



Training Pressure Suit Manual

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Contents

Overview	3
Sizes	4
Suit Layers	5
Limitations	7
CAUTIONS	7
Normal Suit Operations	8
Emergency States and Emergency Procedures	8
Depressurization and Doffing	10
Suit Maintenance	10
Post-Use Suit Treatment	10
Suit Cleaning	10
Suit Technician Kit	10
Suit Storage	11
Communications	11
Pressure Suit Checklist	12
Procedural Photos	13

Overview

The Center for Human Space Exploration (CHaSE) training pressure suits are airtight garments used for operational and instructional demonstrations. The suits are meant to be used in a positive pressure state in which breathing gas (BG) is supplied from an outside source. The BG raises the suit pressure to above ambient atmospheric pressure. This document is a brief introduction to these suits and their basic operation.

The garment is a ‘flowthrough’ suit in which CO₂, body heat and humidity are constantly flushed from the suit via continual gas flow out of one or both suit gas exit valves. Operated in the correct manner, the suit allows comfortable standing, walking, kneeling, rudimentary climbing / scrambling and acceptable finger mobility for working with basic hand tools.

As a training device, the suit introduces personnel to the options and constraints of a pressurized garment while in these postures; for example, while bending at the waist is largely precluded at pressure (a constraint), the stiffness of the pressurized suit can assist in returning to a standing posture from the kneeling posture, with leg stiffness acting as a spring mechanism.

These suits are composed of two main layers, and several components. The layers are the pressure bladder layer and the pressure restraint layer. These layers should be understood by suited persons and any technicians who will assist with suited procedures.

Suit mobility while pressurized is achieved by means of deep flat pattern convolutes, a.k.a. ‘pleats’ of the bladder layer textile at the elbows and knees. Stresses of the inflated suit are distributed and otherwise constrained by a variety of straps located on the pressure restraint garment. Useable mobility of the gloves while pressurized is achieved by a variety of design elements of the gloves, including metal hoops sewn into the glove restraint.

The suits are designed to fit a wide range of suited person heights, torso girths, arm- and leg-lengths and hand- and foot-sizes.



Figure 1 UA students during a full pressure suit training

Sizes

CHaSE currently uses two training pressure suits for education. Size tall and size medium. As bodies come in all shapes and sizes, personal measurements may or may not allow someone to don the suits successfully. If body measurements are close to the given values, it is still not a guarantee an individual will be able to don either suit. If body measurements are smaller than the suit sizes outlined below, the suits should be easily able to accommodate.

Maximum Tall size (inches)

Height: 72-74

Waist circumference: 46-48

Bicep circumference: 14-17

Thigh circumference: 24-26

Shoe: size 11 men's

Maximum Med size (inches)

Height: 68-70

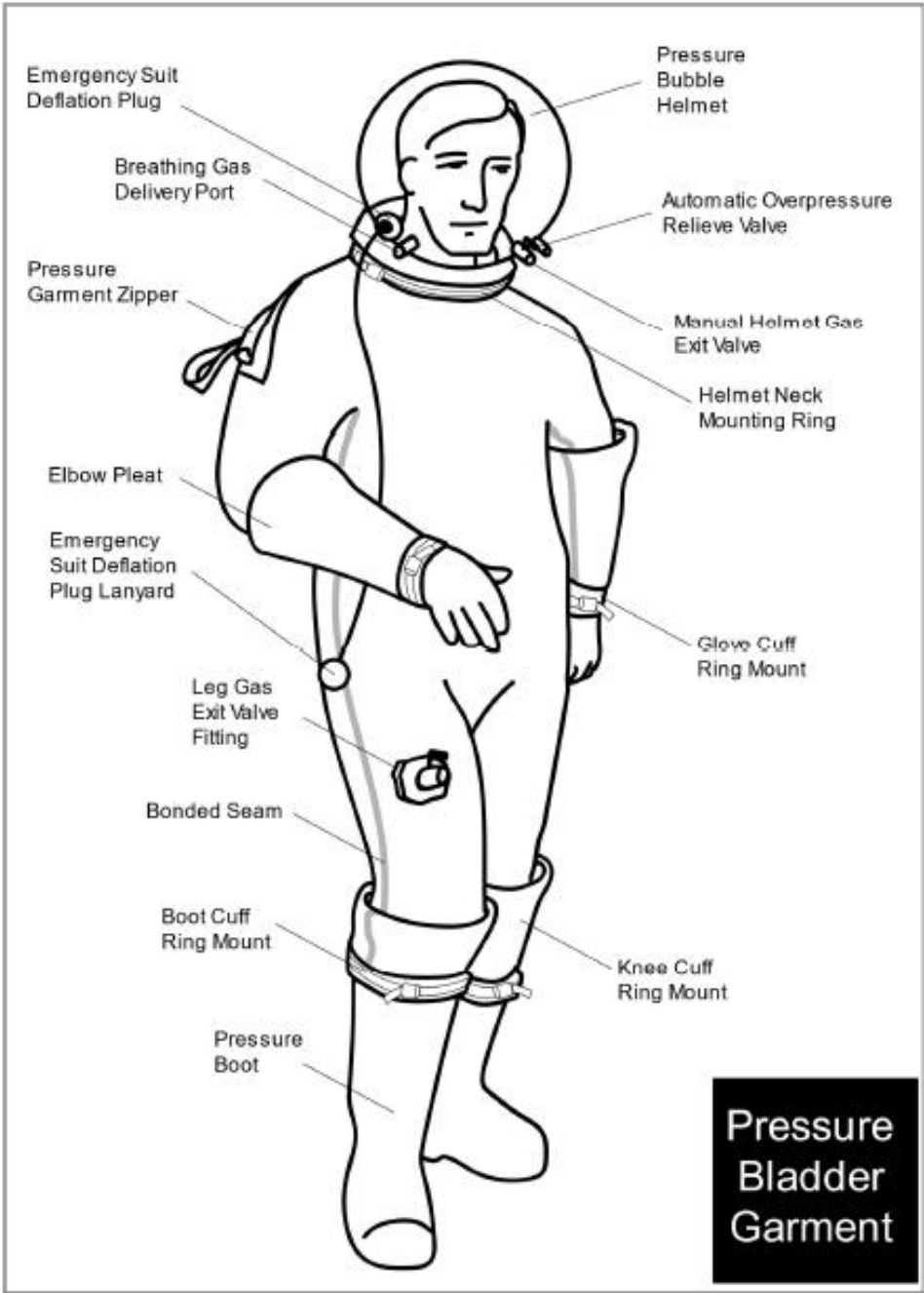
Waist circumference: 44-47

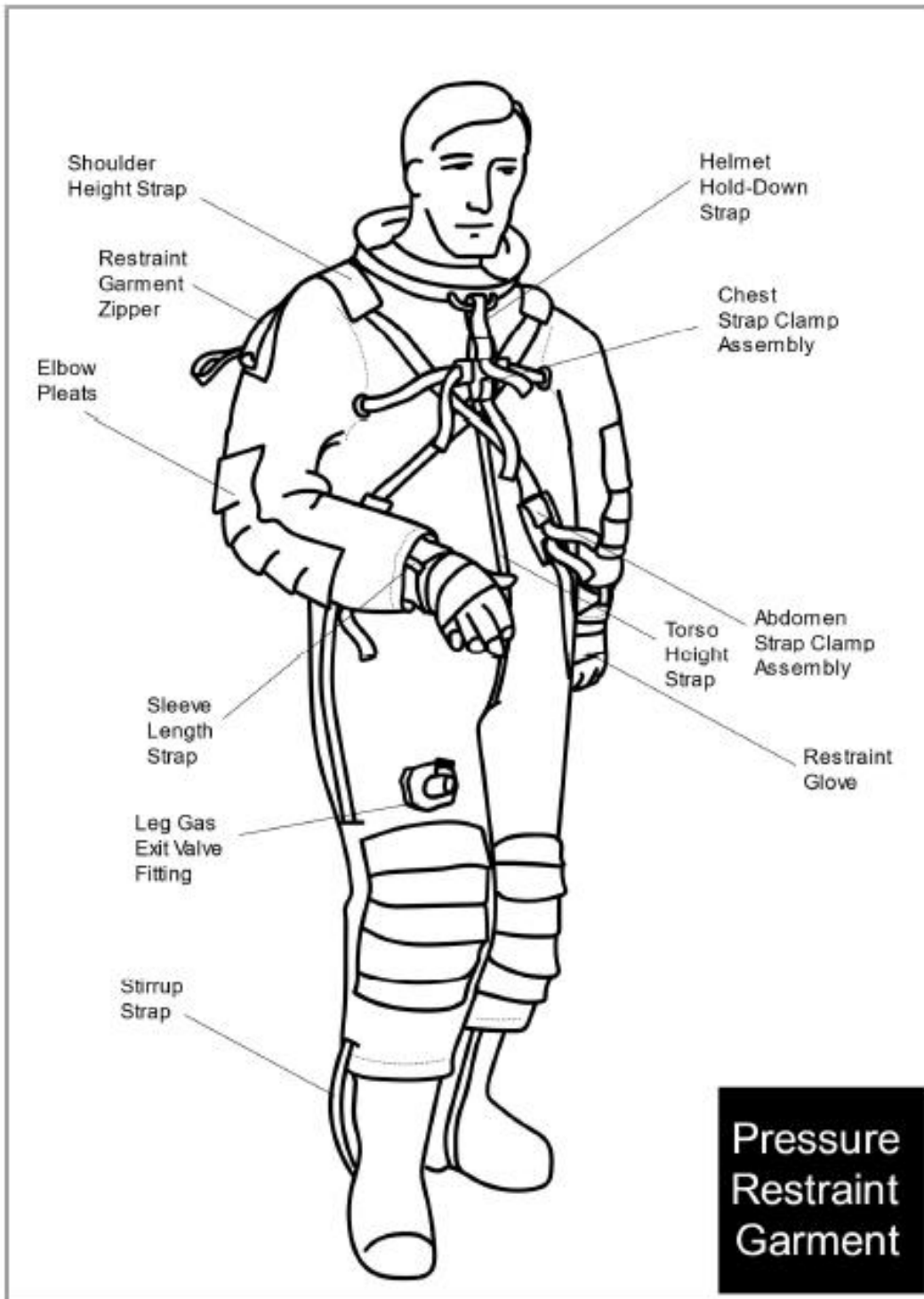
Bicep circumference: 14-17

Thigh circumference: 22-24

Shoe: size 11 men's

Suit Layers





Limitations

Maximum Operating Pressure: 1.5 PSIG / 77.25 mmHg / 0.10 bar standing

Suit Inflation / Breathing Gas (BG) Composition: normal air (never >21% oxygen)

Breathing Gas (BG) Flow Rate: minimum 28 LPM / 1 SCFM maximum 35LPM / 1.24 SCFM

CO2 Level: <5,000 PPM

Maximum Operating Internal Temperature: <90F / 32.2C

Operating Internal Humidity: <70%

Valve States: Suit valve must always be at least partially OPEN

CAUTIONS

- The consequence of exceeding the Maximum Operating Pressure is a significant and mobility-debilitating reduction of the suited person's mobility, followed by suit rupture and rapid, possibly injurious, depressurization.
- The consequence of delivering a BG other than normal air is either a reduced O2 partial pressure, leading to hypoxia, or an increased O2 partial pressure, resulting in a fire hazard.
- The consequence of delivering BG at a less-than-indicated flow rate is a rapid and potentially dangerous buildup of internal suit CO2.
- The consequence of delivering BG at a greater-than-indicated flow rate is suit overpressure and subsequent rupture with potential barotrauma.
- The consequence of exceeding safe CO2 levels is CO2 toxicity and/or hypercarbia, which can be fatal.
- The consequence of exceeding temperature levels is hyperthermia, which can be fatal.
- The consequence of exceeding humidity level is reduced capacity for the body to thermoregulate via sweating, which can lead to heat exhaustion.

Normal Suit Operations

Normal procedures are actions or sets of actions carried out in the suits when it is properly pressurized and in all other ways in a Safe State (contrasting to Emergency States indicated).

Before entering the suit, persons should have changed into athletic style clothing (shorts, tee shirt) at a minimum, however it is preferred that each persons cover as much of their body as possible to maintain maximum cleanliness inside the suit i.e. long shirt top and bottoms as well as cotton gloves. When changing into this suit base layer, it is a perfect time to use the bathroom as there is no way to do so inside the suit.

Before use, the suit must be prepared. Once the donning checklist below has been completed, suit pressure should be stabilized and the “okay” signal given to the suited individual to begin any movements. During the inflation procedure, the suited person may wish to yawn or Valsalva to equalize the ears and sinus cavities. Once the suit pressure is stabilized the suit is ready for normal use.

Never completely close helmet control valve and always deliver 1-2scfm or 28-60 Lpm breathing gas. Breathing gas must not be >21% oxygen in these training suits.

Emergency States and Emergency Procedures

Emergency Procedures are actions or sequences of actions used to bring the pressurized garment from an Emergency State to a Safe State. When used as directed by this manual, there are five Emergency States possible in the suit:

- Breathing Gas Cutoff
- Overpressure
- Carbon Dioxide Overload
- Overheating
- Unconscious Suited Person

The corrective actions for the first four conditions are very similar, essentially focused on opening the helmet valve. Once the helmet valve is opened, the suited person may be confident that the suit is well on the way to a corrected state. In the case of opening a valve in an emergency condition, the suited person should evaluate whether or not the procedure has been effective: depending on the nature of the emergency, it may be best to remove the helmet from the neck ring at this time.

In the case of the fifth Emergency State, unconscious person, the helmet should be immediately removed, and first aid administered immediately. Before resuming use of the suit, the cause of the emergency condition must be identified and corrected.

Emergency States

Breathing Gas Cutoff. If BG flow is stopped while the suit’s helmet is locked onto the neck ring, the following steps must be taken. 1. Open helmet valve 2. Place lips on helmet valve orifice to breathe outside air. 3. Remove helmet. Before returning to normal operation, the reason for the BG cutoff event must be identified.

Overpressure. If the suit becomes pressurized beyond the suited person’s comfort level, or exceeds the maximum operating pressure of 1.5 PSIG / 77.25 mmHg / 0.10 bar, the following steps must be taken. 1. Open helmet valve 2. Reduce suit pressure to an acceptable level, using the valve. Stop demonstration and remove helmet as per doffing procedures if required. Before returning to normal operation, the reason for the suit overpressure event must be identified.

Carbon Dioxide Overload. If the suit CO2 level becomes uncomfortable (or any suit CO2 monitor reaches 5,000PPM for more than 60 seconds), the following steps must be taken. 1. Open helmet valve fully 2. If continued use of the suit is planned, flush suit with fresh air for two minutes while at the normal BG delivery rate before returning suit valves to operating pressure positions. Stop demonstration and remove helmet as per doffing procedures if required. Before returning to normal operation, the reason for the high CO2 level must be identified.

Overheating. If the suit temperature becomes uncomfortable (or reaches 90F / 32.2C), the following steps must be taken. 1. Open helmet valve 2. If continued use of the suit is planned, flush suit with fresh air for two minutes while at the normal BG delivery rate before returning suit valve to operating-pressure positions. Stop demonstration and remove helmet and suit as per doffing procedures if required. Before returning to normal operation, the reason for the high suit temperature must be identified.

Unconscious Suited Person. Remove helmet and administer first aid. Stop demonstration and remove suit as per doffing procedures if required. The suit can be cut with shears if necessary.

The Emergency Procedures noted are the first actions for normal use of the suit and will normally return the suit to a Safe State. In most cases, the Emergency Procedures noted in this section will be sufficient to return the suit to a Safe State. For safe operations, suit technicians and persons preparing to wear the suit must understand and practice these procedures.

CONDITION	LIKELY CAUSE	CORRECTIVE ACTION / PROCEDURE	CORRECTIVE ACTION RESULT
BG Cutoff	BG supply (e.g. compressor or tank) failure. BG hose obstruction / kinking.	1. Open helmet valve 2. After one second. place lips on helmet valve orifice to breathe outside air. 3. Remove helmet	Breathing is made possible by opening the helmet valve and breathing through the helmet valve orifice while the helmet is being removed.
Overpressure	Closure of both Leg and Helmet valves. Unexpected increase in BG flow.	1. Open helmet or thigh valve 2. Reduce suit pressure to an acceptable level	Suit pressure is reduced by opening leg and /or helmet valves.
CO2 Overload	Overclosure of helmet and/or leg valves. High physical workload and/or ambient conditions.	1. Open helmet or thigh valve 2. If continued use of the suit is planned, flush suit with fresh air	CO2 is flushed out of suit at high rate by incoming BG when opening leg and /or helmet valves.
Overheating	High physical workload and/or ambient conditions.	1. Open helmet or thigh valve 2. If continued use of the suit is planned, flush suit with fresh air	Body heat is flushed out of suit at high rate by incoming BG when opening leg and /or helmet valves.

Depressurization and Doffing

At the end of pressurized suit use, the suited person should prepare to equalize the ears and sinuses as suit pressure is decreased. A common method is to yawn. This should commence just as suit pressure is being reduced, either by the suited person or a suit technician. Suit pressure should be reduced slowly by gradually opening, to the fully OPEN position, the leg and/or helmet valve. When suits are depressurized, rotate the helmet counterclockwise (while facing the suited person) to unlock the helmet, then lift it over the suited person's head. See doffing procedure checklist for further instructions.

Suit Maintenance

Like all garments and tools, these suits will accumulate wear and require regular maintenance for a good use life. Maintenance can be done with the suit laid on a clean work surface.

Post-Use Suit Treatment

Immediately after use of a suit, technicians should remove and save any data-logging devices, make note of any suit damage, and take measures to dry the suit interior. The suit may be dried by using a compressed air source to blow air, down hoses inserted into the suit, into each glove and boot. This requires four hoses splitting the air flow, easily done with a small gas manifold and some lengths of tubing that can be pushed down into the boot and glove cavities. Additionally, desiccant packets (e.g. silica gel) can be placed into gloves and boots to reduce humidity. If they are used, it is important to remove these before the next suit operation.

Suit Cleaning

Isopropyl alcohol may be used to wipe down the interior of the suit bladder layer. All surfaces of the suit may also be cleaned with a light soapy water solution and a soft cloth. Occasionally it is suitable to flush the suit's pressure bladder layer interior with clean water, to reduce build up odors from sweat. A light showering of the inside suit is sufficient, and then the suit should be suspended upside down to let water drain out; the gloves will then have to be upended for draining as well. Prevention of microbial growth inside the suit is mainly achieved by drying, so after using water to clean the inside of the suit, it is important to use compressed air, towels and/or desiccant packets to dry the suit interior.

Suit Technician Kit

A pack containing these items should be kept with the suits and used to ensure all fasteners are appropriately tightened, all moving parts (e.g. strap clamps) are moving freely and zippers are properly conditioned.

- 1x Zipper wax (to lubricate pressure bladder zipper)
- 1x Needle and heavy thread (for small tears, other wear)
- 1x Seam-grip, silicone or other sealant for miscellaneous pressure bladder gas leaks
- 1x Hot dry iron and spare bladder patches
- 2x crescent wrenches (for tightening helmet and gas valve fittings and boot ring nuts)
- 1x socket-head screwdriver (for tightening/loosening glove compression clamps)
- 1x flashlight (for looking inside the suit to find foreign objects)
- 1x Philips head screwdriver (for securing boot-cover screws)
- 1x Thread tape

Suit Storage

For periods of more than a few hours the suits should be stored in a dry place away from UV exposure. The suit may be laid flat or hung with a strong hanger; put the hanger (such as a drysuit hanger) into the suit through the pressure bladder layer. Leave the pressure bladder open but zip the restraint garment zipper to give the suit some support as it hangs. A towel can be placed between the hanger and the pressure bladder layer to prevent bladder stress by the hanger.

The helmet is best stored flat on its mounting collar on a hard surface; this allows any moisture inside to dry out. Desiccant pouches may be placed into suit boots, gloves, and helmet for long-term storage.

Leave all suit valves in the OPEN position for storage.

Communications

The suits are capable of radio integration, however, are not currently equipped with the technology. A set of modified scuba hand communication signals can be employed for the suited persons and technicians to effectively communicate. All parties involved with any suit demonstrations should be well versed to use the below signals to communicate during operations.



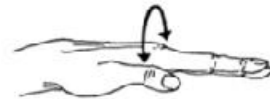
Okay



Here/There



Calm / Slow down



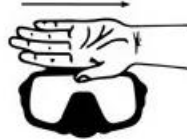
Problem



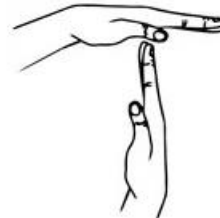
Look



Out of air



Hot / Tired



Termination of operation



Pressure Suit Checklist

Standard Checklist Don

Checklist should be read by suit technician 1, while technicians 2 and 3 aid suited individual with the following steps.

1. Lay suit in a clean dry place.
2. Undo the back buckle and unzip the two suit entry zippers.
3. Please remove any items in pockets, jewelry, etc. Remove any potentially sharp items.
4. Participant should now be seated for suit ingress at the head of suit (seat or floor).
 - a. Reminder that slow is smooth and smooth is fast, do not rush the process or force movement to fit inside the suit.
5. Insert right leg until foot is secure in boot.
6. Insert left leg until foot is secure in boot.
7. Gently stand and pull suit up to waist (can grab anywhere on the suit to support its weight).
8. Right arm in suit to glove, suit tech support by bracing at the wrist ring.
9. Left arm in suit to glove.
10. Neck ring over head (careful not to scrape head on ring bolts).
11. Zip pressure bladder closed carefully (suited persons arms straight in front helps zipper closure).
12. Visually verify bladder zipper is fully closed.
13. Zip restraint layer closed.
14. Secure back zipper buckle.
15. Adjust suit straps and clips to appropriate fit/tightness.
16. Helmet valve to the open position, visually confirm its open.
17. Breathing gas “on” to helmet.
18. Helmet ring clear of obstacles.
19. Place helmet over head and engage to the locked position (push down and clockwise).
20. Adjust valves to produce desired pressure.
21. When all steps are complete, give suited persons the “okay” signal to begin suit use.

Doff

1. Signal to the suited persons “T” for termination of operation.
2. Suit valve to the fully open position.
3. Suit gas turned off.
4. Observe suit pressure decrease to full deflation.
5. Remove helmet (push neck ring down and turn counterclockwise).
6. Adjust suit straps to the loose positions.
7. Unclip back buckle and unzip restraint layer.
8. Unzip bladder layer.
9. Assist suited persons to dip head down/back/and out of the neck ring.
10. Hold glove fingers individually help to release hand from glove.
11. Hold wrist ring to remove arm from sleeve.
12. Repeat for opposite hand/arm.
13. Slide suit down over waist and have participant sit down on a chair or the floor.
14. Grab boot and pull away from participant to release leg.
15. Repeat for opposite foot/leg
16. Commence suit aeration and cleaning.

Procedural Photos



Figure 2 Lay suit in a clean dry place





Figure 3 Undo the back buckle and unzip the two suit entry zippers



Figure 4 Participant should now be seated for suit ingress at the head of suit



Figure 5 Insert right leg until foot is secure in boot



Figure 6 Insert left leg until foot is secure in boot





Figure 7 Gently stand and pull suit up to waist



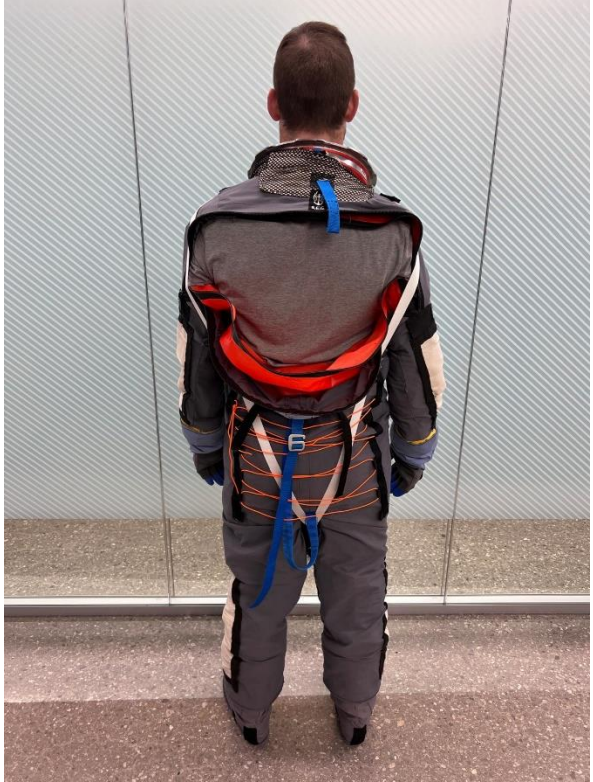
Figure 8 Right arm in suit to glove



Figure 9 Left arm in suit to glove



Figure 10 Neck ring over head (careful not to scrape head on ring bolts)



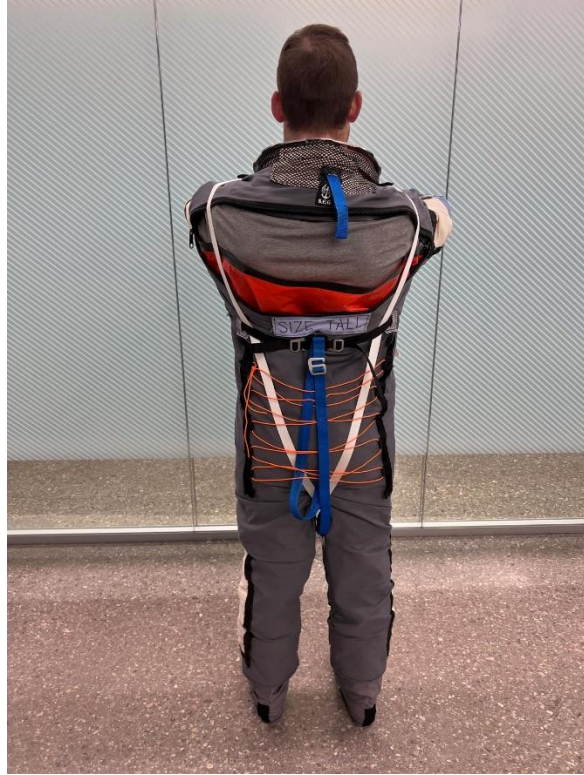


Figure 11 Zip pressure bladder closed carefully (suited persons arms straight in front helps zipper closure)





Figure 12 Visually verify bladder zipper is fully closed



Figure 13 Zip restraint layer closed





Figure 14 Secure back zipper buckle



Figure 15 Adjust suit straps and clips to appropriate fit/tightness



Figure 16 Helmet valve to the open position, visually confirm its open



Figure 17 Breathing gas "on" to helmet



Figure 18 Helmet ring clear of any obstacles





Figure 19 Place helmet over head and engage to the locked position (push down and clockwise)

