weights for Mars (1/3rd Earth gravity) and/or Lunar (1/6th Earth gravity) masses.
- High School students: calculate center of gravity based on weight of components and location within the PLSS.

DATA COLLECTION SHEET

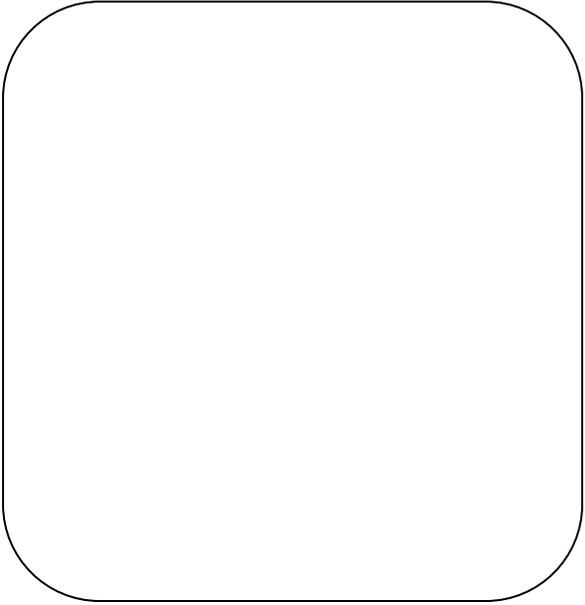
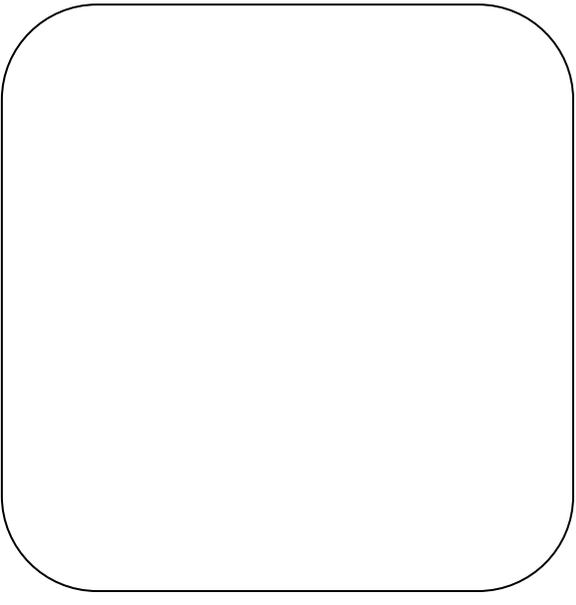
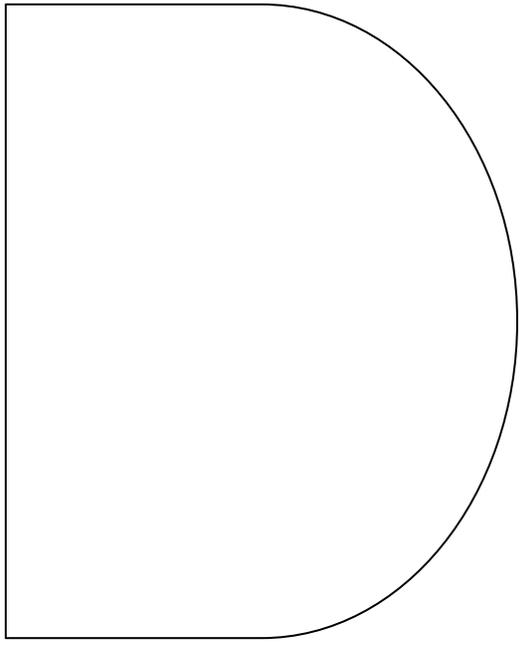
	Shirtsleeve	1st Weighted Test	2nd Weighted Test
BALANCE: Test Subject stands in comfortable standing position.			
WALK: Test Subject walks forward 10 steps, turn, walk back to starting point (10 steps), turn and return to standing position.			
TOOL PICK-UP: Test Subject begins in a standing position and bends down to pick up a tool that the Test Conductor has placed on the floor. Test Subject picks up the tool and returns to a standing position.			

The Data Collector will fill each corresponding box with notes.

Notes should include:

- How the subject feels and responds during each test point.
- Overall responses from the entire test team requested after completion of Step 9.

BACKPACK LAYOUT SHEET

<p>1ST Weighted Test BACK VIEW</p> 	<p>2ND Weighted Test BACK VIEW</p> 
<p>SIDE VIEW</p> 	<p>SIDE VIEW</p> 